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Sustainable Development Disciplines for Society

Breaking Down the 5Ps—People, Planet, Prosperity, Peace, and Partnerships

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Preface

The Japanese Ministry of Education, Culture, Sports, and Science and Technology (MEXT) implemented the Top Global University Project (TGU) in 2014 to prioritize support to the universities actively promoting internationalization[1]. Waseda University was selected to be a part of this project.

The Global Asia Research Center (GARC) is one of the centers responsible for world-class education and research at Waseda University, under the framework of the TGU[2]. The purpose of the GARC is to study historical reconciliation and sustainable development from an interdisciplinary perspective, and to disseminate the outcomes globally. The Sustainable Development Goals (SDGs), adopted at the United Nations Sustainable Development Summit in September 2015, are global development goals. One of the objectives of the TGU is to achieve the SDGs.

Reconciling history and promoting sustainable future development in East Asia present significant challenges. In pursuing reconciliation in East Asia, a critical re-examination of Japan's war responsibility and colonialism is necessary. In Europe, war and colonial responsibilities have been discussed separately. While advances have been made on the question of war responsibility, the debate over the legacy of colonialism has only recently begun. Promoting sustainable development and reaching a regional agreement on a common goal appears to be more challenging for the nations of East Asia, where there are greater differences in religion, culture, economic development, political systems, and other aspects when compared to Europe.

Studies to overcome these challenges should be conducted from an interdisciplinary perspective, incorporating multiple disciplines. The GARC brings together researchers from various specialized fields such as history, development studies, economics, sociology, international relations, international law, regional studies, peace studies, conflict resolution, political science, urban and rural planning, business administration, and management engineering. At the GARC, a diverse group of researchers is pursuing interdisciplinary research by building on their disciplines through innovative approaches.

[1] https://tgu.mext.go.jp/en/index.html.

[2] https://www.waseda.jp/global-asia/.

This book and accompanying volume[3] report on GARC's research, to date, on sustainable development. Specifically, research focusing on evidence-based policymaking for realizing the SDGs is introduced in a simple manner. Though each study is based on different disciplines, the achievement of the SDGs is the common goal. I hope that readers will obtain the interdisciplinary knowledge necessary to understand the challenges and possible strategies for achieving SDGs in East Asia from these books. While the focus is East Asia, the issues addressed are globally relevant. Readers are recommended to refer to the introductory chapters of the books for a review of the content, significance, and relevance of each book.

I would like to express my sincere gratitude to Prof. Naoyuki Umemori, Director of the GARC, Waseda University, and Ms. Juno Kawakami and Ms. Saranya Devi Balasubramanian of Springer for their efforts toward the publication of this book. The editors also wish to acknowledge the extraordinary and dedicated support provided by Mr. Rui Asano, Research Associate of Waseda University, for editing this book. Additional thanks go to the anonymous reviewers for their supportive and intellectual guidance. Finally, the editors specially acknowledge the organizational support provided by the GARC and the Institute of Advanced Social Sciences of Waseda University and the funding support provided by the TGU Project of MEXT.

Tokyo, Japan Shujiro Urata

[3]Sustainable Development Disciplines for Humanity: Breaking Down the 5Ps—People, Planet, Prosperity, Peace, and Partnerships

Introduction

This multidisciplinary book provides 14 problem-solving lectures on the sustainable development of people, peace, planet, and prosperity—four of the five keywords for the Sustainable Development Goals (SDGs),[4] namely people, planet, prosperity, peace, and partnerships (5Ps). According to the *Resolution adopted by the General Assembly of the United Nations* (2015, p. 2), the SDGs are intended to promote the following actions in these five areas:

(1) For people: end poverty and hunger in all their forms and dimensions, as well as ensure that all human beings can fulfill their potential with dignity and equality and in a healthy environment.
(2) For planet: protect it from degradation, including through sustainable consumption and production, by sustainably managing natural resources and taking urgent action on climate change, so that it can support the needs of the present and future generations.
(3) For prosperity: ensure that all human beings enjoy prosperous and fulfilling lives and that economic, social, and technological progress occurs in harmony with nature.
(4) For peace: foster peaceful and inclusive societies that are free from fear and violence.
(5) For partnerships: mobilize the means required to implement this agenda through a revitalized Global Partnership for Sustainable Development based on a spirit of strengthened global solidarity, focusing, in particular, on the needs of the poorest and most vulnerable and with the participation of all countries, all stakeholders, and all people.

Each lecture is classified as one or more keywords for the SDGs and based on planning, law, economics, management engineering, and business. Furthermore, each lecture delineates the essence of each discipline when it is practically applied to development studies. This book along with its sister book on people, peace, partnerships, and sustainable development disciplines for humanity will be useful for development studies in society.

Interdisciplinary research is necessary to achieve the SDGs advocated by the United Nations. Hence, it is essential to learn the basics of individual disciplines, as they offer ample knowledge to foster problem-solving through

[4]See Appendix 1 for an explanation of each of the 17 goals.

Fig. 1 Relationships between chapters, disciplines, and the SDGs

the accumulation of existing research. This and its sister book are the first comprehensive textbooks summarizing the essence of each necessary discipline to approach development studies from an interdisciplinary perspective. The 14 lectures enable readers to effectively learn the main aspects of each discipline necessary for research in development studies, and the careful interweaving of the aspects learned by the reader enables the implementation of interdisciplinary development research. Table 1 shows the relationships between keywords, disciplines, and the SDGs in all chapters. Figure 1 also illustrates the interrelationships between chapters, disciplines, and the SDGs in an intelligible manner. As each lecture corresponds to certain keywords, disciplines, and SDGs, readers can focus on topics that are relevant to them.

Chapters 1–4 of this book focus on prosperity and introduce research to help achieve mainly Goal 11 (sustainable cities and communities). These chapters are based on the discipline of planning studies.

Chapter 1 explains the importance of implementing holistic strategic management of open social innovation through Education for Sustainable Development (ESD) to achieve Goal 11 (resilient community). This chapter considers social innovation for community development through ESD based on examples such as the integration of disaster resilience and regional knowledge in Japan and the integration of environmental resilience and traditional knowledge in Japan.

Chapter 2 examines the "balancing reconstruction with decommissioning" problem of reviving Fukushima after the double disasters of the Great East Japan Earthquake and the 1F (Fukushima Daiichi Nuclear Power Plant) nuclear disaster. This chapter contributes to making cities and human settlements inclusive, safe, resilient, and sustainable, thus achieving Goal 11.

Table 1 Relationships between keywords, disciplines, and the SDGs in all chapters

For	Chapter	Keywords	Discipline	Detailed discipline	SDGs	SDGs Targets	Related SDGs
Prosperity (Town planning)	1	Community development, education for sustainable development (ESD), knowledge integration, context building, open social innovation	Planning	City planning	11	–	–
	2	Nuclear disaster, Fukushima, resilience, decommissioning, creative reconstruction		Environmental impact assessment	11	–	–
	3	Rural development, community, settlement, local resources, agriculture		Rural planning	11	–	7, 15, 17
	4	Photograph, Japan, occupation period, photographic archives, contemporary history		Urban history	17	–	7, 11
Planet	5	SDGs, Satoyama, nature park, ecosystems	Law	Environmental law	15	–	7, 11,13
	6	International trade, regulations, private standards, sustainability	Economics	Development economics	12	12.4, 12.a	2, 3, 5, 6, 7, 8, 11, 14, 15
	7	Operation management, JIT production system, sustainable production system, supply chain management	Industrial engineering	Management technology	9, 12	–	7, 8, 13, 17
	8	Sustainable development, limits to growth, tragedy of the commons, intergenerational equity, discounted utilitarian approach	Economics	Environmental economics	8, 13	–	–
Prosperity (Economic activity)	9	Economic growth, catch-up, productivity, technological progress		Macroeconomics	8, 9	–	–
	10	Input–output table, smart society, information and communication technology, structure of development		Input–output economics	9	9.4, 9.5	2, 5, 7, 8, 11, 12, 13
	11	Global value chains, free trade agreements, infrastructure		International trade	8	–	–
	12	Base/bottom of the pyramid (BoP), inclusive business, multinational corporation (MNC), triple bottom line	Business	International business administration	1, 3, 5, 6, 8, 9, 13	–	4, 10, 12, 14, 15
People	13	Global food security, developing countries, agricultural and economic development, Food problem	Economics	Food economics	2	–	1, 7, 12, 13, 15

(continued)

Table 1 (continued)

For	Chapter	Keywords	Discipline	Detailed discipline	SDGs	SDGs Targets	Related SDGs
Peace	14	Economic problems, claims problems, allocation rules, axiomatic approach		Economics of institutional design	16	16.7	8, 10

Footnote: Contents of SDGs targets.
9.4 By 2030, infrastructure and retrofit industries should be upgraded to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.
9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, particularly developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending.
12.4 By 2020, the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, will significantly reduce their release to air, water, and soil to minimize their adverse impacts on human health and the environment.
12.a Support developing countries to strengthen their scientific and technological capacity to move toward more sustainable patterns of consumption and production.
14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported, and unregulated fishing and destructive fishing practices, and implement science-based management plans to restore fish stocks in the shortest time feasible—at least to levels that can produce maximum sustainable yield, as determined by their biological characteristics.
16.7 Ensure responsive, inclusive, participatory, and representative decision-making at all levels.
Source United Nations (n.d.)

Chapter 3 provides an overview of Japan's rural development, pointing out that regional functions are declining; thereafter, the various efforts necessary to achieve Goal 11 in rural areas are discussed.

Chapter 4 is unique in that it exhumes the photographic historical materials of Japan's occupation period (1945–52) after World War II and re-examines the meaning of the SDGs—especially Goals 7 (affordable and clean energy) and 11, by considering the gap between them and the current situation. To formulate a roadmap for the future, it is necessary to have a deep understanding of history up to the present.

Chapters 5–8 focus on planets and introduce research to help achieve Goals 8 (decent work and economic growth), 9 (industry, innovation, and infrastructure), 12 (responsible consumption and production), 13 (climate action), and 15 (life on land). These chapters are based on the disciplines of law (Chap. 5), economics (Chaps. 6 and 8), and industrial engineering (Chap. 7).

To achieve Goal 15, Chap. 5 analyzes the protection and sustainable use of territorial ecosystems in Japan, focusing on sustainable agriculture and forestry. As social and economic factors should be interwoven for ecologically sustainable development, this chapter discusses the following themes: the role of natural parks, the conservation of "satoyama (woodland close to the village or living area)," the development of legal systems and NGOs, farmland restoration projects, scale-up of farmers, and solar sharing.

Chapter 6 assesses two approaches to achieve Goal 12. One is based on laws (including international agreements)—the de jure approach; the other is based on market forces, such as voluntary sustainability standards (VSS)—the de facto approach. Additionally, the de jure approach includes efforts

both at the global (international agreements) and domestic levels, and this chapter also discusses their interrelationships. Regarding VSS, the chapter focuses on private standards with third-party certification schemes and analyzes their impact on international trade.

Chapter 7 discusses environmentally conscious operations management to achieve Goals 9 and 12 from an industrial engineering perspective. First, representative operations management systems such as inventory management and total quality management (TQM) are introduced. Second, the Just in Time (JIT) production system is explained. Finally, this chapter considers environmentally conscious manufacturing and describes a closed-loop supply chain that includes the activities necessary to acquire end-of-life products from customers to recover value.

Chapter 8 discusses the concept of sustainable development, related to Goals 8 and 13. After introducing the controversies regarding the concept in economics, the chapter presents the economic conditions for achieving sustainable development and the mechanism by which rational agents choose an anti-sustainable path. The chapter also refers to the climate change issue, which raised and fired the controversies.

Chapters 9–12 focus on prosperity and introduce research to help achieve mainly Goals 8 (decent work and economic growth) and 9 (industry, innovation, and infrastructure). These chapters are based on economics (Chaps. 9–11) and business administration (Chap. 12).

Chapter 9 develops a macroeconomic growth model that explains observed facts, such as steady growth in some developed countries and the huge international difference in economic growth, to contribute to the achievement of Goals 8 and 9. It presents a basic theory of growth with capital accumulation as the driving force and clarifies the effect of firm innovation on economic growth. It also discusses factors that create international differences in economic growth, such as education, institutions, and the misallocation of resources.

The construction of a smart society utilizing information and communications technology (ICT) has attracted attention for the simultaneous achievement of various SDGs. Using the input–output analysis, Chap. 10 elucidates the economic structure of a smart society in relation to Goal 9. Here, a smart society enables waste to be eliminated and people's utility to be increased by strengthening management in all fields of society using ICT. It is argued that a smart society will achieve an industrial structure with a lighter environmental load and sustain moderate economic growth. Japan plays a key role in building a smart Asian society.

From the perspective of international economics, Chap. 11 examines the experiences of East Asian developing countries in achieving rapid and inclusive economic growth, by focusing on the role of international trade and the foreign direct investment nexus created through global value chains (GVCs) by multinational corporations (MNCs). Moreover, the construction and maintenance of well-functioning soft and hard infrastructure by the government and international donors have contributed to the creation of a business-friendly environment. In light of the absence of an effective global

economic order, regional economic frameworks in the Asia-Pacific region have proven to be effective in achieving Goal 8.

From the perspective of business administration, Chap. 12 discusses the role of MNCs in addressing the social challenges faced by the poor in developing countries. Initially, MNCs focused on the poor, targeting Goals 1 (no poverty), 3 (good health and well-being), and 6 (clean water and sanitation). Subsequently, they adopted social agendas targeting Goals 5 (gender equality), 8 (decent work and economic growth), and 9 (industry, innovation, and infrastructure). This has led to significant changes in MNCs in these countries. More recently, these businesses have embraced environmental challenges, including Goal 13.

Finally, Chaps. 13 and 14 focus on people and peace from the perspective of economics. Economic theoretical considerations can contribute to the achievement of Goals 2 (zero hunger) and 16 (peace, justice, and strong institutions).

Chapter 13 presents the factors affecting global food demand and supply conditions and identifies potential solutions to global food security problems. The factors determining the supply and demand conditions of food are detailed in relation to the linkages between food, agriculture, and rural development. Furthermore, climate change issues have been discussed in relation to global food and energy security. This chapter examines the effectiveness of crop-based energy production and the potential conflicts with food production.

The aim of Chap. 14 is to construct "good" rules leading to the achievement of Goal 16. The axiomatic approach was adopted in the study of these rules as it: (i) formulates rules (mathematically), (ii) introduces "desirable" properties of rules (called axioms), and (iii) studies those implications (e.g., identifies rules that satisfy those properties). The results of these analyses will be useful for building a society system.

Readers should refer to Table 1 and Fig. 1 to identify the relevant chapters to achieve a particular SDG and determine what wisdom each discipline in each chapter provides. It is also useful to refer to the sister book "*Sustainable Development Disciplines for Society: Breaking Down the 5Ps—People, Planet, Prosperity, Peace, and Partnerships*" at the same time and find a roadmap for achieving a specific SDG by effectively combining the wisdom of several disciplines. In developing countries, these considerations will provide access to development research for readers aiming to develop their home countries further. Moreover, in developed countries, these considerations provide access to problem-solving research for readers seeking holistic measures to achieve the goals in Table 2.

Table 2 Contents of the sustainable development goals (SDGs)

Goal		
1	No Poverty	Economic growth must be inclusive to provide sustainable jobs and promote equality
2	Zero Hunger	The food and agriculture sector offers key solutions for development and is central for hunger and poverty eradication
3	Good Health and Well-Being	Ensuring healthy lives and promoting the well-being for all at all ages is essential to sustainable development
4	Quality Education	Obtaining a quality education is the foundation to improving people's lives and sustainable development
5	Gender Equality	Gender equality is not only a fundamental human right, but a necessary foundation for a peaceful, prosperous, and sustainable world
6	Clean Water and Sanitation	Clean, accessible water for all is an essential part of the world we want to live in
7	Affordable and Clean Energy	Energy is central to nearly every major challenge and opportunity
8	Decent Work and Economic Growth	Sustainable economic growth will require societies to create the conditions that allow people to have quality jobs
9	Industry, Innovation, and Infrastructure	Investments in infrastructure are crucial to achieving sustainable development
10	Reduced Inequalities	To reduce inequalities, policies should be universal in principle, paying attention to the needs of disadvantaged and marginalized populations
11	Sustainable Cities and Communities	There needs to be a future in which cities provide opportunities for all, with access to basic services, energy, housing, transportation, and more
12	Responsible Consumption and Production	Responsible production and consumption
13	Climate Action	Climate change is a global challenge that affects everyone, everywhere
14	Life Below Water	Careful management of this essential global resource is a key feature of a sustainable future
15	Life on Land	Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss
16	Peace, Justice, and Strong Institutions	Access to justice for all, and building effective, accountable institutions at all levels
17	Partnerships	Revitalize the global partnership for sustainable development

Source United Nations (n.d.)

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Contents

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List of Figures

List of Tables

Part I
For Prosperity (SDG 11)

Knowledge Integration and Open Social Innovation for Sustainable Development

1

Osamu Soda

Abstract

This chapter will consider Goal 11. In particular, Target 11.2 focuses on Inclusive and Sustainable Urbanization. By 2030, it aims to enhance the capacity for participatory, integrated, and sustainable human settlement planning and management. Target 4.7 in SDGs Goal 4 is Education for Sustainable Development and Global Citizenship, which educates people about sustainable lifestyles, global citizenship, and the contribution that culture makes to sustainable development. However, the outcomes of education require a long time. Education changes people's minds, local cultures, and socioeconomic systems. This process requires knowledge integration from diverse sectors, especially for historically accumulated knowledge. It is necessary to develop new theoretical and practical skills for building local context. The case study describes several good practices in Japan.

Keywords

Community development · Education for sustainable development (ESD) · Knowledge integration · Context building · Open social innovation

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1.1 Introduction

This chapter focuses on Goal 11(sustainable cities and communities), and considers that Goal 4 (quality education) can support it, and discusses community development and the Sustainable Development Goals (SDGs) from the perspective of planning studies. Sustainability is an urgent issue for humankind and the Earth. Achieving environmental goals such as the Paris Agreement and the SDGs with current efforts and progress will be quite difficult. Environmental sustainability can be transformed only by the interaction of economic and social sustainability. To accelerate the SDGs, we need to raise awareness of the crisis and involve people at multi-levels, including the community level, and work together to find a sustainable transition pathway. The main field of SDGs from community development is Goal 11 Resilience City. In addition, this chapter focuses on Goal 4 Educational Approach.

1.2 Education for Sustainable Development (ESD)

The SDGs consist of 17 targets and 169 targets, and the fundamental goal is to restore the environment (Targets 6, 13, 14, 15). We need to learn how to understand ecologically and change ourselves. The power of education is a driving force

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to promote sustainable development. Rockström et al. (2016) proposed a wedding cake model for a better understanding of the structure of the SDGs. From top to bottom, the pyramid is the economy, society, and environment (Fig. 1.1). The goal is to expand the base and restore balance.

'Education for Sustainable Development' (ESD) was advocated by the Government of Japan and NGOs at the Johannesburg Summit in 2002. Shortly thereafter, the 57th United Nations General Assembly adopted 'The United Nations Decade of Education for Sustainable Development (UNDESD)' (2005–2014).

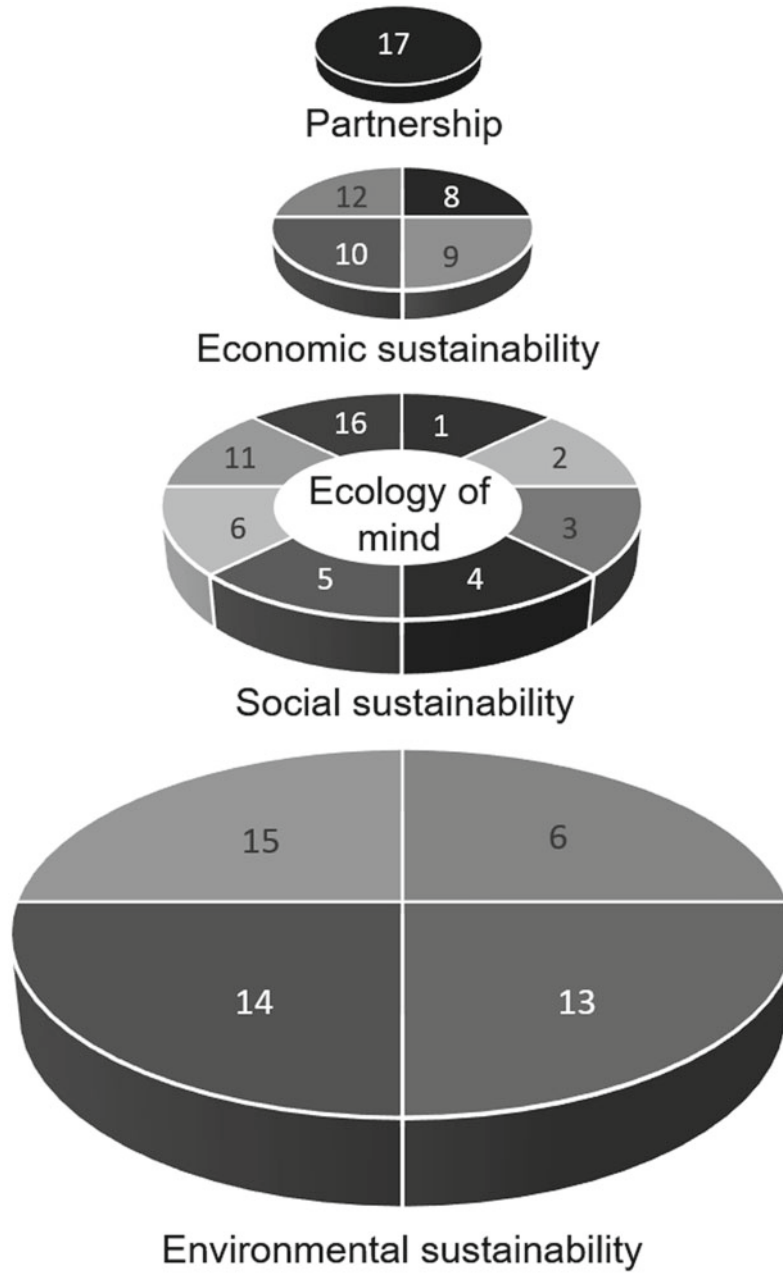

Fig. 1.1 SDGs wedding cake and the ecology of mind

ESD consists of three types of learning: cognitive learning, social and emotional learning, and behavioral learning. Cognitive learning understands complex problems and explores innovative ideas and alternative solutions. Social and emotional learning builds core values and attitudes for sustainability and fosters empathy and compassion for others and the planet. Behavioral learning learns the practical actions for sustainable change in the personal, social, and political arenas.

Ecology of mind is necessary at the core of the SDGs wedding cake. It is ecological understanding, empathy, and preparedness of behavior. It brings the entrepreneurial spirit, technology, and social innovation of the SDGs.

1.3 Community Development

1.3.1 Field and Issues of Community Development

Community development is an academic subject and practical field that focuses on the role of local communities and addresses socioeconomic and environmental problems. Originally, human beings had lived in harmony with nature and the economy since ancient times, but after the agricultural industrial revolutions, those contradictions between man and nature have expanded. Community development was built to address the negative aspects of modern capitalism and development. Today, it is established worldwide as a professional practice and research field. Generally, the research theme focuses on problem solving at the local level. Its major themes include local water, forestry, agriculture, fishery, vulnerable groups, indigenous people's livelihood improvement, poverty, housing, disasters and displacement, infrastructure, sanitation, cooperatives, microfinance, etc. In developed countries, the following are additional major themes: migrants and refugees, voluntary groups, community enterprise, asset-based community development, community renewal, youth, gender, and ICT.

1.3.2 Social Design Approach

Community development includes an economic mechanism approach, a government approach, and a social design approach. Social design is the theory and practice of design thinking about social values, actors, resources, social structures, social norms, symbols and tools, and social processes, and it develops specialized planning and engagement skills such as regional profiling, civic pride development, value co-creation, scenario planning, consensus building, context building, and transition management.

1.4 Knowledge Integration

As discussed above, community development is an interdisciplinary research and practice area in which diverse stakeholders participate. In order to change the status quo, it is necessary to activate the interaction between the local ecosystem and the practice of management centered on ecological knowledge and understanding.

1.4.1 Various stakeholder's Knowledge

Folke (2006) discussed the framework of social evolution and its elements. From an administrative point of view, social and political leadership, transformability, and systems of adaptive governance are important factors. Socially, the focus will be on strengthening agents and actor groups, adaptive capacity (voluntary sector), and social networks. These elements address the social memory through the social learning process as well as the integration of mental models and knowledge system. Under these social conditions, collaborative visioning can proceed

effectively, and then institutional and organizational inertia will start to change.

1.4.2 Historically Accumulated Knowledge

Layers of historical knowledge have its own knowledge system, which has been upgraded from indigenous knowledge, traditional knowledge, technical knowledge, and recently, a knowledge-based society. All these knowledge systems are aggregated in a knowledge-intensive society. Indigenous knowledge restores new meaning and power within the information sphere. Bohensky & Maru (2011) discussed the dialogue between knowledge systems, methods and processes of integration, social context of integration, and their assessment as being important.

For example, Japanese 'satoyama' is country hills or village forests that are close to human settlements and connected to people's lives. Starting originally from hunting and harvesting, it became a fertilizer supply place in the agricultural society. It was then forgotten in the industrial world, but in the next information society, people realized due to the influence of various media that it was an important place for the ecosystem. Currently, it is becoming a nodal place that raises ecological knowledge and expands the environmental behavior network.

1.4.3 Knowledge from the Inside of Social Memory

As mentioned in Fig. 1.1, ecology of mind is necessary at the core of social reform. The beliefs of individuals and communities will transform society. The ecology of mind and the ecology of society are integrated to create new knowledge. According to Hussein et al. (2020), cultural memory forms the identity of the place and the sense of place, which form the attachment to the community, enhances psychological well-being (quality of life), and contributes to social sustainability.

1.4.4 Local Context Building

Community development emphasizes context building (Fig. 1.2). Herzele (2004) and Soda (2018) considered the integration of civic and expert knowledge in the design of places. Experts try to achieve policy objectives efficiently during the project period, while citizens try to envision the future from the extension of their collective memory. Experts try to promote the planned program, while citizens try to develop new actions in connection with various cultural [political/environmental] movements in other regions. A new story will be built by this dialogue and dynamism.

As a typical example, the Agency for Cultural Affairs of Japan officially recognizes a story that tells the culture and traditions of Japan through the historical charm and characteristics of a region as 'Japan Heritage'. The conditions for certifying a story are a clear theme that conveys the charm of the area, an explanation that anyone can understand, and a composition that people are interested in.

1.5 Context of Community Development in Japan

Community development is influenced by the environment and political economy of each country and region on Earth. Pawar (2012) published a book on community development in the Asia-Pacific region. The field of community development in Japan is wide, but there are few books and dissertations that describe the whole picture. In this chapter, I will try to explain the highlights of Japanese research and practice from the perspective of contemporary Japanese studies.

1.5.1 Land and Climate

It is 3000 km from north to south of Japan, and in the Köppen climate classification, Cfa (humid subtropical climates) is in the south (Tokyo) and Dfb (warm-summer continental climates) is in

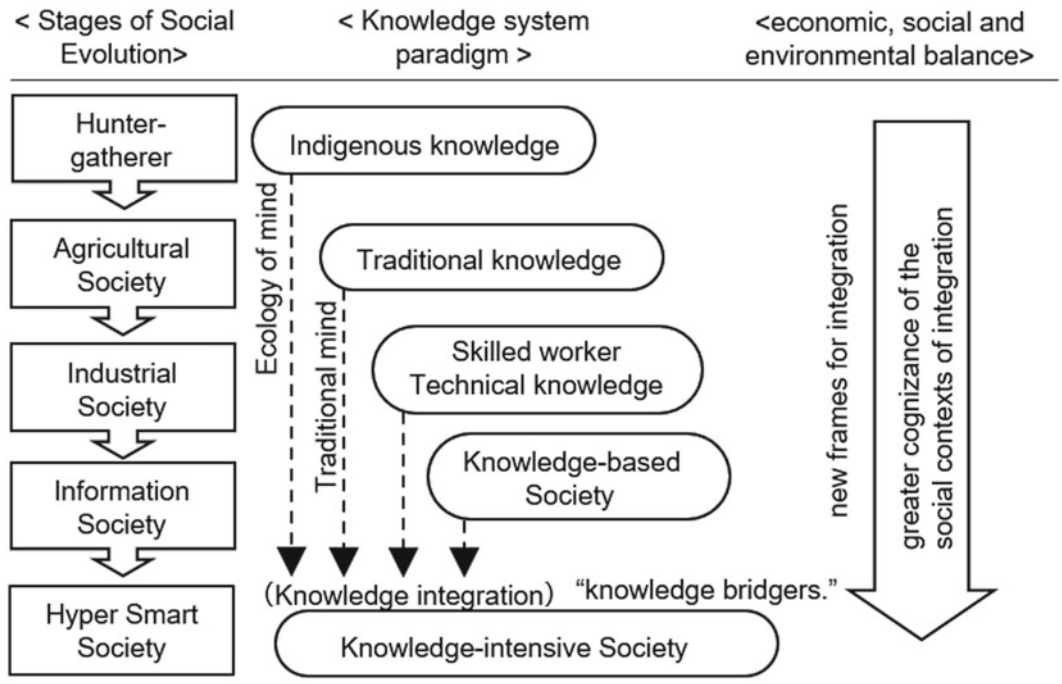

Fig. 1.2 Social evolution and knowledge integration

the north (Sapporo). Due to the hot and humid climate of the monsoon, vegetation grows faster, rice is the staple food instead of wheat and corn, and heavy rainfall causes it to rain 1.5 times more in Tokyo than the Earth's average, thus increasing the risk of flooding. This climate fostered a self-help spirit in which Japanese people can live sustainably as long as they carefully manage their land.

1.5.2 Indigenous People

The Japanese archipelago is basically the Yamato people, but Okinawa has the Ryukyu people. Okinawa has its own culture. There were Ainu people in Tohoku and Hayato people in southern Kyushu. In 2008, a resolution was passed in the Diet (Japan's parliament) to recognize the Ainu as indigenous people. It is said that there is the largest number of people in Hokkaido, about 13,000 and more than 10,000 in the Tokyo metropolitan area. The Ainu have an ecological culture of hunting and gathering. There is ecological wisdom in words such as 'suy-sukup' (if you cut a branch of a cornus tree and stab it in the ground, the cuttings will grow again), 'iteki-opitta-kar' (never pick all the edible wild plants), and 'a-anu' (leave something for those who come later).

1.5.3 Ancient and Medieval Japan

The population of the hunter–gatherer society was about 270,000, but rice cultivation was transmitted from the continent to Northern Kyushu in the tenth century BC. Paddy rice cultivation spread to the center of Japan at around the seventh century BC. In 743 BC, a law was enacted recognizing the private property and property rights of the land on which the paddy fields were built. Once reclaimed, the lands could be owned by the claimants forever. A peasant and product management system based on a mansion was established, and powerful tribes emerged from each region.

1.5.4 Local Governance of Early Modern

In the Battle of Sekigahara in 1600 AD, Samurai Feudal Lords fought as two powers. General Tokugawa's side won the battle and unified Japan to establish a ruling system. The side that was on the side of the Tokugawa family was called the 'Fudai' daimyo, and the side that was hostile was called the 'Tozama' daimyo. The Fudai daimyo was assigned the territory of the clan, but the Tozama daimyo was assigned to a remote land from Edo to guard against rebellion. Tozama was also ordered to defend the military from other countries. Satsuma Domain (currently Kagoshima Prefecture), Choshu Domain (currently Yamaguchi Prefecture), Tosa Domain (currently Kochi Prefecture), Hizen Domain (currently Saga Prefecture), and Yonezawa Domain (currently Yamagata Prefecture) are Tozama areas.

1.5.5 Local Self-Sufficient Economy

Because the Tokugawa shogunate did not have a national tax system, the clan prospered its own economy. Therefore, its ability to govern independently was questioned. As a result, the plant[/animal] breeding industry such as processed products and crafts other than agriculture was encouraged. As a result, unique special products of each clan were created, and the distribution economy developed. Eventually, the population at the beginning of the eighteenth century stabilized at about 25 million. Japan reached the limit of its population capacity that can be supported by an agricultural-based society.

1.5.6 Education System Established Based on Asian Thought

A clan school was established in each domain, and scholarship and martial arts were encouraged. The first school was built in 1669 in Okayama. Terakoya also taught reading and writing at a private school in a temple. Even farmers in Japan had a high literacy rate from early on. Reasonable thinking and education were carried out at the clan school. Neo-Confucianism, usually the Zhu Xi theory, became the standard in the Tokugawa shogunate and Fudai domain school. In contrast, the Tozama domain school tended to choose Wang Yang-Ming theory, which seeks the unity of knowledge and action and encourages critical thinking, deliberations, and positive innovation. In the eighteenth century, the Tokugawa governmental regime's central academy of Shoheizaka-Gakuimonjo began teaching both the Zhu Xi theory and Wang Yang-Ming theory. The Matsushiro Domein (now Nagano Prefecture) was one of the first to adopt Western education and abandon Confucianism. During this period, many excellent feudal lords, scholars, and military personnel appeared. Wang Yang-Ming theory scholar Nakae, Toju (1608–1648), Yonezawa feudal lord Uesugi, Yozan (1751–1822), agricultural politician Ninomiya, Sontoku (1787–1856), and Satsuma feudal lord Saigo, Takamori (1828–1877) are the most representative social innovators of Japan.

1.5.7 Mutual Self-Help

There is always a risk of failed crops and famine due to climate change, and in 1838, an early model of agricultural cooperatives was formed by OHARA, Yugaku (1797–1858). KAGAWA, Toyohiko (1888–1960) was a social reformer and activist who established a pre-war labor movement and farmers' movement [established pre-war labor and farmers' movements]. He worked on improving slums and founded the Japanese Farmers' Union. Although Japan is self-help based, cooperatives are highly developed to avoid that risk. Currently, at a total of 105 million people, the added value created by the cooperatives is 5.6 trillion yen. At 100 million yen, more than half of Japan's domestic agriculture, forestry, and fisheries output is shipped and sold through cooperatives. Some 23% of domestic savings are deposited with cooperatives.

1.5.8 'Machizukuri' Emphasizes Civic Engagement

As a compound word of 'machi' (means town) and 'zukuri' (means making), 'machizukuri' means town planning, place making, community development, and community governance, which includes asset management, construction, and environmental actions. Words appeared in the seventeenth century, and after 1970, they are often written in hiragana characters, emphasizing a citizen-centered and community-based approach in contrast to government-led city planning and administrative management. There is a synonym of 'murazukuri'. Mura is a village.

1.5.9 'Kyosei' is the Idea of Coexistence

'Kyosei' means living together. Originally referring to a symbiosis of biology, it means the interaction between different organisms living in close physical association. In Buddhism, it means that oneself and others live together. In the machizukuri field, it means social inclusion or environmental harmony.

1.5.9.1 SDGs and Open Innovation in Japan

In Japan, of the approximately 1700 local governments, nearly half will be promoting the SDGs. Among them, 124 SDGs Future Cities have been selected by 2021. Each has originality, and all plans are shared on the Web. Local governments are raising the level of awareness through collaborative learning. In that process, open innovation occurs, and knowledge coevolves.

1.6 Culture of Public Spiritedness by Region

The public spiritedness of people in the local community is very important due to the human resources of community development. It is an independent variable that does not correlate with the economy (GDP) or society (population size).

Areas with many environmental volunteers are Shiga (7.4% of the population) and Kagoshima prefectures (7.3% of the population) (Fig. 1.3). These areas are rich in nature, and historically, practical civic education has been provided by excellent educational leaders and institutions to form civic pride.

Areas where many people participate in the Japan Overseas Cooperation Volunteers are Kagoshima (884 people from 1965 to 2021 and 56.1 people per 100,000 population) and Shimane (369 people from 1965 to 2021 and 55.5 people per 100,000 population) prefectures (Fig. 1.4). Historically, many people have migrated overseas from these areas, and they still value their connections. A support group has also been established. The data of Figs. 1.3 and 1.4 are correlated.

1.7 Case Study: Context-Building Process of Kagoshima Area

Kagoshima Prefecture is located in the south of Japan and is a gateway to the sea route. The Köppen climate classification is Cfa. The Hayato people lived in ancient times. The active volcano Sakurajima erupts frequently. This land was ruled by the Shimazu clan from the end of the twelfth century. The context of community development is shown in Fig. 1.5.

During the Warring States period, Shimazu, Tadayoshi (1492–1568) (called 'Jisshinko') gained power. He emphasized the practice of wisdom. Shimadzu clan was the first in Japan to purchase a gun from Portugal and use it in practice. They belonged to the Western Army in the Battle of Sekigahara, and after the war, they ruled the Satsuma Domain as Tozama daimyo. However, they did not abandon the consciousness of being equal to the Tokugawa shogunate. The Satsuma Domain in the Edo period established the school 'Zoshikan' (meaning to create ambition, currently Kagoshima University). The basis of learning was 'Jisshinko's thought. Critical thinking, deliberation, and mutual help were emphasized. They offered a unique 'goju' education. The area was divided into 18 sub-units,

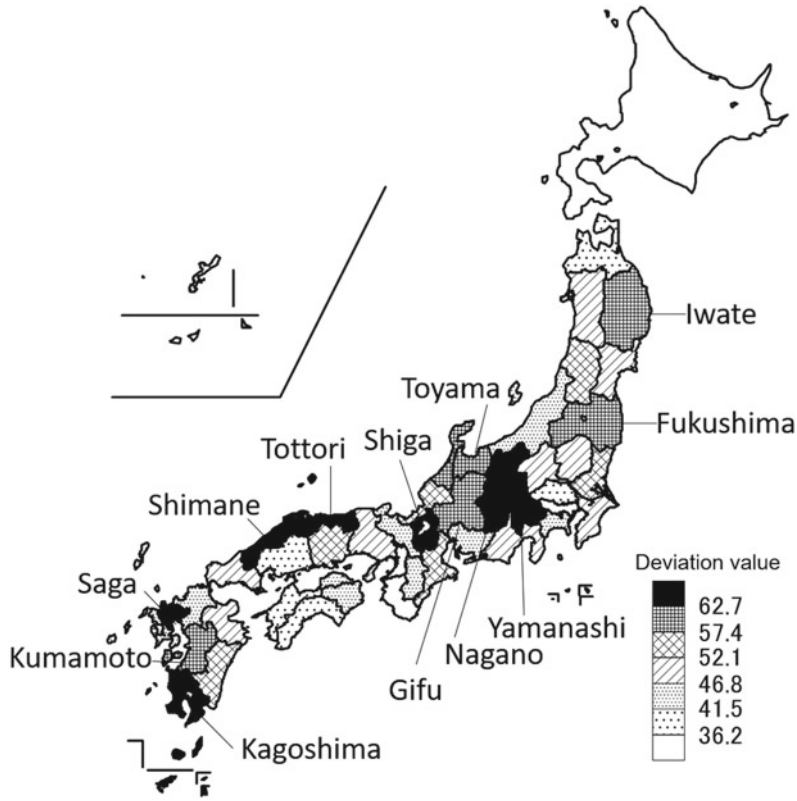

Fig. 1.3 Number of environmental volunteers by prefecture. *Data source* Survey on time use and leisure activities 2016

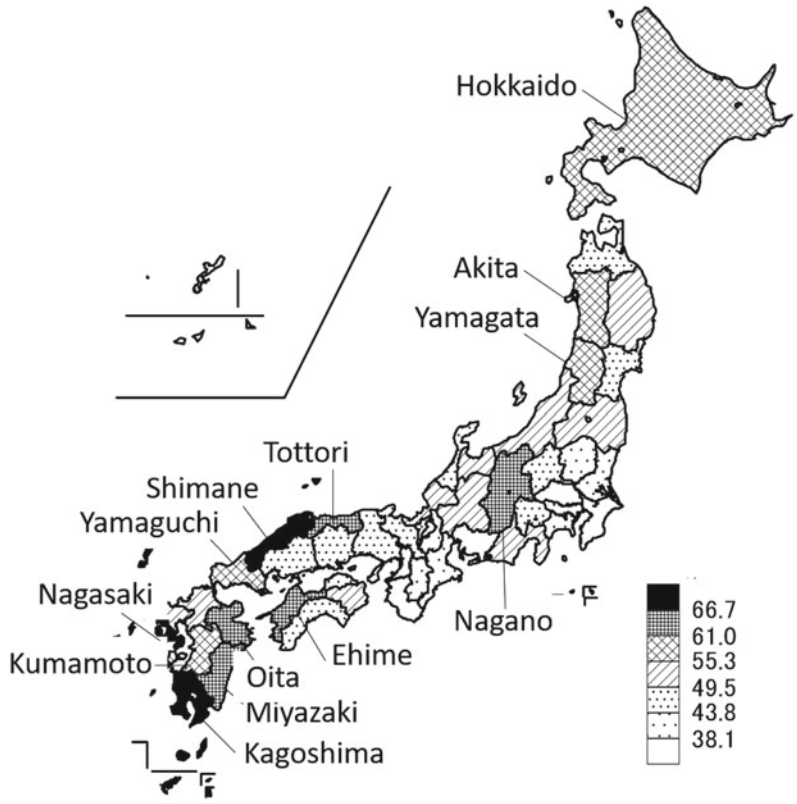

Fig. 1.4 Number of Japan overseas cooperation volunteers. *Data source* Japan International Cooperation Agency 2021

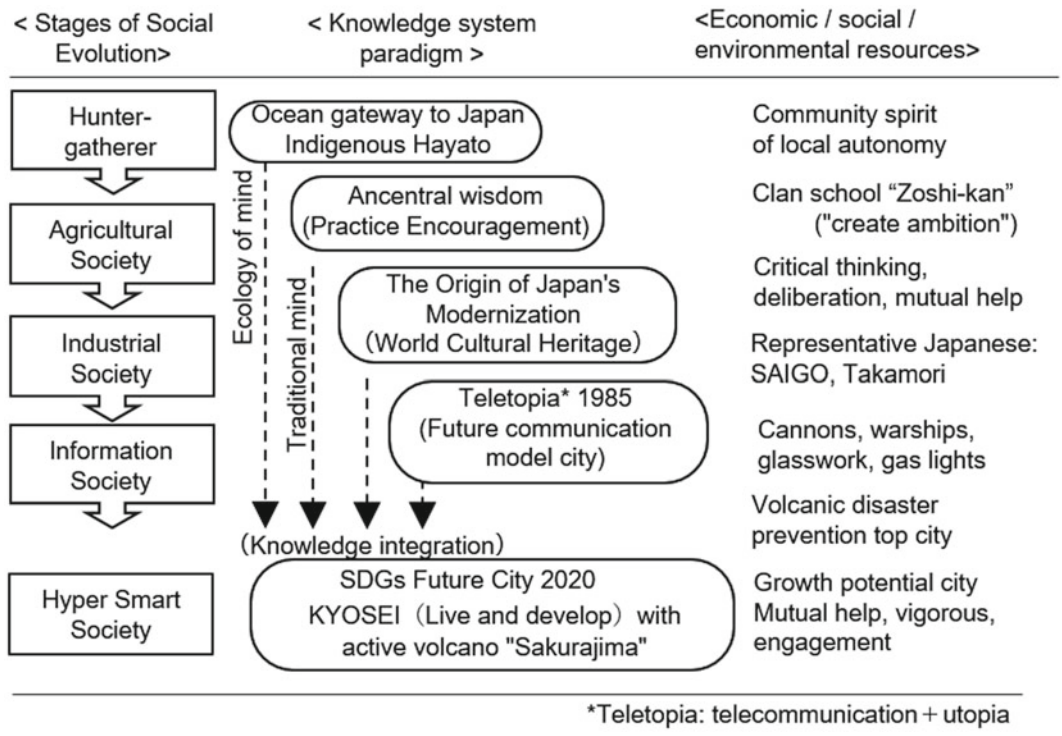

Fig. 1.5 Context-building process of Kagoshima area

and children from 6 to 25 years old were taught martial arts and scholarship by collaborative learning. Satsuma has developed modern technologies such as cannons, warships, glass crafts, and gas lamps and led the industrial revolution and modernization of Japan (World Heritage). Many social innovators such as Saigo, Takamori (1828–1877) and Okubo, Toshimichi (1830–1878) studied at Zoshikan. In recent years, these include Isamu Akasaki (1929–2021), who won the Nobel Prize. In 1985, when the information society began, Kagoshima was designated as a 'Teletopia' (telecommunication + utopia) by the Japanese government. They introduced early warning systems and emergency evacuation policies for volcano eruptions.

In 2020, Kagoshima was selected as a SDGs Future City by the Japan Government. The concept is to 'Kyosei' (coexist) and develop sustainably alongside with the active volcano Sakurajima. Today, Kagoshima is well established as a vital and potential area through civic engagement and mutual help. In Minamisatsuma City, the Jisshinko's 'karuta' (Japanese traditional card game) tournament event for children is held regularly.

1.8 Concluding Remarks

In this chapter, I have explained the theory of Sustainable Development Education (ESD) in community development and its practice in Japan. Goal 4 (quality education) can change people and change the innovative practices of Goal 11 (sustainable cities and communities). As the famous phrase 'Think globally and act locally' suggests, Goal 11 is responsible for creating an arena where people can practice the SDGs. For Goal 11, all 17 goals need to be subsumed within the local community and considered holistically. ESD enhances the interaction between an outside-in approach that motivates people from the transformation of the social

system and an inside-out approach that transforms society by recovering the ecology of mind from social memory and social consciousness. Historically accumulated knowledge is important for the formation of civic pride and the community of practice. In Asian countries and regions, cultural experience is layered in the history of the colony. The socioeconomic environment is becoming more complex, and a framework for temporal and spatial knowledge integration and context building will become increasingly important. International research and the practice of open innovation will be expected. However, knowledge of the effectiveness of education takes time, as clear socioeconomic evidence emerges. Open social innovation can support this effectively.

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2 Reconstruction Under Nuclear Disaster and Making Resilient Society in Fukushima

Shunji Matsuoka

Abstract

This chapter examines the "Balancing Reconstruction with Decommissioning" problem of reviving Fukushima from a double disaster called the Great East Japan Earthquake and the 1F (Fukushima Daiichi Nuclear Power Plant) nuclear disaster. This issue is a typical case of sustainability and resilience in the twenty-first century in the century of the disaster. First, this paper discusses that it is the reconstruction policy of the declining and aging population with the creative reconstruction in a century, the twenty-first century of the disaster in Japan. This paper then examines the reconstruction policy from the Great East Japan Earthquake and the way of the Fukushima nuclear accident processing before establishing "incompleteness of the nuclear crisis response and surplus of the Great Earthquake disaster reconstruction policy." Finally, this paper clarifies the difficulty of the issue called "Balancing Reconstruction with Decommissioning" in Fukushima based on the analysis of 1F decommissioning policy, and Fukushima lectures possibly falling into a state such as "Mutual Destruction of Reconstruction and Decommissioning" without altering 1F decommissioning governance. This chapter contributes to SDGs 11; Make cities and human settlements inclusive, safe, resilient and sustainable.

Keywords

Nuclear disaster · Fukushima · Resilience · Decommissioning · Creative reconstruction

2.1 The Reconstruction of Fukushima and the Decommissioning of the Fukushima Daiichi Nuclear Power Plant in the Post-Trans-Science Era

This chapter examines the "Balancing Reconstruction with Decommissioning" problem of reviving Fukushima from a double disaster called the Great East Japan Earthquake and the 1F (Fukushima Daiichi Nuclear Power Plant) nuclear disaster. This chapter contributes to SDGs 11; Make cities and human settlements inclusive, safe, resilient and sustainable.

2.1.1 The Trans-Science Era

In 1972, Alvin Weinberg, an American nuclear physicist, who participated in the Manhattan Project, published a paper entitled "Science and

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Trans-Science" in the social science journal *Minerva*. In the paper, he argued that societal risks such as serious nuclear power plant accidents and the health effects of low-level radiation were "questions which can be asked of science and yet cannot be answered by science" and proclaimed the arrival of the trans-science era (Weinberg 1972).

The Fukushima nuclear accident in March 2011 confronted Japanese society head-on with the risks posed by science and technology, and the trans-scientific era concept has since become widely recognized by risk researchers. Of course, there are various interpretations of how to think of the trans-scientific questions presented by Weinberg in specific terms.

However, be it risk directly related to science and technology, such as low-level radioactive contamination from a nuclear disaster or the scientific assessment of biological disaster risk given the COVID-19 pandemic, the twenty-first-century human society faces wide-ranging scientific and technological risks, including risks posed by the development of advanced science and technology in life science and artificial intelligence (AI). Many of these risks are "questions that can be asked of science, but cannot be answered by science."

Accordingly, a consensus was reached that risk-response measures in the trans-science era should not be decided by scientists living in the twentieth-century "Republic of Science" (Polanyi 1962) but instead through collaboration between science, politics, and society. Meanwhile, social understanding and acceptance of risk-response measures by science and government alone are low.

2.1.2 The Post-Trans-Scientific Era

In response to this trans-scientific era, the importance of participatory democracy and deliberative democracy has been emphasized in the second half of the twentieth and twenty-first centuries, and efforts to complement parliamentary democracy with new mini-publics, such as consensus conferences and debate polls (DP), have been trialed in many democratic societies (OECD 2020).

However, more than two decades into the twenty-first century today, it is challenging to conclude that approaches based on the democratization of knowledge, such as the French Committee for National Debate (CNDP)—which could be considered the epitome of deliberative democracy—consensus conferences originating from Denmark, and debate polls originating in the USA effectively create social consensus (Matsuoka et al. 2019).

In response to the discussion around the democratization of knowledge in the second half of the twentieth century, the British sociologist of science, Harry Collins, argued for the need for a "third wave of science" in scientific research. Collins offered the criticism that the more citizens participate in building a social consensus around science and technology risks, the better they create social failures given their lack of expertise, from which the question of who takes the responsibility emerges (Collins & Evans 2002).

The Japanese sociologist of science and technology, Miwao Matsumoto, also characterized the theory of democratization of knowledge in the age of trans-science as the "theory of monotonically increasing participation" and characterized the arguments of critics such as Collins as the "non-monotonic theory of participation" (Matsumoto 2009). Collins claims his theory has an advantage over other theories that invariably call for increased public participation in that he calls for increased participation at certain periods and decreased participation at others. There are well-known dangers involved in over-expanding the definition of expertise. He holds that the public can be wrong and that a distinction should be made between instances in which participation and deliberation should be promoted and instances in which expert decision-making is desirable.

In the twenty-first-century society, the time has come to move away from the trans-science era of "the more participation and deliberation

the better" to a post-trans-science era, which instead asks how social acceptability and social understanding should be fostered through the participation of which experts and which citizens to create what kind of "space" (Matsuoka 2020b, Matsuoka et al. 2021a, b).

2.1.3 The Reconstruction of Fukushima and Decommissioning of the Fukushima Daiichi Nuclear Power Plant as Post-Trans-Scientific Issues

The accident at the Fukushima Daiichi Nuclear Power Plant (herein referred to as 1F), triggered by the Great East Japan Earthquake on March 11, 2011, resulted in a Level 7 nuclear disaster on the International Nuclear and Radiological Event Scale (INES), the most severe classification of such disasters. More than 160,000 people were forced to evacuate because of the accident at 1F. Even now, more than a decade after the accident, 35,107 people continue to live as evacuees throughout Japan (survey by the Reconstruction Agency, as of June 9, 2021). The seven municipalities around 1F—Tomioka, Okuma, Futaba, Namie, Minami-soma, Iitate, and Katsurao—remain designated as areas challenging to return to, and it is thought that it will be many years before such designations are completely lifted[1].

In addition to the situation away from the offsite (outside 1F), the situation within the decommissioning on site (348.5 ha) also remains uncertain. The 1F decommissioning project aims "for the completion of decommissioning in 30–40 years" ("Medium and Long Term Roadmap," December 2019, p. 27) since the declaration in December 2011 that cold shutdown had been achieved. However, the planned removal of spent nuclear fuel from the cooling pools of Units 1 and 2 has been significantly delayed. The questions of how exactly to remove the fuel debris and how to store, manage, and dispose of the fuel debris remain issues for the future. Ten years have passed since the accident, and it will be challenging to finish the 1F decommissioning project within the next 20–30 years (Matsuoka 2021a, b).

In the "Medium to Long-Term Roadmap" that defines the current government's 1F decommissioning policy, revised for the fifth time in December 2019, the phrase "compatibility between reconstruction and decommissioning" was newly added as the first of four principles for the decommissioning of 1F (Matsuoka 2020a). It is noted that the new principle of the 1F decommissioning project, "compatibility between reconstruction and decommissioning," would ensure that the decommissioning of 1F would not hinder the reconstruction of surrounding areas in response to the progress of decontamination work in designated reconstruction and revitalization zones in Okuma Town and Futaba Town—the municipalities where 1F is located—and the partial lifting of the difficult-to-return zone.

However, the social significance of the new principle to the "Medium to Long-Term Roadmap" in December 2019 must be understood as the intention of the national and local governments to promote the return of residents to areas surrounding 1F and a strongly mutually prescribed relationship between reconstruction in Fukushima and the 1F decommissioning project. That is, the origin of the Fukushima reconstruction is the nuclear disaster from the 1F accident, and the completion of the Fukushima reconstruction will be the completion of the 1F decommissioning project. If the technical and social safety of the 1F reactors can be guaranteed, and the 1F decommissioning project can be concluded in a way acceptable to Fukushima and wider Japanese society, then Japanese society can also conclude the reconstruction of Fukushima.

Thus, when considering the new principle, the issues surrounding the reconstruction of Fukushima and the decommissioning of 1F are typical of post-trans-scientific questions, where

diverse experts and residents create a "forum (Ba) for dialog" and discuss various options, inducing the development of social conviction and social acceptance among a wide range of people. Meanwhile, it is an important social condition that the Hamadori community in Fukushima Prefecture, which has long depended on nuclear and coal-fired power plants, has not been involved in the trans-scientific problem-solving methods of participation and deliberation. Further, the national government, Fukushima Prefecture, and local governments in Fukushima Hamadori have relied exclusively on conventional methods such as holding explanatory meetings for local residents and have a little social capacity to create a "forum for dialog" between experts and residents.

This study defines reconstruction in Fukushima and the decommissioning of 1F as a post-trans-scientific issue. In the last decade of Fukushima reconstruction and 1F decommissioning projects, policy decisions and implementation have been reached solely via the conventional top-down approaches of briefing sessions and opinion-gathering, rather than a "forum for dialog" between diverse experts and residents to obtain solutions to post-trans-scientific issues. Thus, this study holds that it is essential to create a new social system via a "forum for dialog" between diverse experts and residents to respond to the post-trans-scientific issues that characterize the reconstruction in Fukushima and the decommissioning of 1F. From this perspective, the lack of progress in social innovation in creating this new social system may have increased the uncertainty and complexity of the Fukushima reconstruction and 1F decommissioning projects, further increasing their ambiguity.

Thus, to verify the hypothesis, this study focuses on the issue of discharge of Advanced Liquid Processing System (ALPS) treated water (tritiated water) into the ocean under the 1F decommissioning policy, the Fukushima Innovation Coast Framework, the international education and research base, and national projects that are key to the Fukushima reconstruction policy, a decade into its reconstruction and the decommissioning of 1F. This study employs the science-policy interface research framework to discuss the post-trans-scientific questions of why it is challenging to create social acceptance for the policy of discharging ALPS-treated water into the ocean, the Fukushima Innovation Coast Framework, and the international education and research base.

The rest of the paper is arranged as follows. Section 2.2 describes the science-policy interface research framework and the methodology used for this analysis. Section 2.3 analyzes the process of examining the issue of treated water (contaminated water) in the 1F decommissioning project using the science-policy interfaces research framework. This study considers expert and local knowledge in the process leading to the decision to discharge ALPS-treated water[2] into the ocean at the Inter-Ministerial Council for Contaminated Water, Treated Water and Decommissioning Issues on April 13, 2021, and why it has been challenging to create social acceptance for the policy to discharge treated water from 1F into the ocean. Section 2.4 analyzes the Fukushima Innovation Coast Framework (proposed as a national project central to the Fukushima reconstruction policy) and the international education and research base initiative, a hub for regional innovation. It discusses the difficulties of fostering social acceptance and understanding for the Fukushima Innovation Coast and the international education and research base initiatives. Finally, Sect. 2.5 discusses a model for creative reconstruction in the reconstruction in Fukushima as a post-trans-scientific question.

2.2 The Science-Policy Interface Research Framework

Science-policy interface research has developed around the question of how society should address science and technology risk issues characterized by uncertainty and complexity. Responding to such issues cannot be solved by

regular science; it requires a new approach, referred to as trans-science, (Weinberg 1972) or post-normal science (Funtowicz and Ravetz 1992). "Democratizing Knowledge Production" and "Creating Socially Robust Knowledge" through participation and deliberation have been considered important new approaches.

This study focuses on Spruijt et al. (2014) in the Netherlands, who summarizes science-policy interface research, and establishes its framework to analyze the Fukushima reconstruction and 1F decommissioning projects. Spruijt et al. (2014) conduct a meta-analysis by collecting 267 articles, reports, books, and other research findings on the role of expert knowledge in the formation of policy to address uncertain and complex issues across diverse academic disciplines over a decade, spanning 2003–2012. Two important implications for studies on Fukushima reconstruction and 1F decommissioning based on Spruijt et al. (2014) science-policy interface research framework are as follows.

2.2.1 Unknown Unknowns: The Limits of Expertise

There are limitations to expert knowledge from specialist fields used to address complex and ambiguous risk issues, such as nuclear disasters (i.e., "unknown unknowns"; issues we do not know about) (Wynne 1992).

Thus, it is important to design interdisciplinary expert groups to overcome the limitations of expert knowledge posed by unknown unknowns. There is a need to include experts with different positions and views even within the same field of expertise and actively utilize technical experts and social science experts to address the social aspects of risk based on the characteristics of the risks in question.

However, the collaboration between various forms of specialized knowledge alone is insufficient to overcome the limitations of unknown unknowns: The formation of socially robust knowledge through collaboration between specialized knowledge and local knowledge is required.

2.2.2 Designing a "Forum" for Collaboration Between Expert Knowledge and Local Knowledge

The democratization of knowledge creation through participation by diverse citizens, including stakeholder discussions, the formation of epistemic communities, and participation and deliberation processes, is necessary to form socially robust knowledge.

The mode of collaboration between expert and local knowledge is the key to forming socially robust knowledge. Moreover, it is important to design a "forum" that can broadly, deeply, and practically incorporate diverse stakeholders and citizens into the expert and local knowledge collaboration.

Notably, given the nature of the field of research, the conventional science-policy interface research framework mainly focuses on specialized knowledge and experts as a research framework for trans-scientific (not post-trans-scientific) questions. Therefore, there are limits for government and authoritative persons who use specialized knowledge.

The main user of expert knowledge in policy formation is, in general, the government (administration). The government presides over the "forum" (e.g., expert committee), the experts comprising the members of the "forum" are selected per the government's decision criteria, and the government sets the rules of the "forum." The influence of experts on the design of the "forum" is in many cases limited. For more information on the theory of "forums," see Chap. 9 of Matsuoka 2018a, b.

Similarly, although the design of participation and deliberation processes, such as stakeholder discussions and civil dialog, may be based on laws and social norms, the specific design of the "forum" for participation and deliberation is often a matter for the government that presides over the forum. Of course, the government cannot freely design the "forum" either. The government designs a "forum" subject to external and internal factors and constraints, such as

political, economic, and social power relations; organizational capabilities such as financial and human resources, authority, specialized knowledge, and information possessed by the government (administration); and the ethical viewpoint of its organizational culture.

The current mode of "reconstruction knowledge" in the Fukushima reconstruction and "decommissioning knowledge" in the 1F decommissioning project (Matsuoka 2019a, b) is determined by the diverse relationships among experts from various fields in the reconstruction, the government, and relevant factors such as politics, economy and society, and local community residents.

2.3 Why is It Challenging to Create Social Acceptance for the Release of ALPS-Treated Water into the Ocean?

2.3.1 The Spill of Contaminated Water from 1F into the Ocean in August 2013

First, the study probes into the August 2013 incident involving the leakage of contaminated water into the ocean, which became a major turning point in the 1F contamination problem.

"According to TEPCO and others, the starting point was at around 9:50 a.m. On March 19, an employee on patrol discovered water flowing from two drainage valves on the reinforced concrete cisterns installed under the tanks to prevent water leakage in the event of a leak. On the outside of the barrier, two puddles of water were found, three meters length by three meters width by one centimeter in depth" (*Nihon Keizai Shimbun*, August 20, 2013). Subsequent investigations by the Nuclear Regulation Authority (NRA) and others confirmed that approximately 300 tons of contaminated water containing highly radioactive materials from the accident at the 1F had leaked from above-ground tanks on the 1F site and flowed directly out into the ocean outside the power plant port via drainage channels and other means. It resulted in the leakage of approximately 24 trillion becquerels of radioactive material (*Asahi Shimbun*, August 23, 2013).

The NRA had initially assessed the accident as Level 1 on the INES but revised its assessment to Level 3 (Serious Incident) on August 28, 2013 (Japan Nuclear Regulation Authority, 2013). The NRA's on-site inspection also revealed that TEPCO had not kept records of its twice-daily tank inspections, including the time spent on patrol and radiation levels. Moreover, Toyoshi Fuketa, then a member of the NRA, who inspected the site, criticized TEPCO's response in harsh terms, saying, "The inspections can only be called sloppy" (*Nihon Keizai Shimbun*, August 24, 2013).

Even before the leak (outside the harbor) on August 19, 2013, approximately 11,000 tons of highly contaminated water from the immediate aftermath of the accident on March 11, 2011, had flowed into the tunnels beneath the buildings of Units 1, 2, and 3 at 1F. A massive 1000 tons a day of groundwater flowed in from the mountainside, and about 300 tons of radioactive water leaked into the ocean daily (inside the harbor) through cracks in the concrete of the tunnels and other structures (*Asahi Shimbun*, August 3, 2013). Figure 2.1 shows an outline of the leak of contaminated water from 1F.

What is more serious is that TEPCO did not confirm the leakage of contaminated water until July 18, 2013, even though radioactive materials had been detected in the ground on the ocean-facing side of the building in late May 2013, and there were strong suspicions of leakage of contaminated water into the ocean given the inflow of underground water. Furthermore, on July 19, 2013, TEPCO's then-President, Naomi Hirose, instructed local fishermen's cooperatives to contact them about the contaminated water leaking into the ocean, but TEPCO did not disclose the information until its regular press conference in the evening of July 22, 2013 (*Asahi Shimbun*, July 29, 2013).

Toshimitsu Mogi, then Minister of Economy, Trade and Industry, visited the site on August 26, 2013, and said, "Contaminated water countermeasures are an important issue that cannot be separated from efforts to decommission

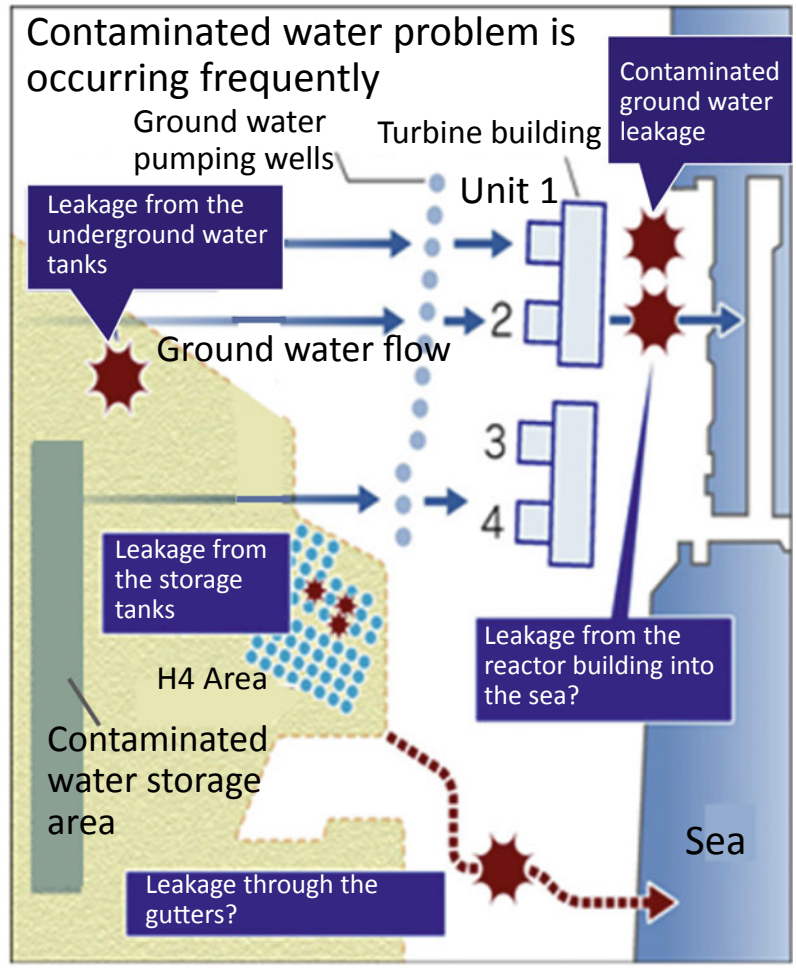

Fig. 2.1 Leakage of contaminated water from 1F into the ocean. *Source Nihon Keizai Shimbun*, August 27, 2013

Fukushima Daiichi. It will be challenging to solve the problem if it is left to TEPCO" (*Nihon Keizai Shimbun*, August 27, 2013). The Minister announced that the government would consider bringing forward the installation of a frozen soil wall using fiscal 2013 reserve funds, emphasizing the government's stance of taking the lead in dealing with the contaminated water.

In response to this situation, the Soma-Futaba Fishery Cooperative in Soma City, Fukushima Prefecture, which had been conducting trial operations since June 2012, decided to suspend those trial operations from September 1, 2013. Further, the Iwaki City Fishery Cooperative in southern Fukushima Prefecture was forced to postpone trial operations, scheduled to resume for the first time since the accident at 1F beyond September 2013. The fishermen voiced their dismay, saying that "all the hard work we have done so far has gone down the drain," and there were concerns about the impact on the local economy—the fishing and tourism industry—and the entire Fukushima reconstruction process (*Nihon Keizai Shimbun*, August 23, 2013).

The accidental discharge of contaminated water from 1F into the ocean in the summer of 2013 was widely reported overseas. In South Korea, there were calls for a total ban on the import of Japanese marine products (*Asahi Shimbun*, August 30, 2013), and the South Korean government subsequently imposed a ban on the import of marine products from

Fukushima and eight other prefectures from September 9, 2013 (*Nihon Keizai Shimbun*, September 7, 2013).

Furthermore, to bid for the Tokyo Olympics, then Prime Minister Shinzo Abe was forced to announce at the International Olympic Committee General Assembly in September 2013 that the Japanese government would take responsibility for dealing with the contaminated water problem (*Nihon Keizai Shimbun*, September 8, 2013).

2.3.2 Tritium Water Task Force

Following the accidental discharge of contaminated water into the sea on August 19, 2013, the Japanese government formulated the "Basic Policy for the Contaminated Water Issue" at the Nuclear Emergency Response Headquarters on September 3, 2013. In this "basic policy," the government took the lead in fundamentally solving the worsening contaminated water problem, rather than leaving it to the Tokyo Electric Power Company (TEPCO). To strengthen the system, the government established the "Inter-Ministerial Council for Contaminated Water, Treated Water and Decommissioning Issues (2019)" to actively utilize the expert knowledge of the Committee for Contaminated Water Treatment.

The committee was established on April 26, 2013, comprising 16 members: five members from universities; four from national research institutes, such as the Japan Atomic Energy Agency (JAEA); three from private companies, such as Toshiba; two from TEPCO; one from METI; and one from the NRA. Most of the committee members are technical and engineering experts involved with nuclear power.

The Task Force for the Landside Water Barrier (July 1, 2013, to November 8, 2018), the Task Force for the High-Performance Multi-Nuclide Species Removal Facility (November 29, 2013, to March 30, 2015), and the Tritiated Water Task Force (December 25, 2013, to June 3, 2016) were established under the Committee for Contaminated Water Treatment.

The Tritiated Water Task Force, the starting point in developing the policy of releasing treated water into the ocean, was established on December 25, 2013. It was headed by Kazuyoshi Yamamoto (Nuclear Engineering, Nagoya University), a member of the Committee for Contaminated Water Treatment, and comprised ten members: six from research institutes such as the JAEA (one from the medical and one from the fisheries chemistry fields), one from a university (biological science), one from a cooperative (Fukushima Co-op), and one from the Nuclear Regulation Authority.

The Tritiated Water Task Force held a total of 15 meetings during a two and a half year-long study period (the final meeting was held on May 27, 2016), and the "Tritiated Water Task Force Report" (hereinafter the "Tritiated Water TF Report") was published on June 3, 2016, concluding its role.

The "Tritium Water TF Report" was positioned as a "basic document" for deciding policy for the long-term handling of water treated using ALPS (tritiated water) and contained a technical evaluation of various options. A "proviso" was also added to the "Tritiated Water TF Report," stating that it was not intended to coordinate opinions among the parties concerned or unify options.

The "Tritium Water TF Report" establishes cases for evaluation based on uniform conditions and conducts a technical evaluation of 11 options (policy options) involving the combination of five methods of disposal (i.e., geosphere injection, offshore release, vapor release, hydrogen release, and underground burial) and their methods of pretreatment. Table 2.1 shows the results of the technical evaluation in the "Tritium Water TF Report" per period (months) and disposal cost (yen, hundreds of millions) required to complete the disposal (see Appendix 2 for a list of results for each evaluation case in the "Tritium Water TF Report"). From Table 2.1, the results strongly suggest offshore release strategy to be the best option in time and cost.

The "Conclusion" of the "Tritiated Water TF Report" states the following:

Table 2.1 Technical evaluation of tritiated water treatment options

Methods of disposal	Required time (Month)	Cost (¥ billion)
Geosphere injection	69 ~ 156	11.7 ~ 397.6
Offshore release	52 ~ 88	1.7 ~ 3.4
Vapor release	75 ~ 115	22.7 ~ 34.9
Hydrogen release	68 ~ 101	60.0 ~ 100.0
Underground burial	62 ~ 98	74.5 ~ 253.0

Source METI 2016

"This report is a compilation of the matters, including reports from experts (Reference Materials 1–18), that were deliberated under the Tritiated Water Task Force over a total of 15 meetings from December 25, 2013–May 27, 2016, and it discusses the contaminated water issues at Fukushima Daiichi NPS, in particular the handling of tritiated water, from a technical perspective. It is hoped that this report will serve as basic data for future discussions. Also, since handling tritiated water can largely influence rumors, it is hoped that future discussions about handling tritiated water will be advanced in a comprehensive manner, touching upon both technical perspectives, such as feasibility, economic efficiency, and duration, as well as social perspectives, such as damage caused by rumors." (Tritiated Water TF Report, p. 13).

In response to the suggestion in the Tritium Water TF Report that "it is hoped that future discussions about handling tritiated water will be advanced in a comprehensive manner, touching upon both technical perspectives, such as feasibility, economic efficiency, and duration, as well as social perspectives, such as damage caused by rumors," the Subcommittee on the Handling of ALPS-treated water (ALPS Subcommittee) was established on November 11, 2016, under the Committee on Countermeasures for Contaminated Water Treatment.

2.3.3 The ALPS Subcommittee

Kazuyoshi Yamamoto (Nagoya University, Nuclear Engineering), the lead investigator of the Tritiated Water Task Force, chaired the ALPS Subcommittee, comprising 14 members: five university staff (including experts in sociology and agricultural economics), five members from research institutes, one member from a nonprofit organization (NPO), one member from a consumer group, and one from a business operator (TEPCO). The ALPS Subcommittee is highly regarded from a science-policy interfaces research framework perspective in that it comprises experts from interdisciplinary and diverse fields, including experts in social sciences such as sociology and agricultural economics and members from NPOs and consumer groups. However, in terms of the inclusion of experts with different positions within their fields of expertise, the government (METI), which effectively presided over the "forum," did not seem to have criteria for selecting committee members, and experts uncritical of government policies were generally selected.

The ALPS Subcommittee met twice in 2016, four times in 2017, six times in 2018, four times in 2019, and once (the final meeting) in 2020. On February 10, 2020, The ALPS Subcommittee Report was released, concluding the subcommittee's role.

Notably, ALPS Subcommittee held explanatory and public hearing meetings (hereinafter "Briefing and Public Hearing") on August 30 and 31, 2018, in Tomioka Town, Fukushima Prefecture, Koriyama City, Fukushima Prefecture, and Chiyoda Ward, Tokyo.

Opinions were heard from 44 people at the three venues (14 at Tomioka, 14 at Koriyama, and 16 at Tokyo), and 274 people participated (101 at Tomioka, 88 at Koriyama, and 85 at Tokyo). Meanwhile, a call for written comments was made; 135 comments were submitted over 39 days (METI, 2018, p. 2).

In the explanatory and public hearing meetings held at the three venues, participants expressed extreme concern and opposition to the idea proposed by the Tritium Water TF Report that the offshore release of treated water would be the most efficient countermeasure in terms of time and cost. Regarding the four other policy options in the "Tritiated Water TF Report" besides oceanic release (geosphere injection, vapor release, hydrogen release, and underground burial), concerns about adverse effects on the environment (vapor release, hydrogen release) and the monitoring challenge (geosphere injection and underground burial) were also raised. As an alternative to the five countermeasure options in the Tritium Water TF Report, the audience proposed long-term above-ground storage in large tanks such as oil storage tanks.

The author attended the explanatory and public hearing meeting held at the Tokyo venue on the afternoon of August 31, 2018, attended by many activists from nuclear opposition groups and other organizations, including those who gave their opinions. The atmosphere was noisy, with those who expressed their opinions doing so in a one-sided manner, with heckles and angry shouts flying across the venue. In the deliberative process, participants must discuss the issues calmly to confirm the basis for and dissimilarity of their respective claims and encourage the discovery of new approaches to the issues. The formation of socially robust knowledge and the democratization approach to knowledge production, as proposed by the science-policy interfaces research framework, is also premised on the formation of a "forum for dialog." However, it was not the case at the explanatory and public hearing meetings.

As their name would suggest, the explanatory and public hearing meetings in August 2018 may initially have been intended to be a two-way communication between the ALPS Subcommittee, providing an explanation to the public as the public gave their opinions, which is a departure from the traditional method of public hearings where only the opinions of selected residents are heard. Thus, one can appreciate that it could potentially be an ambitious initiative. Ultimately, it did not become a "forum for dialog."

As the presiding body, the government seems to lack a consistent stance in designing the "explanatory and public hearings" as "forums for dialog." Thus, a "forum for dialog" between the government, experts, and citizens and residents was never formed, despite opponents of nuclear power plants. Further, the process was half-hearted, consisting only of conventional explanations and public hearings by the government and experts.

Subsequently, the ALPS Subcommittee held its final seventeenth committee meeting on January 31, 2020, and released the ALPS Subcommittee Report on February 10, 2020.

The report concluded that the most realistic options among the five methods of disposal presented in the "Tritiated Water TF Report" by the Tritiated Water Task Force in June 2016 (i.e., geosphere injection, offshore release, vapor release, hydrogen release, and underground burial) would be vapor release or offshore release. The report also compares the merits and demerits of vapor release and offshore release, noting that the vapor release measure has no Japanese precedent, monitoring may be destabilized by factors such as weather conditions, and the influence of rumors may be wider reaching than offshore release. Although the ALPS Subcommittee Report does not draw any conclusion, it strongly suggests offshore release to be a more realistic and reliable option than vapor release and can be said to have, in practice, proposed offshore release.

2.3.4 The Offshore Release of ALPS-Treated Water as a Post-Trans-Scientific Issue

Considering the formation of socially robust knowledge and democratization of knowledge proposed by the science-policy interface research framework in depth and the issue of the offshore release of ALPS-treated water as a post-trans-scientific issue, the first point to be considered is

the adoption of the two-stage approach between the Tritium Water Task Force and the ALPS Subcommittee. Moreover, the second point is that for the duration (more than six years) of the study process, from December 2013 to February 2020, except for explanatory and public hearing meetings by the ALPS Subcommittee in August 2018, an investigation was conducted, exclusively drawing on limited expert knowledge.

What the government presiding over the "forum" envisaged was a government-led policy-making scenario. In the first stage, the Tritiated Water Task Force would present countermeasure options from a technical perspective, followed by a second stage in which the ALPS Subcommittee would examine social angles, such as rumors, narrowing down the options via dialog with citizens and local residents.

The government may have contemplated this two-stage approach to ensure the legitimacy of a key policy in decommissioning 1F (i.e., the offshore release of ALPS-treated water legitimacy), which has uncertainty, complexity, and ambiguity risk characteristics. Was it not the case, however, that the formation of diverse options needed to be implemented as a knowledge production that democratizes the process of forming socially robust knowledge?

It is also highly puzzling that the above-ground storage tank option was excluded from the Tritiated Water Task Force's considerations from the outset. In the debate surrounding the management and disposal of high-level radioactive waste, long-term above-ground storage is a well-known policy option grounded in the principle of reversibility, which guarantees the right of future generations to make policy decisions (Matsuoka et al. 2019). For tritium (half-life: 12 years), with a much shorter half-life than highly radioactive neptunium-237 (half-life: 2.14 million years) and zirconium-93 (half-life: 1.53 million years), above-ground storage is a realistic policy option.

In any case, the activities of the ALPS Subcommittee, premised on the five vaguely credible policy option assessments of the Tritiated Water Task Force, can only be called a failure of the premise. It is also natural that the explanatory and public hearing meetings held by the ALPS Subcommittee based on this Tritium Water TF Report did not result in the formation of socially robust knowledge.

The tragedy of the ALPS Subcommittee, whose discussions were based on the questionably reliable "Tritium Water TF Report" and held explanatory and public hearing meetings, can be attributed to the fact that it separated technical considerations of potential countermeasures from social considerations in the first place.

Regarding the formation of socially robust knowledge proposed by the science-policy interfaces research framework and the ultimate democratizing approach to knowledge production, technical and social aspects must not be separated when considering options. It is only by cooperation between technical and social expertise and between technical and social expertise and the local knowledge possessed by the local community that the formation of socially robust knowledge (i.e., reconstruction and decommissioning knowledge) becomes possible.

2.3.5 April 13, 2021: The Government Decision to Release ALPS-Treated Water Offshore

Given that the ALPS Subcommittee Report was published on February 10, 2020, the government proceeded with discussions with relevant local organizations in Fukushima, focusing on measures for offshore release. The government held meetings to gather the opinions of concerned parties seven times in Fukushima Prefecture and Tokyo and heard opinions and solicited written opinions from 43 people from 29 organizations, including Fukushima Prefecture, local municipalities, neighboring Miyagi Prefecture, Ibaraki Prefecture, other local governments; agriculture, forestry, and fisheries businesses, consumer groups; and economic organizations. Moreover, the municipalities of Okuma and Futaba, on which the site of 1F is located, and the Liberal Democratic Party's Headquarters for Accelerating Reconstruction After the Great East Japan Earthquake, petitioned the government for an

early decision on the policy for the disposal of the treated water.

However, given the Act on Special Measures against COVID-19, which was enacted in response to its spread from early spring 2020 (enacted March 13, 2020), the decision to postpone the Tokyo Olympics for one year (March 24, 2020), the declaration of a state of emergency, and the transition from the Abe administration to the Suga administration, the official decision by the government to release the ALPS-treated water offshore was repeatedly postponed.

Finally, on April 13, 2021, the Japanese government decided at the Inter-Ministerial Council for Contaminated Water, Treated Water and Decommissioning Issues to release the ALPS-treated water in offshore, given the increasing amount of contaminated water and the fact that the storage tanks will reach capacity circa autumn 2022. At the Inter-Ministerial Council for Contaminated Water, Treated Water and Decommissioning issues, Prime Minister Suga said: "How to dispose of treated water is an issue we cannot avoid while proceeding with the decommissioning of the Fukushima No. 1 nuclear plant. The government will ensure the safety of the water to a level that goes well within the standards and take thorough measures to address potential damage from negative rumors about local products." (*Asahi Shimbun*, April 13, 2021).

In light of the official decision on April 13, 2021, the Japanese government established the "Inter-Ministerial Meeting for the Implementation of the Basic Policy on the Disposal of ALPS-Treated Water" (meeting for the first time on April 16, 2021) and established the "Inter-Ministerial Meeting Working Group for the Implementation of the Basic Policy on the Disposal of ALPS-Treated Water" to exchange opinions with various stakeholders, including the Japanese government, TEPCO, Fukushima Prefecture, Miyagi Prefecture, and Ibaraki Prefecture. This working group met for the first time on May 31, 2021, and held its sixth meeting on July 9, 2021. The METI Agency for Natural Resources and Energy also established the Office of Support for Responding to Damage from Treated Water on April 27, 2021, and established a system to support the implementation of prompt and proportionate compensation for damage caused by harmful rumors[3].

Controlled concentrations and quantities of tritiated water have been released from nuclear power and reprocessing plants in Japan and worldwide. The Japanese standard for tritiated water discharge is 60,000 Bq (becquerel) per liter. According to the plan for the offshore release of ALPS-treated water from 1F, the ALPS-treated water will be diluted approximately 100 times with seawater to achieve the same standard as the operational target discharge concentration of 1500 Bq per liter of water discharged from the sub-drains of 1F (wells for pumping groundwater near the main structure, installed to prevent groundwater from entering the damaged reactors). The offshore release of ALPS-treated water will begin in 2023. About $140m^3$ of contaminated water is still generated daily at 1F (as of 2020), and a total of $1{,}265{,}060m^3$ (as of June 17, 2021, TEPCO website) of treated water (71% of which is not yet fully treated) is stored in tanks, amounting to approximately 900 trillion becquerels of tritium (*Asahi Shimbun*, April 13, 2021).

The April 13, 2021, decision document (Outline of the Basic Policy on Handling of the ALPS-treated water [at TEPCO Fukushima Daiichi Nuclear Power Station]) states that offshore release will be conducted at a level lower than the annual total of 22 trillion becquerels, the operating target for tritiated water discharge prior to the accident at 1F. It is a method of discharge to manage the impact of rumors as much as possible. Assuming the total annual offshore release of tritium to be 22 trillion becquerels, 900 trillion Bq ÷ 22 trillion Bq/year = 40.9 years. Assuming there is no increase from the current total tritium level of 900 trillion becquerels, it would take approximately 41 years to release all the ALPS-treated water currently held into the ocean. Assuming offshore release begins in 2023, it will end in 2064.

The "Medium to Long-Term Roadmap," which defines the basics of the 1F decommissioning policy, has consistently set "a goal of

completing decommissioning in 30–40 years" since the announcement that cold shutdown had been achieved in December 2011. Ten years have passed since 2011, and if we assume a goal of completion after another 30 years, the goal is to complete the decommissioning of 1F by the end of 2051. The decision to release the ALPS-treated water into the ocean to advance the project to decommission 1F requires an additional decade beyond the 2051 target to complete the 1F decommissioning project.

2.4 Why is It Challenging to Foster Social Acceptance of the Fukushima Innovation Coast and the International Education and Research Hub Initiatives?

2.4.1 Low Awareness of the Fukushima Innovation Coast Framework Among Fukushima Citizens

The national government formulated the Fukushima Innovation Coast Framework as a national project, central to the Fukushima reconstruction policy, and plans to open an international education and research base in 2024 that will assume a commanding role therein. This section focuses on the Fukushima Innovation Coast Framework, and the international education and research base and considers the reconstruction of Fukushima as a post-trans-scientific question.

The Fukushima Innovation Coast Framework is "a national project designed to build a new industrial infrastructure in the coastal region of Fukushima Prefecture to recover the industries that were lost there given the earthquake and tsunami on March 11, 2011, and the nuclear disaster." (Fukushima Prefecture, Fukushima Innovation Coast Framework Promotion Office 2020). The main project focuses on promoting the buildup of advanced industries in eight fields: decommissioning, robotics, drone technology, energy, environment and recycling, agroforestry and fisheries, medical care, and aerospace.

The Fukushima Innovation Coast Framework originated from the Fukushima International Research and Industrial City Study Group (Akaba Study Group, chaired by Kazuyoshi Akaba, Vice Minister of Economy, Trade, and Industry and Director General of the Local Nuclear Emergency Response Headquarters). It was established in January 2014 and compiled the "Fukushima International Research and Industrial City (Innovation Coast) Framework Study Group Report" (hereinafter the "Akaba Study Group Report") in June 2014.

This "Akaba Study Group Report" formed the basis for the Fukushima Innovation Coast Framework, which was positioned in the government's "Framework Policy 2014" and requested for inclusion in the FY2015 budget, solidifying it as a national project within Fukushima reconstruction policy. The Fukushima Innovation Coast Framework was subsequently given legal status through the May 2017 revision of the Act on Special Measures for the Reconstruction and Revitalization of Fukushima. Moreover, the government established the Ministerial Council on the Fukushima Innovation Coast Scheme in July 2017. In the same month, the Fukushima Innovation Coast Framework Promotion Organization was established as the implementing organization, thereby establishing the promotion system as a national project.

However, the level of recognition of the Fukushima Innovation Coast Framework among the people of Fukushima prefecture is low. For the first time, the 2019 edition of the annual Fukushima Prefectural Government Public Opinion Survey asked about Fukushima residents' awareness of the Fukushima Innovation Coast Framework directly using a questionnaire (Fukushima Prefecture 2019). The results showed that 46.3% of the respondents "do not know either the name or the contents" of the Fukushima Innovation Coast Framework, and 37.1% "have heard of the name but do not know much about the contents" of the Fukushima Innovation Coast Framework (Fukushima Prefecture 2019, p. 17).

In fact, 83.4% of Fukushima Prefecture residents either do not know the name of the Fukushima Innovation Coast Framework or had heard of it but did not know what it is, which is a shocking result for a national project. Perhaps because the impact of the 2019 prefectural government opinion survey was significant, the 2020 prefectural government opinion survey did not include a questionnaire item asking about the level of awareness of the Fukushima Innovation Coast Framework among Fukushima residents (Fukushima Prefecture 2020).

Beyond the people of Fukushima Prefecture having a low awareness of the Fukushima Innovation Coast Framework national project, it is also challenging to explain the logic of the initiative to those involved in the reconstruction of Fukushima.

2.4.2 Creation of Regional Innovation and the International Education and Research

The creation of innovation requires the effective functioning of two processes: a knowledge creation process to create new ideas and a resource mobilization process to give form to such ideas in society and the market (Matsuoka 2018a, b). In particular, the existence of "knowledge hubs" such as universities and research institutes, which play the role of "forums" for knowledge creation, is important for regional innovation.

Typical examples include Stanford University (founded in 1891) in Silicon Valley, California; MIT (Massachusetts Institute of Technology, founded in 1865) and Harvard University (founded in 1636) on Route 128 in Boston, Massachusetts; North Carolina State University (founded in 1888); University of North Carolina at Chapel Hill (founded in 1789); and Duke University (founded in 1924) in the Research Triangle Park (RTP, founded in 1959), North Carolina.

Boston, in the eastern USA, is significantly different from Fukushima Hamadori in history and culture to allow for comparison. Silicon Valley in California also has a history of active industrial development through Stanford University and other institutions since before World War II and is now home to global companies such as Apple and Intel, bearing little comparison with Fukushima.

RTP in North Carolina, developed in the southern part of the USA, may provide some reference for the Fukushima Innovation Coast Framework. RTP was established in 1959 by the Research Triangle Foundation, comprising North Carolina State University, the University of North Carolina at Chapel Hill, Duke University, state and local governments, and private companies. Today, 300 companies, including IBM and Cisco Systems, are concentrated within the 28Km^2 site, employing 55,000 people[4].

These business agglomerations and concentrations of creative talent (Florida 2008) include two of the nation's most prestigious universities, having produced several Nobel Prize winners: the University of North Carolina at Chapel Hill, founded in 1789, and Duke University, founded in 1924 by the Duke family, who made their fortune in the tobacco industry[5].

The challenge and incomprehensibility of the Fukushima Innovation Coast Framework are that it prioritizes a policy of attracting companies in the form of the agglomeration of advanced industries in eight fields, decommissioning, robotics, drone technology, energy, environment and recycling, agriculture, forestry and fisheries, medical care, and aerospace. The creation of the "forum" for the knowledge generation essential to the agglomeration of these advanced industries is discussed later in this paper.

On December 18, the National Reconstruction Promotion Council (2020) (chaired by Prime Minister Yoshihide Suga) established an international education and research base in the disaster-stricken area of Fukushima Hamadori as a new "knowledge hub" that plays a commanding role in the Fukushima Innovation Coast Framework (definite plan).

According to the government's definite plan, the international education and research base will serve as a "key center for creative reconstruction" in the Fukushima Hamadori area, which suffered extensive damage from the nuclear

disaster. It will assemble wisdom from within Japan and abroad to develop the talent essential for creative reconstruction, including environmental restoration and the creation of new industries.

Further, as the international responsibility of disaster-affected countries, it will disseminate and share experiences and achievements with the world, using the strength and knowledge gained to strengthen Japan's industrial competitiveness and generate innovations to solve issues shared by Japan and the rest of the world (Reconstruction Agency, 2020, p. 1). Five specific research fields are being examined: robotics, agriculture, forestry and fisheries, energy, radiation science, and the accumulation and dissemination of data and knowledge on nuclear disasters.

Incidentally, the *Mainichi Shimbun* (March 7, 2021) published an article titled "10 years after the Great East Japan Earthquake, townspeople are cold to the innovation initiative." The article describes a study session on the international education and research base held by the Reconstruction Agency at the Namie Town Chamber of Commerce and Industry on January 18, 2021. The Reconstruction Agency explained that the international education and research base would "include about 600 researchers and aim to create 5000 jobs, including [jobs] in the surrounding areas," and "there are precedents such as Tsukuba, which has 10,000 researchers."

Meanwhile, a Namie resident in attendance embodied the cold response of local residents, saying, "It's pie in the sky. Everyone's puzzled." The report introduces earnest voices from those involved in the Namie Town Chamber of Commerce and Industry, saying, "There is a definite gap between the reconstruction sought by the townspeople and that envisioned by the town, the prefecture and the national government," and "We are told that it will take many years to turn Namie Town into an advanced industrial city, but we need to survive today... it has been 10 years since the earthquake."

The international education and research base, established as a national research and development (R&D) agency in the nuclear disaster-stricken area of Fukushima Hamadori, is scheduled to partially (fully) open in 2023(2024). What should be considered carefully here is that it takes at least 30 to 40 years for the societal effects of "knowledge hubs" such as universities and research institutes to manifest, as in the case of Silicon Valley in California and RTP in North Carolina; such a turnover does not happen overnight.

Diverse creative human resources and a network of human relationships are formed over time, resulting in the buildup of rich social relationship capital, characterized by trust, reciprocity, and networks. A "knowledge ecosystem" in the local community is formed by accumulating rich social relationship capital within the local community, driving the knowledge creation and resource mobilization processes required for regional innovation.

2.4.3 The 2014 Akaba Research Group and Fukushima Reconstruction as a Post-Trans-Scientific Question

This segment considers the reconstruction of Fukushima as a post-trans-scientific question by reflecting on the discussions of the 2014 Akaba Study Group, the starting point of the Fukushima Innovation Coast Framework, and the international education and research base.

On January 21, 2014, the first meeting of the Fukushima International Industrial City (Innovation Coast) Framework Study Group was held, chaired by Kazuyoshi Akaba, then Vice Minister of Economy, Trade and Industry and Head of the Nuclear Emergency Response Headquarters. The study group comprised 21 members, including officials from the national government, such as the METI, the Reconstruction Agency, the Ministry of the Environment, and the Ministry of Agriculture, Forestry and Fisheries. It also comprised officials from local municipalities, such as Fukushima Prefecture, Iwaki City, Futaba District Town and Village Association, Soma District Town and Village Association, and Minamisoma City; officials involved with nuclear officials, such as the Tokyo Electric Power

Company, JAEA, and International Research Institute for Nuclear Decommissioning; and university officials. The METI led the Akaba Study Group. However, it can be surmised that the group considered the development of the framework using a top-down approach that emphasized consensus building across a wide range of stakeholders, including the state and local communities.

Incidentally, the chairperson of the study group, Kazuyoshi Akaba, toured the USA between January 12 and January 19, 2014, just before the first study group meeting, and visited Texas A&M University and Hanford. The "Akaba Study Group Report" (2014) was compiled on June 23. Nonetheless, it is reasonable to assume Kazuyoshi Akaba had already solidified the basic points of his concept by late 2013.

The document "Document 5: Matters to be considered by the study group" from the first meeting held on January 21, 2014, sets out the following five points as the purpose of establishing the study group (Fukushima International Research and Industrial City [Innovation Coast] Framework Study Group [Akaba Study Group] Secretariat, 2014, p. 2).

The local economies of many of the municipalities in Hamadori have formed around the business activities of nuclear power-related companies, and the decommissioning of the nuclear power plant will result in the loss of that foundation. Henceforth, it will be necessary to create new technologies and industries to rebuild the industrial base of the region and realize the recovery of the entire regional economy.

However, considering the decommissioning of the Fukushima Daiichi Nuclear Power Plant over the next 30–40 years, it is necessary to establish R&D centers in a wide range of fields, including robotics, prototype production, and production centers for parts, components, and consumables that support the R&D and decommissioning work, together with training and education centers for researchers and engineers engaged in these activities in the surrounding areas, thus ensuring smooth decommissioning.

Many researchers and related industrial workers live in the area during the R&D to decommissioning process. Therefore, it will be necessary to improve various services and life and transportation infrastructure for the new residents.

The strategic development of international research and industrial base is a nursery for the agglomeration of research and industries related to decommissioning, and the comprehensive development of policy necessary to form industrial clusters over a wide area beyond the conventional municipality framework induces the creation of new technologies and new industries in the future.

Further, to clarify the direction of regional industrial policies that should be implemented in the areas affected by the nuclear power plant disaster, the "Fukushima International Research and Industrial City (Innovation Coast) Study Group" will be established as a private, round-table meeting with the head of the Local Nuclear Emergency Response Headquarters, Mr. Akaba, where experts from the industry, academia, and government will discuss the future direction of R&D and industry and human resource development bases, together with regional development. By June, proposals for future visions for the regional economy, necessary steps to take, and support measures should have been compiled.

In general, the report emphasizes that the creation of new industries to replace the nuclear power industry is essential for the regional reconstruction of R&D and industry and human resource development bases. Moreover, regional development based on industrial clusters involved with the decommissioning of 1F should be developed over a wide area extending beyond the conventional municipality framework.

Similarly, in "Document 5" from the first study group session, under "Preservation and development of ruins from the earthquake," some fascinating points are made, including "[is it not] important to preserve facilities and data from the 1F and 2F (Fukushima Daini nuclear power plant) for education and training purposes?" and "From the perspective of education and training, [is there not] a need to preserve the facilities and archive materials to ensure an understanding of the situation at the time of [the] accident is

passed on to future generations?" (Fukushima International Research and Industrial City (Innovation Coast) Framework Study Group (Akaba Study Group) Secretariat, 2014, p. 37).

The Akaba Study Group, beginning on January 21, 2014, completed its role by compiling the "Report of the Study Group on the Fukushima International Industrial City (Innovation Coast) Framework" ("Akaba Study Group Report") as early as at the 7th Study Group Meeting on June 23, 2014.

Section 2.2 of the "Akaba Research Group Report," released on June 23, 2014, states that "2. International joint industry-academia-government research site for domestic and foreign research institutions" is the starting point of the international education and research base currently being promoted by the Reconstruction Agency. It is stated that "possible research themes include research examining environmental contamination and environmental recovery, research into the restoration of agriculture, forestry, and fisheries, research into robotics technology, technical research involving the reconstruction of Fukushima, social science research, medical research linked to ensuring residents' health, and advanced basic research related to solving the problems of decommissioning and contaminated water" (Akaba Research Group, 2014, p. 14), clearly positioning social science research linked to the reconstruction of Fukushima.

The discussions and reports of the Akaba Study Group, which formed the starting point for the Fukushima Innovation Coast Framework and International Education and Research Base, discuss the preservation of Fukushima Daiichi and Fukushima Daini nuclear power plants from an educational and academic perspective, clearly positioning social science studies linked to the reconstruction of Fukushima as a topic of research within the international joint industry-academia-government arena, thus underpinning the current Reconstruction Agency International Education and Research Base.

The Akaba Study Group substantively formed the idea in late 2013 and published it as the Akaba Study Group Report in June 2014. Seven years have passed since then, and it is necessary for the Fukushima Innovation Coast Framework and the International Education and Research Base to go back to the starting point of the project—the Akaba Study Group.

However, merely going back to the starting point does not clarify the question of the Fukushima reconstruction as a post-trans-scientific question (Unknown Unknowns). In addition to the top-down approach planned by the Akaba Study Group (the top-down or bottom-up binary is not particularly significant to Fukushima's recovery from the nuclear disaster: both are important and necessary), creative reconstruction must materialize the knowledge creation process and resource mobilization process through the formation of a "forum for dialog" between diverse experts and residents.

2.5 The Strong Path Dependency of the Fukushima Reconstruction and 1F Decommissioning Policies and the Need for Social Innovation

This chapter examines the "Balancing Reconstruction with Decommissioning" problem of reviving Fukushima from a double disaster called the Great East Japan Earthquake and the 1F (Fukushima Daiichi Nuclear Power Plant) nuclear disaster. This chapter contributes to SDGs 11; Make cities and human settlements inclusive, safe, resilient and sustainable.

This chapter defines the issues surrounding the reconstruction of Fukushima and the decommissioning of 1F as post-trans-scientific issues. It discusses the challenge of fostering social acceptance of the release of ALPS-treated water created through the decommissioning of 1F into the ocean and the challenge of fostering social acceptance of the Fukushima Innovation Coast Framework and the international education and research base in the course of the reconstruction of Fukushima.

The accidental offshore discharge of contaminated water in August 2013 was a major turning

point in the processes surrounding the issue of the disposal of treated water, and the Tritiated Water Task Force was established in December 2013. The Tritium Water Task Force, comprising only technical experts, compiled the "Tritium Water Task Force Report" on June 3, 2016, substantively decided offshore discharge to be the most practical direction to take. The subsequent ALPS Subcommittee, which included social science experts, also moved discussions along with the path dependency of legitimizing the offshore release, and the February 2020 "ALPS Subcommittee Report" settled on the offshore release of ALPS-treated water.

This path-dependent discussion process between government and experts can be understood as a process of legitimization for stakeholders who are members of the "forum" in that the options are narrowed down during the process of building up evidence-based discussions. However, for residents consistently excluded from the "forum for dialog" of task forces and committees on various options available for the disposal of the ALPS-treated water, even if they are asked to express their opinions, being told by the government that the options have been narrowed down to a final decision (offshore release) does not foster social acceptance or ensure the legitimacy of the decision.

The Akaba Study Group was the origin of the Fukushima Innovation Coast Framework and the international education and research base, national projects central to the Fukushima reconstruction policy. The Akaba Study Group began in January 2014, compiling the "Fukushima International Industrial City (Innovation Coast) Framework Study Group Report" ("Akaba Study Group Report") in June 2014. Based on the Akaba Study Group Report, the Fukushima Innovation Coast Framework has been established as a national project, and an international education and research base has been envisioned to assume a commanding role therein.

However, the Fukushima Innovation Coast Framework and the international education and research base have low levels of recognition and expectation among the people of Fukushima Prefecture and cannot be said to have fostered social acceptance as policies for the reconstruction of Fukushima. This notion is strongly influenced by the fact that the Akaba Study Group, the origin of the project, was grounded in a top-down approach led by political, administrative, and Tokyo-based leadership at the outset. The subsequent Fukushima Innovation Coast Framework and international education and research base were fundamentally conceived and implemented following the path laid out by the Akaba Study Group.

However, there were some interesting issues in the 2014 discussions of the Akaba Study Group, such as the preservation of 1F and a clear mention of the importance of social scientific research linked to the reconstruction of Fukushima as a research theme for the formation of an international "knowledge hub." Many things can be learned from the Akaba Study Group by tracing its roots.

Had an approach to post-trans-scientific issues been developed during the seven years between the June 2014 Akaba Study Group Report and today, the degree of recognition and expectations of the people of Fukushima Prefecture toward the Fukushima Innovation Coast Framework and the international education and research base might be quite different.

If the political, governmental, and Tokyo-led initiatives of seven years ago had been replaced by more concrete attempts to establish a knowledge creation process and resource mobilization process through the formation of a "forum for dialog" between a diverse range of experts and residents, it would have been possible to develop the Fukushima Innovation Coast Framework and the international education and research base in collaboration with local communities.

The path dependency of the Fukushima reconstruction and 1F decommissioning policies is strong, and unlocking ourselves from the existing pathway is challenging. However, regarding post-trans-scientific issues, to formulate policies that enable the reconstruction of Fukushima (the Fukushima Innovation Coast Framework and international education and research base) and the decommissioning of 1F

(the offshore release of ALPS-treated water and removal of debris), thereby fostering social acceptance and understanding of these policies, it is essential to create social innovation by creating a "forum for dialog" among experts, government, and residents.

Notes

(1) The current (as of July 18, 2021) difficult-to-return zone comprises seven municipalities (Minami-soma City, Iitate Village, Katsurao Village, Namie Town, Futaba Town, Okuma Town, and Tomioka Town), approximately 3.37 million km^2, and approximately 20,000 registered residents. The Specified Reconstruction and Revitalization Base (approximately 27.5 km^2) is expected to have its evacuation order lifted in 2022 or 2023. For the remaining areas, the tenth proposal made by the Liberal Democratic Party's Headquarters for Accelerating Reconstruction after the Great East Japan Earthquake on July 6, 2021, calls for the lifting of evacuation orders for all areas in the 2020s (*Mainichi Shimbun*, July 7, 2021), though it remains uncertain.

(2) The term "ALPS-treated water" has been used since the official decision to release water into the ocean on April 13, 2021. The Ministry of Economy, Trade and Industry (METI) states that ALPS-treated water is defined as "water that meets the regulatory criteria for environmental release for nuclides besides tritium." https://www.meti.go.jp/press/2021/04/20210413001/20210413001.html (accessed on July 15, 2021).

(3) Please refer to the following website for more information on the Office of Support for Responding to Damage from Treated Water at the Agency for Natural Resources and Energy of the METI: https://www.meti.go.jp/press/2021/04/20210427003/20210427003.html (accessed on July 15, 2021).

(4) For more information on RTP companies and employment data, please visit: https://www.bizjournals.com/triangle/subscriber-only/2019/05/10/largest-research-triangle-park.html. (accessed on July 15, 2021).

(5) The University of South Carolina at Chapel Hill has produced nine Nobel laureates, and Duke University has produced 15 Nobel laureates (up to 2019).

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Rural Development in Japan

3

Mototsugu Ochiai

Abstract

In this chapter, I will give an overview of the development of rural areas in Japan and then refer to the problems that they currently face, such as the weakening of the community, deterioration of the management function of the local environment, deterioration of the function of agricultural producers, damage caused by wildlife birds and beasts, and response to climate change and disasters. Thereafter, I shall discuss the rebuilding of communities through exchanges with cities, establishing next-generation agriculture by utilizing information and communication technology (ICT), developing renewable energy by utilizing local resources, and establishing new connections that complement each other's roles within the region, as necessary, for sustainable rural development in the future. Hence, this chapter is related to all 17 goals because it describes the sustainable development of rural areas and, in particular, contributes to the "Sustainable Cities and Communities" of SDG 11.

Keywords

Rural development · Community · Settlement · Local resources · Agriculture

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3.1 Introduction

This chapter contributes to the "Sustainable Cities and Communities" of SDG 11.

In this chapter, I will first give an overview of the development of rural areas in Japan and then touch on the problems these areas are currently facing, such as weakening of the community, deterioration of the management function of the local environment, deterioration of the function of agricultural producers, damage caused by birds and beasts, and response to climate change and disasters. Finally, I discuss the rebuilding of communities through exchanges with cities, establishing next-generation agriculture by utilizing ICT, developing renewable energy by utilizing local resources, and establishing new connections that complement each other's roles within the region as necessary for sustainable rural development in the future.

3.2 Development of Rural Areas in Japan till Date

3.2.1 Rural Areas up to the 1940s

Rice farming, which was introduced in Japan during the Yayoi period, has been the center of Japanese agriculture to date and has had a great influence on the formation of settlements where people live. It requires farmland and water and

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requires the cooperation of groups, not individuals, to develop and maintain farmland and waterways. In addition, because cooperation is required for harvesting work, groups were formed in that cooperative relationship, which later formed settlements. Although various governance mechanisms have emerged over time and various systems related to agriculture and rural areas have been applied accordingly, these settlements are still the smallest regional units in Japan.

3.2.2 Rural Areas Since the 1950s

At the end of World War II, there was an urgent need for postwar reconstruction throughout Japan, including major changes in rural areas. The land reform dismantled the former parasitic landlord system (form of farming management, in which a landowner, who owned many farmlands, rented his farmland to a farmer called a tenant farmer and obtained a tenant fee as rent), and many small landed farmers emerged. The Cropland Act was enacted in 1952 to stabilize the status of these farmers. As a result, although the Agricultural Commission established in the municipalities permitted the sale and rent of agricultural land, this was to be suppressed, and self-produced farming was to be protected.

As a consequence of postwar reconstruction, the Japanese economy, centered on heavy industry, has developed tremendously, mainly in urban areas. During that time, rural areas supplied labor, land, and water to rapidly developing urban areas. As a result, the disparities between urban and rural areas and between industry and agriculture have widened, and the problems of depopulation, aging, overdevelopment, land use confusion, and pollution have arisen in rural areas. The Agricultural Basic Act, enacted in 1961 with the aim of reducing these disparities, stipulates the basic direction of agricultural policy and realizes an increase in agricultural income through improvements in agricultural productivity.

One of the major events in Japanese agriculture centered on rice farming is the "rice surplus" and the accompanying "rice acreage-reduction policy." Rice production increased as a result of various agricultural reforms, such as postwar reconstruction and policies such as the Agricultural Basic Act, and by the end of the 1960s, production exceeded consumption. The Ministry of Agriculture, Forestry, and Fisheries requested that farmers reduce their production areas to curb production and maintain rice prices. Despite the completion of this rice acreage-reduction policy in FY 2018, about one-third of the paddy field area is not used for producing rice, but to produce wheat and soybeans instead.

Furthermore, owing to a period of high economic growth, a large demographic, especially the younger age group, moved from rural areas to cities. As a result of this trend continuing until now in rural areas, the birthrate is declining, the population is decreasing and aging, and the term "marginal settlement" has become synonymous, especially in the hilly and mountainous areas that have a high aging rate of population. With such a population decline, declining birthrate, and an aging population, issues have arisen, such as the weakening of rural communities, lack of supply of living services, deterioration of the functions of agricultural producers, lack of management of rural resources, damage caused by wildlife, and response to disasters (details of these issues are outlined in Chapt. 3).

3.2.3 Settlement as a Japanese Community

Administratively, the entire country is divided into regional units, which are further divided into prefectures and municipalities. Conversely, the smallest and most basic self-government unit in a rural area is the settlement, which has the smallest and strongest relationships between residents and can be termed a local community. Each settlement has a more autonomous function than before, which is still important, and discussions

are held on a settlement basis when deciding on something in the area. As a "connection" (Yui in Japanese), a settlement is still very closely related to the lives and livelihoods of local residents, such as helping each other in agricultural work, cooperating in the development of agricultural land and waterways for agriculture, and holding festivals and ceremonial occasions. In rural areas, various activities continue to be carried out, considering the settlement as a unit.

These photographs, Figs. 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, and 3.8, are typical rural landscapes of Japan.

3.3 Problems in Current Rural Areas

The problems currently faced by rural areas are intricately intertwined. The depopulation trend in the rural areas of Japan began in the 1950s and has not changed even now. One cause is the increase in employment due to economic development in urban areas during periods of high economic growth. Most of the population decline is due to the outflow of young people to cities, which causes problems such as the weakening of communities, deterioration of the functions of agricultural producers, and poor management of the local environment. Furthermore, owing to these factors, the damage caused by wildlife, as well as disasters, is expanding. In addition, the supply of services necessary for various lifestyles has stagnated. This has led to a vicious circle of further population decline. The following sections describe each of these issues.

3.3.1 Weakening of the Community

When many young people living in rural settlements graduate from high school, they leave the settlement by going to university or getting a job in the city. As the number of people living in settlements decreases, the power of the community weakens in many settlements. If the population decreases sharply, it will not be possible to hold ceremonial occasions such as festivals, which were previously held in the settlement through mutual assistance. Roads will become unmanageable for driving, and the number of people who can take up official positions in the settlements will be limited. The settlement will eventually cease to function as a rural community. There are many autonomous settlements in rural areas in which functioning as a community can no longer be fulfilled.

Fig. 3.1 Maintained paddy fields (Yamagata Prefecture)

Fig. 3.2 Spacious fields (Hokkaido)

Fig. 3.3 Rice terraces in mountainous areas (Yamagata Prefecture)

In Japan, settlements are called "marginal settlements if the percentage of elderly people (aged 65 and over) accounts for more than 50% of the population. The term is used to signify that there is a limit to how settlements function as a community and enable people to live there. This term symbolizes the weakening of rural communities.

3.3.2 Lack of Various Living Services

In rural areas, the critical mass refers to the minimum population required to maintain a service. If the population declines and interrupts this critical mass, then with regard to public services, such as government offices, schools, post offices, hospitals, and services, such as gas stations,

Fig. 3.4 Tea plantations (Shizuoka Prefecture)

Fig. 3.5 Reservoir for sending water to rice fields (Oita Prefecture)

shops, and public transportation in the region, residents' access to services becomes more difficult year by year due to integration and reduction of the supply side. In fact, in many rural areas, the number of public transportation systems, such as railroads and fixed-route buses, has decreased owing to a decrease in the number of passengers caused by the declining population. There have been cases in which they were compelled to withdraw from the area. Similarly, a decline in the number of users forced gas stations and shops to close or withdraw from the area.

Fig. 3.6 Settlement in a mountainous area (Fukuoka Prefecture)

Fig. 3.7 Thatched roof houses (Toyama Prefecture)

3.3.3 Deterioration of the Function of Agricultural Producers

The shortage of farmers' successors has become a major problem due to the outflow of young people from rural areas. Previously, farmers who were aging and unable to farm asked other farmers in the settlement to cultivate when they had no successors. Because it is easy to cultivate on flat land, many farmers are willing to receive such farmland. However, in hilly and mountainous areas, where the tendency of population decline is even more severe, there are few recipients, particularly since farmland is small and irregular, and it is difficult to handle agricultural machinery. Furthermore, there is no one

Fig. 3.8 Waterways and turbines (Fukuoka Prefecture)

who can take over and cultivate the farmland of other farmers because the recipients themselves, who are also aging, are exhausted from cultivating their own farmlands. As a countermeasure to these problems, the number of areas where community farming is being implemented is increasing.

3.3.4 Deterioration of the Function for Managing the Local Environment

Until 50 years ago, there were many places in rural Japan where electricity and gas could not be used, and firewood was used to prepare meals and boiling water for bathing. To secure this firewood, rural areas managed the mountains near their settlements, called "satoyama," a Japanese term applied to the border zone or area between mountain foothills and arable flat land. However, with the availability of electricity and gas, firewood should not be secured and mountains should be managed. In addition, the number of people entering the mountains has decreased due to the slump in the forestry industry. Hence, mountains are no longer managed. Further, owing to the declining and aging population within the settlements, the number of abandoned cultivated lands as well as vacant houses, whose inhabitants have disappeared, is increasing. In addition, there are cases in which farm roads and waterways cannot be managed sufficiently.

Thus, the management function of the local environment is declining in many mountains, farmlands, and living environments in rural areas.

3.3.5 Damage Caused by Wildlife

In recent years, especially in the agricultural lands of hilly and mountainous areas, damage caused by wild boars, deer, and monkeys has become a major problem. One reason why the damage is more widespread than before is that the relationship between people, mountains, and farmlands has changed. As mentioned in the previous section, examples of this include the fact that owing to fewer opportunities for people to enter the mountains, animals have come closer to settlements where people live, and abandoned farmlands have become a place for wildlife to hide. Another factor is that wildlife habitats of wildlife have changed due to climate change, such as global warming. Wild boars have

become common in the Tohoku region in recent years and have been previously unseen. Rural residents are taking measures against these damages, such as enclosing the entire settlement with a 2-m-high fence (to prevent deer from jumping over), enclosing the farmland with an electric fence, traps for animals, etc.

In addition, the physical damage—eating the produced agricultural products and digging up the surface of the farmland—that is, of course, extensive, mental damage to the farmer is also great. In particular, elderly farmers give up farming because they think, "the animals are just going to eat them, so why bother." According to national statistics, in recent years, the amount of damage caused by wildlife has decreased. This is partly owing to the fact that measures to protect farmlands with fences have been effective, but conversely, farmers who have given up farming may not have presented the amount of damage.

3.3.6 Damage Caused by Climate Change and Disasters

Global warming has gradually affected agriculture in Japan. For example, the production area may change in the case of agricultural products. In addition, the frequency of torrential rains is higher than before, and damage occurs almost every year somewhere in Japan, most of which damages rural settlements and agricultural lands. Furthermore, great damage has also been caused by large earthquakes, such as the Great East Japan and Kumamoto earthquakes. Damage to rural areas, which is already in a difficult situation due to population decline and aging, will cause great damage to the areas and residents.

3.4 What is Necessary for the Sustainable Development of Rural Areas in the Future?

The declining population has led to the occurrence of the deterioration of local environmental management, expansion of damage by wildlife and disasters, and reduction of the supply of living services, and it can be said that the vicious cycle of further population decline caused by these factors is a major issue facing rural areas. Conversely, to sustainably develop rural areas, it is important to make the best use of their strengths, break this vicious circle, and move toward a virtuous cycle.

3.4.1 Rebuilding the Community by Interacting with People Outside the Region, Such as Cities

To rebuild a weakened community, it is necessary to stop population decline and move toward maintaining or increasing the population. It is conceivable that people will not leave the settlement to maintain or increase the population. Instead, they return to the settlement, and new people may even come to the settlement.

However, regarding the fact that "people do not leave the settlement," the tendency of young people to move out continues, and dealing with it is difficult. It is conceivable to build attractive destinations such as universities or workplaces in rural areas, but rural areas cannot compete with cities in this regard. Therefore, the advantages of rural areas that are not found in cities must be considered.

"People returning to settlements" is the so-called U-turn, which means that persons, who have left the settlement, will return again. Having lived there before, they are acquainted with the local residents and know the local circumstances; thus, the hurdles are fewer than when they move to a new place. Nevertheless, it is necessary to prepare an environment in which people who have left once can return again. Moreover, in recent years, the term "grandchild turn" has been used to describe a phenomenon in which the children of people who left the settlement and went to cities migrate to a rural area where their grandparents are. What should be considered first is that people who were originally related to the area will return.

It is conceivable that new people will move to the settlement as the next step for U-turns. This is called "I = turn." When urban residents move to a rural area, there is an attraction toward a place to live in that area and work that can be done there. Hence, the issues are as follows: a house to live in and farmland to farm. In rural areas, vacant houses have become a problem owing to the declining population, and although the government operates "vacant house banks" to introduce vacant houses to those who wish to move, in reality, it is not easy to rent vacant houses. Many homeowners, who have left the area and now live in the city, are reluctant to let go because "there is a Buddhist altar" or "they return and stay once a year." It is not possible to rent farmland unless there is a relationship between trust and the owner. It is important to have a good relationship between newcomers and the community, including teaching agriculture after borrowing. In addition, owing to the COVID-19 pandemic, many companies in Japan allow remote work, and a younger generation that seeks a new life of living in rural areas and working remotely in urban companies is emerging. They were expected to be members of a new community.

However, although policies regarding U-turns and migration have been implemented in rural areas throughout Japan to maintain and increase population, it is difficult to achieve results. In recent years, the concept of the "related population" has been presented, saying that it is important to have a continuous relationship, even if it is not "living" in a rural area. There are ways to connect with various rural areas, for example, a person has left the area but lives at a distance of about an hour by car and on weekends goes home to help with farming; or urban residents continue to have relationships with rural areas as a result of urban–rural exchanges, such as farming experiences and lodging at farmer guesthouses. To rebuild the community, in addition to complete U-turns and migration, measures to include people who are not living in rural areas but are continuously involved in the community as its sub-members are needed.

3.4.2 Establishment of Next-Generation Agriculture Utilizing ICT

Although the issue was the decline in the functions of agricultural producers, "smart agriculture" utilizing ICT has been proposed as a method to address this issue. There are unmanned rice transplanters and combine harvesters equipped with GPS, drones that automatically fertilize, and automatic mowers that move even on slopes. For large-scale agriculture in plains, it is possible to develop farming in a large area with a smaller number of people. Meanwhile, in hilly and mountainous areas, ICT is expected to play an active role in dangerous and labor-intensive work, such as mowing ridges that have become large due to slopes. In addition to reducing labor related to agricultural work through mechanization, ICT is expected to be utilized to make agricultural management smarter, such as cultivation management, work process management, and the inheritance of elderly people's agricultural experiences.

In Japan, machines were introduced into farm work in earnest in the 1960s, and it became possible to carry out farm work with a smaller number of people. In addition to being a necessary technology introduction in rural areas, where the population is declining and aging, it also means that a smaller number of people would be sufficient for farming. As technology progresses and fewer people are involved in farm work, one possible extreme in the future is that rural areas will be empty and cities will be able to remotely control agricultural facilities and machinery. With an eye on the future image of an ideal rural area, ICT should be used to support the future image of rural society.

3.4.3 Development of Renewable Energy Utilizing Local Resources

"Decarbonization" has become the mainstream worldwide. Likewise, in Japan, the shift from petroleum-derived energy to renewable energy

will progress given that renewable energy has a high affinity for rural areas. For example, energy supply utilizing woody biomass comprises energy derived from wood, which is abundant in rural areas and is considered a method that can reduce carbon dioxide emissions while properly managing forests. The use of small hydropower, wind power, and solar power has a high affinity in rural areas. In Japan, where rice farming is flourishing, long waterways are laid out in rural areas, and power generation by small hydropowers using this water flow can be expected. Until now, rural areas have had to pay external agencies to obtain energy derived from petroleum, but if it is renewable energy, it can be produced within the area. Furthermore, if it is possible to sell it to the outside world, it will be economically effective and sustainable.

Alternatively, we must focus on methods to develop the installation location of such facilities because there are large-scale facilities for generating wind and solar power. In particular, logging in mountainous areas to install solar panels may cause disasters due to debris flows and landslides caused by heavy rain. Therefore, there are many cases in which conflicts occur between developers, neighboring residents, and local governments. This is because previous laws on land use in forest areas did not envisage the development of solar panels and were not sufficiently regulated. It is necessary to enact a law to respond to such new situations.

3.4.4 Establishing New Connections that Complement Each other's Roles Within the Region

As a social aspect of rural areas, there is a neighborhood association with settlement residents as a unit, and it is still a large presence within a settlement. Each inhabitant participates in the residents' association in units of the "family" and cooperates in situations, such as ceremonial occasions, cleaning of waterways in the area, and maintenance of common land. The traditional role of these neighborhood associations has focused on maintaining and protecting settlements. In addition, discussions and decisions on residents' associations operate in units of the family. Therefore, older men participated as family representatives, and the opinions of women and young people were rarely considered.

However, the situation in rural areas has changed drastically, and it is becoming difficult to maintain and protect the area through conventional methods, owing to the declining and aging population. It is also necessary not only to maintain and protect the area, but also to take on new challenges, and the idea of a limited number of older men is no longer sufficient. In other words, a different activity entity was required.

In addition to the involvement of residents' associations, it is necessary to create a new organization in which various local residents are members, sometimes beyond the unit of settlement, or by involving urban residents. Depending on the purpose of the activity, there can be various forms, such as forming a group that produces processed agricultural products with women in the settlement as members, a group that operates farmer restaurants and direct sales offices, creating a new group of people involved in rural tourism, forming an agricultural production corporation with multiple settlement leaders as members, or settlement residents and urban residents forming a group to conserve rice terraces.

The advantage of these individual group activities was that, in the case of residents' associations, since they comprised activities for the entire region, the burden of activities and profit equality were taken into consideration. However, in the case of individual groups, since decision-making can be made by the members of the group, the range of activities can be expanded and the speed of decision-making and activity development can be increased. In addition, even if there are problems, such as lack of human resources or equipment with only one settlement, it is possible to compensate for it by collaborating with multiple settlements or with the help of city residents.

Alternatively, it is important to understand and support the entire region when working with these individual groups in rural areas. For example, in the case of female group activities, some rural areas still have an atmosphere of male domination, and male residents who do not welcome female group activities may resist such initiatives. In such cases, support from men in women's families is essential. Additionally, the fact that only some groups are economically profitable arouses the jealousy of other residents. In such cases, it is better to return part of the profit from group activities to the community. It is indispensable to gain an understanding of the entire region and continuously obtain support by utilizing part of the profits made at the direct sales offices and restaurants for the welfare of the region.

National and local Japanese governments have also started to support the activities of these individual groups. The Ministry of Agriculture, Forestry, and Fisheries will provide support to regional management organizations.

Issues in rural areas are becoming more complicated, and to deal with them, it is necessary to seek a more flexible form of activity, not just the conventional residents' association, but also public support.

3.5 Concluding Remarks

The title of this chapter, "Rural Development in Japan," can be rephrased as "Sustainable Development of Rural Japan." In other words, it can be said that it is deeply related to all 17 of the SDGs. In particular, not only the public sector, such as the government, but also the private sector, such as residents, will play a leading role in rural areas in the future, and collaboration between the public and private sectors, as well as with urban residents who have relationships with rural areas, will be important factors. The various people inside and outside the rural area complementing each other with their strengths will also be an important factor. Therefore, the 17th goal, "Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development," is especially necessary for rural development. In addition, the development of renewable energy, that can be supplied by rural areas in connection with the 15th goal, "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss," is greatly related.

References

If you need more information about rural development policies of Japan, please refer to the following link.

Ministry of Agriculture, Forestry and Fisheries (MAFF) https://www.maff.go.jp/e/index.html

Ministry of Internal Affairs and Communications (MIC) https://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/

Ministry of Land, Infrastructure, Transport and Tourism (MLIT) https://www.mlit.go.jp/en/index.html

If you need more academic information about rural development of Japan, please refer to the following link.

National Agriculture and Food Research Organization (NARO) https://www.naro.go.jp/english/index.html

Association of Rural Planning (ARP) http://rural-planning.jp/en/

If you can read Japanese and need more academic information about rural development of Japan, please refer to the following book.

Tsugihiro Watanabe et al *Nouson Chiiki Keikaku Gaku (Rural Planning)*, Tokyo: Asakura Shoten

4 Sustainable Development Goals from the Perspective of Photographic Archives: A Case Study on Photographs from Occupied Japan

Yoichi Sato

Abstract

In this chapter, I present a novel way to examine the historical background of the issues discussed in sustainable development goals (SDGs) using historical photographs. Considering the 17 SDGs, and Japan's occupation period (1945–52) to construct a case study, I demonstrate how to interpret the gaps and connections between the situations observed during the occupation period and the present. Finally, I refer to SDGs 7 and 11 in detail; however, this is not a summary for a particular SDG, but a way to think about the background of the issue for all SDGs.

Keywords

Photograph · Japan · Occupation period · Photographic archives · Contemporary history

4.1 Introduction

4.1.1 Thinking from the Other Side

In this chapter, I consider how photography can function for SDGs from old photographic archives and make a proposal using these photographs taken in Japan immediately after the end of the war as an example.

When I see the SDGs, the images that come to mind are those of photographs that I collected in Japan during its occupation (1945–52). "No poverty (SDG1)," "zero hunger (SDG2)," and "good health and well-being (SDG3)" were the major issues facing Japan during the occupation. The generation that lived through the postwar period battled against these challenges. However, the issues of "affordable and clean energy (SDG7)" and "job satisfaction and economic growth (SDG8)" are in different phases. For example, the switch from charcoal to fossil fuels, and the decline in the number of primary industry workers did not occur until 1955, after the occupation. These SDGs, therefore, images of the prehistory of this issue to resurface.

The SDGs, as this book shows, are very broad in scope and require various research approaches to engage and involve many people. The SDGs are a current and future issue; however in this study, I consider what can be done from the "opposite perspective" of historical photography.

4.1.2 My Research and SDGs

My research field is photo archiving (Satō 2006, 2015, 2021), which involves the collection of old photographs from various places, passing them on to those who need them, and considering how

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to utilize them for various people. However, I am not aware of any paper or book that squarely addresses the question of how photo archives can help SDGs. Photo archiving is a public field. There are many points of contact between collecting, researching, and utilizing historical photographs and advancing on the SDGs.

Photographs have many possibilities, especially those photos are "open to reading" for the viewer (Ueda et al. 2021). It is not always a given that the viewer will understand exactly what the photographer intended, but the viewer can focus on areas that the photographer was not aware of. Photography allows the viewer the freedom to make discoveries and encourages fresh thinking.

Although my research has mainly focused on photographs of occupied Japan, I present a methodology that can be applied in other parts of the world under different conditions and at different times. I hope that readers will consider the following text and study the photographs while keeping in mind the history of the region, even though they may not wholly be related to the occupation or Japan.

4.2 The SDGs and the Role of Photography

In this section, I present three main ways in which photography contributes to SDGs. (Fig. 4.1).

4.2.1 Encountering Photographic Expression

In the specialized field of photographic expression, there exist photographers and news reporters who present photographic works based on their awareness of the issues expressed in SDGs. There are also global events that curate and introduce such works. For example, "The Prix Pictet," an award for photography and sustainability (Fig. 4.2), decides on a theme each year and nominates and awards photographers for their work (The Prix Pictet 2021). In many cases, the viewers are presented with trends and

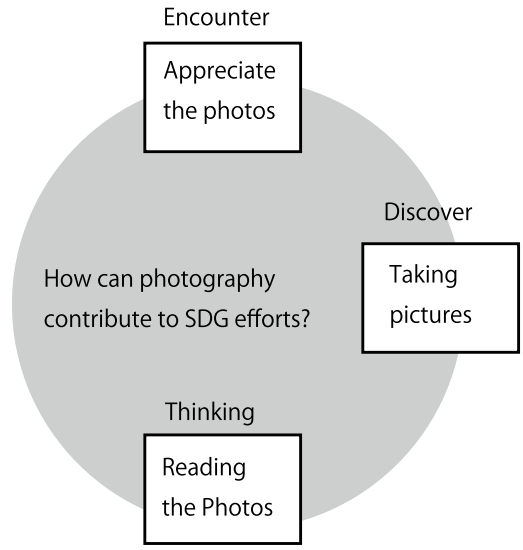

Fig. 4.1 Contribution of photography to SDGs

Fig. 4.2 The Prix Pictet. The photograph shows the catalog of the 2021 theme "Fire"

conditions of the world that they may not have been aware of. Through these photographs, the viewers are able to imagine the situation and share the photographer's awareness of issues.

Some well-known photographic works can provide questions to be considered.

Most of us are committed to these photographic expression activities as viewers. Encountering these works at some point in time can open our eyes of interest. In addition to promoting the creation of such works, it is necessary to pick up the works, introduce them to others, and communicate them widely.

4.2.2 Discover Through Photography

In the field of education, there are workshop programs and contests in which students think about SDGs by taking pictures of things that interest them in their daily lives. SDG photograph contests, for example, the SDGs Student Photo Contest (Fig. 4.3) launched in 2016, have been held at various locations.

In the classroom, while learning the value of the SDGs, students observe daily life, discover problems, take pictures, and discuss them. By taking photographs, we can build a bigger picture using the fragmented facts embedded in our daily lives. It confirms that we are also a part of the problem and allows for discussion. This can be done through various means—on a smartphone inside or outside your home. The photographs present in the camera roll of a smartphone can also be analyzed.

Having a camera as a medium encourages discovery, and looking at these photographs further imparts values and views.

4.2.3 Thinking Through Archived Photographs

The use of archived photographs makes it possible to consider the history of how humanity acquired the values set forth in the SDGs. I attempt to establish the role of these photographs in this chapter. By comparing old photographs to those of the present, we can confirm the gaps and connections between them. For example, most of the photographs of the occupation period presented here were taken around 1950, but we can ask the following questions: What were the values of the world 70 years ago? What has improved and what has not changed over the past 70 years? What were the common problems? What are the new problems that have emerged?

Many digital archives of photographs are available on the Internet. For example, Japan Search is a leading portal site for digital archives in Japan (Fig. 4.4), and we can very easily view these archives on our own desktops.

4.3 Effectiveness of Using Photo Archives and How to Utilize Them

The values set forth in the SDGs are historical initiatives based on the history of human struggle, and without an attitude to learn from history work toward the future, the significance of the goals cannot be shared. If we do not know the depth of the historical background or have a "historical perspective" on the problems we face, it is difficult to reach the goals.

In order to realize the SDGs, various factors must be coordinated. These factors include the relationship between humans and the earth, the development of material civilization and its relationship with nature, changes in lifestyles, the increase in entropy, and the benefits and sacrifices of the cultural framework. As we learn more about these factors, we can also discover questions that we can commit ourselves to, and continue to work on them as our own research themes. Photography gives us a chance to think about the connection between ourselves and the big questions that humanity is facing.

4.3.1 Why Photography?

With the promotion of digitalization in society, digitized data is being provided for various uses. The digital image in the form of a photograph is one of the targets of this trend. In the field of humanities, there is a subfield called "digital humanities." Research using digital images has also become increasingly common.

Fig. 4.3 Photo contests on "SDGs" in Japan

First, what does a photographic archive mean as a historical document?

A photograph is a material that provides an opportunity to relive the long experience of humanity. We own the experience in the form of photographs and share it by preserving it as an archive. Photography was invented in the 1820s. In the 200 years since, various landscapes and situations have been photographed, and these photographs belong to the human race.

Additionally, photographs show facts as well as perspective. When photographing a person, the difference between taking a close-up of the person alone or framing the image to include the background is not just a difference in photographic technique, but also a difference in the

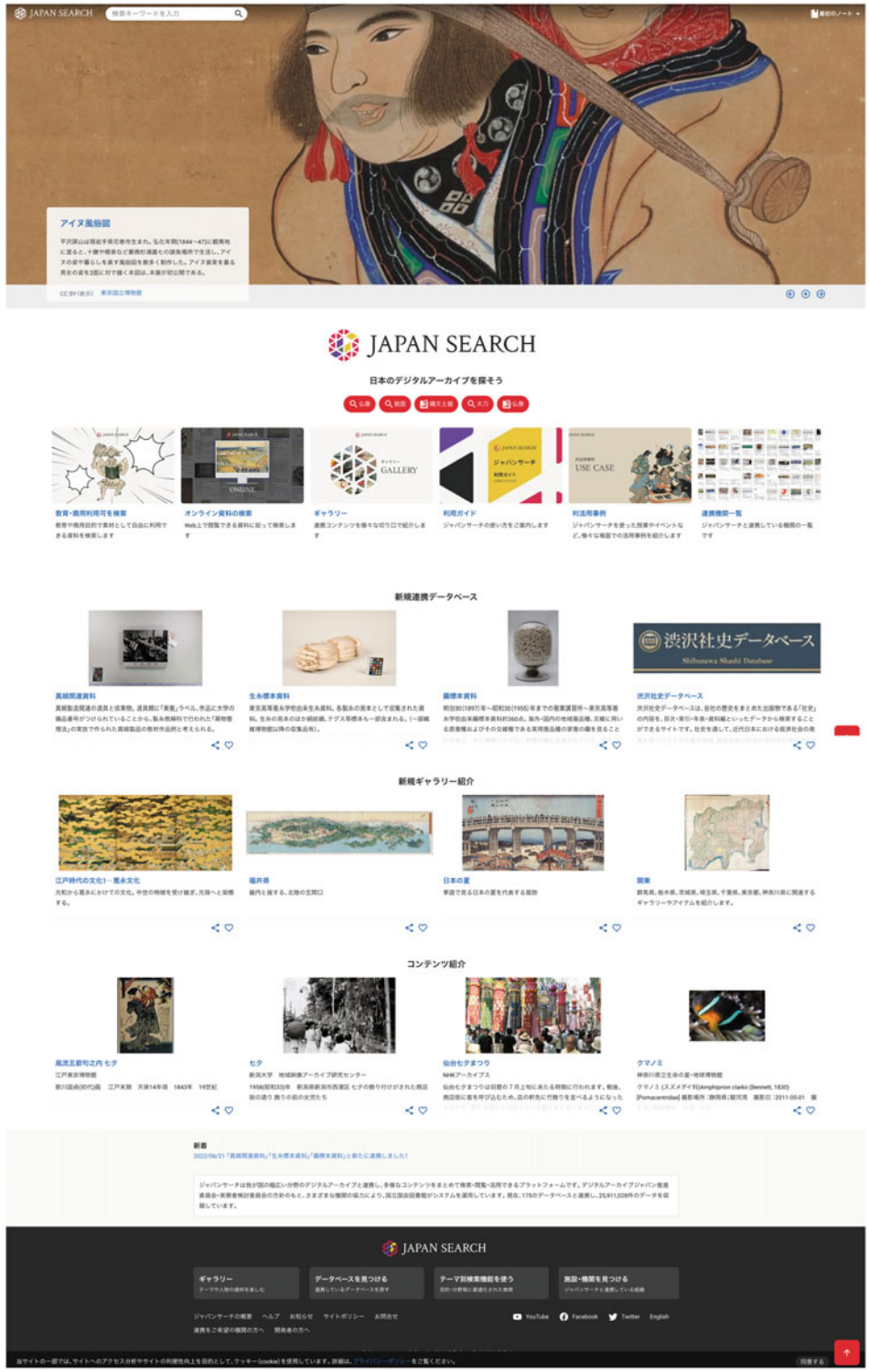

Fig. 4.4 Japan search: a leading portal site for digital archives in Japan

way things are perceived. In addition to information about the other side of the picture, it is also possible to consider the differences in the way we perceive things by reading information about the distance from the subject, the height of our gaze, and the framing.

With these points in mind, we will consider what can be known from old photographs in the next section.

4.3.2 How Can Old Photos Help?

By using photographs from the past, the analysis of SDGs can take three forms (Fig. 4.5).

4.3.2.1 Tracing the Process of Formation

How were the environment and society formed? Using photographs, we can trace the process. In particular, we can ask the question of what changed and how it did not change during the milestone period of the social transformation.

Additionally, how have perceptions of the environment and society been shaped? How have our perceptions of the environment and society changed? These questions can be answered by looking at actual photographs.

4.3.2.2 Reading the Way Issues Are Recognized

The SDGs are based on the recognition of various social and environmental problems. Photography has also been used as a direct means of documenting and sharing (or denouncing) such issues. How long have the problems been recognized? What was the occasion? In what ways were the problems captured in photographs? The photographic document provides us with clues to infer the answers to these questions.

Fig. 4.5 Information that can be read from old photographs on SDGs issues

4.3.2.3 Knowing How to Improve or Develop a Response

If a problem has been recognized, and measures have been taken to improve or respond to it, how these methods have developed and evolved can also be analyzed. Specific remedial measures can change and evolve depending on the social institutions, laws, and even technologies of the time.

Not all measures bring about improvements and forward movement. There are many examples of cyclical behavior, or remedial measures that lead to other problems. A critical retrospect is necessary, and suggestions for further improvement can be made using photographs.

4.3.3 Proposal of Two Methods Using Photographs

Based on the discussion in the previous section, I propose two historical methodologies using photographs as historical documents.

One method is to use the framework of the SDGs to understand the situation of a certain period of time in a certain society and compare it to the present to understand the history of the mission of the SDGs.

The other method involves tracing the transition of a single issue in the SDGs through photographs to understand how the issues have been recognized and solved (Fig. 4.6).

(1) Understanding the historical situation
For a hypothetical purpose, we can frame the period as one in which the foundations of the current state were formed, various problems surfaced, and responses and reforms were undertaken. In the case of postwar Japan, we can frame the period of occupation (1945–52), the period of rapid economic growth (1955–1972), the bubble economy period (1986–1991), and the present day as periods of reform and value change. Through the photographs of each of these periods, we can

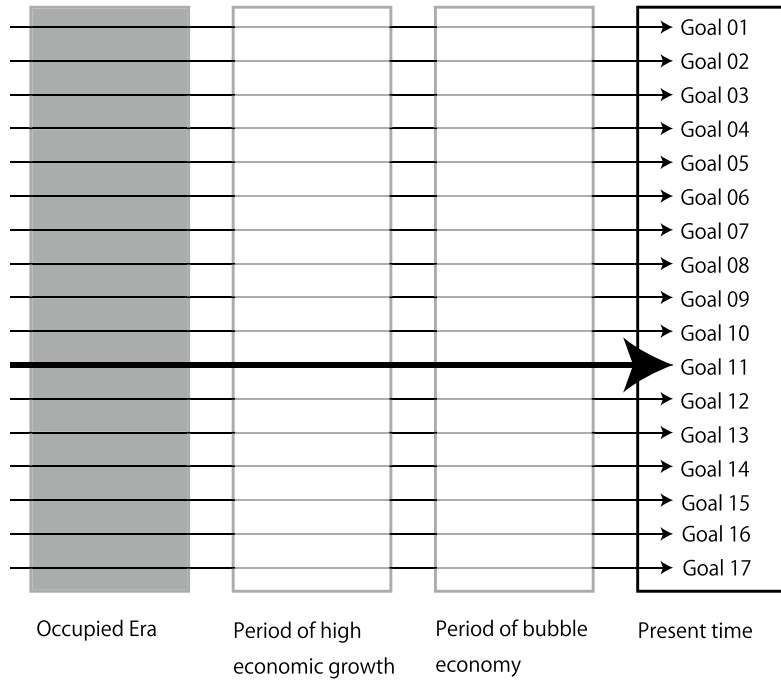

Fig. 4.6 Two approaches to the SDGs challenges: to understand the situation at a specific time and evolution of individual issues

consider the reality of society and how they perceived social issues.

(2) Understanding the transition of the problem
Let us look back at how society has responded to specific SDGs by using multiple photographs and connecting them. For example, if you have three photographs, A, B, and C from different times, think about what changed from A to B to C, and what the social response was during those times. Take up a specific issue from the objectives and think about its transition through photographs.

4.4 Practice from the Archives Photographed in Occupied Japan

4.4.1 Description: Photographs Taken in Occupied Japan and Their Archives

The occupation period was important in that it that defined the present state of Japanese society, and many of the issues addressed by SDGs came to the forefront. Before looking at specific photographs, let us summarize the characteristics of photographs taken in Japan during the occupation.

4.4.1.1 Photographs of Occupied Japan

In postwar Japan, the number of photographs taken by Japanese civilians was extremely small due to the scarcity of photographic materials and economic deprivation. Under these circumstances, it was the occupying forces who were trying to observe Japanese society and understand its problems, with the USA playing a central role. The photographs taken in Japan by the occupying forces and their associates can be divided into the following three categories in terms of the subjects photographed:

(1) Official photographs
Photographs were taken by the occupying forces in an official capacity. Photographs have undergone several stages of screening and are archived in the US National Archives and are available to the public.

(2) Press photographs
Photographs were taken for business purposes by organizations such as newspapers and news agencies.
(3) Personal photographs
Occupation forces personnel also took many personal photographs. Some of these photographs are held in libraries around the USA and are available for viewing.

In the following sections, I introduce some of these photographs, including (1) and (3).

4.4.1.2 Who Took the Photographs and for What Purpose?

The main task of the occupying forces was to dismantle and democratize the warlord regime in Japan. A certain percentage of the official photographs taken by the occupation forces were taken as surveys of the situation in order to promote this mission. This is symbolized by the photographs taken by the Strategic Bombing Survey Group, in which the camera focuses on how the wartime regime was organized, how the military industry functioned, and how it was damaged by the war. Photographs related to democratization have been taken in a variety of locations, not only in political situations such as elections, but also in labor movements and school education (Robin 2015).

While these major regime changes were underway, the people of Japan were still faced with serious issues related to their own survival. The realities of the homeless and war orphans were not only documented in official photographs, but also in personal photographs. There are many photographs documenting these measures to cope with life, especially in the early postwar period.

As the motives and purposes of some photographs are personal, the images contained in them are very diverse (Morris 2015; Satō 2020). These personal photographs contain images that could not be captured or preserved in official photographs.

4.4.2 Photographs of Occupied Japan in Relation to the 17 SDGs

In the following section, I reconsider the historical photographs of the occupation period in the context of the 17 SDGs, showing the relevant photographs in the order of the SDGs and explaining what can be considered from them.

Goal 1: No poverty

Poverty is one of the biggest challenges of the present, and there is no shortage of photographs depicting this (Fig. 4.7); for example, personal photographs in places like Ginza, the central shopping district of the capital city of Tokyo. The image of the homeless living on the streets is easily caught by visitors to the city. Similar images can be found in official photographs (Fig. 4.8), but these are intended for research or propaganda purposes.

Goal 2: Zero hunger

Extreme food insecurity was also a major challenge, and photographs of food rationing, which was an official measure, frequently appeared in official and press photographs (Fig. 4.9). Rationing alone was not enough to provide food for the people, so urban residents went to the countryside to buy food, which was illegal, but done openly. There are not many photographs of such activities, probably because they were subject to control. Similarly, there are few photographs of the black market, which was an informal source of food, because the occupying forces were forbidden from entering it (Fig. 4.10).

Goal 3: Good health and well-being

Sanitation was also a major issue, and photographs of dichlorodiphenyltrichloroethane (DDT), an insecticide sprayed in public places to prevent epidemics, are symbolic images of this era. In addition, the photographs (Fig. 4.11) of social improvement projects, such as a survey on sanitation in a so-called bad housing area (slum), may be in line with the SDGs perspective (Fig. 4.12). The images illustrated above can also be considered as interrelated with SDGs 1–3.

Fig. 4.7 Homeless on Sukiyabashi Bridge, Tokyo, 1952. From the collection of Taichi Kinugawa (original in color). Taichi Kinugawa is a Japanese photograph collector

Fig. 4.8 An orphan lying on the street. Ueno, Tokyo, August 11, 1948. US Army Signal Corps (USASC) photo. 111SC-293123, National Archives and Records Administration (NARA). The photographs in NARA's collection are official photos. This photograph is one of the more well-known signal photos

Goal 4: Quality education

As school facilities were destroyed in the war, public education was offered in different locations. The photograph of the "open-air classes" is one such example (Fig. 4.13). Many photographs of war orphans and orphanages can be seen in both official and personal photographs. Some of the personal photographs are taken by people who supported the operation of the individuals (Fig. 4.14), suggesting that the occupation officials were aware of their "savior" status.

Goal 5: Gender equality

Prostitutes working for occupation forces personnel, known as "pan-pan," were also a social problem due to the perception that they were disruptive to public morals; but they were also deeply rooted in society because of poverty. Because the occupying forces were forbidden to set foot in the areas where prostitution was tolerated (red-light district), photographs taken in those areas are few, but do exist (Fig. 4.15). Such images speak eloquently of the situation women

Fig. 4.9 Flour ration. Location unknown (Japan), June 11, 1946. USASC photo. 111SC-237386. NARA. In effect, rationing of major grains was in place until around 1950. It was not until 1981 that rationing was legally abolished

Fig. 4.10 A black market in front of the railroad station. Shinbashi, Tokyo, 1946. From the collection of Taichi Kinugawa (original color). The black market gradually disappeared as Japan's economy began to recover after the special demand from the Korean War in 1950

found themselves in, but to make them public was a matter of hesitation, and there is the issue of portrait rights in photography. Gender issues in the contemporary sense have also been taken up in policy as women's labor issues, and many photographs have been taken to investigate the working conditions of women workers (Fig. 4.16).

Goal 6: Clean water and sanitation

The sewerage system in the capital city of Tokyo was not built in earnest until after World War II, with a penetration rate of 49% in 1970 and 100% in 1995. The occupation forces conducted a survey of drainage systems and public toilets during the postwar survey of areas lost to air raids, and photographs of these facilities have been preserved (Fig. 4.17).

Fig. 4.11 Spraying children with DDT, 1945–1947, George C. Mergens photograph collection, US Army Heritage and Education Center (USAHEC). George C. Mergens was a US Army officer. He graduated from the United States Military Academy (USMA), West point, in the class of 1923. After the World War II, he was stationed in Japan and Korea

Fig. 4.12 Sanitary survey of a poor housing area. Fukagawa, Tokyo, March 17, 1947. USASC photo. 111SC-286158. NARA

Many of the photographs taken by the occupation forces show "honey buckets," or manure buckets, and people collecting them (Fig. 4.18). It is likely that the occupation forces learned of the existence of these buckets from the odor and captured it on camera. In any case, human waste generated in urban areas was purchased and transported to farming villages in the suburbs for use as fertilizer, but the occupying forces adopted the hydroponic method for growing vegetables for their own food because of the risk of parasites and other hygiene problems.

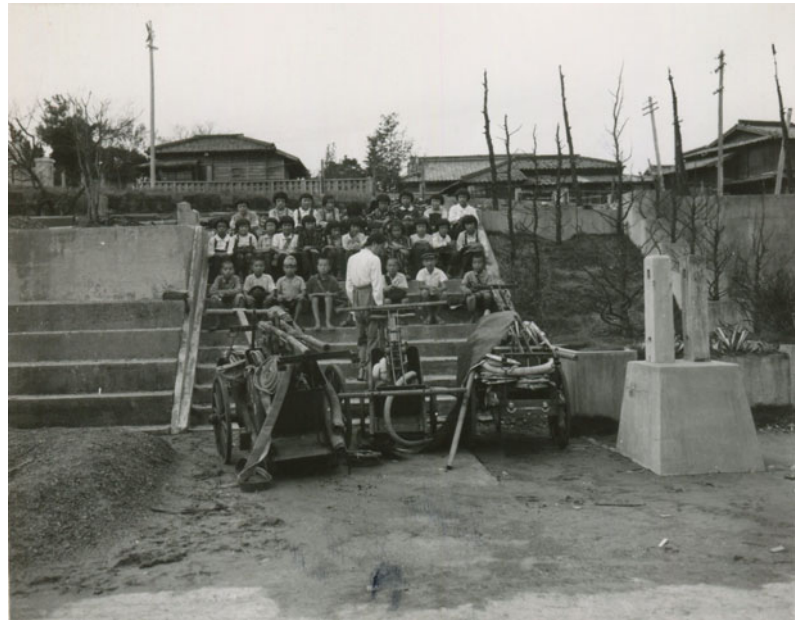

Fig. 4.13 An empty classroom in an elementary school that no longer has a school building. Sasebo, Japan, October 2. 1945. US Marine Corps photo.127–150422. NARA

Fig. 4.14 Children digging a well at an orphanage in Setagaya Ward, Tokyo. 1950. Kenneth Kantor papers, Hoover Institution Archives. Kenneth Dwight Kantor was an American journalist who spent most of his career in Japan and Korea. He and his wife personally provided support and cooperation for the operation of the orphanage

Fig. 4.15 Yoshiwara, Tokyo. One of the areas where prostitution was legal, May 1950, Kenneth Kantor papers, Hoover Institution Archives. The author added blur to a part of the photograph. Kenneth Kantor covered post-World War II Japan and the war in Korea, including subjects such as the status of women's rights in Japan and refugees in Korea

Fig. 4.16 Photograph of a visit to the Fuji Spinning Oyama Factory, Shizuoka, 1946–1949. Mead Smith Karras papers, 0011-GWP, Special Collections and University Archives, University of Maryland. Mead Smith Karras was instrumental in advancing the rights of women and minor laborers in post-World War II Japan. She was recruited to work as an economist for the labor division of the economics and scientific section during the allied occupation of Japan from 1946–1949. While a part of the labor division, she worked with US and Japanese officials to develop and implement occupation policies on problems affecting women and children in the workforce

Fig. 4.17 A temporary toilet built in a burned-out area, November 3, 1945. Tokyo, Japan. US Strategic Bombing Survey (USSBS) photo. 243-GM-1G06. NARA

Goal 7: Affordable and clean energy

The depletion of commonly available fuels was severe to the extent that gasoline for automobiles was not generally available, and coal was used as a fuel for power (Fig. 4.19). Fuel for household use was charcoal and coal, but since the period of rapid economic growth, fossil fuels were replaced by kerosene stoves and other fuels for ordinary households.

Goal 8: Decent work and economic growth

The trade union movement was banned during the war, but resumed, and the occupying forces worked to improve the inhuman working environment caused by unfair exploitation. The labor movement also gained momentum in many parts of the country, and the occupation forces supported the movement while carefully watching over political developments. The May Day march in Hibiya Park, Tokyo, was captured in various photographs (Fig. 4.20).

Photographs of surveys conducted by labor policymakers in various parts of the country (Fig. 4.21) also show that the working environment at that time was problematic.

Goal 9: Industry, innovation, infrastructure

The occupying forces' efforts to dismantle the warlords and munitions industries, and to replace them with peaceful industries, have left behind a

Fig. 4.18 An ox cart carrying a manure trough passing by with a sign at the entrance to Grant Heights, 1949. Narimasu, Tokyo. From the collection of Taichi Kinugawa (original in color). Grant Heights was a residential area for the families of the occupation forces, and there was a huge disparity in terms of the size of the housing and sanitary conditions from those of ordinary Japanese residential areas at the time

variety of symbolic photographs. These include abandoned munitions factories and scenes of fighter jets being burned (Fig. 4.22). Some of these factories were later taken over by heavy industries, while others were cleared for public use, and it is only in modern times that the SDGs have begun to address the issue of sustainable industry.

Goal 10: Reduced inequalities

The improvement of the status of former colonists was a major theme of the postwar process. The movement by the natives themselves was one of the targets of the occupation policy, and there exist various records (Fig. 4.23). Some problems were resolved during the occupation and some were not, and this is one of the issues that have remained unresolved since. There has also been researched into the Ainu ethnic minority in the country, and both official and personal photographs exist (Fig. 4.24).

Goal 11: Sustainable cities and communities

Immediately after the end of the war, barracks and shelters were the predominant living spaces in burnt-out urban areas (Fig. 4.25), and the focus turned to residential environmental issues, along with sanitation and disaster prevention issues. Urban housing construction in the context of war reconstruction proceeded, followed by the rapid construction of housing complexes. A symbolic topic in the issue of intra-city housing is that of people living on the water, "floating population." Their hygienic conditions were poor, and while surveys were conducted in light of these conditions, they were also recognized as an extremely Asian urban landscape (Fig. 4.26). Although many other urban planning issues existed, the occupation forces had little touch with urban planning itself, and it was only in the later phases of the occupation that urban development with new values began to take off.

Fig. 4.19 Cleaning up the coal cinders that power this car. Tokyo or Yokohama. US Marine Corps (USMC) photo. 127-135403. NARA. Coal-powered vehicles can frequently be found in photographs taken by the occupying forces

Fig. 4.20 Workers' rally on May Day. probably 1948, Mead Smith Karras papers, 0011-GWP. Special Collections and University Archives, University of Maryland

Fig. 4.21 Photograph of a visit to a sewing factory, 1946–1949. Mead Smith Karras papers, 0011-GWP. Special Collections and University Archives, University of Maryland

Fig. 4.22 Destroyed Nakajima Aircraft Co. Musashi Plant, November 3, 1945. Tokyo, Japan. USSBS photo. 243-GR-1T06,07. NARA. Panoramic photograph created by merging two photos by the author. The USSBS has taken many photos of large munitions factories that have been burned to the ground. NARA. (Panoramic photograph created by merging two photos)

Fig. 4.23 Chinese people in a parade, February 25, 1946. Sasebo, Japan. USMC photo 127-146758. NARA

Goal 12: Responsible consumption, production

The Natural Resources Section (NRS) of Supreme Commander for the Allied Powers (GHQ/SCAP), a section of the occupation forces, was in charge of managing the natural resources that were devastated during the war, and its policies include researching new natural resources and protecting the existing environment. For example, the NRS started to protect wild birds that were almost extinct due to mass captivity caused by food shortages, especially during and after the war, as can be seen from the photograph of the person in charge (Fig. 4.27).

Goal 13: Climate action

Flood damage caused by heavy rainfall due to typhoons and other causes was a frequent occurrence in Tokyo, and there exist photographs of rescue operations and other activities at the time (Fig. 4.28). In response to such heavy water damage, the city implemented flood control measures during the period of economic growth by strengthening the levees of rivers in the capital with concrete; however, the rivers became "backspaces" in the city, and the connection between water and land was severed. This fragmentation of environmental ecosystems due to robust infrastructure has continued ever since.

Goal 14: Life below water

The NRS conducted research on Japan's fisheries in relation to marine resources. For example, laver fishing was conducted in Tokyo Bay, which was rapidly reclaimed during the period of rapid economic growth (Fig. 4.29), and it can be understood that the coastal ecosystem that was subsequently lost was still alive.

Goal 15: Life on land

During the war, trees were cut down in many areas for material use, resulting in serious degradation of forest resources. This situation can be clearly seen in the photographs of the bald mountains (Fig. 4.30). As a result, coniferous trees such as cedar, which were planted at a rapid pace after the war, were the main cause of pollinosis.

Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective,

Fig. 4.24 Ainu couple, Dimitri Boria collection, MacArthur Museum. The author added blur to a part of the photograph. G. Dimitria Boria was the supervisor of the color photographic laboratory of the far East command during the occupation of Japan, 1947–1952. He traveled around Japan mainly to take photographs for the US military's publicity. It is believed that this photograph was taken as a part of such activities

accountable and inclusive institutions at all levels.

The photographs taken by the occupation officials include many pictures of children carrying their siblings on their backs (Fig. 4.31). In these photographs, children were portrayed as being forced to work. These scenes were commonplace, but disappeared with declining birthrates, economic growth, and changing lifestyles.

Goal 17: Strengthen the means of implementation for sustainable development and revitalize the global partnership.

Assistance during this period was provided by Licensed Agencies for Relief in Asia (LARA), which focused on food, and was supported by private organizations in many countries (Fig. 4.32).

4.4.3 Transition of the Problem

Here are some examples of how the issues related to Goals 7 and 11 have evolved from several pictures.

Fig. 4.25 A burnt-out shelter. The roof was dug into the semi-underground, September 17, 1945. US Navy photo. 80G-495627. NARA

4.4.3.1 SDG 7

Postwar Japan was severely depleted of commonly available fuels (Fig. 4.13). Earlier, charcoal and coal, but since the period of rapid economic growth, fossil fuels have been replaced by kerosene stoves in general households (Fig. 4.33).

Nuclear power has been in operation since the period of high economic growth: in a photograph taken in the 1960s, the six letters of "Nuclear Energy Research Institute" written as an assignment in calligraphy, a traditional Japanese art form, indicating the values of this era (Fig. 4.34).

This was followed by the Great East Japan Earthquake in 2011, which led to the shared need to revise that value system.

4.4.3.2 SDG 11

After the defeat of Japan in World War II, barracks buildings appeared in the burned areas (Fig. 4.25).

In order to solve housing difficulties, apartment complexes were built (Fig. 4.35), such that the houses became non-combustible, larger, and taller. Among the postwar housing complexes, those built in the 1960s and 1970s are being rebuilt and have already been replaced by a new generation. In recent years, high-rise residential complexes (tower condominiums) have been built in former factory areas such as the bay area (Figs. 4.36 and 4.37), but it is questionable whether they are sustainable in terms of the life span of the building and the urban environment.

Fig. 4.26 Boats of "floating population" at the mouth of the Sumida River, Tokyo. July 15, 1947. USASC photo. 111SC-295446 NARA. Toward the end of the nineteenth century, as the size of cargo ships calling at ports around Japan increased and barges became a popular means of shipping and harbor logistics, some dockworkers who owned barges and moved from place to place began to turn a corner of their barges into housing for their families. In the latter half of the 1960s, the shift to containerized cargo ships reduced the demand for barges in logistics, leading to a decline in the number of barges and a sharp drop in the number of people living on the water due to job changes

Fig. 4.27 Photograph of a haze net hunter, not visible in the photograph, which has been banned in principle under the wildlife protection act since 1947, 1948, Courtesy of Annika A. Culver, Curator, Oliver L. Austin Jr. photographic collection, at the Institute on World War II and the human experience at Florida State University. Oliver L. Austin Jr. first came to Japan in 1946 and stayed there until 1950, when he temporarily returned to Japan

Fig. 4.28 Flood damage caused by the Kathleen Typhoon in September 1947. Arakawa River Basin, Suburb of Tokyo, A. Laflamme photograph collection, USAHEC. A. Laflamme was a photographer for the US Army Signal Corps

Fig. 4.29 Fishing for seaweed in Tokyo Bay. Omori, Tokyo, May 23, 1947, Hubert Gregory Schenck papers, Hoover Institution Archives. The industrialization of Tokyo Bay since the 1950s has led to rapid land reclamation, which has completely changed the nature of the inland sea. He was a geologist and Chief of the Resources Division of the Occupation Forces in Japan from 1945 to 1951

Fig. 4.30 The Bald mountains in the background are probably caused by excessive logging during the war. From the collection of Henry H. Soulen Collection, Taichi Kinugawa, Gunma Prefecture, Japan (original color)

Fig. 4.31 Two girls giving piggyback rides to their siblings, October 1945. Location unknown. USMC photo. 127-140131 NARA

Fig. 4.32 Float made by a town's community to show appreciation for food aid, September 15, 1946. Kanda, Tokyo. USASC photo. 111SC-279683. NARA. Float mimics the shape of bread that is commonly eaten in Japan

4.5 Concluding Remarks

As established in the previous chapter, although some issues have been resolved, others remain unresolved. In postwar Japan, we can see that the issues considered in SDGs 1–4, which fulfill basic human requirements, have already been solved, but there is still room for discussion regarding SDGs 6–9 and 13–15, which are relevant in the context of the transition to an industrialized society.

Progress regarding SDGs 5, 10, and 16, related to gender equality, seem to have remained stagnant since the end of World War II.

This chapter is not intended to present an in-depth discussion of each of these goals, but rather introduces various photographs of occupied Japan and focuses on the images left behind by the era as a whole. It is based on photographs I have personally researched, and it has limitations as a source of historical material. However, I wanted to demonstrate the act of looking at photographs from the perspective of the SDGs during a period of great historical change. This is to rediscover the potential value of photography. From the standpoint of researchers involved in archiving, it is a way to discover and revive photographs that may be buried under the mountain of historical records.

I want to recommend that attention be paid to photographs of the past social changes in certain regions of interest and that they are examined. The photographs should raise a variety of questions and overlap with other interests.

In this chapter, I have presented photographs related to all 17 goals; however, you can explore the photographs while framing the issues based on your interests. As you look through the numerous photos, you will get a clearer picture of where the present problem originated and how it has changed since.

Furthermore, if future studies can consciously create opportunities to "take pictures" based on this foundation, the connection between historical background and contemporary issues can be better clarified.

Fig. 4.33 Charcoal briquettes and an oil stove coexist in a show window of a fuel store in Minami Inari-cho, Taito Ward, Tokyo, December 1961. From the collection of the Shitamachi Museum of Taito Ward, Tokyo

A final point must be made.

Some of the photographs reflecting the past are abhorrent scenes or dark chapters in history from the perspective of today's values, such as Fig. 4.15 and Fig. 4.24 in this chapter. These are records of the past that we have been struggling with, but at the same time, these issues are connected to various issues of the present. It is important to be conscious of how these photographs, as a source of knowledge, will be made available when considering the historical background of the SDGs.

Fig. 4.34 School lunchtime at a public junior high school in Tokyo. The words "Atomic Energy Research Institute" are pasted on the back. 1965. Collection of Taito City, Tokyo

Fig. 4.35 Construction of public housing by the Tokyo Metropolitan Government. Built on former military land, January 13, 1949. USASC photo. 111SC-317993. NARA

Fig. 4.36 Ishikawajima shipyard damaged in the war. Toyosu, Tokyo, October 17, 1945. USASC photo. 111SC-215969 NARA

The sanctuary of archival records should be made available for any possible future activities and should not be modified or abolished due to contemporary values. Of course, they should not be entirely destroyed, but they should not be circulated openly either. I would like to emphasize that these images must continue to be introduced with care.

Fig. 4.37 Image from the same location where the photograph in Fig. 4.36 was taken. Toyosu, Tokyo. 2021 by Google Map

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author introduces official photographs of the U.S. military, i.e., Signal Photo, Navy, Army Air Forces (later Air Force), and Strategic Bombing Survey Group

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Satō Y (2021) Beikoku ni okeru senryo-ki nihon no shashin shiryo o dou toraerunoka : genjo, zentai-zo, nihon eno kangen ni okeru kadai (photographic materials of occupied Japan in the United States—their current status, overall condition, and issues in returning them to Japan) in Karento Aweanesu (current awareness) (347), CA1993:10–16

Ueda K, Kinugawa T, Satō Y (2021) Sengo kyoto no iro wa amerika ni atta: karaa shashin ga egaku okyupaido japan to sonogo (The colors of postwar Kyoto (1945–52), found in the USA!–occupied Japan and beyond, captured in vintage color photographs). Kyoto: Kyoto Bunka Hakubutsukan

Website

The following website is a collection of photographs taken by researchers who were in Japan. You can view the photographs online and use them in your research

The Oliver L. Austin Photographic Collection at the Institute on World War II and the Human Experience at Florida State University. Oliver L. Austin() was an ornithologist. https://austin.as.fsu.edu/. (Accessed 04 Jan 2021)

John W. Bennett Collection, in the Rare Book Room, Thompson Library, Ohio State University, USA. John W. Bennett (1915–2005) was a sociologist. https://library.osu.edu/site/japanese/2005/04/08/john-w-bennett-digital-collection/. (Accessed 10 Jan 2022)

Lennox and Catherine Tierney Photograph Collection (Marriott Library, University of Utah, USA). Patrick Lennox Tierney (1914–2015) was an expert in art education. https://collections.lib.utah.edu/search?facet_setname_s=uum_lctpc. (Accessed 10 Jan 2022)

Part II
For Planet

Ecology and Sustainable Development in Japan

5

Satoshi Kurokawa

Abstract

This chapter fits Goal 15 of the SDGs and analyzes the protection and sustainable use of territorial ecosystems in Japan, focusing on sustainable agriculture and forestry. The beautiful natural landscape and pristine nature in Japan are protected in nature parks. After the Earth Summit in 1992, the government committed to protecting socio-ecological landscapes referred to as "satoyama." They include farmland, pastureland, and forests for logging. They are deteriorating because the population of farmers and forestry workers is declining and aging. The Natural Parks Act introduced a scheme to ensure that environmental NGOs maintain these areas on behalf of the farmers and forest workers. Modernization of agriculture has caused the loss of biodiversity in farmlands. Restoration projects have been implemented to restore biodiversity in rural areas. To reduce farmland abandonment, the government grants subsidies to help encourage eco-friendly agriculture. The government is encouraging active farmers to scale-up agricultural management to be competitive in the marketplace. Solar sharing is one way to help farmers. Ecologically sustainable development is thus interwoven with social and economic factors.

Keywords

SDGs · Satoyama · Nature park · Ecosystems

5.1 Introduction

This chapter explores legal schemes that protect the biodiversity and ecosystems of Japan. In other words, this chapter considers the legal mechanisms that "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss." (Goal 15 of SDGs). The protection of ecosystems in Japan depends on the sustainable development of agriculture and forestry. Therefore, this topic relates to Goal 11. Sustainable management of farmlands and forests sometimes incorporates renewable energy and therefore relates to Goals 7 and 13.

Nature parks play an important role in nature protection schemes. The nature parks concept was originally established to protect areas of natural scenic beauty and pristine nature. But people in Japan realized that ecosystems and biodiversity need to be protected, and people became aware of the conservation of ecosystems

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in socio-ecological production landscapes such as farmlands.

Socio-ecological production landscapes are degraded through the abandonment of rural farmland and forest management. The socio-ecological production landscapes, which are called "satoyama"[1] in Japanese, are dominant rural landscapes with high-level ecosystems and biodiversity values. Therefore, legal schemes to protect the agricultural and forestry industries are important aspects of nature protection laws. In this way, protecting nature concerns "various fields, such as law, economics, and sociology, as well as ecology, because the problems are extremely widespread, as they are intricately interlinked, and arise directly from our civilization and way of life" (Murasawa 2020, p9).

Socio-ecological landscapes such as the satoyama areas are not unique to Japan and are found in many countries worldwide. Traditional rural landscapes in other part of Asia are similar to the satoyama of Japan. Outside Asia, traditional agricultural fields and pastures are partially artificial and natural areas that have been conserved for a long time. Therefore, the Japanese government and United Nations University jointly initiated the Satoyama Initiative. The International Partnership for the Satoyama Initiative (IPSI) was established in 2010 to facilitate its implementation. (IPSI 2021).

Previously, legal schemes to protect nature were not cognizant of the ecosystems and biodiversity. Even the Nature Parks Act was implemented to protect areas of scenic beauty and pristine nature. But, after the Earth Summit of 1992, protecting ecosystems and biodiversity became an important aspect of environmental law. The Environmental Policy Act of 1993 §14 requires governments "to protect biodiversity, such as the diversity of ecosystems and wildlife species, and to systematically conserve various features of the natural environment, such as those in forests, farmlands, and riverside areas, in accordance with the natural and social conditions of the area."

Satoyama landscapes have been formed and maintained alongside agricultural activities or forestry activities over centuries. These industrial activities have disturbed the vegetation transition and kept the landscapes under specific conditions, such as those in paddy fields. These are partially artificial and natural environments, and people depend on them to obtain food, fuel, timber, and other materials necessary for their livelihoods. However, economic development and urbanization after World War II changed the situation in rural areas.

Now, the population of farmers and forestry workers has declined, and they have become too old to continue farming and logging. The disturbance caused by agricultural and forestry activities is not sufficient to maintain the satoyama landscapes, and they are at stake. This crisis relates to Goal 15 of the SDGs which states that it is important to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss." Sustainable use of territorial ecosystems and sustainable management of forests are essential to maintain a socio-ecologically productive environment that dominates the natural environment in Japan.

This chapter starts by analyzing the nature park initiative and demonstrates that the satoyama landscapes are included in these. The Nature Parks Act has employed a new scheme, in which environmental NGOs help farmers manage their farmlands and pastures. This section then analyzes why agriculture in Japan was not competitive in the world market and reveals the policy that encourages active farmers to be competitive. In this context, the reintroduction of the storks and crested ibis that were once extinct in the wild in Japan is described in detail. In this regard, the protection of migratory birds is discussed too. Domestic and international protection

[1] "Satoyama is a Japanese term for a mosaic of different ecosystem types—secondary forests, farmlands, irrigation ponds, and grasslands—along with human settlements, which has been managed to produce bundles of ecosystem services for human well-being. Satoyama found largely in rural and peri-urban areas of Japan is a way of life; in other words, a classical illustration of the symbiotic interaction between ecosystems and humans. This concept has been recently extended to satoumi, which constitutes marine and coastal ecosystems." (JSSA 2010, p4).

schemes are also mentioned. Finally, I will discuss the trend of policy and legislation that requires the government to include environmental factors in their decision-making processes. In addition to agricultural legislation and forestry legislation, legislation concerning roads, rivers, and urban planning is now part of environmental law.

5.2 Nature Protection Schemes in Japan

5.2.1 Nature Reserves

5.2.1.1 Nature Parks and Natural Scenic Beauty

The nature park initiative is at the center of nature protection in Japan with nature parks occupying approximately 15% of the land. There are 34 national parks (2,194,931 ha), 57 quasi-national parks (1,445,150 ha), and 311 prefectural nature parks (1,948,730 ha). Among them, national parks are the most important, accounting for 5.8% of the land. The nature park initiative was established by the National Parks Act of 1931. The Nature Parks Act replaced the 1931 Act and made the initiative sophisticated. The nature park initiative was introduced to protect places of natural scenic beauty so that people could visit and enjoy them. Nature parks were expected to contribute to the health, recreation, and culture of citizens by promoting their utilization. The Ministry of Environment has been promoting the "Project to Fully Enjoy National Parks" and has enhanced "the branding of the national parks to attract more domestic and international visitors by implementing measures to facilitate the utilization of national parks while protecting what needs to be protected and conserved." (MoE 2021b, p12).

The National Parks Act defines national parks as "places of the greatest natural scenic beauty, representing the exemplary scenic beauty of our country"(§2). The Act did not have the words 'ecosystems' and 'biodiversity' before the 2003 Amendment Act introduced them. The 2010 Amendment Act added "the contribution to the conservation and sustainable use of biological diversity" to the purpose of the Act. However, the Nature Parks Act had already been protecting ecosystems in Japan. As beautiful scenery reflects the vegetation and ecosystems of a land, protecting it leads to the protection of the vegetation and ecosystems.

The turning point was the Earth Summit (United Nations Conference on Environment and Development) of 1992, which was held in Rio de Janeiro. The Convention on Biodiversity was agreed upon. It allows people in Japan to realize the importance of biodiversity and ecosystems and helps them to understand that ordinary nature is important and should be protected as is beautiful and pristine nature. The concept of ecosystems and biodiversity provided reasons why productive landscapes such as paddy fields, pastures, and forests for logging should be protected in nature parks. The Biodiversity Policy Act was legislated in 2008, the preamble of which stipulated, "biodiversity is facing serious crises, including the extinction of species and destruction of ecosystems due to development and other activities by human beings, deterioration of satoyama (managed woodlands or grasslands near human settlements), etc., due to reduced human activities along with changes in socio-economic conditions."

5.2.1.2 Protection and Utilization of Natural Environment in Nature Parks

Historically, the recreational mission of nature parks has become important. Nature parks have played an important role as places where people interact with nature and enjoy outdoor activities. They have provided recreational facilities constructed within them, such as park visitor centers, trails, and campgrounds, to help people access and enjoy nature. This has encouraged local tourism in park areas.

Personal income and leisure time increased from the 1960s to the 1970s in Japan. Consequently, the number of visitors to nature parks also increased. The designation of land for nature parks was accelerated to meet this demand. In addition, new roads and accommodation

facilities were constructed to help visitors access natural parks. However, the number of visitors increased beyond the holding capacity of the parks, which has damaged the ecosystems with compaction of the ground, increased waste, increased wastewater discharge, and so on. To help solve the problem of overuse, the 2002 Amendment Act introduced the Regulated Utilization Area to restrict the number and behavior of visitors. The contradiction between the protection of nature and its overuse for recreational purposes is a flaw of the nature park scheme. Therefore, the Natural Environment Conservation Act which focuses on protecting pristine natural areas was legislated in 1972. However, the areas protected by this legislation are minor, accounting for less than 0.3% of the land in Japan.

Japan has five natural heritage sites: The Yakushima, the Shirakami-Sanchi, the Shiretoko, the Ogasawara Islands, and recently listed southwest islands, including Amami-Oshima Island, Tokunoshima Island, the northern part of Okinawa Island, and Iriomote Island. These World Natural Heritage sites are pristine in nature and ecosystems and are protected by the Nature Parks Act and the Nature Conservation Act.

5.2.1.3 Nature Park as Regional Park

Nature parks in Japan are nature reserves but are not necessarily public properties. They are regional parks designated as nature parks through zoning. Privately owned land is included in nature park areas, in addition to publicly owned land. This scheme differs from national parks in the United States and Australia which had vast pristine territories that were suitable for nature parks. Japan has a small surface area which is densely populated. Japan also has a long history of private land ownership, and therefore, areas with valuable ecosystems are sometimes already utilized as paddy fields, pastures for grazing, forests for logging, and so on. These valuable ecosystems were protected by law from disruption caused by excessive development activities. Natural areas are designated by the government as nature parks consisting of public and private land. "Many people live in areas belonging to national parks, which are home to several industries including agriculture and forestry" (MoE 2021a). The government designates the natural areas that it wants to protect as parks.

The government can designate areas of land as natural parks without obtaining ownership. It then imposes regulations on landowners. Around a quarter of the land in national parks belongs to private entities. Many people live inside natural parks. They cultivate farmland, use grassland for grazing, or use forest for logging. For example, in the Ise-Shima National Park, privately owned land accounts for over 90% of the park land. In the Oze National Park, the most valuable wetland area, which is a Ramsar site, is owned by an electric power company. The company possesses 40% of the Oze National Park area and has taken care of the wetland for a long time as a corporate social responsibility (CSR) activity. Most land in nature parks owned by the government is managed by the Forestry Agency of the government, which engages in logging.

The positive aspect of the regional park scheme is that the government does not need to obtain land ownership to make the land a part of a nature park. Therefore, natural areas that should be protected can be included in nature parks without any monetary exchange. The negative aspect of the regional park scheme is that it is necessary to reconcile the protection of nature with protection of the property rights of landowners, which are well protected by the Constitution.

The areas in national parks are divided into subcategories. The most beautiful places in the parks are designated as exceptional zones. These zones are further classified into four categories: special protection and special zones of class I, class II, and class III. Other areas are classified as ordinary zones that work as buffers against the influences of the areas surrounding the parks. In the special zone, development activities such as building construction, land formation, and logging need permission from the government and the special protection has the most stringent

restrictions. In the special protection, the behaviors such as tree cutting, plant cultivation, campfires, or gathering materials are prohibited without the permission of the government. These activities are permitted only if the natural environments are not threatened. In ordinary zones, large-scale construction of facilities, extraction of minerals, or setting up advertising displays is regulated and needs to be reported to the government beforehand.

5.2.1.4 Socio-Ecological Production Landscapes in Nature Parks

Nature parks include a variety of socio-ecological landscapes. Among them, the landscape of grasslands on the lower slopes of Mt. Aso in Aso-Kuju National Park is well known. The beautiful grassland scenery was created and is maintained by dairy farmers who graze cattle and horses there. They practice controlled burning of the grasslands every spring to renew them as the cattle and horses prefer the soft grass that grows from under the ash. It takes physical strength and energy to burn large grasslands. As the livestock farmers got older, it becomes harder for them to burn the grasslands every spring. Therefore, the areas burnt become smaller year by year. Bamboo and trees have regrown in some of the former grasslands and destroyed the beautiful landscapes and grassland ecosystems. To overcome these problems in socio-ecological landscapes, a landscape protection agreement scheme was introduced into the Nature Parks Act. Landscape protection agreements can be made between landowners (e.g., farmers) and park management organizations. Usually, environmental NGOs become park management organizations and manage land in parks on behalf of landowners. The grassland for grazing on the lower slopes of Mt. Aso is protected by the local environmental NGOs through the landscape protection agreement. The members of the NGO help farmers burn the grasslands every spring, and, as a result, the grasslands have almost recovered. Place-based solutions for the conservation and restoration of social-ecological production landscapes are often attempted in Asia (Kozar et al. 2020).

As mentioned above, there are two types of problems in nature parks, one being overuse and the other underuse. To deal with the overuse problem, a regulated utilization zone scheme was established as well as the no-enter zones. The intention is to balance the conservation of ecosystems and their sustainable use by restricting entry into the sensitive area without permission. A landscape protection agreement scheme was established to deal with the underuse problem. Environmental NGOs are meant to help farmers manage farmland and maintain the natural beauty and ecosystems in socio-ecological production areas.

5.2.2 Other Legal Schemes Protecting Species and Ecosystems

5.2.2.1 Protection of Animals and Birds

The Nature Parks Act and the Natural Environment Conservation Act protect the natural habitats of wild fauna and flora, and, in addition to these nature reserve legislations, Japan has several statutes that protect species and ecosystems. Among them, the Act on the Control of Animal Hunting and Protection of Animals is important. The statute was first legislated as a hunting law in 1895, but gradually changed its format to protect birds and animals in their habitats. To keep the population of birds and animals hunted was inevitable for hunters to enjoy hunting.

Currently, statutes prohibit the capture and killing of wild birds and wild mammals, and only 28 species of birds and 20 species of mammals are listed as game birds and mammals that can be legally hunted according to the law. Hunters must obtain hunting licenses from the prefectural governor and register themselves as hunters. The hunting period, areas, and methods are restricted, and the number of captures is restricted. In addition, this statute has established wildlife protection areas and special wildlife protection areas. Conservation projects have been conducted in these areas, and the capture and hunting of birds and animals are strictly prohibited.

5.2.2.2 Protection of Migratory Birds

Migratory birds are protected internationally. Japan is party to the Ramsar Convention (Convention on Wetlands of International Importance, especially as Waterfowl Habitat) and now has 53 Ramsar sites (155,174 ha). In addition, Japan has bilateral conventions for the protection of migratory birds with the United States and Russia. Japan has bilateral agreements for the protection of migratory birds with China and Australia. To protect migratory birds, it is necessary to protect them both in breeding and wintering grounds. Protecting habitats such as wetlands is especially important.

The example of Latham's snipe protection shows that protecting migratory birds at all landing grounds, including relay points, is important. Latham's snipe is protected by the Japan-Australia Migratory Bird Agreement and is ardently protected in Australia and Japan. However, the bird population did not recover. It was reported that many snipe that left Japan for Australia were captured on the Melanesian islands. Japan is an active member of the East Asian-Australian Flyway Partnership (EAAFP). The EAAFP was launched in 2006 to protect migratory waterbirds, their habitats, and the livelihoods of people depending upon them and is expected to work effectively. Currently, there are 39 partners including 18 national governments, 6 international agencies, 13 international NGOs, and so on (EAAFP 2021).

5.2.2.3 Conservation of Endangered Species

The Conservation of Endangered Species of Wild Fauna and Flora Act of 1992 has protected the species in danger of extinction. The statute prohibits the capture and killing of listed species. The Red List (2020) includes 3176 threatened (critically endangered, endangered, vulnerable) species. The hunting, taking, killing, or injuring of living endangered species is prohibited unless a governmental permit is granted. In addition, the transfer of endangered species, dead or alive, for commercial or non-commercial use is prohibited. However, the implementation of this legislation has been criticized as being too moderate (Takahashi 2009, pp 1958–1959).

The government rehabilitates the habitats of endangered species and implements conservation projects, such as captive breeding. The breeding of the crested ibis on Sado Island is a well-known example. Many endangered species are protected as natural instances under the Protection of Cultural Properties Act of 1950.

5.2.2.4 Regulation of Alien Species and Genetically Modified Organisms

Alien species are regulated by the Invasive Alien Species Act of 2004 as they disturb the original ecosystem in Japan. For example, racoons have reproduced rapidly in Japan. In many areas, they have replaced the racoon dogs which are one of the major native animals in Japan. Racoon dogs often appear in folk tales and therefore are important animals not only ecologically but also culturally. Racoons were originally imported as pets but were later abandoned by their owners and reproduced in the wild. Another famous invasive alien species is black bass, which prevails in rivers and lakes across the country.

The Invasive Alien Species Act was legislated to prevent the proliferation of foreign species that threatened the habitats of native species. This statute prohibits the cultivation, transfer, and import of invasive non-native species. This statute, however, covers only plants and animals that are imported and does not regulate the transfer of plants and animals within the country. Based on this statute, the government is implementing an extermination project for alien species.

The Act on the Conservation and Sustainable Use of Biological Diversity through Regulations on the Use of Living Modified Organisms regulates living genetically modified organisms (LGMOs). The government is afraid that native species in the ecosystem could be replaced by genetically modified ones. The GMO species could mate with native species, and the offspring might replace untainted native ones. Therefore, the government does its best to regulate LGMOs.

5.3 Restoring Lost Habitats

5.3.1 Agriculture Modernization and Loss of Habitats

In the process of modernizing agriculture, wildlife habitats have been lost in agricultural areas. Previously, many paddy fields in Japan were flooded in winter due to poor drainage. These areas were previously wetlands with a rich biodiversity, and many insects, frogs, and fish were present, even in winter providing rich feeding grounds for many birds. However, it was not easy to use agricultural machinery on this land as it sank into the mud. Therefore, farmers improved the conditions of wet paddy fields to increase rice yield by piling up soil, raising the paddy fields, and improving drainage. They drained the paddy fields in winter to enable them to use their machinery. The irrigation and drainage facilities were covered with concrete. In addition, they used many insecticides and herbicides to help improve their yields. The production of rice increased, but the paddy fields lost their biodiversity. Many small creatures, such as insects and frogs, lost their habitats and disappeared leading to the loss of winter-feeding grounds for many species of birds, such as storks and ibis. Watercourses were also improved to prevent flood damage and riverbeds and banks were covered with concrete, thus depriving the storks and ibis of these feeding grounds too.

The last wild stork (oriental white stork) in Japan was captured in 1971 and transferred to a captive breeding facility. This was the extinction of storks in the wild in Japan. In addition, the last wild crested ibises were captured in 1981 in Japan. Previously, they were common birds found across Japan until the beginning of the twentieth century.

5.3.2 Reintroduction of Endangered Creatures (Stork and Ibis)

Stork and crested ibis became endangered in Japan during the agricultural modernization process. However, people in Toyooka, which was the last wild stork habitat in Japan, wanted storks to return to their landscape. The captive breeding program for storks was finally successful using young individuals gifted by Russia and China in the 1980s. In 2005, five storks were successfully released into the wild in Toyooka. As the population of the storks increased, they expanded their habitats across Japan. In 2021, more than 200 storks were found to exist in the wild.

The reintroduction project was successful because farmers in Toyooka engaged in alternative farming practices to conserve the paddy ecosystems, which recreated the winter-feeding grounds for the storks (Naito et al. 2014). A group of farmers kept their paddy fields flooded in winter to create habitats for fish, insects, and other small creatures. Another group of farmers restored abandoned paddy fields into wetlands. There were many abandoned paddy fields in Toyooka due to the aging population and the low productivity of small-scale farming. Some paddy fields damaged by typhoons were also abandoned and restored into wetlands to recreate habitats for storks. The farmers reduced the use of insecticides and herbicides to encourage the return of small creatures into the fields. Finally, they stopped using insecticides and herbicides altogether.

It was not easy for farmers in Toyooka to abandon modern agricultural practices and implement alternative practices. However, they remembered spending time with storks when they were children, which encouraged them to accept the innovation of agricultural practices to help reintroduce storks to the areas. River ecosystems were also restored to encourage their original biotope statuses. The Maruyama River Basin, which flows through Toyooka, has plenty of wetlands with a rich biodiversity. These wetlands, including paddy fields, contributed to adding the Maruyama River Basin as a listed Ramsar site in 2012.

The stork-friendly farming method implemented in Toyooka requires more labor than in ordinary agricultural practices with the yield per

unit area also being lower. But "the rice raised with storks" has become valued as eco-friendly rice and it has become more competitive on the market, resulting in enough income for the farmers. This increase in income has motivated them to continue farming. The stork-friendly farming led to the reform of rural agricultural practices and contributed to the conservation of the socio-ecological production landscapes.

A similar case can be found on Sado Island, where crested ibises have returned to the wild environment. Even though the crested ibis in Japan was endangered, the Japanese government successfully bred those gifted by China and released them onto the island. To prepare for the reintroduction of crested ibises into the wild, a group of farmers kept sections of their paddy fields flooded in winter to provide feeding grounds for the crested ibises. The rice produced in these paddy fields sells under the brand "the crested ibis-friendly rice."

5.4 Protecting Landscapes and Ecosystems in Rural Areas

5.4.1 Abandonment of Farmland

The abandonment of farmland in rural areas is an ongoing process in Japan, which has caused the degradation of ecosystems. The change in the structure of industry that followed economic growth and the associated rural–urban migration were the leading causes of farmland abandonment in rural areas. Therefore, it is necessary to halt the abandonment and its negative impact on conserving ecosystems in the countryside. The ecologically sustainable development in rural areas is connected to social and economic sustainable development. As the 2030 Agenda for Sustainable Development declared, "we are committed to achieving sustainable development in its three dimensions—economic, social, and environmental—in a balanced and integrated manner."

The productivity of the agricultural sector is lower than that of the industrial and commercial sectors. Therefore, children of farmers are reluctant to inherit the family business. In the high economic development era of the 1960s and the 1970s, many of them went to cities and worked in factories and other businesses. Others became part-time farmers, who worked as city employees on weekdays and on their farmlands on the weekend. Gradually, part-time farmers quit these companies due to retirement. However, they continued to be farmers and later stopped farming when they got too old to cultivate their farmlands. Unless their children inherited the agricultural family business, there was no one to cultivate these farmlands, which led to their abandonment. Paddy field ecosystems were no longer flooded and thus were lost. Farmland abandonment has led to the degradation of the countryside and the loss of biodiversity. Therefore, farmland policy is now a part of the environmental policy.

5.4.2 Farmland Reform After WW II and Smallholder Farming

5.4.2.1 Smallholder Farming

Agriculture in Japan has been low in productivity and uncompetitive for a long time. This is because the amount of farmland per farmer is minimal. Therefore, the government has introduced a policy of encouraging large-scale, motivated farmers to increase their productivity. The government encourages motivated farmers to take over farmland that is no longer utilized and cultivate it on a large scale.

Looking back in history, one realizes that smallholder farming appeared after the farmland reform, which was implemented after World War II. This reform was implemented as a part of the democratization process in Japan, during which the government forced landowners who lived in cities and did not cultivate their farmland to sell it to the government. The government then sold the acquired land to tenant farmers. These previous tenant farmers could purchase around one hectare of farmland, which they cultivated with their families. Farmland reform improved their living conditions which contributed to the access of democracy in rural areas. Each farmer

thus became a landowner with an average of one hectare of farmland, but in many cases, these farmers could not profit from agriculture later. However, they still held onto the land as important property for their families. They were reluctant to sell or rent the farmland to other farmers. As a result, the farmland reform has prevented the development of large-scale agriculture in Japan.

The Farmland Act of 1952 supported the continuation of smallholder farming. (Ito J. et al. 2016) This legislation placed the sale and purchase of farmlands under governmental control, and any transaction of farmland needed to be approved by regulatory authorities. In principle, only farmers can purchase farmland. Businesses were not eligible for their own farmland, and, even now, to be a "corporation qualified to own cropland`(Farmland Act §3), the company needs to show that its main business is agriculture, and most of the main members are farmers. This scheme has prevented land from being sold to companies and from being converted to residential or industrial land for use by them. In this context, the statute protected farmland. However, it prevented farmlands from being acquired by large-scale farmers who are motivated and have sufficient capital to farm efficiently. Ironically, this scheme, which was intended to protect farmlands, became an obstacle to the development of productive agricultural practices, making Japanese agriculture less competitive on the international market.

5.4.2.2 Scale-Up of Agricultural Management for Sustainability of Farmland

The government is now prompting the scale-up of agricultural management to make the agricultural sector competitive. In addition, the government has come to recognize that farmlands should also be protected as ecosystems, as they are the habitats of a variety of species, and that farmlands supply a variety of ecosystem services. This recognition and associated farmland policy was enhanced during the negotiation process of the Trans-Pacific Partnership (TPP). MA (2003, p3) defined ecosystem services, "ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefit."

Even the Agriculture Policy Act of 1961 recommended that farmers expand their scale of farming through the purchase of farmland from ex-farmers and part-time farmers working in cities to increase the efficiency of farm work and income from farming. However, the areas farmed in large scale did not increase so much because weekend part-time farmers and those who quit farming seldom sold or rented their farmland as they wanted to hold onto it. As a result, the average area of cultivated farmland remains small in Japan.

The aging and declining farm population increased significantly around 2000, and the government strongly encouraged active farmers to collect farmland and helped them to incorporate the land. As a result, the government expected them to perform efficient and stable agricultural practices and to be competitive enough to survive in the international market. They were also expected to employ people who were not born into farming families, but who wanted to start farming. The Act on Promotion of Improvement of Agricultural Management Foundation has accelerated the collection by active farmers of farmlands that were no longer farmed by landowners. In addition, the Farmland Act Amendment of 2009 admitted that companies became farming entities and participated in farming businesses. Community-based farm cooperatives (voluntary organizations) are now transitioning to corporate firms.

Historically, efficient and large-scale production systems have often resulted in environmental degradation and loss of biodiversity. Therefore, it is important to develop methods that can conserve ecosystems and biodiversity in large-scale production.

Foreign technical training interns in agriculture play an important role in filling the labor

shortage in farming. However, the operation of foreign technical training interns is different from the original purpose of this scheme and there are many problems that need to be solved, such as improving the working conditions of trainees.

5.5 Sustainability with Sufficient Income

5.5.1 Direct Payments for Environmentally Friendly Agriculture

The government of Japan now recognizes farmland not only as food production sites but also as ecosystems that have many functions. The government's intention is to sustain farmland ecosystems with subsidies. The government has granted subsidies to farmers who cultivate rice terraces in mountainous areas. This type of subsidy is called a direct payment to farmers. It was offered to those engaged in environmentally friendly agriculture. These subsidies are justified as payments for ecosystem services. The Act on Promoting the Introduction of Sustainable Agricultural Production Methods of 1999 declared this policy direction, and the Act on Promotion of Multi-functionality of Agriculture of 2015 created a legal framework for direct payments.

5.5.2 Solar Sharing

It is not easy to continue farming with a small income. Therefore, many farms have been abandoned. As a result, the government has encouraged the installation of solar power generation facilities, such as photovoltaic systems, on farms. The feed-in tariff scheme of renewable electricity guarantees stable income to farmers who have installed it. If the sales of agricultural products and electricity sales are combined, the farmer gains sufficient income to continue cultivating. Some farmers have recommenced cultivation with the introduction of solar panels. This practice is called solar sharing, and it is being practiced across Japan.

To begin solar sharing, the landowner needs to obtain permission for farmland conversion from the local agriculture committee. This permission scheme has been an obstacle to the expansion of solar sharing. It is true that strict regulation of farmlands to prevent them from being used for other purposes has protected them. However, the government, especially the Ministry of Agriculture, Forestry, and Fisheries, is willing to expand solar sharing to protect agriculture and farmlands. Solar sharing will contribute to mitigating climate change by reducing CO2 emissions and maintaining ecosystems and biodiversity in rural areas.

5.5.3 Forest Management

5.5.3.1 Unprofitable Forestry

Forestry management is currently difficult to achieve as the timber produced in domestic forests is not priced competitively because transporting it from the sawmills to the marketplace is costly in Japan. Therefore, forestry workers stopped logging in many forests to avoid losses occurring when they logged and sold the timber. They also stopped taking care of the trees to reduce expenditure. The situation of national forestry, which is owned and managed by the government, is like that of privately owned forests. Previously, the national forestry was financially independent and returned its profit to the national treasury. Previously, the forestry office was blamed for felling too many trees. However, national forestry became unprofitable and was forced to cease the self-supporting accounting system. Currently, the National Forestry Agency manages its forests for public interest with the expenditure of national treasury. National forests are divided into five categories based on their features. The expected functions to be enhanced are disaster prevention, ecosystem protection, recreational usage, formation of comfortable living surroundings, and watershed protection.

5.5.3.2 Matured Forests

The forests in Japan have reached maturity and are therefore ready to be cut down. However, cutting

trees and transporting the timber to markets is costly. Therefore, encouraging the use of domestic wood is an important forest management policy in Japan. Without logging, the old forests will not rejuvenate and will no longer absorb CO_2. The government encourages building wooden houses to increase the demand for timber.

Biomass power generation using wood chips is enhanced to generate income for thinning the planted forests. Wood chips are made from this wood. Biomass power generation contributes to the mitigation of climate change as a renewable energy source. In addition, it is becoming popular to make chopsticks and other articles from thinned wood to help support forest management. These wooden items are supported by green consumers as eco-friendly.

5.6 Consolidation of Development and Environment

5.6.1 Harmonization Between Economic Development and Environment

In the era of economic development and serious pollution of the 1960s, people criticized so-called harmonization clauses which required the regulatory agencies to consider "harmonization between economic development and the environment." These clauses existed within the Pollution Prevention Policy Act and other pollution control statutes and were deleted from these statutes in 1970. People thought that the clause authorized factories to operate while polluting the environment. However, the consolidation of development with environmental protection returned with the enactment of the Environmental Policy Act of 1993 after the Earth Summit, where the concept of sustainable development played an important role. The statute made sustainable development the fundamental principle of environmental law in Japan and recognized that sustainable development meant ecologically sustainable development and that generational ethics between the present and future generations were to be realized. A variety of statutes that promote development have now included environmental protection in their goals to reflect the sustainable development goal in legal schemes. Therefore, many statutes now form part of the environmental law systems. For example, the River Act, the Coast Act, the Road Act, and so on are important parts of environmental law.

5.6.2 Environmental Impact Assessment

The environmental impact assessment (EIA) scheme is an important tool for considering environmental factors in the design of development. At the national level, the Environmental Impact Assessment Act of 1997 was legislated, and Japan had a legal scheme for EIAs. Strategic environmental assessment (SEA) was introduced in 2011. The EIA Act requires the government to consider environmental factors when issuing licenses or permission for development.

The EIA is a scheme of information disclosure and public involvement. Therefore, Japan needed to wait for EIA Act legislation until 1997, because the transparency of Japanese society and the government had not matured. With the Administrative Procedure Act of 1993 and the Freedom of Information Act of 1999, Japan was prepared to legislate the EIA Act.

5.7 Concluding Remarks

After serious pollution cases have disappeared due to strict pollution regulations, climate change and the protection of ecosystems are now important environmental issues in Japan. Previously, the nature protection policy focused on the prevention of development that damaged the natural environment. The Nature Parks Act has played an important role in the protection of beautiful natural scenery and pristine nature. Birds and other animals have been protected by the Control of Animal Hunting and Protection of Animals Act. These have been very successful. However, people have realized that it is important to protect ecosystems and biodiversity rather

than natural beauty. Therefore, the government focuses on the protection of socio-ecological landscapes, such as farmland and forest, that hold valuable ecosystems within them. People are aware that they depend on the ecosystem services to survive. The degradation of ecosystems and biodiversity in socio-ecological productive landscapes has been caused by a decline in the agricultural and forestry industries.

Protecting ecosystems on land is within the scope of Goal 15 of the SDGs. Maintaining farmland, pastures, and logging forests requires sustainable agriculture, livestock farming, and logging. Thus, it involves the social and economic developments covered by other goals of the SDGs concerning people and prosperity. The consolidation of the environment, society, and economy is an indispensable factor in protecting ecosystems in Japan.

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Globalization and Sustainability: De Jure and De Facto Approach

6

Kaoru Nabeshima

Abstract

This chapter covers sustainability issues from the industrial development and international trade perspectives. Issues covered can be broadly regarded as Goal 12: "Ensure sustainable consumption and production patterns" but touches upon various goals. In pursuing the goal of sustainability in economic activities, the society can take two different approaches. One is based on laws (including international agreements), *de jure* approach. The other is based more on the market force, such as based on Voluntary Sustainability Standards (VSS), de facto approach. Within the de jure approach, the chapter will cover efforts at global level (international agreements) and efforts at domestic levels. At the international levels, the chapter introduces some of the key areas and the motivations behind these agreements. For the discussions on the domestic levels, the chapter introduces the differences between the production-based environmental regulations and the product-related environmental regulations, and how this has influenced the industrial activities and international trade. In the part for VSS, the chapter will focus mainly on private standards with third-party certification schemes and how these diffuse across countries through trade linkages and implications to producers especially in developing countries. Finally, the chapter touches upon the governance issues related to regulations and private standards.

Keywords

International trade · Regulations · Private standards · Sustainability

6.1 Introduction

Sustainable Development Goals (SDGs) cover sustainability issues in many economic activities. One focus of the SDGs is to promote sustainable consumption and production in Goal 12 such as on chemical management (target 12.4). Achieving this goal will have impacts on the industrial activities and international trade, and Goal 12 is related to many other goals specified in SDGs. For instance, Goal 2 (target 2.4) focuses on development of sustainable agriculture; Goal 3 (target 3.9) on reducing deaths from pollution; Goal 5 (target 5.1) on gender discrimination; Goal 6 (target 6.3) on reducing water pollution; Goal 7 (target 7.2) on renewable energy; Goal 8

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(target 8.4) on decoupling economic growth and environmental degradation (which is also covered in Goal 12), elimination of forced labor, and other labor issues (target 8.7 and 8.8); Goal 11 (target 11.6) on city environment; Goal 14 (target 14.4) on regulating harvesting and overfishing; Goal 15 on forest management, to name a few.

To achieve these targets specified in Goal 12 and other related goals, introductions of new regulations (including international agreements) or revisions to the existing regulations may be needed to change the behavior of producers and/or consumers. In recent years, in addition to regulations, some firms are actively utilizing Voluntary Sustainability Standards (VSS) to make their products and/or processes to be more sustainable. This chapter will introduce some of these efforts and offer economic analysis on how these will affect the industrial development and international trade, especially for developing countries. This chapter is organized as follows. Section 6.2 presents a simple economic model based on the Melitz model (Melitz 2003). The key concept is the existence of fixed costs associated with exports which affect the entry decision of firms to export market. Then Sect. 6.3 covers regulatory approaches done at the international level (international agreements) and at the domestic level. Furthermore, in Sect. 6.3, the impact of differences in regulations among exporter and importer countries is discussed. Section 6.4 examines the efforts stemming from the private sector, focusing on the VSS and highlights the motivations behind the increasing use of VSS and issues faced by producers in developing countries. And Sect. 6.5 concludes.

6.2 Theoretical Discussion

To achieve sustainability goals and to encourage responsible production and consumption, we need to change how goods are produced and consumed. When it is left to the market force, we tend to underestimate (or ignore completely) the burden we impose on environment (and society) since in many instances these costs are not borne by the economic agents. Therefore, to correct this tendency and change our behaviors, a set of rules are required. Sometimes, that rules are agreed upon a group of countries and become international agreements especially true for the global public good (Rodrik 2019). In other occasions, these are introduced as domestic regulations. Private entities (firms or consumers) may establish new rules, called private standards. In any circumstances, introductions of new rules will have impacts on economic activities.

6.2.1 Entry and Exit Decision of Firms

The impacts of the introduction of new "rules" on international trade can be analyzed by the Melitz model (Melitz 2003). In the Melitz model, there is a large number of firms, each with different productivity levels. Firms decide to stay in the "market" or exit the market depending on whether they can make profits given their productivity level. To operate in the market, a firm must make an initial investment, a fixed cost.[1] Figure 6.1 graphically represents this simple case. In Fig. 6.1, profit a firm earns is represented in the vertical axis. The horizontal axis represents the productivity of firms. To operate in the market, a firm needs to incur fixed cost, F. The curve that represents firms profit starts out with $-F$ (i.e., for a firm that does not produce any quantity). The point A in the graph is where a firm with a particular productivity makes zero profit. For any firm that has lower productivity than firm A, they will exit the market and do not produce. The market will be left with firms with productivity that is higher than firm A.

Now, suppose that a country introduces a new regulation, say a clean water regulation which requires firms to install a wastewater facility to prevent untreated discharge of contaminated wastewater to the nature. To comply with this regulation, firms need to make an additional investment to install wastewater facility. Further

[1] In this simple representation, we abstract away from variable costs (costs that firms incur for each unit of goods produced) and focus only on fixed costs (costs that firms incur regardless of quantity produced).

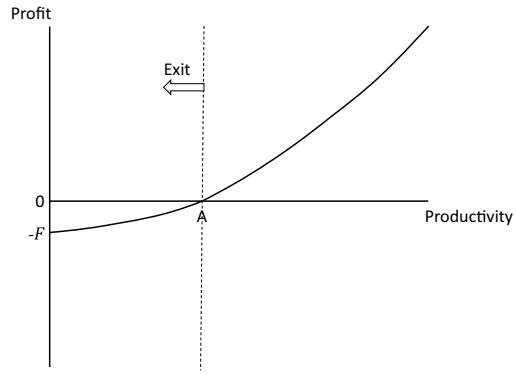

Fig. 6.1 Melitz model only entry/exit decision. *Source* Created by the author

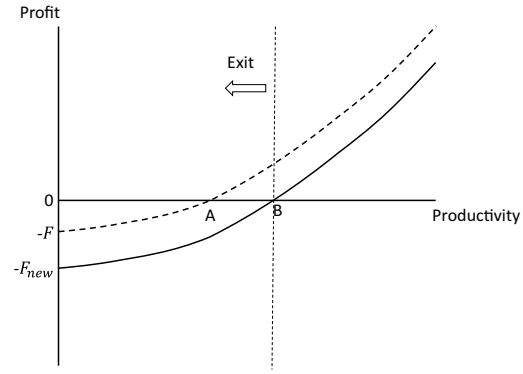

Fig. 6.2 Effect of increase in a fixed cost. *Source* Created by the author

assume that the cost that is required to install wastewater facility is fixed regardless of the production level of the firm. Figure 6.2 shows the impact of increase in the fixed cost in graphical manner. With the increase in the fixed cost by the new regulation, the profit that a firm can make goes down (a curve representing firms' profits shift down from the dashed-line curve to the solid-line curve). As a result, the firm that makes zero profit changes from firm *A* to firm *B*. With the introduction of a new regulations, firms that have lower productivity than firm *B* will exit from the market. Since more firms exit from the market compared to the previous case illustrated in Fig. 6.1, there is a smaller number of firms operating in the market, with the result that only more productive firms survive. Thus, the market is left with fewer number of firms, yet with higher productivity.

6.2.2 Firm's Decision to Export

Now consider the case with some firms exporting. Let us assume that there is a fixed cost that is associated with exporting, represented by F_x.[2] Firms will first serve the domestic market and then decide to export if and only if that can generate higher profits. In Fig. 6.3, there are two curves representing the profits of firms. The dotted-line curve represents the profit of firms that serve only the domestic market. The dashed-line curve represents the profit of firms that serve both the domestic and foreign markets. The assumption here is that at any given level of productivity, the revenues of firms are higher for exporting firms. The profit will be lower for some of the firms because of the additional fixed cost associated with exports, F_x. Similar to the case shown in Fig. 6.1, firms with productivity lower than Firm *A* will exit the market. Firms with productivity higher than Firm *C* will export since the profits from exporting (dashed line) are higher than only serving the domestic market (dotted line). Those firms that are located between Firm *A* and Firm *C* will serve only the domestic market.

Let us consider the last case, where the importing country introduces a new regulation which leads to increase in a fixed cost for exporting firms (from F_x to F'_x). This situation is illustrated in Fig. 6.4. Profits earned by exporting firms are now represented in a solid-line curve. Similar to the case in Fig. 6.3, firms with productivity lower than Firm *A* will exit the market. Firms with productivity between Firm *A* and Firm *C* will serve only the domestic market. However, because of the increase in the fixed cost, only firms with productivity that are higher than Firm *D* will export. That means firms with

[2] The literature has identified a number of factors that can be considered as fixed costs associated with exports such as gathering market information, consumer preferences, and regulations in the destination markets.

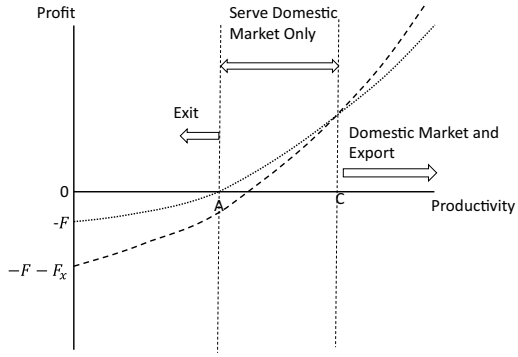

Fig. 6.3 Case of exports. *Source* Created by the author

productivity between Firm *C* and Firm *D* will exit from the export market and serve only the domestic market. Overall, the number of exporting firms decreases. Those that stay in exporting markets have higher productivity than the situation in Fig. 6.3.

6.2.3 Implications from the Theoretical Model

In this section, the Melitz model was used to illustrate the relationship between fixed costs and entry/exit decisions of firms for domestic and foreign markets. When there are fixed costs associated with production, some firms will decide to exit from the market altogether, because the revenue that they can generate cannot even cover the fixed costs. When fixed costs increase, then additional firms will exit from the market.

This mechanism holds true for the exporting market also when there are fixed costs associated with exporting. When fixed costs of exporting increase, then some firms may decide to exit from the export market and concentrate on serving the domestic market. To the extent that development of export industry is an important element for sustaining growth in developing countries, reductions in the number of firms are of great concern.

There are many factors that can lead to increase in fixed costs of exporting, one of which is the introductions of new "rules". Such "rules" can include international agreements, regulations in the importing countries, and/or the use of private standards. In the next sections, we will cover official rules (international agreements and government regulations) and unofficial rules (private standards).

6.3 *De Jure* Approach

When left to the market force alone, economic agents may overdo certain activities when the costs of such activities are not borne by the economic agents. For instance, if the economic agents do not bear the costs of extinction of certain species, and such species (or some parts of) have economic values, they tend to overhunt or overfish, leading to possible extinction of the species. In another case, it may be chemical substances that are harmful to human health and/or environment. If such chemical substances

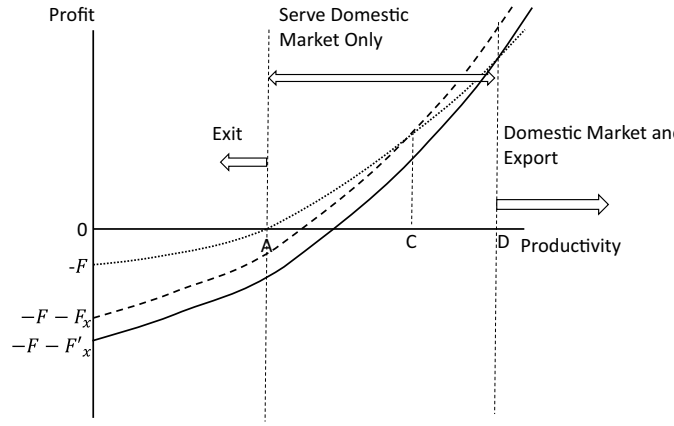

Fig. 6.4 Effect of increase in fixed costs for exporting. *Source* Created by the author

are economically useful, firms will use them, especially when the firm does not bear the costs of ill human health and/or environmental damages resulting from such use.

To correct these problems, often "regulations" are created to control the behavior of economic agents. In this chapter, we will make a distinction between "regulations" and "standards". *Regulations* are created and enforced by public agents, are mandatory, and legally bounding. Often, the violations of regulations carry some penalties. In contrast, *standards* are created by either public or private entities, and standards are voluntary in nature. They are not legally binding and do not carry any (official) penalties when one does not follow standards. We will discuss the nature of standards in more detail in the next section.

Here, we focus on the regulations (mandatory rules). When one thinks of regulations, there are regulations that are supranational in nature (including international agreements) and domestic regulations. In the following subsections, we will cover international agreements and then domestic regulations and assess their impacts on international trade.

6.3.1 International Agreements

There are many international agreements in force focusing on sustainability issue. Each of them focuses on a certain issue. Let us look at some of the agreements below.

One of the well-known agreements is "Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)". The main purpose of this international agreement is to make sure that international trade in wild animals and plants does not cause harm to their survival, and it covers a wide range of wild animals and plants. Wild animals and plants listed in Appendix I mean that they are threatened with extinction, and, in general, commercial international trade[3] of these is prohibited. Those listed in Appendix II are not facing immediate extinction risk, if and only if international trade is controlled sufficiently. Appendix III includes wild animals and plants that are already subject to regulations by a country and require cooperation from other countries (importing countries) to ensure that these are not traded illegally (Table 6.1).

The main mode of regulation takes the form of quotas, the restrictions on quantity.[4] Those listed in Appendix I, the commercial international trade is prohibited; hence, the quota is zero. For those in Appendix II, if they are captured in accordance with domestic regulations, catch or extraction of these do not threaten the survival of the species (which is verified in scientific manner), and have requisite certificates and permits that can be traced through the trade, then international trade is allowed in limited quantity. The quota can be set by the domestic country or through collective agreement.

The previous example was wild animals and plants and trading of species or their artifacts. In addition to this, there are many international agreements related to chemicals that may be harmful to human health and/or environment. For instance, "Montreal Protocol on Substances that Deplete the Ozone Layer" aims to phase out the consumption and production of nearly one hundred ozone depleting substances (ODSs) such as chlorofluorocarbons (CFCs), halon, carbon tetrachloride, and others.[5] Use of CFCs was widespread in our lives such as in air conditioners and refrigerators as refrigerants and aerosol cans as propellants. CFCs were also used in some medical device such as inhaler for asthma patients. ODSs are also widely used in

[3] In some instance, international trade for scientific purpose is allowed.

[4] Similar kind of approach is taken in many different efforts for conservation. For instance, Atlantic bluefin tuna is regulated by the International Commission for the Conservation of Atlantic Tunas (with contracting party of 52) to control the catchment of tuna in the Atlantic Ocean. They determine the amount of quota based on the stocks of bluefin tuna. This is an important fish for Japanese since much of bluefin tuna ends up as sushi or sashimi consumed in Japan. For year 2022, the quota for Japan increased by 257 tons for a total of 3,483 tons (Japan Times 2021).

[5] For a complete listing of the substances, please see Ozone Secretariat (2020).

Table 6.1 Number of species and subspecies covered by CITES

	Appendix I	Appendix II	Appendix III
Number of species	1082 species and 36 subspecies	37,420 species and 15 subspecies	211 species and 14 subspecies and 1 variant

Note Appendix I lists wild animals and plants threatened with extinction. Appendix II lists those that are not immediate risk of extinction but requires tight control on international trade. Appendix III lists those that are subject to regulations by a country and require cooperation from other countries to prevent illegal trade
Source CITES (2021)

the manufacturing processes. The adoption of the Montreal Protocol has led to the changing in production process as well as changes in products mainly by the use of alternative substances. The Kigali Amendment aims to phase down the projected consumption and production of hydrofluorocarbons (HFCs), which was developed as substitute for CFCs yet known to be greenhouse gases. The goal is to reduce the consumption and production of HFCs by 80% in the next 30 years. Developed countries are already starting the phase-out process, while developing countries will start from consumption freeze in 2024 (or 2028 for come countries) (Ozone Secretariat 2019).

The Stockholm Convention on Persistent Organic Pollutants regulates chemicals (persistent organic pollutants: POPs) that can linger in the nature for a prolonged period of time and cause harm to human health and environment. These cover some of the chemicals used in pesticide[6] and for industrial use. Those POPs listed in the Annex A are subject to ban on use, manufacture, and trade. Those in Annex B faces restrictions on the use, manufacture, and trade (Secretariat of the Stockholm Convention 2020).

Recent addition to management of chemical substances at the global level is the Minamata Convention on Mercury[7] This convention regulates the mining and trading of mercury, phasing out the use of mercury in certain products, and reduces the emission and release of mercury. It requires countries to phase out the mining activities of mercury and control the export and import of mercury between countries. In addition, the year 2020 marks the year to completely phase out the manufacture, export, and import of mercury-added products listed in Part I of Annex A. Mercury is (was) used widely in our daily lives. They are used in batteries, lamps (such as compact fluorescent lamps),[8] and non-electronic measuring devices such as thermometers, cosmetics, pesticides, and switch and relays.[9] Mercury is also used in manufacturing processes. Part I of Annex B requires countries to phase out the use of mercury in acetaldehyde production (by 2018)[10] and chlor-alkali production (by 2025). Other manufacturing processes[11] listed in Part II of Annex B do not have specific phase-out dates, but countries are required to reduce and restrict the use of mercury and mercury compounds in the manufacturing processes (UNEP 2019).

Another international agreement on chemicals, the "Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International

[6] For a complete listing of the POPs, please see Secretariat of the Stockholm Convention (2019).

[7] This convention is named after a city in Japan, Minamata, where they suffered from mercury poisoning (the Minamata disease).

[8] Because of the concerns for global warming, people were switching from in incandescent lamps to compact fluorescent lamps since the latter is more energy efficient. In more recent years, people are switching again to more energy-efficient light-emitting diodes (LED) lamps (UNEP 2017).

[9] Dental amalgam is the only product listed in Part II of Annex A.

[10] This is one of the significant achievements of the convention, since the use of mercury in acetaldehyde production and releasing the untreated wastewater to the river was the main cause of the Minamata disease.

[11] They are vinyl chloride monomer production, sodium or potassium methylate or ethylate, and production of polyurethane using mercury containing catalysts (UNEP 2019).

Trade", focuses on the information exchange of hazardous chemical substances between exporters and importers, and these chemical substances need to be clearly labeled (Secretariat of the Rotterdam Convention 2020). "Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal" controls the international movement of hazardous wastes which was adopted focusing on the notification of transboundary movements of hazardous wastes, but starting in 2019, there is now a ban on exports of hazardous wastes covered in Basel Convention that are intended for final disposal, reuse, recycling, and recovery from countries listed in Annex VII (such as OECD) (Secretariat of the Basel Convention 2020).[12]

Some of these international agreements rely on quota (including ban) to achieve the sustainability goal, which naturally have impact on international trade and consumption. Others rely on notification and information exchange to make importing countries (especially developing countries) aware of the trading activities, to raise the awareness of the sustainability issue. The latter type of agreements can be considered as part of fixed costs described in Sect. 6.2.

6.3.2 Domestic Regulations

For the international agreements to have any legal weights, applicable laws corresponding to the international agreements need to be introduced in each country. When doing so, a country (or a region) may introduce additional requirements. For instance, the implementation of "Montreal Protocol on Substances that Deplete the Ozone Layer" in EU is backed by the Regulation (EC) No 1005/2009,[13] which includes five additional ODSs that are not covered in the Montreal Protocol.[14] Thus, even in the case of international agreements, domestic implementations may differ from countries to countries.

In addition to these international agreements, countries introduce numerous laws to safeguard human health and to protect environment. In almost every country, there are food safety regulations to ensure that the agricultural goods and processed foods are safe for human consumption. Regulations may restrict maximum residue levels (MRLs)[15] and require affixation of labels showing information on the manufacturer, source of inputs, ingredients, nutrition, and potential allergic substances used. Exporting firms need to comply with these regulations if they wish to export agricultural and food products to the destination. Even though they are exported, these products are subject to inspections at the point of entry to make sure that these products comply with domestic regulations. Sometime, imported products fail to meet these requirements, and they are rejected. For instance, the statistics from the UNIDO reveal that in 2013, an estimated US $9328 million worth of agriculture and food products (all food and feeds) were rejected at the borders of four markets (Australia, EU, Japan, and USA) (UNIDO 2015). Often cited reasons for the rejections are the violations regarding residue agricultural chemicals[16] and residue veterinarian drugs (IDE-JETRO and UNIDO 2013; UNIDO 2010, 2015).

These regulations are well known, yet many countries still fail to meet these requirements sufficiently, but the awareness among farmers is

[12] For a list of wastes that are covered in the Basel Convention, please see Annex VIII. Recently, plastic wastes were added and came into force in 2021 (Secretariat of the Basel Convention 2020).

[13] See https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R1005&from=EN for the full text of the regulation.

[14] They are halon 1202, methyl chloride (MC), ethyl bromide (EB), trifluoroiodomethane (TFIM) and n-propyl bromide (n-PB) (European Environment Agency 2021).

[15] Codex Alimentarius offers some base MRL and streamlining regulations to this may facilitate international trade (Li 2018; Rusch, Cameron and Hohgardt 2019) and more stringent requirements are likely to have negative impacts on international trade, especially on exports from developing countries (Otsuki, Wilson and Sewadeh 2001; Wilson and Otsuki 2004), although this is difficult since MRL in each country is set based on their dietary habits.

[16] Developing countries seem to have difficult times in meeting the MRL requirements in developed countries (Xiong and Beghin 2014), mainly because the MRL requirements in developed countries are more stringent than in the developing countries (Winchester et al. 2012).

not keeping up with the regulation information and the domestic regulatory systems (Schreinemachers et al. 2015). The problem is compounded especially for the processed food industry. They need to make sure that all inputs used in each step of manufacturing process comply with the regulations. For instance, when a firm manufactures frozen shrimp, it needs to ensure that the shrimp they use do not contain excessive amount of residue chemicals (for instance, antibiotics or in some cases, antioxidants). If the shrimp they use as inputs already contained these substances above the allowed amount, then there is nothing that the manufacturers can do to correct this problem.

How can the final good manufacturers ensure that their products will comply with the requisite regulations? First, the manufacturers need to know the regulation of the destination countries. Such information is considered as a part of the fixed cost of exporting as described in the theoretical section. Second, the manufacturers need to ensure that suppliers also know these regulations and these inputs need to be checked along the supply chain, to make sure that after each stage of the supply chain, the products (or inputs) meet the requirements. This checking can be done by the buyer firms (firms located in the downstream), the seller firms (firms located in the upstream), or rely on third party (in many instances, public research institute). In the case of residue chemicals, these tests need to be done scientifically. Thus, either at firm or at the country level, there must be a sufficient scientific capabilities and facilities. In addition to this, to trace back the origin of the problems, traceability system along the supply chain is needed to make sure that only "qualified" (or checked) inputs are used in the supply chain and to quickly identify the source of the problem if arises.[17]

This poses a large concern on producers, especially in developing countries. Often small-scale farmers in developing countries are not aware of regulations (domestic and/or foreign ones). Because they are unaware, they do not take the necessary steps to ensure that their products meet the regulatory requirements of importing countries such as correct applications of agricultural chemicals. From government's point of view, there are two policy levers that they can utilize. One is the establishment of quality assurance system (including public research institutes assisting firms in scientific measurements), and the other is the information dissemination and training of farmers (IDE-JETRO and UNIDO 2013).

Manufacturing industries also face many regulations, especially on the environmental issues.[18] Many countries have introduced pollution abatement regulations. Typically, these traditional types of environmental regulations have focused on the production processes of domestic entities. If a country is keen on environmental protections, their regulations on manufacturing processes tend to be stricter compared to the other countries where they are not too concerned with environmental damages. This can result in the movement of production processes from developed to developing countries through foreign direct investment.[19]

Gradually, there seem to be a shift in the orientation of environmental policies in many countries, notably in developed countries. Even though there have been regulations concerning product characteristics such as energy efficiency requirements or emission restrictions for automobiles, there is now an increasing tendency to do so, especially focusing on chemicals. Environmental policies now are focusing more on product-related environmental regulations (focusing on product characteristics) (PRERs) rather than traditional pollution abatement regulations. Pollution abatement regulations regulate

[17] Different supply chains of agricultural and food products deal with this issue differently. See Mori, Nabeshima and Yamada (2013) for the eel industry in China. There are many studies on shrimp industry (IDE-JETRO and UNIDO 2013;Suzuki and Nam 2016;Tran et al. 2013).

[18] On the survey of political factors on environment, see Hu et al. (2021).

[19] This is so-called pollution haven effect. On this, please see Kellenberg (2009) and Erdogan (2014). While the traditional literature has looked at FDI and gross exports, Duan et al. (2021) focus on trade in value added and find that firms tend to relocate "dirty" processes to developing countries and forming "global pollution chain".

domestic production activities by domestic law. The cost of regulatory compliances is borne by domestic producers. PRERs regulate the products regardless of where they are produced, resulting in a mismatch of location of production and consumption. The cost of complying of regulations is borne by domestic and foreign producers.

One such example of PRERs is the Restriction of Hazardous Substances in Electrical and Electronic Equipment (RoHS) (Directive 2011/65/EU), a regulation by the European Union. The regulation essentially limits the use of ten chemical substances in electronics that are known to cause harm to both human health and environment.[20] This directive, coupled with the regulation on waste electrical and electronic equipment (WEEE) (WEEE Directive, Directive 2012/19/EU), is used to minimize the risk to human health and environment stemming from the use, recycling, and disposal of electronic equipment. Since RoHS directive applies to electronic products sold in EU, this applies to both domestic and foreign producers. When RoHS was introduced, there were much discussion on the impacts of this on the production and exports of these products from East Asia to EU (Michida 2017). Similarly, the introduction of Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (Regulation (EC) No 1907/2006) has caused concerns among producers in East Asia. REACH requires that chemicals to be used in the product must be first registered at the European Chemical Agency. And for the registration, it requires scientific evidence (risk and hazard analysis) that chemical is safe (Humphrey 2017). A study by Honda and Otsuki (2017a) finds that firms in Malaysia and Vietnam that are able to meet these requirements actually increased their exports to the EU markets. At the same time, these firms also seem to concentrate on the EU market once they comply with these regulations. This may be because they have invested substantially to meet the requirements, and to recoup their investments, they are now focusing more on the EU market. Other studies such as Fontagné and Orefice (2018) find that when firms are faced with technical barriers to trade (TBT), some exporter firms, especially if they export to multiple destinations, tend to focus on the market with more relaxed TBT.

Overall, if a firm belongs to global production networks, they invest in compliance requirements even if that entails additional investments (often in terms of increase in the fixed costs, but sometimes of variable costs) (Honda and Otsuki 2017b; Michida et al 2017; Ueki et al 2017). To assist firms in maintaining export activities to the regulated yet lucrative markets, governments typically provide assistance through establishments of quality assurance facilities if that were lacking as well as introducing similar regulations domestically (Michida 2017; Ramungul 2017). In fact, many countries in East Asia have introduced similar regulations concerning chemicals to reduce the information costs. This is done to reduce the export-specific fixed cost. These studies tend to focus on certain issues, and there have been relatively few studies that look at the impact of domestic regulations on international trade.[21] We turn to this issue in the next subsection.

6.3.3 Economic Assessment of the Impact of Regulatory Differences Between Exporters and Importers

There are only limited number of studies systematically looking at the impact of domestic regulations on international trade relative to the overall international trade literature.[22] This is because there was no comprehensive data on the domestic regulations. The past literature has

[20] They are lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE), bis (2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP), and diisobutyl phthalate (DIBP).

[21] For instance, Disdier and Marette (2010) and Xiong and Beghin (2014) look at the impact of MRL. Other studies have sectoral focus (Bao 2014) or country focus (Portugal-Perez, Reyes and Wilson 2010).

[22] For the review of the literature, please see UNCTAD (2018).

relied on the estimation of ad valorem equivalents (AVE) to measure the trade impacts (such as Kee et al (2009)). Some are based on the notifications to WTO (Bao and Chen 2013; Bao and Qiu 2012), but the number of notifications is much fewer in number compared to the overall domestic regulations that may have impacts on international trade. In the case of Japan, the total number of non-tariff measures (NTMs) reported to WTO is 383, while the total number of NTMs coded from domestic regulations is 1278 (Nabeshima and Obashi 2020). The effort by the United Nations Conference on Trade and Development (UNCTAD) has created a data set that can be utilized by the researchers.[23]

In most studies, they take the existence of regulations in importing countries as the main indicator of interest. However, as we have seen, many countries ratify international agreements, and therefore, corresponding domestic regulations exist, which are similar across countries. In addition, governments introduce regulations to safeguard human health and environment, but they tend to introduce similar regulations. Since domestic regulations apply to domestic entities, even exporting firms need to meet domestic regulations (fixed cost, F, in subsection 6.2). In addition to this, exporting firms need to meet the requirements imposed by importing countries (F_x, in the theoretical subsection 6.2); however, there may be significant overlap between the two since countries implement similar kind of regulations. To account for this overlap, some research utilizes differences in regulations between exporting and importing countries to better identify the true fixed costs, F_x. Among many methodologies,[24] one methodology is the use of cosine similarity,[25] which is based on comparing two vectors (each vector representing a set of regulations) and measures the difference

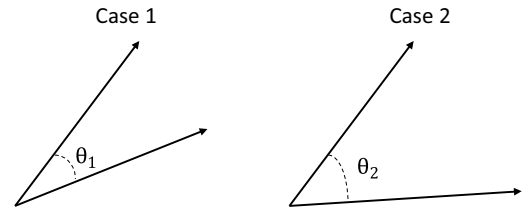

Fig. 6.5 Illustration of cosine similarity. *Source* Created by the author

in angle. Figure 6.5 illustrates this. In case 1, two vectors are facing similar directions, compared to case 2 (smaller angle in the case 1). One can utilize this information to construct the cosine similarity index.[26]

Nabeshima and Obashi (2021) construct the additional compliance indicator (ACRI) based on cosine similarity. They find that the differences in regulations between exporting and importing countries negatively impact international trade. If the regulation changes from "completely the same" (ACRI = 0) to "completely different" (ACRI = 1), bilateral trade between two countries is reduced by 22.9% (or 14.4% when zero trade is taken into account). They also find that exports from developing countries decrease both to developed and developing countries when there are differences in regulations, while developed countries do not seem to be affected by the differences in regulations (Nabeshima and Obashi 2021). This supports the general observation that developing countries often find it difficult to comply with the regulations in developed countries. Furthermore, the so-called South–South trade (trade between developing countries) is also affected by differences in regulations. This finding points the general weakness of firms in developing countries to comply with regulations in destination countries, especially if they are different from the domestic regulations that they are familiar with.

Another study by Nabeshima et al. (2021) find that decomposes the negative impacts of differences in regulations by looking at the intensive

[23] For the details on how regulations are collected and coded, please see UNCTAD (2021).

[24] For other methods, please see Drogué and DeMaria (2012) and Winchester et al. (2012) using MRL data and Cadot et al. (2015)on UNCTAD NTM data.

[25] Cosine similarity is often used method in the patent literature to measure the similarity between patent documents (Branstetter 2006;Jaffe 1986).

[26] For the detail, please see Nabeshima and Obashi (2021).

and extensive margins of international trade.[27] Like other studies, they find that additional regulatory burden negatively affects intensive margin (less trade). When decomposing this to the price and quantity effect, they find that additional regulatory burden negatively affects quantities[28] and increases prices. Since the reductions in quantity outweigh the increase in price, overall, the trade decreases.

These and other studies suggest that firms in developing countries are finding it difficult to comply with regulations in destinations.

6.4 De Facto Regulation (Private Standard) Approach

The previous section has examined the impact of regulations on international trade. In general, the regulations tend to reduce international trade (sometime by design like the case in many international agreements focusing on conservation efforts). Research also points out that differences in regulations tend to discourage exports especially from developing countries. Recently, there is a widespread usage of private standards to respond to consumers' demand for sustainable products. The final product makers are keen on meeting such demand and offer products labeled as sustainable. To do so, the final product makers need to make sure that suppliers also follow certain production processes or other requirements for the final product to be called sustainable. This leads to the creation of private standards, and the final product makers require meeting this private standard as a condition for the procurement. Because of this, for the supplier firms, private standards (even though voluntary in nature) are a mandatory requirement and perceive it the same as regulations. Even though standards are voluntary in nature, but for certain firms, they become de facto regulation.

There are many different private standards globally, but in this section, we focus on the private standard with third-party certification scheme.

6.4.1 Types of Private Standards

The main difference between regulations and standards is that regulations are mandatory, and standards are voluntary.[29] Standards can be created by any entity, and depending on the nature of the entity, it is called international (such as by the International Organization for Standardization: ISO), industrial (created by a group of firms in an industry), national/public, and private standards.[30] Standards exist to ensure consistent quality of products or process or assuring the compatibility of products. For instance, there are well-known standards for management such as ISO9001 for quality management or ISO140001 for the environment management. These specify the processes. Then, there are standards that assist in interoperability of goods. Paper size is defined in ISO216, and because of that, it is easier for the consumers to know whether certain products that use paper as inputs (such as printers) can accept the paper consumers want to use, regardless of the manufacturers of papers or printers. In this chapter, we focus on process standards.

Among the private standards, we can broadly divide them into three different categories as

[27] Intensive margin refers to the changes in the trade volume of the existing trading relationship. For instance, if a country exports more of the same goods, we say increase in intensive margin. Extensive margin refers to the number of products that a country exports. For instance, if a country exports ten goods in one year, and 11 in the next year, there was an increase in extensive margin.

[28] This is in line with the Melitz model described in the theoretical section if one assumes that a firm produces a variety. As the fixed costs of exporting increased, the number of exporting firms decreases, hence, reductions in varieties and quantity exported.

[29] What makes it confusing is that standards are voluntary. But if a regulation includes a standard, that becomes a mandatory standard, for instance, Japan Industrial Standard (JIS) technical specifications. If a regulation calls that certain item needs to confirm to JIS, then that particular JIS becomes a mandatory standard. EU for instance would like the charging of smartphones to follow USB-C, following their past attempts in the past with micro-USB (European Commission 2021; Fanta 2019).

[30] In this chapter, we do not cover the so-called de facto standards, which become "standard" (everyone uses it) in the marketplace. We focus on standards that are intentionally created by an entity to set certain rules.

Table 6.2 Differences among three types of standards

Type	Checked by	Credibility to others
Self-check	Self (first party)	Low
Supplier audit	Buyer (second party)	Medium to high
Third-party certification scheme	Certification firm (third party)	High

Source Created by the author

shown in Table 6.2. In the first case of "self-check", checking of whether one follows the standard is done by oneself. It is a self-claim, and the credibility to the others (especially to strangers) is low. However, this is still useful in, say, dissemination of "best practices". The second type is often utilized in the business relationships. The buyer firms require the supplier firms to follow certain rules (such as procurement rules created by the buyer firm, which may include external standards). The check (auditing) is done by the buyer firm to make sure that suppliers follow the rule. Continuation of business relationship depends on whether the supply follows the rules set by the buyer. The credibility is medium to high, typically resting on the reputation of the buyer firm. Then the final category is the third-party certification scheme. In this category, the buyer firm requires supplier firms to be certified in specified external standards. Since the buyer is not involved in the certification process, the credibility of this is high (to the extent of credibility of the certification firm).

According to UNFSS (2020), there are now more than 250 voluntary sustainability standards (VSS) globally. Fairtrade and Rainforest Alliances are examples of such VSS. In examination of VSS contributions to SDGs, many VSS contribute to Goals 12 (especially on target 12.4 on chemicals, 12.5 on recycling, and 12.6 on encouraging multinational firms to integrate sustainability information) of the SDGs since many VSS focus on the sustainability issues (UNFSS 2018). While these VSS are utilized in the business relationships between buyers and suppliers, VSS can be integrated in other aspects such as the Olympics. Since the London Olympic, the sustainability issue has been integrated in hosting of the Olympic games. This tradition is carried on by the Rio and also the Tokyo Olympics. Table 6.3 lists the private standards with third-party certification schemes to achieve sustainable procurements for the commodities utilized in the Tokyo Olympic.[31]

6.4.2 Impacts on Developing Countries

Prevalence of private standards is challenging for the producers, especially in developing countries. For instance, agricultural food suppliers need to meet traditional regulations on the use of agricultural and veterinary chemicals, but also humane treatment of livestock and agricultural laborers (some by regulations and some by private standards), while improving the productivity of agricultural productions to achieve lower prices and more quantity produced (Saitone and Sexton 2017). To the extent that the private standards are used as the conditions for the exports, if a firm obtains necessary certificates, then a firm is well positioned to expand on their export activities. In fact, research shows that obtaining international certificates seems to have good effects in the development of coffee industry in Ethiopia (Minten et al. 2019) that obtaining organic and GlobalGAP certificate led to increase in pineapple exports from Ghana (Kleemann Abdulai and Buss 2014), and that Fairtrade certification contributed to increase in job satisfaction among pineapple workers in Ghana (Krumbiegel et al. 2018). A product carrying some indication of "desirability" (such as "organic" or "natural" labeling) seems to be able

[31] In addition to procurement, reducing food loss was identified as one of the sustainability efforts for the Olympic. However, reducing food loss in a sufficient manner is rather difficult because food providers need to meet the food safety regulations (Kasza et al. 2019).

Table 6.3 Private standards identified in the procurement guidelines for Tokyo Olympic

Type of products	Private standards
Agriculture products	GlobalGAP, ASIAGAP, Organic
Livestock	JGAP or GlobalGAP
Fishery products	Marine Eco-Label (MEL), Aquaclture Eco-Label (AEL), Marine Stewardship Council (MSC), Aquaculture Stewardship Council (ASC)
Timber	Forest Stewardship Council (FSC), Programme for the Endorsement of Forest Certification schemes (PEFC), Sustainable Green Ecosystem Council (SEGC)
Paper	Forest Stewardship Council (FSC), Programme for the Endorsement of Forest Certification schemes (PEFC)
Palm oil	Indonesian Sustainable Palm Oil (IPO), Malaysian Sustainable Palm Oil (MPO), Roundtable on Sustainable Palm Oil (MSPO)

Source Created by the author from the sustainable procurement guidelines of Tokyo Olympics (Tokyo Organizing Committee for the Olympic and Paralympic Games 2020)

to sell at higher prices compared to more generic products (Bonanno et al. 2018).[32] Because of these advantages, some governments are using the adoption of VSS as a policy tool for export promotion (UNFSS 2020).

However, adoption of VSS is not without concerns. There are at least three different concerns that come from the proliferation of VSS to producers in developing countries (UNFSS 2018). First is that these VSS are now becoming de facto regulations for producers in developing countries, since obtaining some certificate is required as a part of business transactions. Some suspect that buyer firms are using the certificate as a way of minimizing costs associated with production network. In the past, the auditing of the suppliers was done by the buyers themselves, with the cost of auditing incurred by the buyer firms (often from developed countries). However, increasingly buyer firms are requiring suppliers to obtain third-party certification in lieu of auditing by themselves. Thus, the auditing cost has been pushed to the suppliers as fees associated with obtaining certificates (see Table 6.4).

Developing countries complain that these private standards are promoted with consumers in developed countries in mind, yet the costs of ensuring health and environmental sustainability of consumption (and disposals) in developed countries are borne by producers.

Second, there are many different, yet overlapping private standards that exist, and suppliers may need to obtain several certificates if they deal with multiple buyers (often from developed countries). This can lead to several different outcomes. Firms may choose to obtain several certificates if they are sufficiently large enough. This means that they need to incur multiple costs for obtaining certifications (which are fixed costs). Or it could result in some choosing one particular standard and others choosing different standards. This could create a lock-in effect and reducing the bargaining power of the suppliers to buyers.

Third, in some areas, the governance is moving from the public to the private sector, and the reach of such rule-setting is defined not by the national boundaries but the international trade linkages (see for instance, Michida and Nabeshima (2017)). Private standards are also mainly created by firms in developed countries, and this rule-setting is outside the jurisdictions of both national governments (as well as they are not illegal) and international organizations such as the World Trade Organization, thus lacking

[32] People tend to overstate their willingness-to-pay on sustainability issue. However, even when correcting for these biases, consumers are willing to pay more for these "sustainable" products than the generic products, although the effect is negative for organic foods (Gschwandtner and Burton 2020).

Table 6.4 Cost implications for private standards

Type	Checked by	Cost to suppliers for verification	Cost to buyers for verification
Self-check	Self (first party)	Low	None
Supplier audit	Buyer (second party)	Low	High
Third-party certification scheme	Certification firm (third party)	High	None

Source Created by the author

workable dispute settlement mechanisms. In addition, unlike the case in international agreements (or domestic regulations in certain cases) where differential treatment is available for developing countries, developed and developing countries are treated equally.

Even though these concerns exist, the sustainability concerns are gaining momentum, and the use of these private standards can be an effective way to encourage responsibility consumption and production. However, one needs to be aware that these are putting significant burdens on producers in developing countries.

6.5 Conclusion

To promote sustainable consumption and production (Goal 12), there were large numbers of initiatives implemented through international agreements, domestic regulations, and through private standards. Efforts for Goal 12 have close relationships to the other goals, such as Goal 2 (target 2.4) focuses on development of sustainable agriculture; Goal 3 (target 3.9) on reducing deaths from pollution; Goal 5 (target 5.1) on gender discrimination; Goal 6 (target 6.3) on reducing water pollution; Goal 7 (target 7.2) on renewable energy; Goal 8 (target 8.4) on decoupling economic growth and environmental degradation (which is also covered in Goal 12), elimination of forced labor, and other labor issues (target 8.7 and 8.8); Goal 11 (target 11.6) on city environment; Goal 14 (target 14.4) on regulating harvesting and overfishing; Goal 15 on forest management, to name a few.

In this chapter, we have examined the impacts of regulations and standards on international trade. A simple theoretical model was presented to show that increase in fixed costs associated with exporting negatively influences the entry decision of firms into the export market. Compliance costs associated with either regulations or obtaining third-party certification schemes can be considered as fixed costs of exporting. Hence, if a firm is facing a large number of regulations or significant different regulations from domestic ones, of if a firm needs to obtain multiple certificates, the implication from the theoretical model is that there would be less number of exporting firms. One possible solution to this is to harmonize regulations and streamline certificate requirements[33] to reduce the duplicate efforts by the producers. This can be encouraged through regional trade agreements for instance.

Research also shows that for those firms that can maintain exporting activities, they seem to obtain the benefits from meeting these requirements. However, this seems to be limited to only "capable" existing exporting firms. This is a large concern for developing countries since development of export-oriented industry is a key policy concern for developing countries. Increasingly, the entry barrier to export market is becoming much higher due to these requirements. Looking into the future, additional issues can be woven into the web of agreements, regulations, and private standards such as those on human rights and issues surrounding micro-plastics. Dissemination of the regulatory information is one way of achieving this to reduce the information cost (which are fixed costs in nature) and to assist firms considering exports.

[33] While "harmonization" itself may be difficult, governments and private sector can encourage mutual recognition.

If consumers are willing to consume in more responsible way, and if producers are to respond to such demands for sustainability, producers will need to acquire new sets of skills and supporting infrastructures are needed. Both regulations and private standards require much higher management skills for producers and require easy and affordable accessibility to various testing facilities (to certify that products/processes meet the requirements). Thus, it is critical for governments, especially in developed countries, to "support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production" (target 12.a). This kind of assistance is needed in order for producers in developing countries to participate fully in sustainable globalized world.

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Production and Quality Management for SDGs

7

Kenichi Nakashima

Abstract

Industry has undertaken mass production and consumed resources to optimize only economic efficiency. Most products are discarded or disposed at the end of their lifetimes. Therefore, most companies should design and manage their production system for sustainability. One of the most important factors to develop a sustainable production system is the environmental aspect. Environmentally conscious operations management makes some contributions to sustainable development goals (SDGs) #9 and #12. This chapter deals with production and quality management systems for SDGs. Firstly, representative operations management systems such as inventory management and total quality management (TQM) are introduced. These systems are useful to control the production processes efficiently. Secondly, we explain the Just-in-Time (JIT) production system which is based on the two key concepts, JIT and JIDOKA. Some advantages of the JIT production system include its simplicity in production scheduling, reduced burden on operators, ease of identification of parts by the two kinds of kanbans attached to the containers, and substantial reduction in the process work. Finally, we consider environmentally conscious manufacturing and describe a closed loop supply chain which includes activities necessary to acquire end-of-life products from customers to recover value.

Keywords

Operation management · JIT production system · Sustainable production system · Supply chain management

7.1 Introduction

This chapter deals with production and quality management systems for SDGs which comprise seventeen goals. Here we especially focus on goals #9 (*Industry*, *innovation*, *infrastructure*) and #12 (*Responsible consumption*, *production*) which are related to developing and managing sustainable production systems in the future.

A traditional production and inventory management system controls a mass production process that consumes a lot of new resources. Consumers of these products typically discard the products at the end of their useful life. As a result, the producer needs to manage only the finished products (Fig. 7.1). In contrast, production and inventory management in a remanufacturing system includes products collected from customers.

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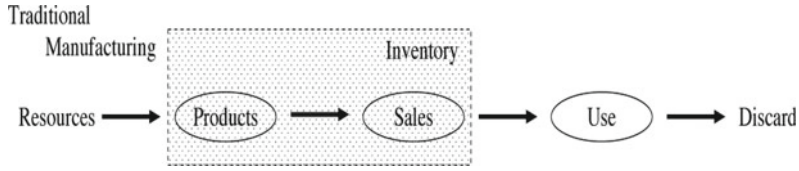

Fig. 7.1 Inventory management in traditional manufacturing

A remanufacturing producer should consider sold products as a part of the future inventory. For this purpose, the lifecycle of every product has to be taken into consideration (Fig. 7.2).

Discarded products must be recovered to make new products for the purpose of conserving resources and practicing environmentally conscious manufacturing. Disassembly process is one of the main processes in a remanufacturing system. In order to retrieve components and materials (for reuse, recycling, and remanufacturing) from consumer products, the first step is disassembly. Recycling means recovering the material content of retired products by performing the necessary disassembly, sorting, and chemical operations. Remanufacturing conserves the product's identity and performs the required disassembly, sorting, refurbishing, and assembly operations in order to bring the product to a desired level of quality. It is important to manage the inventory at every lifecycle level until products are collected and used in remanufacturing (Gungor and Gupta 1999; Nakashima and Gupta 2012).

In the next section, some of the typical operations management approaches to controlling the traditional production systems are examined.

7.2 Inventory Management

7.2.1 Basic Concept of Inventory Management

At a certain point, each of the processes of production, logistics, and sales activities results in products, parts, and/or raw materials being temporarily stocked. These products and parts are called inventory or buffer.

In the case of overproduction, there is an increase in inventory and related costs are incurred. On the other hand, when the production quantity is insufficient, the shortage of stock incurs a loss from the decrease in sales. To prevent a production shortage, we should increase the inventory; but at the same time, we must reduce inventory costs.

To deal with these various problems in inventory management, we believe there are

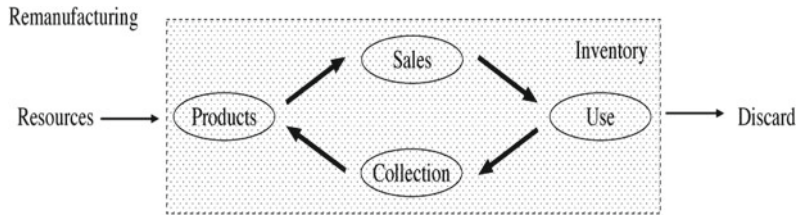

Fig. 7.2 Inventory management in remanufacturing

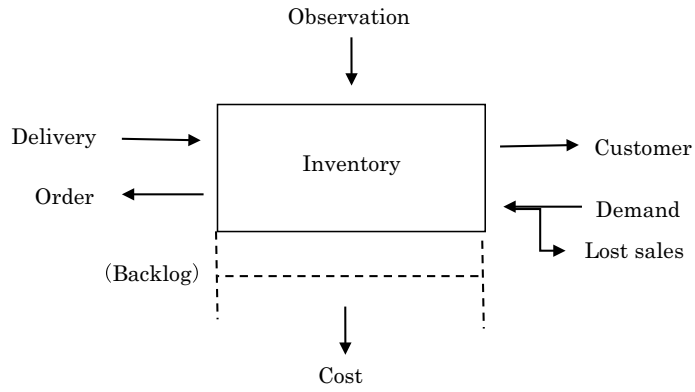

Fig. 7.3 Inventory management problem

three aspects to consider in the system: the demand structure, the cost structure, and the ordering structure, as shown in Fig. 7.3.

(1) Inventory behavior

Figure 7.4 shows the behavior of the inventory quantity over time in an inventory management system where an order is placed for a predetermined quantity Q when the inventory quantity reaches a predetermined value s (reorder point).

The interval from ordering a product or part to delivery is represented by the delivery lead time L, and the period from one order to the next order (order cycle) is represented by R. In addition, the amount of inventory reserved to avoid being out of stock in consideration of fluctuations in demand is called the safety stock (SS).

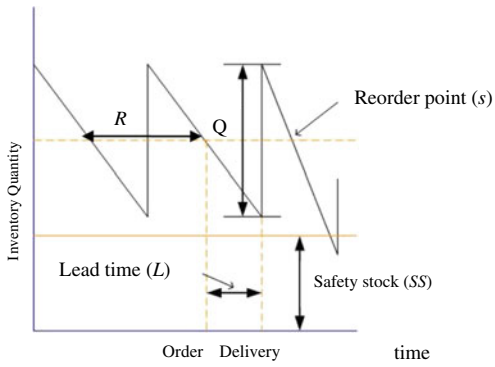

Fig. 7.4 Behavior of the Inventory

(2) Safety stock and shortage probability

The amount of safety stock is determined, based on the average demand per unit time D and the lead time, L, taking into consideration the safety factor n_p corresponding to the out-of-stock probability p. If the demand is normally distributed $N(LD, L\ \sigma^2)$ according to the mean LD and variance $L\ \sigma^2$, then if the safety stock quantity is denoted by SS, it can be obtained by the following equation:

$$SS = n_p\sqrt{L}\sigma \tag{7.1}$$

The safety factor, n_p, corresponding to the probability p of being out of stock is given from the standard normal distribution probability as shown in Table 7.1.

In general, the reorder point s is determined by the following equation:

$$\begin{aligned}\text{Reorderpoints} = &\text{estimator of demand during} \\ &\text{lead time } (LD) + \text{safety stock } (SS)\end{aligned} \tag{7.2}$$

Example

We consider the reorder point system with lead time L. It is assumed that the demand during the lead time is normally distributed with the average demand LD = 500 and the variance $L\ \sigma^2$ = 10,000. Find the safety stock SS and reorder point s under the out-of-stock rate $100 \times p = 2.5\%$.

Table 7.1 Safety factor table

Out-of-stock rate, $100 \times p$	1%	2.5%	5%	10%
Safety factor, n_p	2.326	1.960	1.645	1.282

The way of approaching the above example is as follows:

$$\text{Safety stock } SS = n_{0.025} \times \sqrt{100^2}$$
$$= 1.960 \times 100 = 196$$
$$\text{Reorder point } s = 500 + 196 = 696$$

(3) ABC analysis

There are a wide variety of items to be managed, and treating all the inventory items in the same way may be inefficient in terms of management. Based on the concept of priority approach, we have the method of handling items subject to inventory management by classifying them into three categories, *A*, *B*, and *C*. It is called ABC analysis and is one of the useful tools to control the inventory efficiently. Figure 7.5 shows an example of Pareto diagrams that illustrate the concept of ABC analysis.

Regarding the classification into three categories, items in the range of 5–10% on the horizontal axis that exceed 50% on the vertical axis are classified as *A* items, items that occupy up to about 50% on the horizontal axis are classified as *B* items, and the rest are *C* items. This division is standard, but it may vary depending on the industrial sector.

In the inventory management for each category, efficient management generally requires the application of the various methods described in the next section. *A* items are managed by the "periodic reordering system" that allows priority management. *B* items are managed by the "fixed-quantity ordering system" which can shorten the lead time, and they are not more expensive than *A* items. The remaining *C* items are managed by the "double bin system" that can save management costs.

7.2.2 Typical Inventory Management Systems

(1) Periodic reordering system

The periodic reordering system is a method of placing regular orders, for example, "ordering only the required quantity every two days," and is used to manage the *A* items group in the ABC analysis. For expensive and rarely sold products, it is important to control the order quantity so that they do not sell out. To do so, forecast the demand until the product is delivered. If the product sells more than that, increase the order quantity. When the average demand per unit time is *D*, the lead time is *L*, and the ordering cycle is *R*, the order amount is expressed by the following equation.

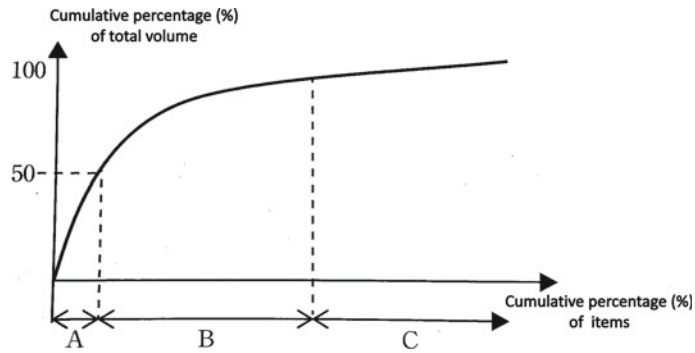

Fig. 7.5 Pareto diagram

Order quantity $= (L+R) \times D -$ Quantity of stock already ordered but not yet received $-$ on hand inventory $+$ safety stock

(2) Fixed-quantity ordering (Reordering point) system

For example, when the stock quantity reaches a predetermined reorder point s, such as "order when the stock quantity reaches 10 pieces," the quantity Q is ordered. It is used to manage the B items group in the ABC analysis. This order system is called the reordering point system because a certain amount of order is automatically placed when the inventory level reaches a predetermined level (ordering point). In this inventory system, it is important to determine the order quantity Q and the reorder point s.

(3) Double bin system

The double bin system is called the "two bin system." This inventory management is performed using two boxes, shelves, or cases with the same capacity Q. It is used for the management of C items in ABC analysis. In the actual operation of the method, we assume that there are two boxes, #1 and #2, each with the capacity Q. We first use the items in the #1 box. After the items in the #1 box are consumed, we use the inventory in the #2 box, then order the capacity Q of the #1 box. By repeating the operations, it is possible to prevent being out of stock easily. Therefore, in the double bin system, the maximum inventory amount is $2Q$, and it can be said that this is a fixed-quantity ordering system in a special case where the reorder point = the order quantity = Q.

7.2.3 Economic Order Quantity (*EOQ*)

When determining the order quantity Q, it is necessary to minimize the total cost by considering the "ordering cost" related to inventory replenishment and the "inventory holding cost" associated with storage after inventory delivery. In this subsection, we explain the economic order quantity (EOQ) as the optimum order quantity determined by the trade-off in the relationship between the two costs.

Here, it is assumed the demand amount per unit time is D, being out of stock is not allowed, a certain order quantity Q is ordered when the stock runs out, and the ordered product is delivered immediately. The total cost for the order quantity Q is denoted by $TC(Q)$, and the following cost parameters are defined to obtain the economic order quantity that minimizes the total cost.

c_o: ordering cost per order
c_p: purchase cost per product
c_h: holding cost per product per unit time

Since the demand quantity per unit time is D and a fixed amount Q is ordered, the number of the orders is placed D/Q times per unit time. Therefore, the ordering cost per unit time is "$c_oD/Q + c_pD$". Moreover, if Q is ordered, it takes Q/D time for the inventory to reach 0, and the average inventory during this period is half $Q/2$ of the maximum inventory regardless of D. Therefore, the holding cost per unit time is $c_hQ/2$, and the total cost TC(Q) per unit time is given by the following formula.

$$\mathrm{TC}(Q) = c_oD/Q + c_hQ/2 + c_pD \qquad (7.3)$$

The total cost TC(Q) $- c_pD$ is the smallest in terms of satisfying $c_oD/Q = c_hQ/2$, and the economic order quantity (EOQ), Q^* is as follows.

$$(\mathrm{EOQ}) : Q^* = \sqrt{\frac{2c_oD}{c_h}} \qquad (7.4)$$

7.3 Total Quality Management

Quality management is, needless to say, one of the means of business management. It can be said that the goal of management is that "the enterprise continues to exist and grow while achieving reasonable profits to fulfill its social responsibilities." Recently, for enterprises that have to survive the worldwide situations where technologies are being revolutionized, quality

requirements are diversified, businesses are internationalized, product liability (PL) issues are becoming critical, and energy/natural resource saving is required. Moreover, as environmental issues have to be addressed, it is believed that business management based on quality management is important and necessary to deal with the requirements of the age that puts emphasis on quality.

In this uncertain business environment, enterprises have to put more emphasis on strengthening their constitution with regard to quality assurance so that they can cope quickly in situations where the needs and requirements for quality or quality assurance change at a dizzying rate according to advances in quality levels, changes in the sense of value regarding quality, internationalization of business, changes in living environment, and other factors.

Total quality management (TQM) is one of the useful approaches to making production and/or various types of operations more efficient. There is a need to involve all the people in the enterprise. TQM and quality assurance activities are applied to production because the production process is most critical to quality, and emphasis is put on quality assurance activities in the planning, development, and design stages because the designs have to meet the user's quality requirements, which is the issue to be addressed before the production process. This stance has continued until today, and in 1987, the International Organization for Standardization (ISO) 9000 series was established and is now adopted for national standards by more than a hundred countries in the world. In Japan, the standard was introduced into JIS. The ISO 9000 series was most recently revised in 2015 and is now widely applied throughout the world.

7.3.1 Fundamentals of Quality Management and Assurance

"Good quality" can be said for a product only when customers who use the product are satisfied with it. This has been true in the past, is still true at present, and will be true in the future. To keep "good quality" and to make it even better, it is necessary to establish an organization and implement solutions based on quality management. To establish a reputation among customers that Japanese merchandise has top quality internationally, to be at the top level in the assessment of customer satisfaction, and to make the primary merchandise produced by the enterprise sufficiently profitable: To achieve these purposes, it is necessary to attempt to enhance the reliability and durability of the products through quality assurance and improvement activities in the fields of development, production, sales, and services.

Moreover, the demand from customers for product quality is becoming stricter in the situation where the merchandise is diversified, complicated, and systematized and where additional issues such as PL are present. Zero defects and zero complaints are not such extreme goals of quality control that they are ideals that cannot be achieved permanently, but are now real target issues that have to be solved. It can be said that the most critical issues of quality assurance are how to eliminate the factors that make it difficult to attain this goal and to attain these zero goals economically. Enterprises have to challenge these issues. Instead of taking action after a failure, which is "locking the garage after the car has been stolen," it is important for enterprises to put emphasis on taking actions proactively ahead of their competitors, to be devoted to proactive management, and to obtain excellent results.

To know the market needs in advance, they are required to know the customers. If they aim at zero defects and zero complaints, attempts to understand the actual state of the production process and markets have to be made before the problem occurs. The essence of quality assurance includes the direct flow of information about quality and technologies between the development division and the plants, which are in the upstream, and the terminal dealers so that these divisions are able to make a tight connection with the customers. A quality assurance system has to be established to collect market quality information and market reliability data, with special

emphasis on the market information system, to understand the movement of competitors and of general markets and to perform benchmarking so that appropriate information is distributed timely among relevant divisions.

It is said that the process of development of new merchandise in enterprises is essentially controlled by their merchandise planning capability that can identify the market needs and realize the plan by grasping the quality requirements. To attempt to increase the level of the planning capability, daily self-development is needed so that the original technologies and management technologies (techniques) can be put to practical use sufficiently. That is, it is essential to upgrade employee capabilities. To achieve this purpose, the quality control (QC) tools and merchandise planning tools are effective.

Market complaints may occur after sale of new merchandise caused by a lack of understanding of problems, occurring from lack of fundamental knowledge of functions of peripheral components and lack of presentation of the improvement ideas. To eliminate these problems, it is hoped that not only the utilization of the technologies owned by the manufacturers of the specific units but also the implementation of reliability design and tests be performed systematically based on design review (DR) and/or failure mode and effect analysis (FMEA).

7.3.2 TQM and ISO 9000s

TQM and ISO 9000s should be unified while compensating for each other to operate the quality management system efficiently so that they contribute to the increase of the profit. One of the methods is to strengthen continuous improvement by introducing ISO 9000s into the quality management of the organization that constructs the quality management system and implements the improvement activities by introducing its TQM activities (Kaneko et al. 2005).

To reform the enterprises, it is necessary to carry out quality management while understanding the difference between TQM and ISO; then at the same time, those enterprises that obtained ISO certification should address the TQM activities in accordance with their capability.

(1) **Features of TQM**

Centered on quality, TQM is an approach in which all the employees participate in management to improve management quality. TQM has contributed to quality improvement, increase of productivity, reduction of costs, etc. Its targets are "quality, participation of all employees, and improvement activities." As compared with ISO 9000, TQM provides the following seven features with emphasis on the improvement activities.

(1) Quality is based on customer evaluation, and customers determine the level of quality.
(2) Customers include all persons in the entire process from production to end-users.
(3) TQM covers overall matters of management, including quality (Q), cost (C), delivery (D), environment (E), security (S), etc. Policy management and functional management are performed through PDCA cycle. (P: Plan, D: Do, C: Check, A: Act)
QC seven tools (Ishikawa 1982) are useful to effectively perform PDCA cycle.
QC seven tools: 1) Check sheet 2) Histogram 3) Pareto diagram 4) Stratification 5) Cause and Effect Diagram 6) Scatter Diagram 7) Graph/Control Chart
(4) It includes all activities for objectives management.
(5) It puts emphasis on continuous improvement activities.
(6) It is developed company-wide through participation of all the employees in all divisions and all levels.
(7) It puts emphasis on the management based on the facts, work sites, realities, actual things, principles and fundamental rules and promotes statistical techniques, scientific solutions, solutions through achievement of targets and utilization of QC stories in a QC circle (small group activity).

(2) **Introducing ISO 9000s into TQM activities**

Enterprises should clearly define each step in quality assurance from planning new merchandise development to sales and services to guarantee the quality for the customers, and at the same time, contribute to the advance of the enterprises. Their connection with the TQM activities can be made closer by introducing the features of ISO 9000s into each function assigned.

It is necessary to introduce the items of ISO 9000s into TQM activities, develop them independently in accordance with the conditions of each enterprise or organization, and incorporate the activities into one to further develop them.

With regard to these activities, it is necessary to perform management of the quality assurance policy in each fiscal year based on the ideas of quality assurance to establish a quality assurance system that is capable of obtaining the perception of reliability from the customers and business partners with a "quality first" stance, to implement renewal of quality assurance activities in accordance with ISO 9000s based on TQM to predict and prevent quality problems, to strengthen cooperation between development, manufacture and sale divisions, to find the root cause of complaints and establish a system for corrective and preventive actions, and to attempt to improve CS by completing the quality assurance in accordance with the site information, actual things, and drawings.

7.3.3 Proactive Management

The improvement of the culture of an enterprise should be implemented aiming at 1) a culture that attempts to identify "the problem" by grasping the facts and having the capability to analyze them, 2) a culture that puts emphasis on the process, and 3) a culture that puts emphasis on certain matters and attempts to eliminate the present customs.

The value of utilization of ISO 9000s should be increased by applying proactive management activities to the eight principles of quality management stated in ISO 9000s, customer satisfaction, internal audit, and other factors. It is strongly desired now that individual enterprises change their cultures to adapt to their most appropriate new TQM activities. The primary five matters to attain this objective are as follows:

(1) **Policy management**
This is attained efficiently through the participation of the overall organization by defining mid- and long-term management plans and short-term management plans based on the management policy. One of the tools that can be used here is "finding and taking action against the true cause of problems," which is one of the fundamentals of TQM. Coordination of development of the president's policy, management strategy and planning of PDCA cycle should be strengthened.

(2) **Self-controlled improvement activities through participation of all the employees**
The primary element of TQM activities is the economical quality improvement, where the improvement of the products, processes, and systems are performed continuously through participation of all the employees. Employees should have the consciousness that "I guarantee the work that I do" and the consciousness that "all the employees participate in the QC circle activities."

(3) **Continuous improvement**
Improvement is not the maintenance of the present status. Activities that put emphasis on preventive measures are improvement. Improvement of the system and product quality should be performed. A method of measurement for both of these improvements, the method of improvement, and the techniques involved should all be systematized.

(4) **New merchandise planning and development**
Source control should be implemented by introducing Total Quality Management (TQM) into the field of marketing and by anticipating of users' needs. It is important to improve new merchandise planning capability and to devise a way to

match the quality of design and quality of manufacture in the process.

(5) **Information system**
Market quality information should be constructed to directly connect all information about the customer quality requirements to the development and manufacture divisions so that the evaluation of design quality is performed by respecting the customer's position.

Any enterprise has to make profit out of the business by all means continuously. It is important that the products and/or services provided by enterprises are bought by the customers continuously with satisfaction. The requirement of quality assurance is that the customers are satisfied. For enterprises, quality assurance and improvement activities are essential to the business. The quality requirements always change objectively and subjectively over time. What is the most important is to enhance the design quality and manufacture quality by understanding "what are the market quality requirements" and then meeting the requirements by properly utilizing technologies. Enterprises should realize a culture that can properly deal with problems such as the environmental one, which is one of the most critical issues now.

To achieve this purpose, TQM should develop toward an economically integrated model by harmonizing items such as ISO 14001(Environmental Management System), ISO 45001 (Occupational health and safety management systems), HACCP (Hazard Analysis and Critical Control Point), IATF (International Automotive Task Force) 16949, Six Sigma, Deming Prize, and moreover ISO 9000s, and the information security management system with TQM activities to evolve into a new one.

7.4 Just-In-Time Production System

Real production systems are multi-item, multi-stage production systems with complicated structure which incorporate the fluctuating uncertainties of final demand, machine breakdowns, defects, unavailable parts, and so on. The Just-in-Time (JIT) production system was invented to aim chiefly at cost reduction by eliminating unnecessary elements in production (Monden 1993, Ohno 1988). There are two key concepts: one is "Just in Time (JIT)" which is based on production smoothing and the other is "JIDOKA." The primary objective of JIT is to produce the right quantity of product in the right place at the right time, while maintaining minimal work-in-process. JIDOKA is for eliminating defects in the parts and products produced in each process. The systems are also supported by the kanban system, setup reduction, total quality management (TQM), and other subsystems to enhance "KAIZEN," which means continuous improvement in the systems. It is well known that the lean production system (Womack et al. 1991) advocated by MIT is based on the JIT production system.

In the JIT production system, a subsequent process withdraws necessary parts from a preceding process at a necessary point in time, and then the preceding process produces the parts withdrawn by the subsequent process using the kanban system. Two kinds of kanbans, that is, a production-ordering and a withdrawal kanban, are used as tools to control the production and withdrawal quantities in each process. Once the number of kanbans used in the process is specified, the process can operate independently of the other processes. Moreover, the supervisor of the process can use as many kanbans as he wants, though he is expected to minimize the number of kanbans used in the process. Therefore, the JIT production system is a decentralized, self-regulating system (Monden 1993). Since the number of kanbans used in each process decides the performance of the system, the method of determining them is essential for the system. In general, the number of kanbans used in each process is usually computed by popular formulas given in Sect. 7.4.2. The formulas include the safety stocks and adapting to uncertainties. Theoretically, it is important to determine optimal number of kanbans to minimize the expected average cost per period. In other words, the optimal amount of safety stock in the formulas are empirically determined.

7.4.1 Kanban System

In the JIT production system, two kinds of kanbans are mainly used: a production-ordering kanban and a withdrawal kanban. The withdrawal kanban specifies the kind and quantity of parts which the subsequent process should withdraw from the preceding process, while the production-ordering kanban specifies the kind and quantity of parts which the preceding process must produce. When the subsequent process carrier withdraws the parts, he detaches the production-ordering kanbans from the containers and places them in the kanban receiving post. He attaches one withdrawal kanban to each container and brings them back to the subsequent process. Production-ordering kanbans in the receiving post are collected regularly and are put into the production-ordering kanban post. The parts are produced according to the ordinal sequence of the production-ordering kanbans in the post. On the other hand, when the first part in the container is used in the subsequent process, the withdrawal kanban is put in the post. In particular, a withdrawal kanban used for making withdrawals from a vendor is called a supplier kanban. The lead time from ordering to delivery of the supplier kanban is relatively longer than that of the ordinary withdrawal kanban. The notation 'a-b-c' is used for specifying the delivery cycle of the vendor, where 'a-b-c' means that the parts are delivered 'b' times during 'a' days and 'c' delivery times later after the ordering. That is, the delivery cycle is a/b and the lead time is ac/b (Monden 1993).

The number of production-ordering kanbans corresponds to the maximum possible stock in the containers of the parts produced in the process. Similarly, the number of withdrawal kanbans corresponds to the maximum possible stock in the containers of the parts used in the production process. As the number of kanbans increases, the stock of parts also increases and overstocking may occur. Conversely, as the number of kanbans decreases, the stock of parts also decreases and a shortage may occur. Therefore, it is essential in the JIT production system to optimally determine the number of kanbans.

7.4.2 Modeling Approaches to Analyzing the System

We summarize early theoretical studies of the JIT production system. In the case where the demand is deterministic, Bitran and Chang (1987) consider a deterministic multi-stage capacitated assembly-tree-structure JIT production system. They formulate the problem of determining the number of production-ordering kanbans for each process into a nonlinear, mixed integer, programming problem. In their paper, it is noted that managers should adjust the number of kanbans determined by their model to take into consideration potential uncertainties in demand and machine breakdowns. Miyazaki et al. (1988) deal with a deterministic process with a variable withdrawal cycle and investigate the problem of obtaining the number of withdrawal kanbans and the withdrawal cycle that minimize the average cost per period under the given safety stock.

In the case where demand is stochastic, Kimura and Terada (1981) analyze by simulation how fluctuations in demand influence the fluctuations of the production and inventory in the preceding processes in a multi-process JIT production system. Deleersnyder et al. (1989) discuss the effects of the number of kanbans, machine reliability, demand variability, and safety stock requirements on the performance of the system using a discrete time Markov chain. Wang and Wang (1990) investigate a JIT production system by a Markovian queue under the condition that both inter-arrival times of the demand and processing times are exponentially distributed. They obtain an optimal number of production-ordering kanbans by calculating a stationary distribution of the system. Furthermore, JIT production systems are thoroughly studied using queueing theory. These analyses are based on the unrealistic assumption of exponentially distributed processing times. Tayur (1992) discusses the structural properties of a general multi-process JIT production system using results on an underlying generalized semi-Markov process.

Most of the previous papers deal with one kind of kanban, mainly, the production-ordering

kanban. In the next subsection, we consider a single-stage JIT production system with the production-ordering and supplier kanbans under stochastic demand and deterministic processing time. In fact, the deterministic processing time is much more realistic than the exponentially distributed processing time.

Denote the number of production-ordering kanbans and supplier kanbans by M and N, respectively. In general, formulas for determining the number of kanbans are as follows (Monden 1993):

$$M = [(DL_p + I_s)/u] \tag{7.5}$$

and

$$N = [(Da(1+c)/b + I_s)/u] \tag{7.6}$$

where $[x]$ is the minimum integer not less than real number x and

D = the average demand per unit time

L_p = lead time from the time a production-ordering kanban is detached to that a full container with is placed in the store,

I_s = safety stock, and

u = the container capacity.

7.4.3 Optimization of the System

We consider a single-stage JIT production system with supplier and production-ordering kanbans, which is shown in Fig. 7.6. Denote by L, M, and N the lead time of the delivery, the number of production-ordering kanbans and that of supplier kanbans, respectively. The preceding process is a supplier, and as note in Sect. 7.4.1, the supplier delivers containers of the parts b times during a days and c times later after the ordering. For simplicity, take the constant delivery cycle as one period. The parts consumed in period k (= 1, 2, …) are ordered from the supplier at the beginning of period $k + 1$, and they are delivered at the beginning of period $k + L + 1$. It is assumed that the demand for the product in each period is independent and identically distributed (*i.i.d.*) with mean D, the excess demand is backlogged, and the container capacity u is equal to one.

Let C be the production capacity of the process and the following notation is used:

D_k = demand in period k,

B_k = backlogged demand at the beginning of period k,

I_k = inventory level of the part at the beginning of period k,

J_k = number of production-ordering kanbans in the production-ordering kanbans post at the beginning of period k,

P_k = production quantity in period k, and

$X_k = B_k + J_k$: the total backlogged demand at the beginning of period k.

The JIT production system is called stable, if the distribution of X_k converges to a stationary distribution, as k tends to infinity. This is called a stability condition (e.g., Wolff 1989). Under the condition, we obtain an algorithm for determining the optimal number of kanbans that

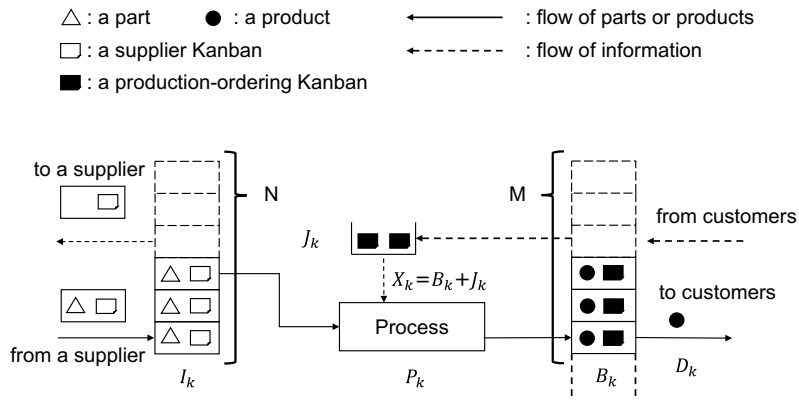

Fig. 7.6 Single-stage JIT production system

minimizes the expected average cost per period (Ohno et al. 1995). The algorithm, needless to say, does not assume the given safety stock. Therefore, the algorithm can be regarded as a procedure for determining an optimal safety stock, if the formulas are adopted.

7.5 Closed Loop Supply Chain

7.5.1 Supply Chain Management

A supply chain means a chain structure that is composed of customers, retailers, wholesalers, manufacturers and parts/material suppliers. Supply chain management (SCM) is a well-known approach to increasing the performance of the whole system. To carry out SCM effectively, it is essential to closely coordinate with the other related companies as well as the processes of one's own company in the supply chain.

Traditionally, in the management of supply chain processes, inventory management described in Sect. 7.2 is challenging because it directly impacts customer service and the gross profit income statement. Inventory management involves managing product stocks, in-process inventories of semi-products, as well as inventories of raw material. Figure 7.7, for example, illustrates a multi-stage supply chain model. If the supply chain consists of some processes with vertical structure shown in Fig. 7.7, the bullwhip effect (Lee et al. 1997), which is one of the issues in the supply chain, occurs. It means a change in amplification of the ordering quantity from downstream (customers) to upstream (suppliers). To deal with such an issue in the supply chain, inventory management with information sharing is one of the powerful tools.

A manufacturer needs an inventory policy for each of its products to define when and how much it should be replenished using information technology (IT). Appropriate inventory control is required to reduce costs, improve service level, and to generate new higher profits. If the inventory is too low, demand and supply fluctuations cannot be balanced, delivery performance will become low, and we end up with lost revenues. If the inventory is too high, working capital will be used up for the unnecessary stock, scrap risk, price down risk, and holding cost. As many suppliers are tasked with helping to create solutions that respond to a specific business need, changes in the inventory policies can lead to a dramatic alteration of the supply chain's efficiency and responsiveness (Kojima et al. 2008).

7.5.2 Concept of Closed Loop Supply Chain

Research in the field of supply chain management has traditionally focused on unidirectional, forward movement, that is transformation of materials from suppliers to inbound logistics, part fabrication, sub-assembly operations, final product manufacturing, outbound logistics, distribution, wholesalers, retailers, customers, end consumers, product maintenance, after-sales service, and later to end-of-life disposal. The reverse-directional flow of products back from end-users for reuse has received comparatively little attention in academic and practitioner circles till the turn of the century. However, in light of natural resource depletion around the globe, many countries are reevaluating their environmental regulations, such as European Union's WEEE directive of 2003, and are bolstering them

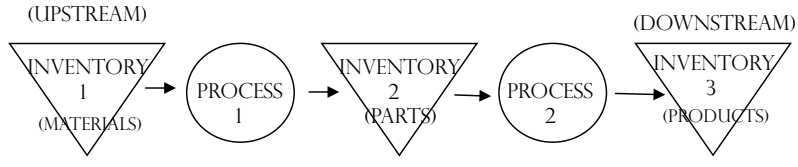

Fig. 7.7 Multi-stage supply chain model

to include recycling initiatives. In addition, consumers are demanding "greener," eco-friendlier products. This macro-trend makes a stronger case for upstream supply chain entities across industries to focus their efforts on reverse supply chain activities so as to enhance their value proposition (Guide and Wassenhove 2002).

Managing a reverse supply chain includes activities necessary to acquire end-of-life products from customers to recover value and eventually dispose of them. In a few decades, reverse supply chains have been garnering increased attention for various institution- and market-based mechanisms. Institution-based mechanisms include considerations such as limited landfill capacity, take-back laws, concerns about the increasing carbon footprint, etc. In contrast, market-based mechanisms include considerations such as increasing the proportion of product returns, consumer preference for "green" products, higher revenues through secondary sales in global markets, second life for discarded products, etc.

Within reverse supply chains, product recovery activities seek to reduce scrap by recovering materials and components from end-of-life or prematurely discarded/returned products from consumers. These activities include: (a) Reuse, where retail function handles the subsequent sale of used product after ensuring it meets quality standards. (b) Refurbish, where a distribution network (or company's outbound logistics) ships the used product to a refurbishing facility to ensure it is brought back to meet quality standards and its service life is extended before offering it for sale; (c) Remanufacture, where the product has to be returned to manufacturing operation for disassembly, remanufacturing, and subsequent reassembly before sale to consumer as a remanufactured/reconditioned offering; and (d) Recycle, where only some components can be salvaged from used products, reutilized in conjunction with virgin materials, and then placed in a forward supply chain via inbound logistics (Loomba and Nakashima 2012).

The concept of the integrated supply chain which includes a forward supply chain and a reverse supply chain is called a closed loop supply chain or closed loop manufacturing. It is important to develop and manage effectively the closed loop supply chain systems for realizing a sustainable society.

7.5.3 Analysis of a Closed Loop Supply Chain

We formulate a closed loop supply chain model with stochastic variability using a discrete time Markov decision process (MDP). MDP is one of the useful tools to control various kinds of stochastic systems such as inventory, production, transportation, and so on (Howard 1960; Nakashima et al. 2004; Nakashima and Loomba 2013). We consider a single process that produces a single item product using a returned part. The finished products are stocked in the factory and are used to fulfill customer demand. The end-of-life products are collected, disassembled, and refurbished, and each returned part is used for remanufacturing.

We suppose that the product is remanufactured using a returned product that belongs to class n ($n = 1, \ldots, N$) quality. Each class has a different acquisition cost, different remanufacturing cost, and different delivery lead time. Therefore, the decision-maker has to control n kinds of inventories for the returned products.

We assume that remanufacturing preserves the product's identity and performs the required disassembly and refurbishing operations to bring the product to a desired level of quality at some remanufacturing cost. All the production begins at the start of a period, and all the products are completed by the end of the period. Product demand is independent and identically distributed (*i.i.d*) with mean D. The remanufacturer orders the quantity of parts of class n that are supplied by the class n supplier, each with its own acquisition cost. It is assumed that the lead time of the part delivery is one. We use the following notations;

$I_n(t)$: inventory level of class n ($n = 1, 2, \ldots, N$) at the beginning of period t

$O_n(t)$: ordering quantity of class n at the beginning of period t

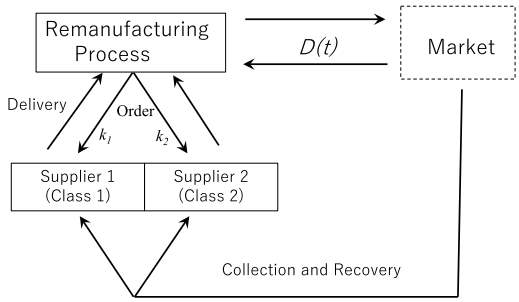

Fig. 7.8 Closed loop supply chain model ($N = 2$)

k_n: action as ordering part of class n ($k_n = O_n(t)$)

$D(t)$: demand in period t

$P_n(t)$: production quantity using pert class n in period t

a_n: acquisition cost per unit part for supplier n

h_n: holding cost per unit part supplied by supplier n

c_n: remanufacturing cost using part class n

c_b: backlog cost

Figure 7.8 shows the closed loop supply chain model with $N = 2$. We can formulate this system into the Markov decision process and obtain the optimal ordering policy that minimizes the expected average cost per periods.

7.6 Concluding Remarks

In this chapter, a summary of the scientific approaches to managing the production and/or the related systems is described to develop a sustainable production system. These management systems, especially, have close relations with SDGs # 9 (*Industry*, *innovation*, *infrastructure*) and/or # 12 (*Responsible consumption*, *production*). Recently, global supply chain management (GSCM) is attracting the most attention to coordinate the whole of the global operational systems because the stakeholders such as suppliers, employees, and others related to the supply chain have been enlarged all over the world. Information and communication technology has changed the conventional process and makes effective global operations possible.

GSCM also covers more sustainable development goals, for example, #7 (*Affordable and Clean Energy*), #8 (*Decent Work and Economic Growth*), #13 (*Climate Action*), and #17 (*Partnerships to achieve the Goal*). It is expected that all of the people in the world recognize the necessity of SDGs and utilize the operation management approaches for realizing a sustainable society in the future.

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8 Sustainable Development: Controversies and Theoretical Results in Economics

Ken-Ichi Akao

Abstract

This chapter presents the economic conditions for achieving sustainable development and the mechanism by which rational people choose an anti-sustainable path. These are theoretical results derived from the standard economic model. However, the model has faced controversy regarding the concept of sustainable development. This chapter introduces these controversies. By doing so, the implications and limitations of the theoretical results can be well-understood. One controversy concerns what should be sustained in sustainable development, and the other intergenerational equity. For illustration, this chapter often refers to the climate change issue, which raised and fired these controversies. Since the topic is sustainable development, this chapter relates to Sustainable Development Goals as a whole, and it contributes to SDGs 8 (economic growth) and 13 (climate action), among others.

Keywords

Sustainable development · Limits to growth · Tragedy of the commons · Intergenerational equity · Discounted utilitarian approach

8.1 Introduction

Sustainable development is a central social value worldwide that compels us to think of the environment and our far-future descendants. As an introduction to the economics of sustainable development, this chapter presents theoretical results in economics regarding the conditions for achieving sustainable development. Conversely, however, the conditions also reveal the limiting factors that prevent society from achieving sustainable development. Furthermore, the chapter reveals the mechanism by which rational people willingly choose an anti-sustainable path, a situation known as the "tragedy of the commons" (Hardin 1968). These theoretical results contribute to promoting "sustained, inclusive, and sustainable economic growth" in SDG 8 by helping to design a sustainable society and preventing policies that conflict with sustainable development.

Sustainable development has faced several controversies, as is common with important value concepts, such as liberty and human rights. In economics, the focus of the argument is the validity of standard economic models for

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studying sustainable development. Since the theoretical results in this chapter are derived from standard economic models, it is crucial to understand the controversies. By doing so, the implications and limitations of the theoretical results may be well-clarified.

This chapter begins with the controversies in economics surrounding sustainable development. One controversy is concerned with what should be sustained. Most economists believe that well-being should be sustained, a view called weak sustainability. Advocates of strong sustainability assert that the sustainability of natural capital should be considered in addition to well-being. Another controversy concerns intergenerational equity: the problem of how much we should sacrifice for the sake of the well-being of future generations. There are two dominant approaches to address this question: utilitarian and egalitarian. Moreover, there is controversy within the utilitarian approach over whether to discount future generations' well-being or not. The answer to this crucially affects the well-being of future generations.

Standard economic models are based on the concept of weak sustainability and take a discounted utilitarian view to evaluate future generations' well-being. At first glance, these concepts may be either unrealistic or ethically unacceptable. In fact, there have been disputes over them, even among economists. However, these alternatives are not without their own problems.

Climate change has been a central concern in economic research on sustainable development and has led to the aforementioned controversies.[1] The present chapter addresses this issue and partly covers the economics of climate change that contribute to SDG 13: Climate Action.

[1] Each controversy has a long history: The argument on discounting future generations' well-being was raised by Ramsey (1928). The egalitarian approach originated with Rawls's *Theory of Justice* (Rawls 1971). Finally, the choice of strong or weak sustainability has become an argument since the publication of *Our Common Future* (WCED 1987).

8.2 Controversies Around Sustainable Development in Economics

8.2.1 Background and Outline

The notion of sustainable development was first popularized by the International Union for Conservation of Nature and Natural Resources (IUCN) in its *World Conservation Strategy* (IUCN 1980). The report stressed the conservation of the ecosystem and sustainable use of living resources. The World Commission of Environment and Development (WCED), established by the United Nations in 1983 to formulate a global agenda to promote international cooperation toward sustainable development, broadened this notion by stressing the well-being of future generations. In the final report, *Our Common Future*, known as the Brundtland report,[2] the Commission defines sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, Chap. IV, para. 27). This definition was adopted at the Earth Summit,[3] the largest United Nations conference in the twentieth century, and this notion has spread rapidly.

Among the definitions of sustainable development,[4] the definition by the WCED cited above is the most prevalent. However, it contains two sources of disagreement that have caused controversy.

One source of disagreement is the role of environmental conservation in sustainable development. Today, environmental conservation is recognized, together with poverty

[2] Gro Harlem Brundtland was the chair of WCED, who also served as Prime Minister of Norway. Before the appointment, she was a member of the Independent Commission on Disarmament and Security, established by the United Nations to discuss nuclear disarmament.

[3] The Earth Summit proclaimed, "Human beings are at the center of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature" (United Nations 1992. The Rio Declaration, Principle 1).

[4] Several definitions of sustainable development are listed in the Appendix of Pearce et al. (1989).

eradication and changing consumption and production patterns, as one of the three "overarching objectives of and essential requirements for sustainable development" (United Nations 2002, Johannesburg Declaration on Sustainable Development, para. 11). However, this notion was initially devised to promote international cooperation to prevent global environmental destruction such as biodiversity loss and climate change. This difference is the source of controversy between strong and weak sustainability.

While the Brundtland report emphasizes the well-being of future generations, the definition provides few substantive ideas on how much the present generation should care for future generations. This is another source of controversy. Nordhaus (1994) criticized this definition, as it posits only Pareto efficiency, whereby something is socially desirable if one becomes better off without anyone becoming worse off, as criterial. Replacing "individual" with "generation" makes this definition of sustainable development precisely the same as that used by the WCED.

If later generations are born worse off, this cannot be considered sustainable development, although it might be Pareto efficient. This is because Pareto efficiency is defined as the condition under which no further improvement is possible without eroding the quality of life of some individuals. Therefore, if one generation cannot be better off without eroding the quality of life of another generation, it would be Pareto efficient. This indicates that the notion of sustainable development must include the idea of intergenerational equity.

Efficiency and equity are independent value concepts. As there are many efficient states, it is natural to seek an efficient state that satisfies equity. However, economists almost always consider only efficiency. The fundamental reason for this is the conceptual difficulty in defining equity. A rigorous definition of equity requires welfare judgment in a situation where one feels happy and the other feels sad in a coherent way. To judge whether it is socially good or not, one must weigh these two utilities, but how can we measure one's happiness and the other's sadness? The problem of the "interpersonal comparison of utility" has not been satisfactorily solved.[5] However, when considering sustainable development, we cannot avoid addressing the issue of intergenerational equity. The dilemma of the necessity of addressing the equity problem and the difficulty in defining it is the source of controversy.

Traditionally, economists have adopted a utilitarian approach that considers the sum of well-being over generations as the social welfare to be maximized following the slogan of utilitarianism: the greatest happiness for the greatest number.[6] This does not distinguish between the well-being of present and future generations; therefore, intergenerational equity is treated indirectly at most. Therefore, alternative approaches have been proposed and investigated. The most prominent is an egalitarian approach that distinguishes the least advantaged as entitled to become better off. However, this approach itself is not immune to criticism, and none of these approaches has displaced the utilitarian approach in economics.

Even within the utilitarian approach, there has been controversy for almost a century that has intensified with the emergence of the climate change issue: Whether it is justified to use the discounting formula to aggregate the well-being of generations as if it were cash flows. Discounting is contrary to egalitarianism.[7] Thus, the undiscounted utilitarian approach is morally superior. However, there are difficulties in practice, as discussed in the next section. This partly explains the dominance of the discounted utilitarian approach in economics.

In the remainder of this section, we examine these controversies. These points, as outlined in

[5] Binmore (2005) has tackled this problem.

[6] The reader may wonder why well-being can be treated as a number and how a single number can represent the well-being of a generation. These are hard questions involving the problems of the cardinality of utility and the interpersonal comparison of utility. Nevertheless, for pragmatic reasons, economists accept these assumptions in most cases. The same holds true in moral philosophy (see Hirose 2015).

[7] The standard utilitarian adds up the well-beings with equal weights and thus can be seen as kind of egalitarian.

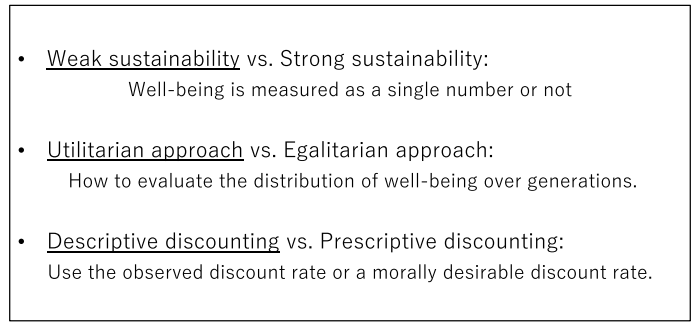

Fig. 8.1 Controversies in economics around sustainable development. *Note* A standard economic model takes the underlined positions

Fig. 8.1, have a nested structure (see the items in the figure from the bottom). First, the choice of discount rates is premised on a utilitarian approach; that is, social welfare (an index of social desirability) is expressed as the sum of the well-being of all generations. Second, the choice between utilitarian and egalitarian approaches is premised on weak sustainability.

8.2.2 Weak Sustainability and Strong Sustainability

Since 1990, the world's forests have decreased by 177 million hectares, which amounts to a 4% loss, larger than China's forested land (134 million hectares; Food and Agriculture Organization 2020). However, the world's human development index has increased consistently from 0.601 in 1990 to 0.737 in 2019 (United Nations Development Programme 2020). The index is calculated based on life expectancy, education, and per capita income. This trend applies to countries at all stages of development.

Confronted by this remarkable gap between the two components of sustainable development, how does one evaluate whether society as whole is on a track to sustainable development? Weak sustainability considers that synthesizing both is possible, with a single number representing the well-being of a generation. The logic is as follows. When a forest is converted to agricultural land, we lose the associated ecosystem services and forest products but obtain food, and this loss may be compensated by the gain, if sufficient. If this relationship, called *substitutability*, holds for all goods and services, then any change results in a change in utility,[8] which is the single number used to evaluate well-being.

The concept of strong sustainability denies this view. There are elements of nature that are essential to life and are not substituted. Greenhouse gases in the air and honeybees as pollinators are examples. They are referred to as *critical natural capital* (Ekins et al. 2003). Irreversibility and threshold also characterize critical natural capital. Once these elements degrade and fall into the critical zone, their restoration is impossible or very difficult, and society suffers fatal damage due to the non-substitutability of these natural elements.

As an indicator of strong sustainability, Ekins et al. (2003) propose the gap between the sustainability standard for critical natural capital and the current situation, terming it as an "S-GAP." The sustainability standard is also called the safe minimum standard for conservation (SMS; Ciriacy-Wantrup 1952).[9] As the number of S-GAPs is the same as the number of critical natural capital stocks, strong sustainability has multiple indicators.

[8] For simplicity, this chapter uses "utility" synonymously with "well-being." Utility is clearly defined in economics: It is the numerical representation of individual preference. By contrast, the definition of well-being is controversial, especially in discussions on equity. See Hirose (2015, pp. 2–3) for a careful discussion and neat treatment and Asheim (2010, p. 201), who gives clear and thoughtful definitions to these terms in the context of intergenerational equity.

[9] The minimum vital population in ecology is an example of SMS. SMS can be not physical but economic such that, although a natural capital is degraded but is still restorable, an economic rationale suggests its unsustainable use. See Clark (1971) and Akao et al. (2011).

To illustrate these two concepts of sustainability, consider the issue of climate change. Policymakers often discuss the carbon budget, which is the total amount of carbon emissions that can be emitted for temperatures to stay below a global target, such as the 2 °C target (United Nations Environment Programme 2020). Minimum-cost emission paths to achieve the target calculated using an integrated assessment model (IAM) have been discussed based on strong sustainability; a climate with a livable temperature is a form of critical natural capital. The world target and carbon budget correspond to the SMS and S-GAP, respectively.

An IAM has also been used to derive an optimal emission path that maximizes social welfare. The Nordhaus dynamic integrated climate economic (DICE) model is a prominent model that expresses the well-being of each generation as a single number—utility.[10] Therefore, it is based on weak sustainability. As shown in Fig. 5.6 in Nordhaus (2008), there is a serious disconnect between the economic-optimal path and the minimum-cost path for achieving the 2 °C target. If the optimal path is taken, the increase in the global average temperature at the end of this century will far exceed 2 °C.

Weak sustainability pays little attention to the non-substitutability and irreversibility of critical natural capital. Therefore, the policy implications may tend to be over-optimistic. However, knowledge of critical natural capital stock is still limited. Moreover, even if we possess knowledge in this regard, there is considerable uncertainty about the threshold in general, as in the case of climate change. Furthermore, capital's non-substitutability and irreversibility do not emerge until the capital stock reaches the threshold, and we know little about what happens at the tipping point. Given these uncertainties, stressing the characteristics of critical natural capital may tend to be too pessimistic. In other words, strong sustainability may be too cautious.[11] Therefore, these two concepts of sustainability can lead to a debate on environmental policy: Environmental regulation may be seen as too lax by the supporters of strong sustainability and too strict by the supporters of weak sustainability.

While the policy implications can differ between weak and strong sustainability, there is no difference in economic modeling. From both views, a desirable state is formulated as a solution to an optimization problem with constraints. Recall previous examples of weak and strong sustainability. As an example of a weak sustainability approach, the DICE model maximizes the aggregate sum of utility over generations with constraints on production possibility, including emission abatement costs and the global climate system. An efficient path satisfying the 2 °C target, as an example that follows strong sustainability, is a solution to a cost minimization problem with the constraint that global average temperatures must be lower than the target. Maximization and minimization are interchangeable; maximizing the good is equivalent to minimizing the bad. Therefore, formally, the debate between the two views concerns the constraints that should be imposed on the problem in question. In contrast, the following two subsections focus on what is optimized.

8.2.3 Utilitarian and Egalitarian Approaches for Intergenerational Equity

In 1972, the first world conference on environmental issues, the United Nations Conference on Human Environment, was held. It cautioned that if the human capability and power are "[w]rongly or heedlessly applied, the same power can do incalculable harm to human beings and the

[10] William Nordhaus was awarded the Nobel Prize in Economics in 2018 for his pioneering and influential works on the economics of climate change.

[11] This leads to how cautious we should be about future uncertain events, which is the central question around the validity of the *precautionary principle*, another essential but controversial concept regarding environmental issues. See Sunstein (2005).

human environment" (Declaration of the Nations Conference on the Human Environment, para. 3).

Before the conference, the Club of Rome report, *The Limits to Growth* (Meadows et al. 1972), was published. The report warned about the sustainability of modern civilization, which depends heavily on nonrenewable fossil resources. The share of fossil fuels in global energy consumption was 94% in 1972.[12] People realized that prosperity was jeopardized due to several problems that emerged alongside steady economic growth, such as environmental pollution, resource exhaustion, and the population explosion. Economists began intensive studies of egalitarian approaches.

One of the reasons is the description of the economy in *The Limits to Growth*, which relies heavily on a nonrenewable resource. A traditional utilitarian approach suggests that an anti-sustainable development path is socially optimal for such an economy. In other words, well-being decreases over time along the optimal path.

An egalitarian approach can help avoid this repugnant result. It is based on the Rawls' Difference Principle, which treats it as distributivity-just to make the least advantaged in society better off (Rawls 1971, Sect. 13). This is also called the maximum approach because maximizing the minimum level of well-being is socially optimal.

With this approach, an optimal path entails the same utility over generations; this is called an egalitarian path.[13] Therefore, a declining utility path is never chosen. However, a problem arises when an increasing utility path becomes feasible. Even in this case, a constant path is optimal. When the utilitarian optimal path increases, the egalitarian approach recommends that the present generation consumes more and pollute more than the utilitarian optimal path; otherwise, the present generation stays in the least advantaged position. This is another undesired result. The attractiveness of this approach over the utilitarian approach is reversed.

The overall appeal of these approaches depends on one's perspective on future development. The egalitarian approach would be supported by people who believe that modern society is on a doomsday trajectory; that is, future generations can be at most as well off as the present generation and, therefore, are likely to be worse off. However, people who believe that sustainable development is achievable would consider that well-being can increase in the future. Otherwise, sustainable development is infeasible and its achievement is logically impossible. From this perspective, the egalitarian approach is less attractive because it leads to the following paradoxical suggestion[14]: Although we can make our children happier than us, it is unfair to us, and the idea of making them better should be dismissed. In contrast, the utilitarian approach suggests that making them happier than us is always good if their gain is more than our loss.

The discussion of sustainable development, as mentioned above, is based on the premise that a sustained improvement in well-being is feasible. However, the social justification of a sustainable development path and the desire of present generation to engage in such development remains unclear. Unfortunately, the egalitarian approach fails to answer the requisite social justification. Hence, this chapter considers these questions of justification and desire within the framework of utilitarianism.

8.2.4 Arguments About Discounted Utilitarianism

Even within the utilitarian approach, there is long-standing controversy as to whether we should discount future generations' well-being.

[12] It remains high: 83% in 2020. (BP Statistical Review of World Energy).

[13] An egalitarian path may be infeasible in an economy heavily relying on a nonrenewable resource. The feasibility depends on whether an essential nonrenewable resource can be substituted by a manufactured product (Solow 1974; Cass and Mitra 1991). Recall the discussion of strong/weak sustainability. Again, the essentiality and substitutability of a natural resource matter.

[14] Rawls (1971) noticed this problem and showed reluctance to applying the maximin approach to intergenerational equity.

This argument has flared because of climate change.

The Stern Review (Stern 2007) is an economic analysis of climate change presented by the British government in 2006. It is prominent not only for its influence, but also for its radical policy recommendation: Urgent, sharp, and immediate reductions in greenhouse gas emissions are needed. The optimal carbon emission reduction is much larger than the other economic analyses. Furthermore, it is larger than the minimum-cost path for achieving the 2 °C target (see Nordhaus 2008, Fig. 5.6).

The model used in the Stern Review is essentially the same as the other IAMs, but the parameter choice is different. In particular, the choice of the discount rate is crucial to the radical recommendation. Therefore, the Stern Review rekindled a long-running controversy over the appropriate discount rate for social decision making. Before introducing the argument, the discount rate and discounted utilitarian approach are briefly explained.

A discount rate transforms a future value to its present value to enable the comparison and summation of values at different points in time. For example, letting r be the discount rate, the present value of 1000 dollars 10 years from now is calculated as $1000/(1+r)^{10}$ dollars. The word "discount" comes from the fact that the present value is less than 1000 dollars if received now, so long as r is positive.

A term similar to the discount rate is the *discount factor*, $d = 1/(1+r)$. With the discount factor, the aforementioned present value is written as $d^{10} \times 1000$. Note that if $r > 0$, then $0 < d < 1$, and if $r = 0$, then $d = 1$.

To illustrate the summation of the present values, assume that we will receive 1000 dollars every year for ten years from today (ten times). The total present value is then calculated as $1000 + 1000/(1+r) + \cdots + 1000/(1+r)^9$. With the discount factor, it is written as $1000 + d \times 1000 + \cdots + d^9 \times 1000$.

Applying this formula, a standard economic model formulates an intertemporal social welfare function as

$$W(u_1, u_2, \ldots) = u_1 + \delta u_2 + \delta^2 u_3 + \cdots, \quad (8.1)$$

where $u_i (i = 1, 2, \ldots)$ is the utility of the i th generation and δ is the discount factor. Let ρ be the discount rate. Subsequently, δ is given by $\delta = 1/(1+\rho)$.[15] The discounted utilitarian approach assumes that $\rho > 0$ (and thus $\delta < 1$), whereas if $\rho = 0$ (and thus $\delta = 1$), the social welfare function follows the (undiscounted) utilitarian approach.[16]

Stern (2007) chose zero discounting ($\rho = 0; \delta = 1$) for the ethical reason that all generations should be treated equally.[17] By contrast, most economists adopt a positive discount rate, although this discounted utilitarian approach has been repeatedly criticized.[18] The most famous and oldest criticism is by Ramsey (1928), a mathematician, philosopher, and economist. Since he first formulated the aforementioned model, it is now called the Ramsey model. In his words, "we do not discount later enjoyments in comparison with earlier ones, a practice which is ethically indefensible and arises merely from the weakness of the imagination." (Ramsey 1928, p. 543).

[15] Note that the notations of the discount rate and the discount factor have been changed because they are used to discount the utility, whereas r and d are used to discount the monetary value. Therefore, they should be distinguished. An intuitive reason for this is simply that happiness and money are different. A fundamental difference is that ρ and δ are part of preference, which constitutes the economy's fundamentals. In contrast, r and d are derived from the fundamentals through a social system of markets and institutions.

[16] The reader may wonder why the model considers the infinite future and if the model can be mathematically well-defined in the undiscounted case. For the answers, see Léonard and Long (1992, pp. 285–287).

[17] In actuality, the Stern Review uses 0.1% as the discount rate. This value reflects "the annual risk of catastrophe eliminating society" (Stern 2007, p. 161). When this kind of risk is incorporated into the model, the discount rate is the sum of the pure rate of time preference, zero in the Stern Review, and the hazard rate. The pure rate of time preference is the parameter representing our impatience.

[18] See Dasgupta (2019), especially Chap. 9, for a comprehensive exposition and in-depth thoughts on this topic.

To indicate the meaning of the "weakness of the imagination," take 1% as an annual discount rate, which is near zero and much lower than usually used in economics. With this discount rate, the current value 10 years from now is discounted by 9.5%, when it is transformed to the present value. The depreciation is not very large. If we consider the current value 30 years from now, the most extended period for a long-term public project, the present value is discounted by 26%. This is still not very large. However, if we consider the current value 100 years from now, the present value is discounted by 61%. In the case of 500 years, the present value is discounted by 99%. If we overlook this unjustly low valuation for distant future generations, we will not escape the accusation of having a weak imagination.[19] It should be noted that 500 years should be incorporated into the timescale of sustainable development.

This example also shows that any small benefit for the present generation can be justified in discounted utilitarianism, regardless of how high the cost is, provided that sufficiently distant future generations incur the cost. For example, assume a project that provides a utility gain of 1 point to the present generation and imposes a 1000-point loss of utility on a future generation. Then, when the discount rate is 1%, if the generation more than 700 years from now suffers from the cost, the project is accepted by a discounted utilitarian because the present value of the 1000-point utility loss is less than 0.95 points, and discounted utilitarian social welfare increases by implementing this project. Chichilnisky (1996) called this property *the dictatorship of the present*.

A discounted utilitarian approach is usually adopted in economic analysis despite these morally unacceptable traits for two reasons. First, we behave impatiently as though we have a positive discount rate. If we use a morally just but unrealistically low discount rate, the associated optimal path over generations would not be optimal in the real world. In the context of the climate change issue, this means that an optimal emission path derived with a zero-discount rate, as in the Stern Review, can be replaced with an alternative path that has the same mitigation effect on the climate with a lower social cost.[20] This problem cannot occur if the discount rate derived from real-world observations is used. This discount rate is adopted in the discounted utilitarian approach. Arrow (1999) views this as a descriptive discount rate, and the zero-discount rate as the prescriptive discount rate.

Second, an optimal path derived with a zero-discount rate seems too radical to implement. We consider the climate change issue. Figure 8.2 illustrates the three *social costs of carbon* (SCC). SCC is defined as the sum of the damages in the future caused by a one-ton current emission of carbon dioxide. Theoretically, to achieve an optimal path, it is necessary to impose a tax per ton of carbon dioxide worldwide of the same amount as the SCC or implement an equivalent policy measure, such as a worldwide emission trading system. The market equilibrium price of the emission permits should be equal to that of the SCC. Both measures are called *carbon pricing* because they price carbon emissions.

Figure 8.2 shows a considerable difference between the SCCs. The DICE2016R is based on a discounted utilitarian, whereas the Stern Review is based on an undiscounted utilitarian. To consider their acceptability, we compared them with actual carbon prices. According to the World Bank (2020, Fig. 2.3), the carbon prices as nominal prices on April 1, 2020, are higher than the Nordhaus SCC in 2020 in six countries, but even the highest price (US\$119/tCO_2e, Sweden's carbon tax) is less than half of Stern's SCC. The report states that approximately half of the covered emissions are priced at less than US \$10/tCO_2e, and the IMF calculates the global average carbon price as only US\$2/tCO_2 (World Bank 2020, pp. 7–8). These figures exemplify the difficulty of implementing an optimal path using an undiscounted model.

Figure 8.2 also shows that the SCC of the 2.5° maximum is similar to that of the Stern

[19] With a 3% discount rate, the discounts are 25% (10 years), 59% (30 years), 94% (100 years), and 99.99996% (500 years).

[20] See Nordhaus (1999) for the illustration.

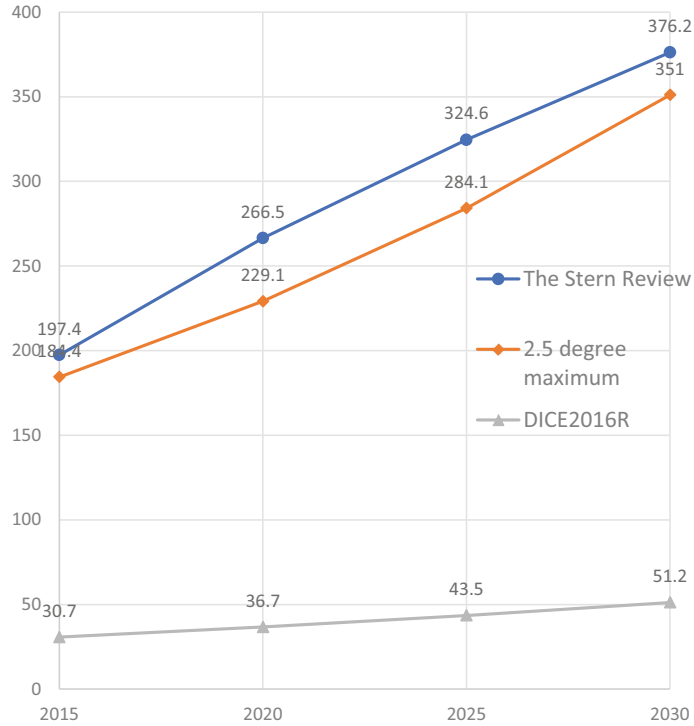

Fig. 8.2 Estimation of the social cost of carbon. *Notes* (1) The SCC is measured in 2010 international US dollars. (2) DICE2016R is calculated along the optimized emission path. (3) The 2.5 °C maximum is calculated along the optimized emission path with constraint. (4) It is expected that without net negative emission technology that has not yet been practically realized, the 2 °C target in the Paris Agreement will inevitably be exceeded. Refer to Ricke et al. (2017) for details. *Source* Nordhaus (2017, Table 1)

Review.[21] This similarity implies that the implementation of carbon prices suggested by the SCC of the Stern Review may be appropriate from the viewpoint of strong sustainability. Hence, we encounter the first controversy between weak and strong sustainability.

Although it is beyond the scope of this chapter, some economists have addressed the justification of high carbon prices in the framework of weak sustainability and discounted utilitarianism, that is, based on standard economics. Gerlaph and Liski (2017) consider non-geometric discounting that may be more plausible to describe our decision making for far-future generations than the standard discounting mentioned. Dietz et al. (2020) reconsider the results obtained from 6 IAMs in economics by updating their climate modules. In these studies, appropriate carbon prices are higher than their reference models. Furthermore, Weitzman (2007) conjectures that explicit incorporation of the possibility of catastrophic risk into economic analysis would be a prospective approach to understanding appropriate carbon prices and solving the discounting argument.

8.3 Economic Conditions for Sustainable Development

8.3.1 Outline

This section presents the conditions for achieving sustainable development within the framework of discounted utilitarianism. As discussed in the

[21] However, they are different in an important respect. While the optimal path by the Stern review is suboptimal in practice, the path induced by the implementation of the SCC of the 2.5° maximum is truly an optimal path under the temperature constraint.

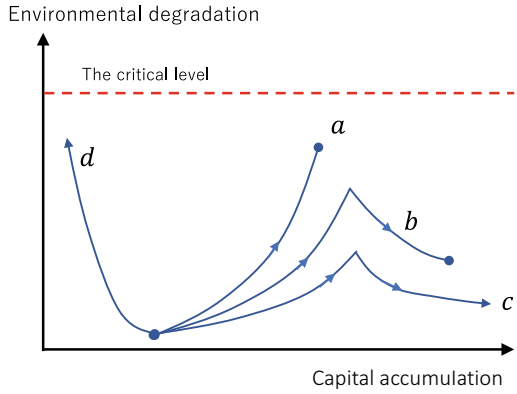

Fig. 8.3 Four paths of development and the environment

previous section, this approach has received moral criticism but has the advantage of reflecting reality better than alternative approaches. In addition, several insightful results follow from using this approach.

Figure 8.3 illustrates four stylized development paths. The horizontal axis represents capital accumulation. A move from left to right indicates economic development. The term "capital" is broadly used to indicate manufactured tangible capital such as machines, plants, and roads; intangible human capital such as knowledge, technology, and the arts; and natural capital such as the climate system, ecosystems, soil, and genetic resources. Capital is a primary source of well-being.

The environment is another primary source of well-being. The vertical axis represents the environmental degradation level. The environment is degraded by, for example, the increase in air and water pollution, destruction of the stratospheric ozone layer, loss of biodiversity, and accumulation of hazardous waste. The horizontal dashed line at the top indicates the critical level of the environment. Once environmental degradation reaches this level, the environment completely loses its regenerative and assimilative capacity, and the economy inevitably suffers fatal damage. These threats include the extinction of renewable natural resources and global warming to a level that releases frozen methane from the oceans into the atmosphere.

The four paths begin from a common initial point. This point indicates a state in the early stage of economic development, where most capital stocks are natural capital and the pollution level is low. Paths A, B, and C represent economic development.

Along Path A, capital increases with a consistent degradation of the environment. Because continuation is a doomsday approach, economic growth must end before the path reaches the critical level of the environment.

In contrast to Path A, Path B has a turning point. After passing the turning point, society enjoys economic growth and environmental improvement. This hump-shaped pattern is known as the *environmental Kuznets curve* (EKC). Grossman and Krueger's (1995) work is one of the earliest EKC studies. Using cross-country data, they showed the existence of the EKC relationship between per capita income and several environmental indices, such as sulfur dioxide emissions and biological oxygen demand. Since their seminal study, intensive empirical studies have been conducted on the existence of the EKC.

Finally, Path C has unlimited economic growth and environmental improvement. Therefore, this may be referred to as a sustainable development path.

All three paths are derived from the maximization problem of the intertemporal social welfare function (1). That is, they are all optimal paths. If Path A is optimal, rational people will willingly take an unsustainable path. If Path B is optimal, they have economic development and environmental conservation; however, there is a limit. If Path C is optimal, they achieve sustainable development. Which path constitutes the optimal path is a crucial question. Section 8.3.2 shows the conditions.

Path D is entirely different from the other paths. Economic decline is accompanied by environmental degradation. Although this worst path can be optimal under certain conditions, suboptimal paths are considered below.[22] In this

[22] This anti-sustainable development path can be optimal if the initial level of capital is lower than the SMS discussed in Sect. 8.2.2 of this chapter. See footnote 9 as well.

case, although Paths A, B, or C are optimal, rational people spontaneously take a suboptimal and anti-sustainable development path. This situation is known as the *tragedy of the commons* (Hardin 1968). "Commons" is a communally farmed land in medieval England, but in Hardin (1968), it is a metaphor for capital that anyone can use freely.

Examples of such capital include high-sea fisheries and the atmosphere as a dumpsite of greenhouse gases. Whales are close to extinction and climate change jeopardizes the well-being of future generations. As such, the tragedy of the commons is ubiquitous. It is also a fact that these issues have been addressed through international conventions: the International Convention for the Regulation of Whaling for the former and the United Nations Framework Convention on Climate Change (UNFCCC) for the latter. The important question is whether these international efforts can remedy the tragedy of the commons. This question is addressed in Sect. 8.3.3, following the exposition of the mechanism by which rational people choose Path D.

8.3.2 Sustainable Development or the Limits to Growth?

This subsection describes the conditions that determine which path (A, B, or C), is socially optimal. To this end, we briefly explain the mechanism of economic development along an optimal path.

If the rate of return on investment measured in terms of utility is higher (lower) than the discount rate, the investment of one additional unit of capital increases (decreases) the intertemporal social welfare (1).[23] In other words, capital accumulates along the optimal path only if its marginal productivity exceeds the discount rate.

This result implies that manufactured physical capital and human capital increase at the early stage of development, whereas natural capital decreases, accompanied by environmental degradation as shown in Paths A, B, and C in Fig. 8.3. Note that natural capital is near physical and ecological equilibrium at this stage. This implies that the marginal productivity is near zero, and thus, is less than the discount rate at the stage.

We now consider the economic mechanism that separates Paths A, B, and C.[24] Along these paths, economic development increases income. As income increases, people consume more goods, and the value of additional consumption decreases relative to the value of services unpurchased in the market, including the quality of the environment. Along an optimal path, this causes an increase in demand for a better environment, and the government reacts by strengthening environmental regulations. Consequently, environmental improvements are accelerated. When the speed of environmental improvement exceeds the speed of environmental degradation at some point in economic development, we have the turning point of Paths B and C. However, if environmental improvement falls behind environmental degradation, Path A is selected as the optimal path.

There are two conditions for society to take Path B or C. First, our preference for tangible and purchasable goods should not be overly greedy. This preference determines the strictness of environmental regulations and thus the speed of environmental improvement. The other condition is that the regeneration and assimilation capacities of nature be sufficiently high to restore the environment. These capacities determine the speed of environmental degradation. That is, the higher the capacities, the slower the environmental degradation. These two conditions work such that an optimal path has a turning point,

[23] The discount rate is the descriptive discount rate (see Sect. 8.2.4 of this chapter). The discounted utilitarian approach assumes that the intertemporal social welfare function introduced in Sect. 8.2.4, which consists of the discount rate and the one-period utility function, can be estimated from the observable data. Moreover, it assumes that the estimated function represents the social preference, that is, the desirability for the society. Arrow et al. (2003, p. 652) urge caution about this view.

[24] The formal exposition of the results can be found in Stokey (1988), Aghion and Howitt (1998, Chap. 5), and Akao and Managi (2007).

after which we have both economic development and environmental improvement.

Whether Path B or Path C is optimal depends on the environmental properties of the growth engine in the economy. The engine is an industrial sector in which the marginal productivity of capital is sufficiently higher than the discount rate to make continuous investment in the industry profitable. Continuous investment enables the industry to grow, which leads to economic growth.

Path C becomes optimal when the economy is equipped with a clean growth engine. The meaning of "clean" is that the economic activities of the growth-engine sector do not negatively affect the environment. Under this condition, the environment is decoupled from economic development. As a result, a path along which society has both unlimited economic development and environmental improvement; that is, Path C can be an optimal path.

If the growth-engine industry is not clean, the industry will eventually cease to grow. To examine this, we consider the effects of environmental regulations on the industry. Environmental regulations are strengthened as the economy grows. As a result, a firm in the industry inputs more resources for environmental measures, sacrificing production and investment. The marginal productivity of capital decreases as environmental regulations become stricter because the return on additional investment is partly used for environmental expenditure. When marginal productivity decreases to the market interest rate, investment becomes unprofitable, and the growth-engine sector ceases to grow. This explains why Path B has limited growth. If the growth engine is clean and unaffected by strengthening environmental regulations, it avoids a reduction in the marginal productivity of capital. Thus, Path C becomes the optimal path.

We have seen that there are three conditions for an optimal path to be a sustainable development path (Path C): (1) less greedy consumers, (2) high resilience of the environment, and (3) a growth-engine sector that is harmless to the environment. The first condition concerns preferences. Therefore, education and culture play an important role in satisfying this need.

The second condition is related to the use of natural capital. For example, if society depends heavily on fossil resources, this condition is not satisfied because the regeneration rate is zero. The same is true for a society in which primary pollutants do not easily decompose naturally. Examples include carbon dioxide and radioactive wastes. Decarbonization and nuclear power phase-out are crucial tasks for avoiding climatic catastrophes and severe radioactive pollution. In addition, the above result indicates that it is necessary to prevent rational people from choosing an anti-sustainable development path.

The third condition implies that leading industries for economic development should use intangible assets, such as knowledge and information as inputs, and output intangible goods, such as knowledge and art. Thus, their activities do not negatively affect the environment. Along a sustainable development path, people in the future will gain utility mainly from intangible goods, and the dematerialization of society will advance.

8.3.3 The Tragedy of the Commons and International Environmental Agreements

This subsection shows how the tragedy of the commons does and does not occur and discusses whether an international environmental agreement can work as a remedy for the tragedy. While the previous subsection considered a socially optimal path, this subsection considers a suboptimal path resulting from collective actions by individually rational people.

Economists distinguish between two types of commons: open-access resources (OARs) and common pool or property resources (CPRs). The difference lies in the number of users of the resource. An OAR is free-entry and has an unspecified number of users, whereas CPR users are fixed. An example of an OAR is a forest that suffers illegal invasion by the landless poor. They come from nowhere, seeking cropland. There are several examples of CPR. For example, several

global environmental issues can be considered problems with CPR. In the negotiations, the people concerned with the problem are represented by fixed countries.

First, we consider an OAR, a distinctive feature of which, owing to its free-entry nature, is that a new resource user continuously enters an OAR as long as there is a positive gain. Therefore, if a user saves resources for future use, the saved resources may be consumed by other users. Users of an OAR behave myopically because saving is meaningless.

In an economic model, myopic behavior is translated into a discount rate with an infinite value. We recall the mechanism of capital accumulation explained in the previous subsection. Marginal productivity is finite and is dominated by an infinite discount rate for any capital stock. Thus, capital stock decreases, accompanied by resource destruction; that is, a society based on an OAR takes Path D in Fig. 8.3.

It still remains unclear whether this anti-sustainable development path is a trajectory to ruin as per Hardin's prediction: "Freedom in a commons brings ruin to all" (Hardin 1968, p. 1244). Dasgupta (1982, p. 13) pointed out that this is not always true. For example, with a classical resource economics model called the Gordon–Schaefer model (Gordon 1954), the equilibrium path of an OAR converges to a positive level of resource stock and ruin is avoided. The mechanism is as follows. In the model, the cost of using one more resource (i.e., the marginal cost of resource use) increases as resources become scarce. There is a positive stock level for the resource, at which point neither further resource use nor new entry is profitable. Thus, resources no longer decrease beyond this stock level.

However, Hardin's dismal prediction may emerge when population growth is combined with the Gordon–Schaefer model. Brander and Taylor (1998) demonstrate this in a theoretical inquiry into the rise and decline of Easter Island. They address the mystery of Easter Island: Why did the civilization of Easter Island collapse, whereas many other Polynesian islands did not? They explained that the difference could be attributed to the regeneration capacity of palm trees, which are critical natural capital on the island. The regeneration capacity of palm trees is remarkably lower on Easter Island than on the other Polynesian islands owing to the unique climatic conditions. With their model, population growth on Easter Island causes resource depletion and famine, leading to war for resource and societal collapse. This occurs in a society that depends heavily on natural resources with low regeneration capacity. Moreover, even if the natural resources had been well-managed and society had taken a socially optimal path, the optimal path might have not been accompanied by environmental improvement, as shown in the previous subsection. The dependence on natural resources with low regeneration capacity threatens sustainable development.

Next, we consider CPR. In contrast to OARs, there are several possibilities for using resources. If other users utilize maximum effort to harvest the resource, the optimal strategy of the user is to follow them. This equilibrium path of resource use leads to the tragedy of the commons. However, another equilibrium path may exist. If other users harvest the resource sustainably, adopting a sustainable harvest strategy can be optimal. This is because when other users adopt a sustainable strategy, a user is not deprived of the resources saved today by the other users. Saving the resource can then make the user better off if the rate of return is higher than his or her discount rate by the same logic of capital accumulation along a socially optimal path mentioned in the previous subsection. Therefore, a sustainable harvest strategy is the best response to the harvest strategies of other users.

This strategic interaction can create various equilibrium paths because the best response depends on other users' strategies. Sorger (1998) illustrates multiple equilibria with a model that he describes as a resource game. He calls the above-mentioned disastrous equilibrium path the most rapid extinction path because the resource becomes extinct at the highest speed. The other paths can be called sustainable equilibrium paths because each of them converges to a positive level of resource stock.

He shows that these equilibrium paths can coexist and that there are uncountably many sustainable equilibrium paths if they exist. However, only the most rapid extinction path exists if the discount rate is high, the number of users is large, or the harvesting ability is high. Although this result is derived from a specific model, it provides important implications on how we can maintain the possibility of taking a sustainable path. For example, it may be necessary to control the use and development of harvesting technology for the sustainable resource use of CPR.

Sorger (1998) also shows that when sustainable equilibrium paths exist, there is an equilibrium path similar to a socially optimal path in resource use when the initial stock is sufficiently close to the socially optimal steady state. This is surprising because rational but non-cooperative people can realize an almost efficient outcome without any rules or institutions. The question, then, is how resource users choose a desirable equilibrium path. One possible answer to this is communication. In theory, they can choose such a path if they communicate before starting resource use.[25] An example in the real world is an international environmental negotiation, in which countries pursue their national profit from environmental agreements. This situation is the tragedy of the commons and is modeled as the resource game of Sorger (1998). As previously mentioned, there are several equilibrium paths. The existence of an approximately optimal path implies that policy coordination can attract interest. It should be noted that coordination, not cooperation, is discussed. Even if cooperation is difficult because of self-interest, countries can agree on policy coordination through negotiations.

For example, the UNFCCC has developed a situation in which all member countries can gain by coordinating their climate policies. As a result, the Paris Agreement was adopted in 2015. Under the agreement, all member countries submitted their climate policies until 2030, called the "Nationally Determined Contributions" (NDCs). However, as is well known, the carbon emission path following NDCs has a large gap with the minimum-cost path to achieve the 2 °C target.[26] Therefore, the United Nations has requested that member countries revise their initial NDCs to a more ambitious plan, and some countries have responded accordingly. This move can be interpreted as a process of selecting a better equilibrium. Whether this approach of the Paris Agreement, known as the pledge and review approach, succeeds in achieving the long-term target, is an essential question for solving the climate change issue and thus for the sustainability of society. Further development of economic theory on CPR would contribute to finding an answer to this question.

8.4 Concluding Remarks

The time horizon for sustainable development covers many generations and centuries. From a long-term perspective, Sustainable Development Goals (SDGs) seek to guide the present generation toward sustainable development. Since there is a trade-off in well-being between the present generation and future generations, we need a value criterion for intergenerational equity to judge a good target and policy. We also need to understand the mechanisms whereby sustainable development is achieved, as well as how an unsustainable path is willingly chosen. This chapter provides theoretical results and discussion of these topics, which potentially relate to all the SDGs, their targets, and the policies to achieve them.

Acknowledgements I thank Jordan A. Sand for helpful comments

[25] Note for readers familiar with game theory: The desirable sustainable equilibrium is the payoff dominant equilibrium. While Aumann (1990) doubts the idea that cheap talk leads players to choose the payoff dominant equilibrium, an international environmental negotiation situation may be different from what Aumann (1990) assumes.

[26] See Fig. 2 in UNFCC (2015). As seen by comparing it with Fig. 5.6 in Nordhaus (2008), the NDC path is similar to the optimal path of the DICE model.

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Part III
For Prosperity (SDGs 8 and 9)

Economic Growth: Why Are There Rich and Poor Countries?

9

Koki Oikawa

Abstract

Sustainable economic growth is one of the main goals of SDGs. To achieve this goal, we need to know what drives the long-run dynamics of the wealth of nations. In this chapter, we first learn how to measure the level of a country's wealth and its growth from data, as well as some widely observed facts such as steady growth in some developed countries, the huge international difference in economic growth, and so forth. Next, we develop theoretical models to explain those observations. We present a basic theory of growth with capital accumulation as the driving force and check the consistency with the observed data. Further, we consider firms' investments into research and development (R&D) and see how innovations drive economic growth. It also tells us the effects of growth policies. Lastly, we discuss other factors that create international difference in economic growth such as education, institution, and misallocation of resources. This chapter contributes to Goal 8 (economic growth) and 9 (innovation) in SDGs.

Keywords

Economic growth · Catch-up · Productivity · Technological progress

9.1 Introduction

People living in the United States earn about 100 times the income of people in the poorest countries, after adjusting for price levels. Why are some countries so rich? Why do some countries grow faster than others? Can a poor country become rich in the future? If they can, how? These are questions in macroeconomics since our predecessors began to study the mechanism of economic growth and development. Honestly speaking, we do not have quick answers to those questions yet. However, accumulated knowledge in this academic field gives us a good perspective on the appropriate approach to tackle them. Learning the fundamental framework to analyze economic growth, which is developed in this chapter, definitely helps us achieve the sustainable development.

In this introduction, we review several important facts about economic growth using worldwide time-series data. Let us start by introducing the data we focus on. The wealth of a nation is usually measured by its gross domestic products (GDP, hereafter), which captures how much final goods and services are produced in a year. Because we are more interested in people's liv-

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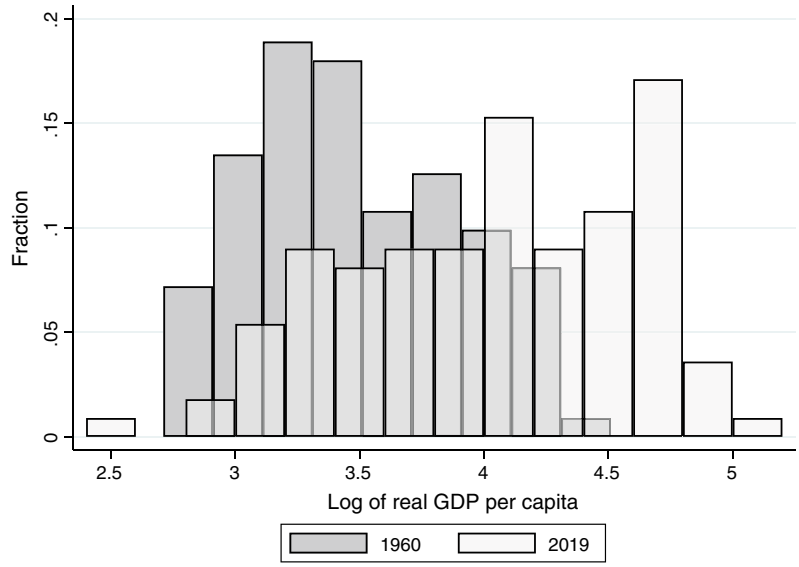

Fig. 9.1 Histograms of log of real GDP per capita in 1960 and 2019. *Source* PWT10.0

ing standards rather than the aggregate size, we divide the total GDP by the population to obtain per-capita GDP. Additionally, we remove the effect of price changes from GDP to avoid misinterpreting an increase in GDP owing to inflation as real economic growth. Finally, we adjust for differences in the price level between international economies to compare multiple countries that use different currencies.

Figure 9.1 shows the histograms of real GDP per capita across countries in 1960 and 2019.[1] We need to clarify how to read this graph. Because the numbers for real GDP per capita are too diverse, for example, from 500 to 23,000 in 1960 (in US dollars based on 2017), to depict in an easy-to-read graph, one can make such a graph readable and concise by taking the logarithm of the numbers. Here, we use a logarithm with the base of 10, or $\log_{10} y_t$, where y_t is real GDP per capita in year t. Note that the logarithm converts 10^x to x, or, in equation, $\log_{10} 10^x = x$. This x is taken as the horizontal axis in Fig. 9.1. So, if a country has $x = 4$ on the axis, its real GDP per capita is $y = 10^4 = 10{,}000$. If country A has 4 and country B has 3 on the horizontal axis, country A is 10 times larger than country B.

The takeaways from this figure are threefold. First, both histograms in 1960 and 2019 have wide ranges on the horizontal axis, implying that there exists a sizable dispersion in the level of per-capita real GDP. Second, the observed dispersion is persistent. Third, the histogram shifts rightward from 1960 to 2019, implying that the real GDP per capita is growing over time on average.

Next, Fig. 9.2 shows a histogram of the average annual growth rate of real GDP per capita from 1960 to 2019. The growth rates are mainly positive, but, again, there is a significant dispersion. Can you imagine how much difference there is between a country with a growth rate of 5% and another with 1% over 60 years? Even though the initial levels are common, the faster-growing country becomes more than 10 times richer than the other after 60 years, as shown in the calculation of $(1 + 0.05)^{60}/(1 + 0.01)^{60} \approx 10.28$.

Figure 9.3 illustrates the relationship between the initial level of real GDP per capita (in 1960) and the average growth rates afterward, using the same data in Figs. 9.1 and 9.2. This figure tells us about international convergence more clearly. If poor countries catch up with rich countries, a

[1]The data source is Penn World Table (PWT), version 10.0. You can download the worldwide data related to economic growth from https://www.rug.nl/ggdc/productivity/pwt/. The histograms consist of 111 countries and regions that have GDP data in both years.

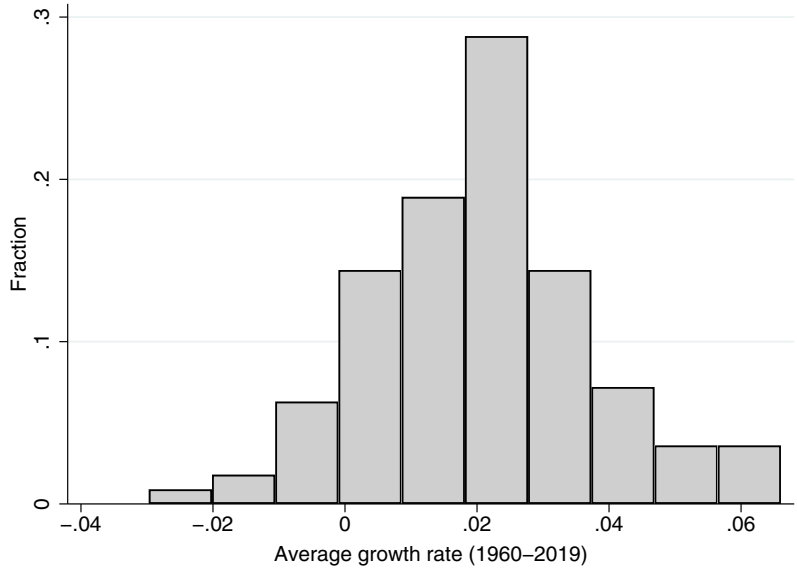

Fig. 9.2 Histogram of growth rate. *Source* PWT10.0

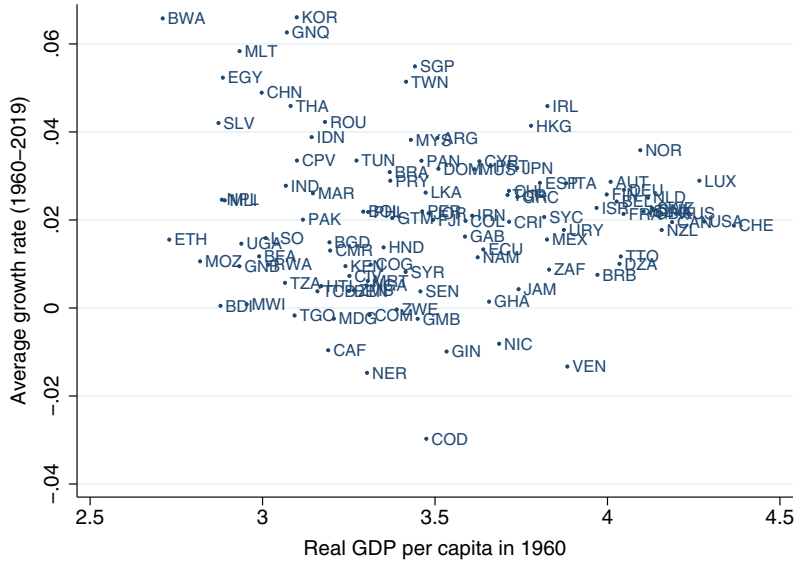

Fig. 9.3 Catching up? *Source* PWT10.0

low initial GDP level (horizontal axis) should be associated with a high growth rate (vertical axis). Indeed, some countries around the top-left corner in the figure, such as Botswana (BWA) and South Korea (KOR), have been catching up during these past several decades. However, it does not hold in general. The countries in the bottom-left area in the figure have low initial levels and low or negative growth rates. Some of those countries are lagging, rather than catching up with the richer countries.

In the next section, we argue about the mechanism behind these observations. To see how the long-run growth is determined, we first introduce a basic economic growth model in Sect. 9.2. The basic model explains some aspects of economic growth but, at the same time, casts a light on what we are ignorant of to explain economic growth.

Hence, in Sect. 9.3 and subsequent sections, we dig deeper into the growth mechanism.

Basics in Macroeconomics

Here, we quickly review the definitions and ideas in macroeconomics used in the following discussions. If you are familiar with introductory macroeconomics, you can jump to the next section.

First, GDP is constructed to represent output, expenditure, and income using a single statistic. The idea is as follows. Produced final goods (output) are purchased by someone (expenditure). Moreover, cash flows to firms through sales are distributed as income to households in various forms such as wages, interests, and dividends (income). The amount of cash flows calculated from the three aspects is identical.

Second, four sectors construct macroeconomy: households, firms, governments, and foreign countries. Each of them purchases goods and services from the market. The expenditure of households in year t is called consumption C_t, expenditure of firms is investment I_t, expenditure of the government is G_t, and the net expenditure of foreign countries is net export NX_t (export minus import). From the expenditure view of GDP, we have the following identity in the national accounts:

$$Y_t = C_t + I_t + G_t + NX_t,$$

where Y_t stands for GDP. In the following arguments, however, we consider the domestic private sectors in the economy, namely households and firms, to focus on the essence of the growth mechanism. Hence, the above identity becomes $Y_t = C_t + I_t$, and then the saving equals investment, i.e., $S_t = Y_t - C_t = I_t$, because Y_t is also the aggregate income by definition, as mentioned in the previous paragraph.

The mechanism behind the equality of saving and investment is the supply–demand equilibrium in the funds market, where saving is the supply of funds and investment is the demand for them. Because high interest rates are a burden for fund-rasing firms, they do not execute investment projects whose expected returns are not large enough, relative to the interest payments. In other words, investment decreases with the interest rate. When the supply of funds is greater than its demand, the interest rate declines so that firms become able to afford to invest more. With the interest rate as the adjusting device, the demand–supply equilibrium in the funds market guarantees the equality of saving and investment.

Third, we consider a production function that generates real GDP, such as $Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}$, where K_t is capital equipments, L_t is labor force, and A_t is productivity. In particular, A_t is called *total factor productivity* (TFP). In the following arguments, we suppose that this production function determines the level of GDP, implying that GDP depends solely on capital and labor endowments and the technology in year t. Note that we care about only the supply-side conditions and do not consider the demand-side conditions, whereas a shrink in demands is considered significant for economic fluctuations. The reason why we ignore the demand-side conditions is that we deal with the long-run behaviors of economies, as we observe economic growth over several decades in the above figures. In the standard arguments in macroeconomics, the long-run trend of an economy is considered to be determined by the supply side conditions, and short-run business cycles, where demand side conditions matter, are considered diversions from the long-run trend.

9.2 Basic Theory of Economic Growth

9.2.1 Solow Model

Sustained growth can be explained by a simple model established by Robert Solow. Figure 9.4 shows the time series of the log of the real GDP per capita in the United States as a typical example of frontier economies, with the fitted linear line showing the long-run trend. The linear trend shows a good fit to the actual GDP data, which implies that the growth rate is constant in the long run. Moreover, we can extend this trend line dating

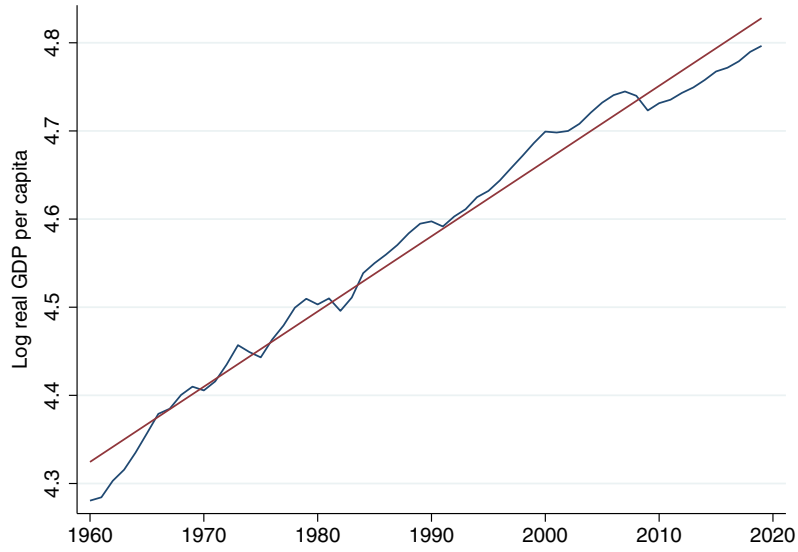

Fig. 9.4 Steady growth in the United States. *Source* PWT10.0

back to the mid-nineteenth century. The average growth rate is slightly less than 2% for over 150 years in the United States. There must be a rationale to support such a strikingly long-lasting steady growth. This is our starting point in the theoretical approach.

The Solow model supposes capital accumulation as the main factor to drive the dynamics of economies. To relate capital formation and economic growth, Fig. 9.5 shows the scatter plot of the average growth rate and the average investment shares in GDP from 1960–2019, with the fitted line. There clearly exists a positive correlation between the average investment shares and the average growth rates, implying that countries with large investments tend to grow faster.

To focus on the essential mechanism, we make the model as parsimonious as possible. Let there be only the domestic private sectors in the economy: households and firms. The real GDP in year t, Y_t satisfies

$$Y_t = C_t + I_t,$$

where C_t and I_t are the real consumption and investment, respectively. We assume a constant saving rate of households, s, so that $C_t = (1-s)Y_t$ and

$$I_t = Y_t - C_t = sY_t, \qquad 0 < s < 1. \tag{9.1}$$

Investment, I_t, is the amount of newly equipped machines in year t, which constructs the real capital in the next year, K_{t+1}, which is the total amount of machines at period $t+1$. Assuming that machines are broken in each period at the rate of δ, we represent capital accumulation as

$$K_{t+1} = (1-\delta)K_t + I_t \qquad 0 < \delta < 1. \tag{9.2}$$

Outputs are produced with capital and labor as inputs according to the production function,

$$Y_t = K_t^{\alpha} L_t^{1-\alpha}, \qquad 0 < \alpha < 1, \tag{9.3}$$

where α represents capital share in the sense that α of total income is distributed to capital owners (and $1-\alpha$ goes to workers).[2] For simplicity, we assume no population growth. L_t is constant over time, and, more specifically, we set $L_t = 1$. Then, Y_t is equivalent with real GDP per capita. The production function (9.3) becomes

$$Y_t = K_t^{\alpha}. \tag{9.4}$$

[2]From the viewpoint of income distribution, real GDP satisfies $Y_t = r_t K_t + w_t L_t$, where r_t and w_t are the real interest rate and the real wage, respectively. The capital share is measured by $\frac{r_t K_t}{Y_t}$, and the labor share is measured by $\frac{w_t L_t}{Y_t}$.

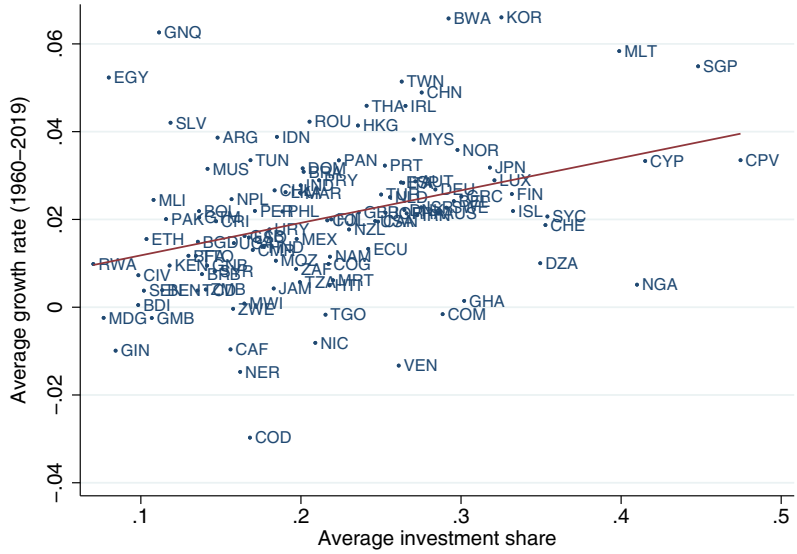

Fig. 9.5 Average investment share and average growth rate (1960–2019). *Source* PWT10.0

Substitute equations (9.1) and (9.4) into (9.2), we have

$$K_{t+1} - K_t = sY_t - \delta K_t = \underbrace{sK_t^{\alpha}}_{\text{investment}} - \underbrace{\delta K_t}_{\text{depreciation}}, \tag{9.5}$$

which determines the law of motion of capital. We find that there are two opposing forces at work. If investment is greater than depreciation, capital increases such that $K_{t+1} > K_t$. Contrarily, if investment is smaller than depreciation, $K_{t+1} < K_t$. Figure 9.6 illustrates how these two forces balance. As drawn in the figure, when capital is K_t^A, investment is greater than depreciation. Then, capital increases in the next period. However, if capital is at K_t^B, depreciation excesses investment, and the capital stock will decrease. Figure 9.6 also depicts K^* at which investment equals depreciation so that the capital stock remains constant. Such K^* is called the *steady state*. If the economy is at the steady state, nothing changes over time unless a shock perturbs the state of the economy. Moreover, Fig. 9.6 tells us that, starting from any positive level of capital stock, the economy converges to the steady state K^*. If the capital is less than K^*, like K_t^A, the capital increases and approaches K^*. If it is higher than K^* like K_t^B, it decreases and gets closer to K^*. Hence, the economy is in the steady state in the long run. In the current setting, the steady-state level of capital is

$$K^* = \left(\frac{s}{\delta}\right)^{\frac{1}{1-\alpha}}. \tag{9.6}$$

Note that the output Y_t is determined by the level of capital K_t. Thus, at the steady state of capital, the output is also in the steady state, meaning no changes over time. The output attains $Y^* = K^{*\alpha}$, and the per-capita real growth rate is zero in the long run.

Exogenous Technological Progress The above simple model can easily incorporate exogenously growing factors. If we introduce population growth such that $L_{t+1} = (1+n)L_t$, the per-capita output remains constant while the aggregate real output grows at the rate of n in the steady state.

Similarly, we can introduce exogenous technological progress in the form of

$$Y_t = K_t^{\alpha} (A_t L_t)^{1-\alpha}, \tag{9.7}$$

where A_t represents the effectiveness of one unit of labor. We assume that A_t grows at the rate of g, or $A_{t+1} = (1+g)A_t$. Then, in the steady state,

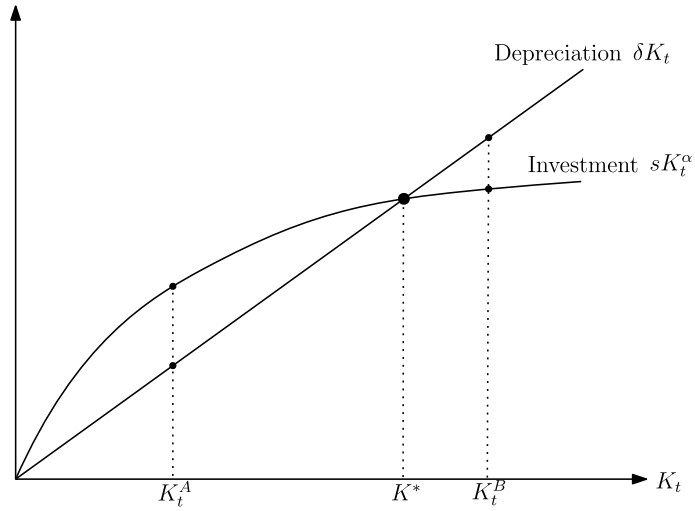

Fig. 9.6 Capital dynamics and the steady state in the Solow model

the per-capita output grows at the rate of g and the aggregate output grows at the rate of $n + g$.

Now, we got the theoretical result of steady growth observed in Fig. 9.4. The growth rate is stable because the economy is in a steady state. Positive growth in the per-capita term occurs because of technological progress. If the technological progress rate is not that turbulent, the economy grows at a constant rate on average.

9.2.2 Conditional Convergence Across Countries

Although the Solow model presents an explanation of economic growth in some frontier economies such as the United States, is it consistent with the international difference in the GDP levels and growth rates, observed in Figs. 9.1, 9.2 and 9.3? Here, we consider whether a poor country will catch up with a rich one in the Solow model.

Let g_t^K be the growth rate of capital from year t to $t + 1$. In an equation, it is given by

$$g_t^K = \frac{K_{t+1} - K_t}{K_t}.$$

The relationship between the level and growth in the Solow model is depicted in Fig. 9.7. It is simply from the law of motion of capital, equation (9.5), such that

$$g_t^K = \frac{K_{t+1} - K_t}{K_t} = sK_t^{\alpha-1} - \delta,$$

which is decreasing in K_t because $\alpha - 1 < 0$. Therefore, a country with lower capital stock, K_a in the figure, has a higher growth rate than countries with abundant capital stock.

So far, it seems like poor countries will eventually catch up with the frontier economies that are considered to be around the steady state, K^*. However, it is the case only when every country has an identical steady state.

As shown in Eq. (9.6), the steady-state level of capital per capita is determined by parameters s, δ, and α. If we incorporate population growth and technological progress, it also depends on the population growth rate, n, and the technological progress rate, g, too. Since those parameters vary from country to country in reality, the steady state also varies.

For example, suppose that countries A and B are different in their saving rates, say $s_A > s_B$, while the other parameters and the initial capital stock, K_0, are the same. From Eq. (9.6), the steady-state levels of capital per capita are $K_A^* > K_B^*$. Even though the initial capital is the same across the two countries, the distance from the initial position to the steady-state level is greater in country A, or $K_A^*/K_0 > K_B^*/K_0$. Now apply Fig. 9.7 to each country separately. In the figure for country A, the initial capital is small relative

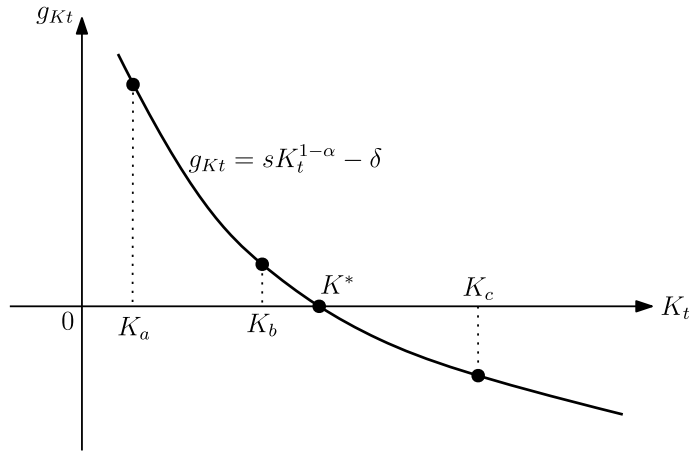

Fig. 9.7 Level and growth of capital in the Solow model

to the steady state as if K_0 is around K_a. On the other hand, in the figure for country B, the initial capital is close to the steady state as if K_0 is around K_b. Then, country A has a higher growth rate than country B even though the initial capital levels are the same.

Therefore, the distance to the steady state is significant in the relationship between GDP levels and growth rates. Low growth countries have low levels of steady state. If this is the case, such a poor country never catches up with a rich country unless there occurs a shock or policy intervention on some parameters such as the saving rate, technological progress rate, and so forth.

Poverty Trap

While we divert a bit from the main context in this chapter, here, we present another way to explain the stagnation of a poor country by extending the Solow model. Suppose that there is a subsistence level of consumption $\bar{C}$. When the income level is less than or equal to $\bar{C}$, they cannot afford to save and just consume all the income. They have positive savings (and investment) only when $Y_t > \bar{C}$. This situation is described by the investment function,

$$I_t = \begin{cases} 0 & \text{if } Y_t \leq \bar{C}, \\ s\left(Y_t - \bar{C}\right) & \text{otherwise.} \end{cases}$$

The other settings are the same as in the baseline model.

The diagram for this modified Solow model is illustrated in Fig. 9.8. The difference from Fig. 9.6 is that the intercept of the investment curve lies at a positive value on the horizontal axis, which creates two intersections with the depreciation curve. The upper intersection at K^* is similar to the steady state in the basic model. The lower intersection at $\hat{K}$ indicates the divide between the shrinking economy and the growing economy. If K_t is greater than $\hat{K}$, the investment is more than depreciation, and the economy grows. If K_t is less than $\hat{K}$, investment is not enough to compensate the amount of depreciation, and capital stock decreases over time.

Even though the upper steady state K^* is potentially possible, a country may be trapped on the left side of the divide at $\hat{K}$ if it initially lacks a sufficient amount of capital stock. This case is called a *poverty trap*. In order for a developing country to escape from the poverty trap, it needs a big push via official development assistance (ODA) or foreign direct investments with which the capital level is pushed up beyond the dividing border, $\hat{K}$.[3]

[3] Although the poverty trap discussed here gives us an insight about economic development, it is difficult to estimate how big is the required push to go across $\hat{K}$. Evidence-based policy evaluation is hard without tracking how foreign aids are distributed into the economy. In response

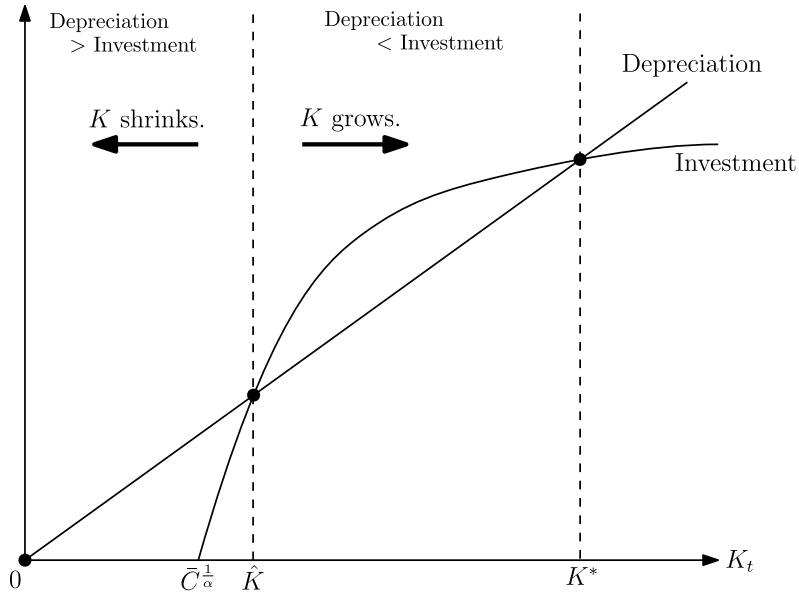

Fig. 9.8 Poverty trap

9.2.3 Growth Accounting

The Solow model focuses on capital accumulation as the growth engine, and population and productivity growth are exogenous factors. However, how important is those exogenous growing factors in the data? In this subsection, we run *growth accounting* to investigate the contribution to the growth of each factor that determines GDP.

We consider a slightly different production function such that

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \tag{9.8}$$

where A_t is TFP.[4] We calculate the relationship among growth rates of variables in this production function. Consider the change rate from t to $t+1$ such that

$$\frac{Y_{t+1}}{Y_t} = \frac{A_{t+1}}{A_t}\left(\frac{K_{t+1}}{K_t}\right)^{\alpha}\left(\frac{L_{t+1}}{L_t}\right)^{1-\alpha}.$$

Define the growth rates $g_t^x = x_{t+1}/x_t - 1$, where x can be Y, A, K, and L. Then,

$$1 + g_t^Y = \left(1 + g_t^A\right)\left(1 + g_t^K\right)^{\alpha}\left(1 + g_t^L\right)^{1-\alpha}.$$

It is well known that the above equation is approximately equal to the following relationship,[5]

$$g^Y = g^A + \alpha g^K + (1-\alpha) g^L, \tag{9.9}$$

where the aggregate data of GDP and related variables are open to the public in many countries. g^Y is the real GDP growth, g^K is growth in real capital stock, g^L is growth in total working hours, and α is the average capital share. Only g^A can

to those critiques, the recent development studies focus on micro-evidences using randomized controls to obtain evidence-based policy evaluation. I recommend Banerjee and Duflo [3] to interested readers.

[4]Note that this function form is interchangeable with Eq. (9.7), where we can define TFP as $A_t^{1-\alpha}$.

[5]To derive Eq. (9.9), we take the logarithm of both sides such that

$$\log\left(1 + g^Y\right) = \log\left(1 + g^A\right) + \alpha \log\left(1 + g^K\right) + (1-\alpha)\log\left(1 + g^L\right),$$

where the base of the logs is e, i.e., natural logarithm, and we drop time subscript for notational simplicity. Next, we use approximation such that $\log(1+x) \approx x$ if x is sufficiently close to 0, which comes from the first-order Taylor expansion.

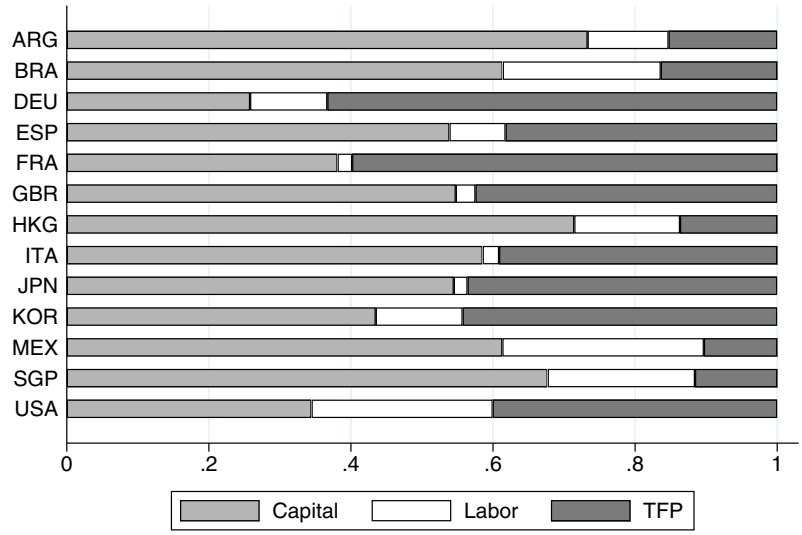

Fig. 9.9 Shares of contribution of capital, labor, and TFP to economic growth. *Source* PWT10.0

not be observed directly, but it is calculated from Eq. (9.9) as $g^A = g^Y - \alpha g^K - (1-\alpha)g^L$.

We are interested in what percentage of economic growth remains unexplained by observable factors such as capital and labor. So, we define the share of contribution of capital accumulation real economic growth as $\alpha g^K / g^Y$ when all growth rates are positive. When some growth rates are negative, we define the contribution as

$$\frac{\alpha|g^K|}{|g^A| + \alpha|g^K| + (1-\alpha)|g^L|},$$

where $|g|$ is the absolute value of g.[6]

Figure 9.9 shows the result of growth accounting for the sample periods of 1960–2019 in 13 countries/regions.[7] The set of the countries/regions is limited mainly due to the lack of data required to conduct the above procedure. The figure confirms that capital accumulation is important, as the Solow model supposes. However, at the same time, it also implies that the contribution from TFP is significant in many countries.[8] The average contribution of TFP in the current sample is about 35%. In some countries, it amounts to 50% or more. This result motivates us to take a closer look at TFP. However, what the Solow model tells us is that per-capita real GDP has steady growth if productivity grows at a given constant rate. It is nothing about what determines the level and evolution of the productivity. We are going to address this question in subsequent sections.

9.3 Endogenous Growth: How Is the Growth Rate Determined?

As discussed above, we need to explain TFP growth to uncover the mechanism of economic growth and to obtain an insight for growth policy. In this section, we introduce a new framework, an *endogenous growth model*, in which the economic growth rate is endogenously determined.

[6]Consider the case in which $g^Y = 0$, $\alpha g^K = 0.05$, and $(1-\alpha)g^L = 0$. In this case, $g^A = -0.05$ and the contribution ratios of capital and TFP are 1/2 for each (and zero for labor). This number is generated by $|0.05|/(|0.05| + |-0.05|)$.

[7]The national account data for Germany (DEU) before the integration at 1991 are estimates based on the growth rates recorded for West Germany (Groningen Growth and Development Centre [5]).

[8]There is a discussion on the undervaluation of the contribution of TFP in the procedure described here. Because TFP includes technological progress, newly introduced machinery embodies higher quality, which increases capital contribution. Thus, part of the contribution of the capital comes from the increase in TFP. Taking this relationship into account, the true contribution of TFP is even higher (and the true contribution of capital is lower) than the shares observed in Fig. 9.9.

Although there are a variety of models of endogenous growth, we mainly focus on productivity growth driven by corporate research & development (R&D) activities, which accumulates ideas, knowledge, and techniques for more efficient production in the society.

9.3.1 Economy of Ideas

Before jumping into the new growth model, it is convenient to discuss an important feature of knowledge or ideas. Let us assume that you were Thomas Edison, a giant inventor. You have come up with a new idea for making a light bulb. This new idea, or innovation, is "yours" in the sense that the patent system prohibits any other person or company from commercializing it without permission. However, the idea itself can be shared with thousands of people who will try to create the next generation of light bulbs based on your idea, including ones that last longer, are safer, and are brighter. An inventor who significantly improves your light bulb will obtain a new patent.

This story highlights three things. First, ideas are *non-rival* goods in the sense that its use by someone else does not prevent others from using the same goods. So, ideas have an aspect of public goods.[9] Second, ideas are inputs for subsequent idea creation. An inventor or researcher learns the existing ideas developed by predecessors and tries to create a new idea relying on them. A little dwarf on the giant's shoulder can see further than the giant.[10] New ideas are born on the giant's shoulder, and these ideas accumulate to make the giant even bigger. Third, as suggested by the above two characteristics, the private and social benefits of innovation are different. The private value is the profit derived from the product designed by the idea, which is only a part of the social value of innovation. The social value also depends on future innovations inspired by the current idea. In the story at the beginning of this subsection, Edison and the subsequent inventors pursue rents from commercializing a new idea, which is the private benefit. If you predict sufficiently large rents, it is worth investing money, time, and effort. However, the innovation is public in some sense because it will be used extensively in subsequent idea creation. Even if the private benefit is negligible, the social benefit might be large. For example, the formula for solving quadratic equations hardly yields profits, but it will help much subsequent research. Because the social benefit of an innovation is greater than the private benefit in many cases, investment for idea creation tends to be smaller than the socially desirable level. This is where we should consider a policy intervention to encourage R&D in the following model.[11]

9.3.2 R&D-Driven Growth

We consider the economy with two sectors in which workers find a job: One is the production sector and the other is the research sector. We assume no skill difference between the sectors for simplicity. Denote L_{Yt} and L_{At} as the production workers and researchers, respectively. Assuming that $L_t = 1$ and define the share of researchers as ρ_t, we have $L_{At} = \rho_t$ and $L_{Yt} = 1 - \rho_t$.

The production sector is the same as in the Solow model with technological progress,

$$Y_t = K_t^{\alpha} (A_t L_{Yt})^{1-\alpha},$$

but now A_t does not grow automatically; it grows in response to the researcher's work.

Because productivity A_t reflects scientific and technological knowledge in the society, we suppose that A_t is the stock of ideas and R&D activity increases A_t. As discussed in the previous subsection, the input of idea creation is the stock of ideas, A_t, and researchers, L_{At}. Let $\mu > 0$ be the efficiency in the research sector, and we suppose that A_t evolves according to

[9] The other aspect of public goods is non-exclusiveness. If goods are exclusive, it is possible to prevent someone from using them if the person does not pay the price. Intellectual property rights give exclusivity to an idea.

[10] Such a metaphor, famously described by Isaac Newton as "by standing on the shoulders of Giants," dates back to the Middle Ages in Europe.

[11] Jones and Williams [8] estimate that actual R&D investment is less than half of the optimal R&D investments.

$$A_{t+1} = A_t + \underbrace{\mu A_t L_{At}}_{\text{new ideas}}. \tag{9.10}$$

In other words, one researcher creates μA_t units of ideas.[12] Then, the growth rate of A_t is given by

$$g_t^A = \frac{A_{t+1} - A_t}{A_t} = \mu L_{At} = \mu\rho_t.$$

Now, we focus on a *balanced growth path*, generalization of steady state, where each variable has a constant growth rate over time. Note that the steady state in the Solow model is a balanced growth path because the output per capita has a constant growth rate of zero. On a balanced growth path, g_t^A is fixed at some constant so that ρ_t must be a constant. Let ρ be the number of researchers on a balanced growth path, and we have $g^A = \mu\rho$. Then, applying the last argument in Sect. 9.2.1, we have $g^Y = \mu\rho$.

The argument so far lets us know that what determines the growth rate is the share of researchers or the intensity of R&D activity in the economy. If an economy is more R&D-intensive, it grows faster. However, in what case, is $\rho > 0$ supported? It depends on the balance between the value of a new idea and the cost to create it. When there is a limited labor supply, wages become higher. A very high wage implies that research costs do not meet the reward from the research, which is the future monopoly rents protected by patents. In such a case, there is no incentive to carry out R&D projects, and ρ turns out to be zero on a balanced growth path. Therefore, we need a sufficient amount of potential resources employed in the research sector to have a positive growth rate in the long run. Certainly, the strength of patent protection is another factor to motivate R&D. Without patent protection, innovators cannot monopolize the market for the product they created because imitators enter the market without paying R&D costs or license fees. The reward for innovation is limited under weak patent protection.[13]

The R&D-driven endogenous growth model opens the black box of TFP at least partly. It illustrates the mechanism that long-run economic growth is achieved by R&D activities. Moreover, it implies that the more the R&D, the higher the growth rate. Hence, the policy implication is straightforward: Encouraging investment in R&D will lead to rapid economic growth. As argued in the previous subsection, promoting R&D is desirable from the social viewpoint.

There are several ways to promote R&D, such as R&D subsidy, R&D tax credit, patent reform, easing of financial constraints on firms, and so forth. Some policies could affect the efficiency in the research sector, μ. Because a better collaboration of researchers can create better ideas, a matching mechanism may help increase research efficiency at the aggregate level. We need to exclude discrimination when building research teams. A researcher with appropriate expertise should be employed as a team member regardless of gender, nationality, or skin color, which increases the efficiency of researcher allocations in the aggregate economy.

9.3.3 Growth Without Scale Effect

The model in the previous subsection has one deficit. If we remove the simplifying setting of $L = 1$, the growth rate becomes $\mu\rho L$ instead of $\mu\rho$. Thus, the above model implies that the scale of the economy matters for its economic growth rate. This is called the *scale effect*. But, if there were two identical countries, would merging the two

[12] One may be wondering how we define the unit of ideas. A standard way to keep track of ideas in empirical research is by counting the number of quality-adjusted patents. Quality adjustment is important because many patents are not used to produce any goods while some patents are essential.

[13] There are many discussions about the patent system. Patents provide an incentive to innovate, but it sometimes imposes a cost for the next innovations. When strong protection is given to existing patents, inventors have to present significant novelty and originality to get a new patent successfully. A company adopting a new technology would have a higher risk of litigation from an existing patent holder. Hence, the optimal design of a patent is a controversial issue. See Jaffe and Lerner [7] for more discussion. Some researchers argue that innovations will continue to occur even without a patent system, using the development of open-source software as an example Boldrin [4].

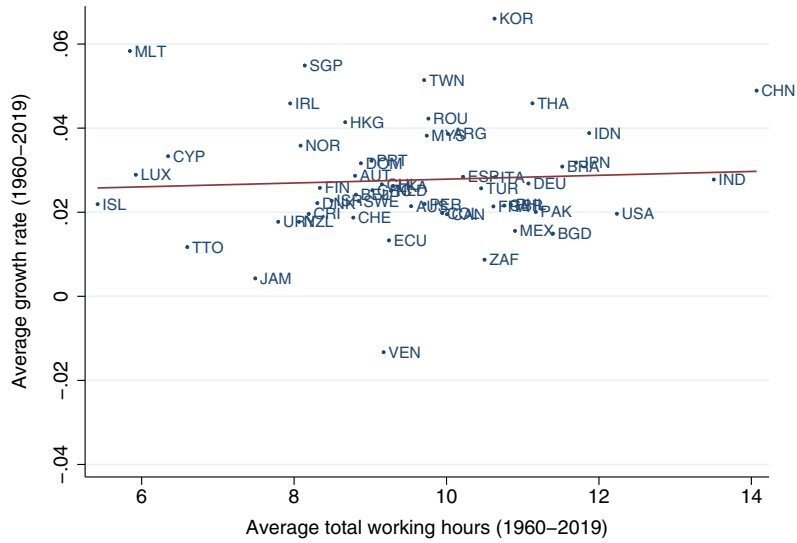

Fig. 9.10 Scale effect? *Source* PWT10.0

produce a country with double the growth rate? Moreover, the above model suggests that the real growth rate increases over time if we allow a positive population growth rate instead of a constant L. Is it plausible?

Figure 9.10 scatters the average growth rates and the average total working hours across countries and regions, and we see no significant correlation between the two variables.[14] Perhaps, the above model overemphasizes non-rivalry and the idea production process, although it captures an important aspect of technological progress. Here, we modify the model to get rid of the scale effect.

The idea production function, equation (9.10), is linear in the stock of ideas. As scientific knowledge evolves, however, it is getting more complicated and catching up with the frontier knowledge requires more effort of learning for researchers than before. It is natural to consider that creating a new idea is getting harder as knowledge accumulates. Then, research productivity is not linearly increasing in the existing knowledge. This situation can be captured by the following slightly modified idea production function such that

$$A_{t+1} - A_t = \mu L_{At} A_t^{\phi}, \qquad \phi < 1.$$

The parameter ϕ stands for an increasing difficulty along with knowledge accumulation.

With this idea production function, the productivity growth on a balanced growth path is

$$g^A = \frac{A_{t+1} - A_t}{A_t} = \mu L_{At} A_t^{\phi-1} = \frac{\mu L_{At}}{A_t^{1-\phi}}, \tag{9.11}$$

where $L_{At}/A_t^{1-\phi}$ must be constant over time. To keep it constant, the numerator and the denominator must have the same growth rate. Since L_{At} stops growing if there is a constant upper bound of L, we allow L_t to grow at rate of n. Then, the balanced growth is achieved when all the growth rates of L_t, L_{At}, and L_{Yt} are n. Hence, $A_t^{1-\phi}$ also grows at n to keep the fraction in the right-hand side of Eq. (9.11) constant, that is,

$$\left(\frac{A_{t+1}}{A_t}\right)^{1-\phi} = 1 + n$$
$$\Rightarrow \quad \left(1 + g^A\right)^{1-\phi} = 1 + n.$$

Then, from a similar procedure in deriving Eq. (9.9), we obtain

[14] It depends on the era on which we focus, though. In the eighteenth century after the Industrial Revolution, the world population and output start to rise explosively, where population size and output growth have a positive correlation. However, the reverse causality could be true, i.e., rapid growth may result in more capacity to increase the population.

$$g^A \approx \frac{n}{1-\phi}.$$

Moreover, since per-capita real GDP grows at the same rate of g^A, economic growth depends not on population size but its growth rate, n.

This modification successfully removes the scale effect. However, it erases the R&D policy implication obtained in the original model. Because the growth rate is determined by population growth rate, a policy promoting R&D activity does not increase the growth rate in the long run, while it leaves short-run impacts on the number of researchers and outputs. Any increase in the policy-promoted research outcomes will be offset by the difficulty in developing more complex R&D projects, leaving no impact on the growth rate.

9.4 Other Factors: Look Inside of A_t more deeply

In this section, we discuss three factors other than technology that construct TFP.

9.4.1 Education and Human Capital

The level of education of the people involved in the labor is one of the important factors that determines production efficiency. Before we look at the overall productivity of a country, let us consider the productivity of individual workers. In the first place, why are you reading this and why are you spending your time and paying for your education? It is probably because there is a return from education. The returns may not always be translatable into money, but there is no denying that getting the job you want and increasing your chances of earning a higher income are important returns. Why do firms pay you a high wage? It is because your skills are enough to produce efficiently. Education increases productivity at the individual level.

Figure 9.11 shows a scatter plot of the average level of education (years of schooling) and real GDP growth rates in each country,[15] showing a clear positive correlation. As with the investment in physical capital, investment in education is expected to contribute to economic growth by improving *human capital* and raising productivity. Let us formulate this situation in a simple model to see the link between education and growth.

The production function in this context is

$$Y_t = K_t^{\alpha} (u H_t)^{1-\alpha}, \tag{9.12}$$

where H_t represents human capital and u is the share that human capital employed in the production sector. The rest of human capital, $(1-u)\,H_t$, goes to the education sector, or school teachers, that contributes human capital accumulation. Suppose that human capital accumulates according to

$$H_{t+1} - H_t = \phi(1-u)H_t,$$

where $\phi > 0$ is the efficiency in the education sector.

In this economy, for a given u, the growth rate of human capital is

$$g = \phi(1-u). \tag{9.13}$$

This human capital growth rate turns out the growth rate of the economy. Let us see how it comes. Similar to the growth rate relationship derived at growth accounting in Sect. 9.2.3, we have

$$g^Y = \alpha g^K + (1-\alpha)g,$$

for a constant u. Because the real output and physical capital should have the same growth rates,[16]

[15] Data on education are from Barro-Lee Education Attainment Data, which are available from http://www.barrolee.com.

[16] From the national income identity, $Y_t = C_t + I_t$. To keep the balance, these three variables must have the same growth rate. Further, capital accumulation equation $K_{t+1} = I_t + (1-\delta)K_t$ implies that K_t and I_t also have the same growth rate. Therefore, $g^Y = g^C = g^I = g^K$ on a balanced growth path.

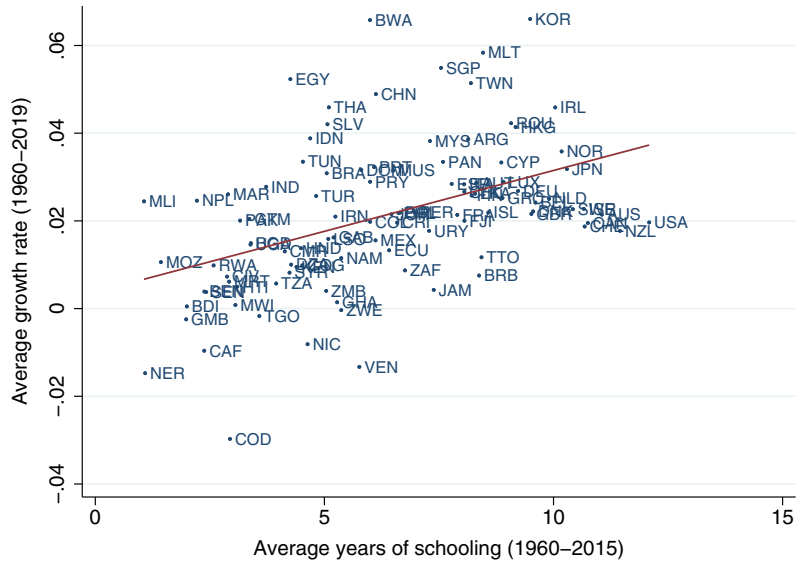

Fig. 9.11 Growth and education. *Source* PWT10.0, Barro-Lee Education Attainment Data

we have $g^Y = g^K = g$. All growing variables have identical growth rates.

The balanced growth implies that

$$\frac{H_t}{K_t} = \text{constant, say } \hat{A}$$

because the numerator and denominator change at the same rate. Using this constant $\hat{A}$ with the production function, (9.12), we obtain

$$Y_t = K_t^{\alpha} \left(\hat{A}u\right)^{1-\alpha} K_t^{1-\alpha} = \left(\hat{A}u\right)^{1-\alpha} K_t.$$

In other words, production in this economy shows a constant marginal product of physical capital on a balanced growth path, unlike in the Solow model. The Solow model investment curve depicted in Fig. 9.6 has a curvature because the marginal product of capital decreases with the capital level. In the current human capital model, the diminishing marginal product of physical capital is offset by the human capital accumulation to keep the marginal product of physical capital at constant $\left(\hat{A}u\right)^{1-\alpha}$. No matter how much is accumulated, the marginal value of capital does not fall, so the economy will continue to grow. Importantly, when more human capital is employed in the education sector, the growth rate is higher.

9.4.2 Institution

Differences in productivity among nations that cannot be explained by the production factor endowments or technology are also created by differences in institutions. At the beginning of their book, Acemoglu and Robinson [1] talk about a region divided by the artificially drawn border between the United States and Mexico. Originally, there was little difference between the north and south of the border, and similar people lived similar lives. However, 100 years after the border was drawn, there appeared a marked difference in the standard of living across the border. The gap in North and South Korea is another example. The border between the two countries was artificially drawn for political reasons due to the Korean War, and there was no intrinsic difference. Seventy years later, however, the difference in wealth between them is enormous.

Such artificial borders are grand social experiments that give us insights. If there is a big difference between two countries that are not different by birth, the cause is the environment in which they grew up. In other words, the laws, rules, political systems, and customs of the countries to which the residents happen to belong are of decisive importance. Are private property rights guaranteed there? Does it allow for free market trans-

actions? Do successful entrepreneurs get paid what they deserve? What kind of education system does it have? How well developed is its social infrastructure? Is its political system democratic?

This argument suggests that some part of TFP, A_t, should be explained by institutions. A more efficient institution results in higher A_t, leading to a greater real output and possibly real growth rate. However, it is not easy to pinpoint what exactly is good and what is bad in the institutions. It is not necessarily true that transplanting the institutions of frontier economies, such as the United States, directly to developing countries will work. It is easier said than done.

9.4.3 Misallocation

One of the most important findings in recent economic growth studies is the impact of *misallocation* of resources on aggregate productivity. Suppose that there are two types of firms operating in the market: One is highly productive and the other is less. Then, it seems efficient to transfer resources employed by low-productivity firms to high-productivity firms. However, such reallocation could not smoothly occur in the market because we observe wide productivity dispersion across firms even within narrowly defined industries. When the misallocation of resources significantly reduces aggregate productivity, policy interventions that promote the reallocation of resources are desirable to improve people's well-being.

Hsieh and Klenow [6] is the seminal work to measure the degree of misallocation. It should be noted that simple observation of productivity dispersion is not an evidence for misallocation. The coexistence of large high-productivity firms and small low-productivity firms may be efficient because of declining marginal products and capacity constraints such as plant size. To quantify misallocation inefficiency, they consider "revenue" productivity instead of the usual TFP, which is coined as TFPR.

The logic is simple and interesting. Suppose that a firm has the production function of $Y = AL$, where A is the firm-level TFP and L is employment, hired at the wage rate of w. The cost to produce one unit of goods is w/A. If this firm determines its price with some markup margin, at the rate of $m \geq 1$, the price of the goods is $P = mw/A$. Then, the TFPR of this firm is

$$\text{TFPR} = \frac{PY}{L} = PA = mw.$$

Therefore, TFPR is independent of A. This result holds even with more general production function such as the Cobb–Douglas type with physical capital as in Eq. (9.3).

This simple calculation implies that all firms should have the common TFPR in theory after controlling markups and wages. Then, if we find a dispersion in TFPR, some wedge exists to generate a gap from the theoretical outcome. Based on this logic, Hsieh and Klenow [6] define the degree of misallocation as the observed dispersion in TFPR. According to their estimates, China and India have higher degrees of misallocation compared to the United States in the manufacturing industries. They also estimate the aggregate productivity of both countries when they have the same degree of misallocation as the United States. The results show that aggregate productivity is expected to increase by 30–50% in China and 40–60% in India, strikingly large numbers.

Reducing misallocation of resources across firms may have a significant impact on the aggregate economy. However, designing a reallocation policy is not simple because the sources of misallocation can be diverse. Adjustment costs such as firing costs would make reallocation slow. Protective policy for small firms would matter. The institution discussed in the previous subsection also matters. Taxation, financial constraint, or any distortions may affect the degree of misallocation in one country. So far, there is no consensus on the most important factor to explain misallocation. Rather, the main source seems different across countries and periods.

9.5 Conclusion

A country does not become rich overnight, and when it starts, the process of steady growth depends largely on historical circumstances. So, it is natural that there are variations in the level of economic wealth or real GDP per capita. The more important question is whether poor countries will turn into rich countries, that is, whether a poor country attains rapid growth and will catch up with the group of rich countries or not. To catch up with and hopefully overtake rich countries in the long run, poor countries need to achieve sustained economic growth rather than a temporary hike in the GDP levels. If a poor country has a growth rate that is 2% higher than a rich country that initially had twice the GDP, it will take 35 years to catch up. If the growth rate gap is 5% instead, it will only take about 14 years. This is not just a play on numbers. It is what actually happened in Japan in the 1960s and in China since the 1990s.

In this chapter, we have outlined the typical mechanisms of economic growth in as simple a model as possible while sorting out the facts related to economic growth. We have covered the accumulation of physical and human capital, technological progress, institutions, and misallocation, but which factors constitute the main problems will vary depending on the country being addressed. Since policies for economic growth will vary accordingly, we must first carefully observe the conditions of the country or region we are dealing with. In this sense, this chapter can be seen as providing a list of points to pay attentions to.

However, there are other factors that we could not cover in this chapter due to space limitations. In particular, trade and cross-border technology transfer are important in international economic interdependence. Trade with technologically advanced countries and direct investments from them cause an influx of ideas and technology to developing countries. Technology adoption and learning through imitation are typical steps in catching up.[17]

Finally, having clarified the causes of economic growth throughout this chapter, we should also remark the consequences of economic growth. Increased GDP leads to higher consumption and living standards, but thriving economic activity places a greater burden on the global environment. We need to consider the balance between economic growth and the environment from multiple perspectives. There is also the issue of inequality: Even if the size of GDP expands, not everyone will necessarily benefit from it. We must always pay attention to the distribution of wealth to ensure that economic growth does not widen the gap and leave some people behind.

[17] See Baldwin [2] for arguments about trade, global supply chains, and international convergence.

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Structure of Development in a Smart Society: An Application of Input–Output Analysis

10

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Abstract

The construction of a smart society utilizing information and communication technology (ICT) is attracting attention to simultaneously achieve various Sustainable Development Goals (SDGs). Using input–output analysis, this chapter elucidates the economic structure of a smart society. This content is an extension of Leontief's "Structure of Development" study of the 20th-century industrial society. Here, a smart society enables waste to be eliminated and the utility of people to be increased by strengthening management in all fields of society using ICT. It is shown that a smart society will achieve an industrial structure with a lighter environmental load and sustain moderate economic growth. Therefore, the movement aiming to build a smart society in Asia and other regions of the world is deemed beneficial and expected to contribute to achieving the SDGs. Additionally, Japan is a developed country with advanced ICT in Asia, and improving the efficiency of Japan's ICT has been found to profoundly affect the entire Asian region. Japan plays a key role in building a smart society in the Asian region. This chapter is not only directly related to SDG9, but also to SDGs2, 5, 7, 8, 11, 12, and 13.

Keywords

Input–output table · Smart society · Information and communication technology · Structure of development

10.1 Introduction

In his (1994) book, *The Digital Economy*, Tapscott states that information technology brings new social norms for wealth creation and social development. This suggests that economic development in the information society requires an analytical perspective that is different from the conventional economic growth theory. Furthermore, Jorgenson and Vu (2016) report that a wide range of policy considerations are needed to guide economic growth through the information and communications technology (ICT) revolution. Jorgenson and Vu (2016) measure the contribution of ICT investment to economic growth and show that China and India are driving the world economy. On the one hand, Kooshki and Ismail (2011) empirically show that

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ICT investment has a positive impact on economic growth in newly industrialized countries in Asia. On the other hand, Pradhan et al. (2015) state that the construction of ICT infrastructure alone does not guarantee economic growth and must be accompanied by financial development. Vu (2013) also states that ICT use contributes to economic growth, while the contribution of ICT manufacturing to economic growth is limited (in the presence of China and India) based on empirical research on economic growth in Singapore. To clarify the effects of the spread of ICT on economic growth, these previous studies show that it is insufficient to investigate the effects of physical production and investment in ICT devices.

To verify the effects of ICT use, it is necessary to study the effects of services that utilize ICT. Toh and Thangavelu (2013) analyze the impact of the information sector on Singapore's economy using an input–output approach, which provides them with a framework for analyzing the linkage between the manufacturing and service sectors. A recent study (Tripathi and Inani 2020; Usman et al. 2021; Murshed 2020) has reported that informatization also contributes to economic growth in South Asia, and the effect of informatization is widespread throughout Asia, thereby suggesting expansion. Moreover, several studies (Usman et al. 2021; Murshed 2020; Lu 2018) argue that ICT contributes not only to economic growth but also to the mitigation of global warming.

Based on the aforementioned points, the following submissions are made: (1) research on the effects of introducing ICT requires an analytical framework that integrates various sectors and regions, (2) the effect of introducing ICT is greater when it is used than when producing ICT devices or investing in ICT infrastructure, and (3) it is necessary to grasp the value of ICT use that exceeds the economic value captured by conventional statistical indicators. Regarding point (1), the input–output framework used by Toh and Thangavelu (2013) is considered to be an appropriate analytical approach for analyzing the effects of ICT introduction. Notably, the framework for international input–output analysis, e.g., World Input–output Database (WIOD),[1] enables the evaluation of interdependencies between regions as well as sectors. At that time, in relation to point (2), it is necessary to consider how to describe the economic activity of ICT use within the framework of input–output analysis. In relation to point (3), it is necessary to expand the sector classification of the conventional input–output database. As Watanabe et al. (2018) indicate, ICT contributes beyond conventional economic values, thereby resulting in uncaptured gross domestic product.

In Japan, a new society that makes advanced use of ICT is referred to as a smart society, and the Japanese government has set the building of a smart society as one of its policy goals.[2] Currently, the building of smart societies is ongoing in other Asian countries. A theoretical understanding of the effects of building a smart society on the economy and how it contributes to regional economic development is an important issue in Asian development studies. Thus, directly related to SDG9, this chapter aims to explain the structure of development in a smart society that utilizes ICT using the input–output analysis framework.

The structure of this chapter is as follows: Sect. 10.2 explains the framework of the input–output analysis. Section 10.3 describes the structure of development theory using the input–output framework proposed by two representative input–output researchers (Professors Leontief and Ozaki), while Sect. 10.4 considers how their theory can be extended to explain the structure of the development of smart societies that utilize ICT. Section 10.5 uses the WIOD to provide an overview of the current state of interdependence between regions and sectors in Asia, including the relationship between the ICT manufacturing and ICT use sectors. Finally, a summary of the chapter is presented in Sect. 10.6.

[1] World Input–output Database, http://www.wiod.org/home.

[2] Cabinet Office, Government of Japan, "Society5.0", https://www8.cao.go.jp/cstp/society5_0/.

10.2 Input–Output Framework[3]

Figure 10.1 is a conceptual diagram of the input–output table used for the analysis. It was originally developed by Prof. Wassily Leontief in the 1930s (see Leontief 1986). This table is a matrix that summarizes the annual transactions between sectors within an economy. The vertical columns show how each sector obtains the required inputs from others. Conversely, the horizontal rows show how the output of each sector of the economy is distributed among the others. This input–output table that describes the relationship between the product of one sector and the input of another sector reveals the interdependence in the economic sectors. In recent years, input–output tables[4] have been used to analyze the effects of sustainable economic structures using renewable energy on the economy and the environment (Washizu and Nakano 2021a).

In this figure, x_{ij} is the component of the intermediate transaction matrix, $\mathbf{X}$, and represents the monetary amount of the ith good consumed by activity j; $\sum_i x_{ij} + v_j = x_j$ is the sum of x_{ij} in terms of the ith good and the value-added, v_j, and it represents the total output for activity j; the ratio of x_{ij} to x_j, $a_{ij} = x_{ij}/x_j$, is called the input or technical coefficient; and the set of input coefficients of activity j, i.e.,

$$\boldsymbol{a}_j = \begin{pmatrix} a_{1j} \\ a_{2j} \\ a_{3j} \\ \vdots \\ a_{mj} \end{pmatrix} \tag{10.1}$$

is called the activity vector of activity j. Leontief defines vector Eq. (10.1) as the representation of

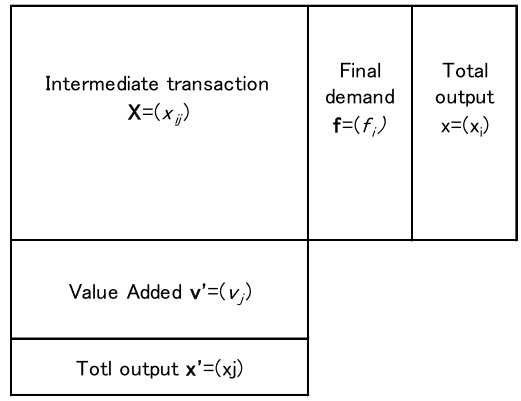

Fig. 10.1 Conceptual diagram of an input–output table

the production technology of activity j. A full set of input coefficients of all sectors is described by the symbol $\mathbf{A}$ and is called the input coefficient matrix. Using an input coefficient matrix, we can express the demand and supply balance as follows (the LHS of Eq. (10.2) is the sum of the intermediate and final demand):

$$\underbrace{\mathbf{Ax}+\mathbf{f}}_{\text{demand}} = \underbrace{\mathbf{x}}_{\text{supply}} \tag{10.2}$$

Here, $\mathbf{x}$ is the output vector (monetary units), $\mathbf{A}$ is the input coefficient matrix, and $\mathbf{f}$ is the vector of the final demand (monetary units).

Solving Eq. (10.2) for $\mathbf{x}$, we can obtain the Leontief inverse matrix $(\mathbf{I}-\mathbf{A})^{-1}$. According to Eq. (10.3), we can see the direct and indirect effects induced by the given final demand vector. The effects contain all production amounts of goods and services directly and indirectly needed throughout the supply chain of goods and services included in the final demand vector.

$$\begin{aligned} \mathbf{x} &= (\mathbf{I}-\mathbf{A})^{-1}\mathbf{f} \\ &= \underbrace{\mathbf{If}}_{direct} + \underbrace{\left(\mathbf{A}+\mathbf{A}^2+\mathbf{A}^3+\cdots\right)\mathbf{f}}_{indirect}, \end{aligned} \tag{10.3}$$

where $\mathbf{I}$ denotes the unit matrix. Figure 10.2 is a conceptual diagram of the direct and indirect effects induced by the final demand of the automobile (the induced effect when the component of the $\mathbf{f}$ vector in Eq. (10.3) is only the

[3] See Nakano et al. (2015) in relation to this section.

[4] Institute for Economic Analysis of Next-generation Science and Technology, input-output table for analysis of next-generation energy system, http://www.f.waseda.jp/washizu/table.html.

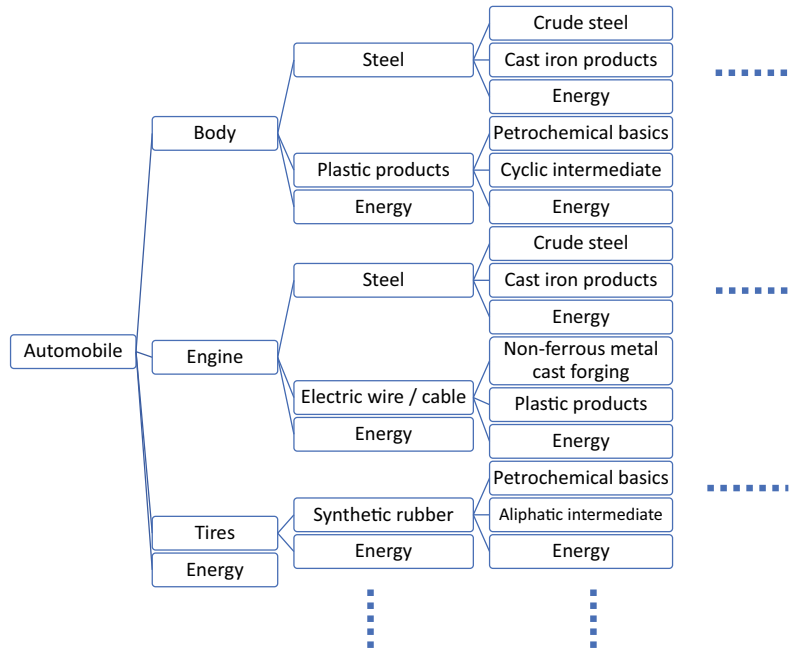

Fig. 10.2 Conceptual diagram of the direct and indirect effects induced by the final demand of the automobile

automobile). Figure 10.2 can be interpreted as an illustration of the automobile supply chain.

The international input–output table analyzes the economic interdependence between sectors as well as between regions by combining the input–output tables of several countries. Figure 10.3 is a conceptual diagram of the international input–output table among three countries A, B, and C. Using this table, we can analyze the effect of the final demand by the people of Country A, for example, on the production activities of the sectors in Countries B and C through international intermediate transactions.

10.3 Structure of Development Theory

This chapter describes the mechanism of economic growth (led by manufacturing), which has been elucidated in previous studies under the framework of input–output analysis. It explains the structure of the development theory proposed in the past by two representative input–output researchers (Professors Leontief and Ozaki).

10.3.1 Leontief's Structure of Development Model[5]

Wassily Leontief is the founder of the input–output table and has been awarded the Nobel Prize in Economics for his work. He said, "It was the labor of computation that promoted the first systematic studies of the structural characteristics of an economy as they are displayed in an input–output table. (The members of US government's project) undertook to rearrange the rows and columns in a table of the US economy in such a way as to minimize the computation required to yield numerical solutions. Such rearrangement brought into sharper relief the inter-industry and intersectoral transactions that tie industries and sectors together in the subunits of the total structure of the economy" (Leontief 1986, p. 166).

According to Leontief, each sector does not have a uniform intermediate relationship with other sectors in the input–output table. Leontief submits that the input–output table can be organized in a form similar to Fig. 10.4 by

[5] For the contents of this subsection, see Chap. 8 "Structure of Development" in Leontief (1986).

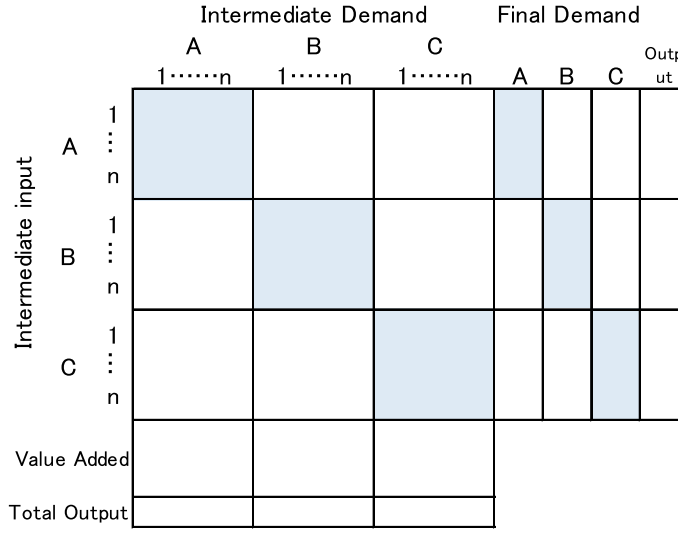

Fig. 10.3 Conceptual diagram of an international input–output table

rearranging the row and column sector array in the actual table because there are some parts where there are almost no intermediate transactions between sectors. He refers to such a structural feature in the input–output table as "triangularity."

Figure 10.4 shows the case where the structural relationships between sectors have the most complete hierarchical relationship. In Fig. 10.4, the first sector purchases inputs from all other sectors, while the tenth sector supplies inputs to all other sectors. The other sectors are arranged in the order of proximity to each role. The first sector, i.e., the automobile sector, produces complex goods with a large number of parts, and the tenth sector, i.e., the energy or corporate services sector produces general purpose and basic intermediate goods. Figure 10.4 illustrates the process whereby the intermediate goods of the sector at the bottom of the triangle are sequentially processed into the goods of the sector at the top of the triangle which are used for final consumption. The actual input–output table is composed of several blocks with a triangular structure shown in Fig. 10.4. For example, there is a machine block and a food block, and each block has a strong interdependence within itself, but the interdependence between blocks is relatively weak. Such a situation whereby the actual input–output table is composed of triangular blocks is called "block-triangularity" of the industrial structure.

According to Leontief, these structural features are discovered in the process of rearranging the order of sectors in the input–output table to simplify computer calculations.

10.3.2 Structure of Development During Japan's High Economic Miracle Period

Ozaki (2004) further extends Leontief's structure of development theory discussed in the previous section and clarifies the structure of development during Japan's high economic miracle period. This section describes Ozaki' s structure of development theory.

10.3.2.1 Rearrangement of Input–Output Sectors Based on Supply Chain

Ozaki (2004) initially considers the factors that cause block-triangularity in the industrial structure mentioned in the previous theory. Leontief (1986) does not explicitly discuss why the industrial structure has the block-triangularity properties. To explore the causes of block-triangularity, Ozaki (2004) assumes that manufacturing industries in each field need to build

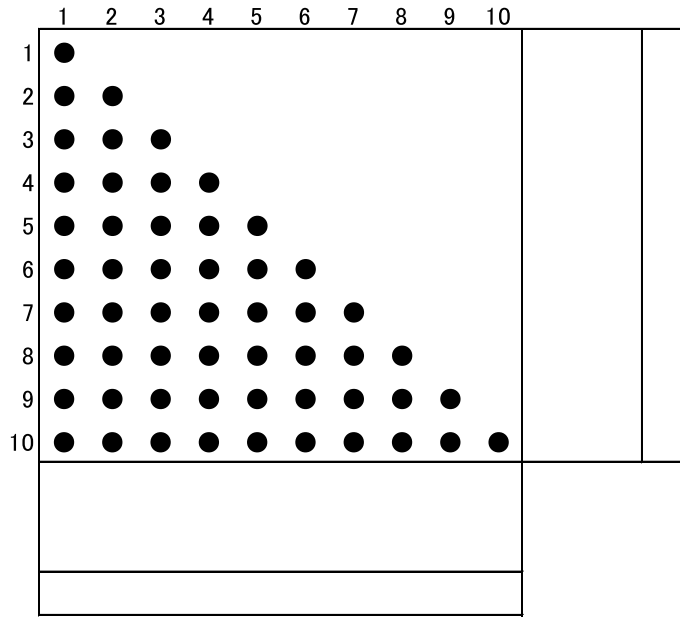

Fig. 10.4 Conceptual diagram of an input–output table with triangularity

their own efficient supply chains in order to establish economic growth through industrialization. He rearranged Japan's input–output table after a period of high economic miracles based on the following theoretical hypothesis:

> In an economic structure, there are several supply chains that connect and integrate multiple sectors. In the process of economic development, limited resources, labor, capital, etc. are sequentially invested along this chain, and one economic structure is formed.

As a result of this rearrangement, he discovers the nature of block-triangularity in the Japanese industrial structure. Ozaki's research process leading up to this discovery is presented as follows:

As a working hypothesis that embodies the aforementioned theoretical hypothesis, Ozaki assumes four supply chains based on the type of natural resource of their origin. They are supply chains from metal ores, natural crops, nonmetal minerals, and crude oil. In each supply chain, starting from the input of natural resources, related industries are ranked according to the processing stage of the product, leading to the final products. The more sophisticated the technology, the more diversified the sectors involved in one supply chain, but the number of main inputs for each final product is relatively limited. Leontief has established that the industrial structure is divided into blocks, and each block has triangularity. Ozaki extends Leontief's theory and clarifies that the blocks in the industrial structure are divided based on the type of raw material and that the triangularity of the industrial structure results from the rearrangement of the sectors according to the processing path of each supply chain. Generally, as technology becomes more sophisticated, the processing stage (supply chain) is extended, and more value-added is created. Therefore, if the technology becomes more sophisticated as the economy develops, the triangularity of the industrial structure will become clearer. At that time, the interdependence within one block will be strengthened, and the interdependence between blocks will simultaneously and gradually occur. For example, a food supply chain originating from agricultural products (natural crops) requires chemical fertilizers (products of the supply chain originating from nonmetallic minerals), and thus, interdependence will occur between a block originating from natural crops and that from nonmetallic minerals.

Based on the aforementioned working hypothesis, Ozaki closely tracks the supply chain originating from different raw materials found in Japan's 1965 input–output table and rearranges approximately 450 sectors therein.

Figure 10.5 shows a conceptual diagram of the sectoral rearrangement according to the supply chain. Starting from a certain raw material input (RM), products are sequentially processed in the order of the main material input (MM) according to the processing route of the supply chain, and the final product is produced. The sectors that support this mainstream concept include energy supply (E), auxiliary material input (Aux) (general-purpose goods and services used in the production of various industries), repair services (Rep), and various other services (S). The goods and services produced by these support sectors are introduced at all stages of the supply chain.

When the input–output sectors are rearranged according to the aforementioned hypothesis, the industrial structure shown in Fig. 10.6 is confirmed. The colored part in Fig. 10.6 shows that the intermediate transactions between sectors are solid, and the white part shows that virtually no transactions are found between the sectors. The six parts of the MM, RM, E, Aux, Rep, and S in Fig. 10.6 correspond to the rectangle of the same name in Fig. 10.5. In Fig. 10.6, the MM part is further divided into five subparts: machinery/metal, food, ceramic, textile, and chemical. Each subpart corresponds to one of the four supply chains (as shown in Fig. 10.5) originating from four types of RM inputs.[6] Figure 10.6 confirms the block-triangularity property. In other words, it has been confirmed that the industrial structure of Japan, which has been completed since the period of high economic miracle, has block-triangularity properties based on the supply chain originating from different raw materials.

Leontief discovers the block-triangularity nature of the industrial structure in the process of rearranging the sectors of the input–output table to simplify computer computation, while Ozaki establishes a similar block-triangularity property by rearranging the sectoral arrangements in the input–output table based on the theoretical hypothesis of the supply chain. Ozaki's work justifies Leontief's discovery.

10.3.2.2 Technology Classification of the Input–Output Sector

Following the rearrangement of the input–output sector, Ozaki measures the production functions of each input–output sector and classifies the sectors based on the measurement results, i.e., based on the nature of the technology.

The most basic production function traditionally used in microeconomics assumes that the factors of production can be flexibly substituted. For example, when the factors of production are labor and capital, if labor is relatively cheap, the technology of using a relatively significant amount of labor will be adopted (and vice versa). However, according to Ozaki, it is unlikely that the production function that allows flexible factor substitution is applicable to heavy industry, which has rapidly developed since the high economic miracle period. Heavy industries require large-scale capital equipment. For example, the steel industry requires the construction of large-scale blast furnaces, and even in countries where capital is scarce, labor cannot be substituted for capital. Moreover, once a capital facility, such as a blast furnace, is constructed, the relationship between the required factor input and production is fixed to some extent by the design value. When the demand is extremely low, it becomes difficult to reduce production according to the demand. Ozaki submits that capital equipment in the heavy industry has such a fixed production scale, and he refers to it as "plant indivisibleness."

Based on these, Ozaki measures the following two types of production functions for all sectors using microdata from industrial statistics.

1. $L = \alpha_L X^{\beta_L}, K = \alpha_K X^{\beta_K}$: Factor-limitational (Ozaki) production function
2. $X = \alpha L^{\gamma_L} K^{\gamma_K}$: Cobb–Douglas production function.

[6] The textile supply chain is an extension of the chemical supply chain originating from crude oil. Ozaki posits that during the period of high economic miracle, a material revolution occurred, and natural fibers used as textile raw materials were replaced by chemical types.

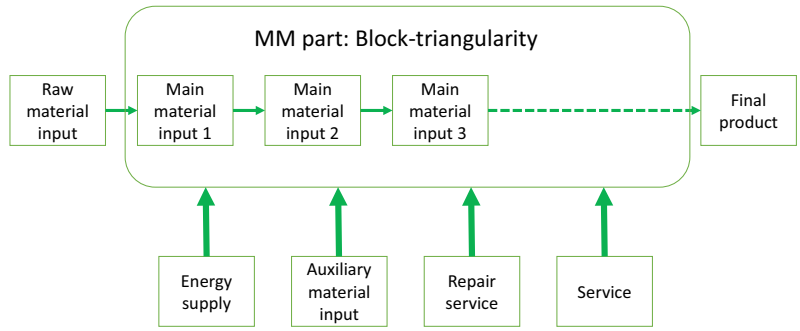

Fig. 10.5 Conceptual diagram of sectoral rearrangement according to the supply chain

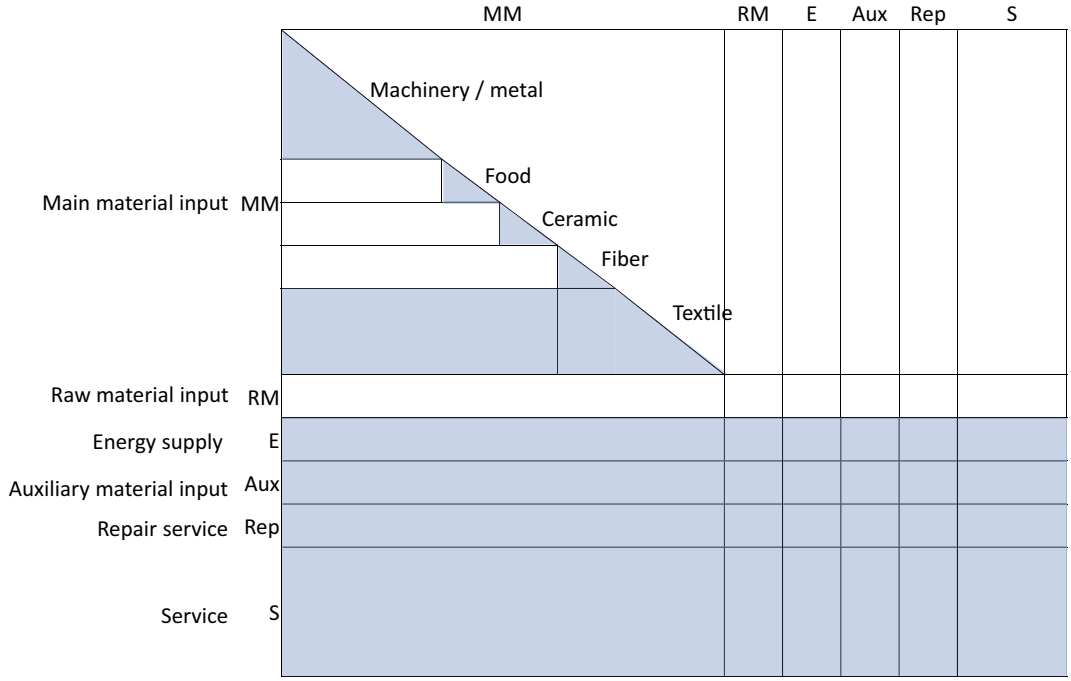

Fig. 10.6 Japan's industrial structure after the high economic miracle period

The factor-limitational production function is that whereby the input of labor and capital is determined independently according to the level of production, and no factor substitution is allowed between labor and capital. Furthermore, when β_L or $\beta_K < 1$, economies of scale work on labor or capital input. The Cobb–Douglas production function, which allows for factor substitution, is traditionally used in microeconomics. Ozaki empirically estimates the two aforementioned types of production functions for all input–output sectors and examines which production function is more applicable to each sector. He further evaluates the parameters of the estimated production function in detail and classifies all industrial sectors into five subgroups according to the estimated parameters of the production functions. He argues that such a classification is based on the "technical characteristics" of each sector. Table 10.1 shows the names given to the "technical characteristics" of each subgroup and a summary of each technical characteristic.

10.3.2.3 Mechanism of Japan's High Economic Growth

Ozaki's structure of development model can be summarized using the industrial structure diagram (Fig. 10.6), in which the order of the sectors is rearranged, and the technical characteristics of each sector (Table 10.1). Figure 10.7 shows a redrawn diagram of Fig. 10.6 for explanation. As mentioned previously, the filled parts in the figure indicate that there are many intermediate transactions. The block-by-block triangular-filled area shows the supply chain inside each block. The wide square-filled area below indicates that energy, auxiliary materials, etc., are universal inputs to various industries. Moreover, the rectangular filled area that extends to the left of the chemical block shows a material revolution, which is a characteristic technological change in the era of high economic growth. In other words, natural materials, such as natural fibers and wood, have been replaced by artificial materials, such as chemical fibers and resins. As a result of this replacement, chemical raw materials have become universal inputs to other sectors. Additionally, after high economic growth, the weight of the machinery and steel industries in the top block of the diagram significantly increases. Furthermore, from the 1970s to the 1980s, the weight of the assembly machinery industry (automobile, electronic/electrical machinery industry), which is located at the top of the top block, increases, and the industrial structure became more sophisticated.

Of the filled parts in Fig. 10.7, the dark-filled blocks are sectors with capital-intensive technical characteristics, in which economies of scale work strongly (sectors with K (I)-type technology). Figure 10.7 shows that the blocks with strong economies of scale are located at the top and bottom of the block-triangularity structure of the MM part. The blocks, such as the food and textile industries, sandwiched between them are a group of sectors with labor-intensive (L-type) technology. Focusing only on the machine-metal refining block located at the top of Fig. 10.7, the assembly machinery industry is located at the top of this block, while the metal refining industry is located at the bottom. These are the sectors with the K (I)-type technology defined by Ozaki. Sectors that produce mechanical parts are located in the middle of these sectors. Mechanical parts are often produced in small-town factories that have labor-intensive technical characteristics.[7]

To summarize the aforementioned, in Fig. 10.7, the capital-intensive sectors with economies of scale are located above and below the block-triangularity structure of the MM part, and the labor-intensive sectors are located between them. The same positional relationship applies to the internal structure of the machine-metal refining block that has driven the Japanese economy since the high economic miracle period.

The industrial structure diagram shown in Fig. 10.7 helps to explain the mechanism of the high economic miracle in Japan. A major feature of this period was the bullish and active investment motivation of companies that "investment calls for investment." The willingness to invest created a high demand for the assembly machinery industry, located at the top of the industrial structure. Large-scale production to meet this demand brought efficiency to the assembly machinery industry with the K (I-M)-type technology by pursuing economies of scale. The large-scale demand generated in the upper part of the block-triangularity structure returned to the supply chain and spread to the sectors in the lower part of the triangularity structure. In other words, the large-scale production of final products also caused the mass production of raw materials and intermediate parts. Consequently, mass production occurred even in the chemical block with the K (I-B)-type technology located at the bottom of the block-triangularity structure, and great economies of scale also occurred in that block. A similar spillover effect was true for the internal structure of the machinery–metal refining block,

[7] Workers in these labor-intensive town factories producing mechanical parts possess sophisticated skills for delicate work. These skills are one factor which supported the international competitiveness of Japanese-made machines. It is desirable to digitize the professional skills of these workers to ensure they are passed on efficiently to future generations. This is also one of the purposes of a smart society described in a later chapter.

Table 10.1 Classification of the technical characteristics of sectors

Name of technical characteristics		Features of technical characteristics
Capital-intensive (K-type) technology	K(I-B) type	Large-capacity processing-type technology. This type of production function applies to sectors with strong economies of scale for labor input and high capital intensiveness, such as the petrochemical industry and steel industry, and electric power. B is an abbreviation for basic materials
	K(I-M) type	Large-scale assembly production type technology. Economies of scale work for labor input and capital intensity is high, but not as much as the K (I-B)-type technology. This type of technology applies mainly to the machinery industry. M is an abbreviation for machine
	K(II) type	Capital use type technology. Economies of scale work on labor input, but the non-economy of scale acts on capital input, and capital intensity is relatively high. This type of technology applies to traditional material production sectors, such as pulp, cement, inorganic chemistry, and coal products
Labor-intensive (L-type) technology	(L-K) type	This type of technology is characterized by constant returns to scale and factor substitutability. This type applies to primary industries, such as agriculture
	L(I) type	This type of technology is characterized by increasing returns to scale and factor substitutability. The capital intensity is low and the labor intensity is high. The L (I) type has a slightly larger scale effect
	L (II) type	

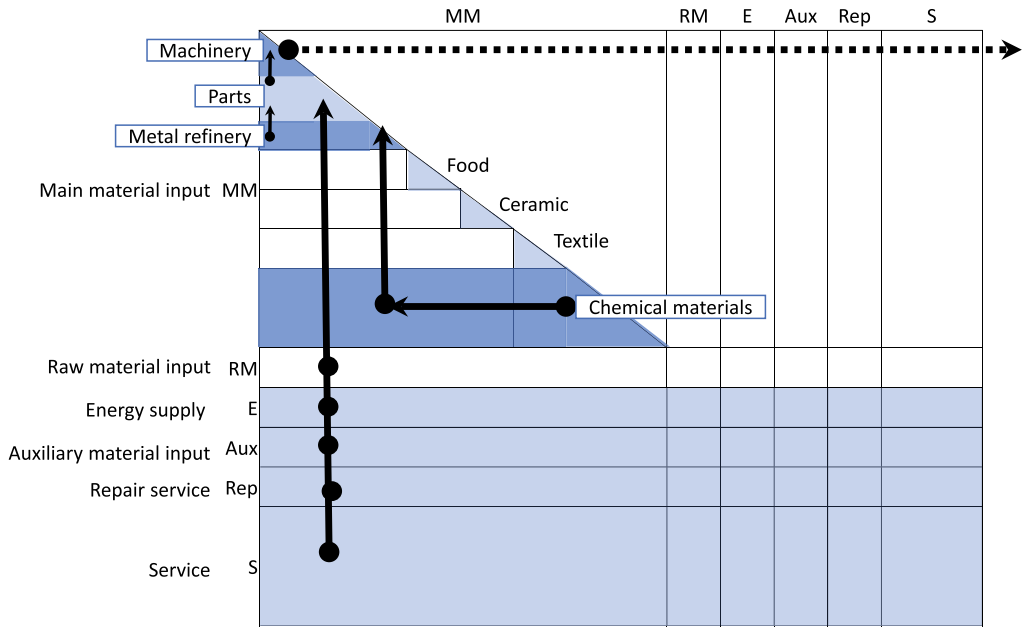

Fig. 10.7 Mechanism of high economic growth

which has been a major part of the Japanese economy during the high economic miracle period. In other words, the economies of scale of the assembly machinery industry at the top of the block triggered economies of scale in the metal refining industry at the bottom of the block.

However, the pursuit of economies of scale is essentially a labor-inhibiting phenomenon. In particular, a major feature of the K (I)-type technology is that economies of scale in labor input work strongly, and the larger the production scale of sectors with the K (I)-type technology, the more labor-saving progresses. When sectors with the K (I)-type technology mainly drive economic growth, it is not expected that labor demand will increase with economic development. In Fig. 10.7, it is important that a labor-intensive sector exists in the middle of the triangularity structure. This is because the spillover effect of large-scale demand generated in the upper part of the triangularity will surely extend to labor-intensive sectors. Large-scale labor absorption occurs in the middle block through the spillover effect from the triangularity upper sectors. An increase in labor demand will lead to an increase in consumer demand through an increase in employee income. In Japan, during the high economic miracle period, this consumption demand formed a large domestic market for products of assembly machinery industries. Certain terms, such as "three sacred treasures (electric refrigerator, electric washing machine, black and white TV)" and "3C (car, cooler, color TV) era," are slang terms that refer to the domestic market for home appliances formed in this way. Apparently, the formation of such a domestic market further strengthened the effect of the previously mentioned ripple mechanism. Similarly, a large-scale employment absorption effect occurred at a small machine parts factory located in the middle of the machine-metal refining block, which was a major part of the Japanese economy during the high economic miracle period.

To summarize, in the Japanese economy during the period of high economic miracle, the expansion of demand for the upper triangularity sectors spread to the lower triangularity sectors, and economies of scale were pursued in those sectors. Meanwhile, large-scale labor absorption occurred in the middle sectors of the triangularity. This mechanism has arisen technically through the transaction of intermediate goods along the supply chain, and thus, it can work in any country, not just Japan. However, in the case of Japan, this technical mechanism was reinforced by the institutional mechanism of affiliated relationships with *Keiretsu* between companies. In general, when discussing Japan's period of high economic miracle, the affiliation relationship between companies centered on banks, remaining from the prewar conglomerate, is emphasized. This affiliated relationship is the relationship between large enterprises and small and medium-sized enterprises (SMEs). The upper and lower sectors of the block-triangularity are dominated by large enterprises. Notably, SMEs dominate the middle sector of the triangularity. Accordingly, the affiliation relationship corresponds exactly to the block-triangularity of the input–output relationship. Therefore, in order to maintain this relationship properly, the Ministry of International Trade and Industry (MITI)[8] took measures to support SMEs as part of its industrial policy during the high economic miracle period. Thus, during the period of Japan's high economic growth, the efficient economic cycle mechanism functioned by mutually reinforcing the technical input–output relationships and institutional corporate relationships.

The key to this efficient economic cycle mechanism is the high final demand for the machinery sector located at the top of the triangularity structure. This stimulus of final demand generated an efficient cycle in the entire economic system through input–output relationships, and Japan's high economic growth was realized. However, when the high economic growth ended, domestic investment demand for machinery stagnated. Rather, from the late 1970s to the 1980s, the international competitiveness of Japan's machinery sector increased, and export demand replaced domestic investment demand, thereby driving the economy. However, in the 1990s, the catch-up of Asian countries reduced the international competitiveness of Japan's machinery sector, thus resulting in a decline in export demand for the upper sectors of the triangularity structure. Thereafter, the economic

[8] The predecessor of the current Ministry of Economy, Trade and Industry (METI).

circulation mechanism malfunctioned, and the economy stagnated. This is one of the causes of the stagnation of the Japanese economy in the 1990s, which is referred to as the "lost decade."

10.4 Structure of Development of a Smart Society

In the analysis of a modern economic society, wherein the weight of production activities in the service industry has increased, it is necessary to pay more attention to the input–output relationships between the service sectors located in the Aux, R, and S parts and to expand the discussion in Figs. 10.6 and 10.7 accordingly. Especially in recent years, with the development of ICT, new business services (information processing services, data provision services, etc.) that have never existed in the past are developing. Therefore, it is necessary to consider the role of ICT-related service sectors in the entire industrial structure. As mentioned in the introduction, it is important to focus on the economic activity of ICT use. Moreover, ICT will create unprecedentedly new economic values such that it may be necessary to expand the conventional input–output database. Section 10.4.1 explains how the structure of development theory presented in Sect. 10.3 is extended when focusing on the service industry of ICT use. Section 10.4.2 provides a perspective on how to expand the conventional input–output database for the analysis of a smart society.

10.4.1 Information Service Industry and Industrial Structure

Nakano and Washizu (2018) focus on the smart food industry and divide ICT-related industries into manufacturing sectors necessary for ICT infrastructural development and service sectors that utilize it. Furthermore, the latter is divided into sectors that provide general purpose and basic ICT services such as communication services, i.e., the primary information service (PIS) part, and sectors that provide ICT utilization services customized for each customer in detail according to user requests, i.e., the secondary information service (SIS) part.

Subsequently, Nakano and Washizu (2018) visualize the emergence of new input–output relationships between ICT-related (manufacturing and service) industries and food-providing sectors. In a smart society, it is expected that such new input–output relationships between ICT-related sectors and those that produce goods and general services are progressing in various industries other than the food industry. Figure 10.8 is a conceptual diagram of the input–output structure of such a smart society, which is created by extending Figs. 10.6 and 10.7. In Fig. 10.8, the service sectors at the bottom of Figs. 10.6 and 10.7 are expanded to the PIS, SIS, and general service sectors.

Here, the PIS sector refers to those that produce the basic information services necessary for the production of the SIS described below, such as the Internet, communication, broadcasting, as well as research and development. Secondary information services are sectors that produce application services customized for industry, such as wholesale/retail, finance, advertising, transportation, and legal/accounting services, which are produced by combining information goods and the PIS. The information goods sector is the manufacturing sector of MM parts that produces sensors and computer equipment. General services are other service sectors that are not included in the PIS and SIS sectors, and the quality of services provided can be improved by utilizing information goods as well as PIS and SIS. It can be thought of as a production sector for more highly customized services for end consumers, including households.

In the MM part, rearranging the sectors to trace back to the final goods production process shows a triangularity structure. Similarly, if we rearrange the service sectors in the order of general services → SIS → PIS, a triangularity structure will be shown in the service part as well. Furthermore, large IT companies, such as GAFA (Google, Apple, Facebook, and Amazon), are currently attracting attention. Our empirical study using the Basic Survey of Corporate

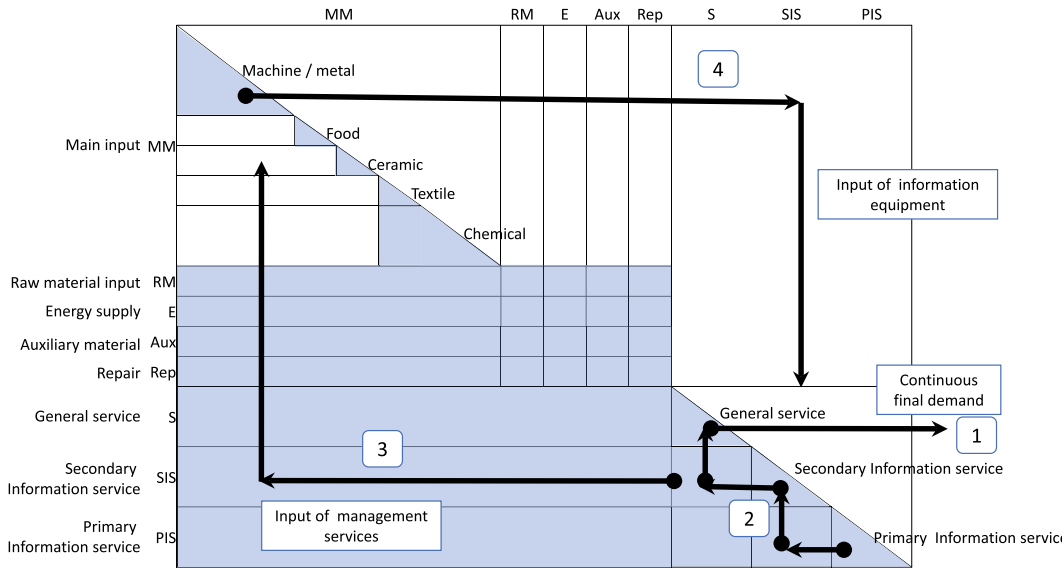

Fig. 10.8 Conceptual diagram of the input–output structure of a smart society

Activities in Japan suggests that the PIS sector, which provides the communications infrastructure (platform), is capital-intensive and is increasing returns to scale (Washizu and Nakano, 2021b). This property is similar to that found in large-scale equipment industries, such as the steel and chemical sectors in the MM part. Washizu and Nakano (2021b) also suggest that not only the information service sectors but also the general service sectors are shifting to a capital-intensive industry through the strengthening of equipment related to computerization.

The economic cycle in the industrial structure shown in Fig. 10.8 can be explained as follows: a variety of end services that are customized for individual service consumers have a continuous end demand (arrow 1). The final demand induces economies of scale for the PIS block below the triangle of the service part and increases the productivity of the block. Increased productivity of the PIS block located in the lower triangle will contribute to lower prices of general services in the upper triangle of the service part through the supply chain of the service part (arrow 2). According to Ozaki (2004), the service industry is a basic input in all industries, including the MM part sector (arrow 3), so the effect of increasing the efficiency in service sectors and lowering service price will bring cost reduction effects and productivity increase effects to the sectors in the MM part. The decrease in the price of information materials in the MM part increases the capital intensity of the service part, including the general service sectors, and activates the flow of information equipment input from the MM part to the service part (arrow 4). As the demand for general services is less likely to be saturated than the demand for goods and is considered to be continuous, the economic effects of the previously mentioned economic cycle are also expected to be continuous.

10.4.2 Toward the Input–Output Analysis of a Smart Society

Watanabe et al. (2018) report that ICT may create new economic values that cannot be captured by means of conventional economic indicators. Nakano and Washizu (2018) also attempt to capture such a new economic value. They define a smart society as that wherein management is highly sophisticated by utilizing ICT. They focus

on "management activities" as economic activities that create new value using ICT. However, it can be difficult conceptually and statistically to estimate the actual size of those activities and values because they are not properly captured in conventional input–output tables, and they are often buried beneath the surface of an industry. Nakano and Washizu (2018) undertake this difficult task by referring to Porat (1977).

It is useful to review Porat (1977) when considering the estimation method of the actual size of information activities and those values that are buried beneath the surface of other industries and not captured at present. In the late 1960s, Porat set out to quantitatively measure what fraction of the gross national product (GNP) in the USA is related to information activities. He proposes a new definition for "information industry" and measures the amount of value-added by information industry, finding that these industries' proportion of the overall GNP is 46%. According to Porat, information activities can be divided into two types: activities of primary information sectors already on the market and activities carried out in secondary information sectors within each industry. The GNP of primary information sectors can be measured by clarifying the definition of "information industry." Meanwhile, a secondary information sector is buried inside an industry, and thus, it is more difficult to define and measure. Porat separates the internal information activities of each industry from the industry's main business based on each industry's occupation composition ratio. He defines "occupation to process information" and separated value-added as a result of information activities from value-added as a result of non-information activities according to the proportion of employees engaged in those occupations within each industry. For example, as a physician, in addition to the technical work of patient treatment, there are many tasks related to information activities, such as collecting patient information, conducting medical research, and processing patient accounts. Porat investigates the average time allocation of doctors' daily tasks and estimates the allocation ratios for time related to technical work vs. time related to information work. Using these ratios, Porat separates the value-added by internal information activities from that of the medical industry as a whole.

Nakano and Washizu (2018) employ the same method as Porat to identify and isolate internal ICT-based management activities within an industry. They focus on the food industry and separate the internal management activities according to the proportion of occupation to process information in that sector. By applying the separation method developed by Nakano and Washizu (2018) to all sectors, internal management activities in all industries can be separated. These are economic activities that are not identified in the conventional input–output table. By explicitly separating these activities, it is possible to analyze the effects of management activities that utilize ICT, and eventually the effects of building a smart society. By separating the internal management activities of all sectors according to the proportion of occupation to process information in specific sectors and incorporating this into the service part in Fig. 10.8, the structure of the economic cycle indicated by arrows in this figure will become clearer. We will undertake this task in future research.

10.5 International Interdependence of Information Society in Asia

Figure 10.3 in Sect. 10.2 explains the international input–output table. Based on the discussions so far, this section attempts to analyze some of the international interdependencies in the modern Asian region that have been informatized. One international input–output table is the WIOD created by the University of Groningen. The WIOD (2016 Release) describes the transactions of goods and services between 43 countries and 56 sectors in 2014. In the table, six countries—China, Indonesia, India, Japan, South Korea, and Taiwan—are listed for Asia. Using the international input–output table, it is possible to calculate the amount of production and income (value-added) that the final demand of one

Table 10.2 Amount of production and value-added that the final demand of China and Japan has induced in their own country and others

Nation	Sector part	FD in China		FD in Japan	
		Induced production	Induced value-added	Induced production	Induced value-added
China	MM	33.46%	27.53%	2.79%	1.36%
	RM	8.98%	4.88%	1.79%	0.61%
	E	5.07%	2.94%	0.20%	0.10%
	Aux	13.63%	9.06%	0.21%	0.09%
	S	12.49%	20.50%	0.62%	0.68%
	SIS	8.33%	13.74%	0.19%	0.17%
	PIS	5.66%	7.58%	0.05%	0.04%
China Total		87.62%	86.22%	5.85%	3.05%
Japan	MM	0.35%	0.23%	12.87%	8.75%
	RM	0.31%	0.33%	4.18%	2.88%
	E	0.10%	0.08%	2.00%	1.16%
	Aux	0.03%	0.03%	9.37%	7.68%
	S	0.14%	0.24%	21.01%	24.34%
	SIS	0.04%	0.08%	19.02%	27.01%
	PIS	0.01%	0.01%	10.71%	13.25%
Japan total		0.98%	0.98%	79.15%	85.08%
Asia[a] total		90.50%	89.02%	86.95%	89.46%
Total inducement for world (trillions of US dollars)		28.3	9.7	8.8	4.5

MM: main material input, RM: raw material input, E: energy supply, Aux: auxiliary material input, S: general service, SIS: secondary information service, PIS: primary information service

[a] Asia: China, Indonesia, India, Japan, Korea, Taiwan

country has induced in the sectors of the country and other countries through the worldwide supply chain. Table 10.2 shows the results of calculating the amount of production and value-added that the final demand of China and Japan has induced in the industries of their own country and other countries using the WIOD in 2014.[9]

According to Table 10.2, the final demand in China induces a production of US$ 28.3 trillion worldwide, while the final demand in Japan induces a production of US$ 8.8 trillion, and the amount of added values generated by these induced productions is US$ 9.7 trillion and US$ 4.5 trillion, respectively. In China, the induced value-added is 34.2% of the induced production value, while in Japan it is 51.1%. Of the value-added induced by final demand, the domestic induction is 86.2% in China and 85.1% in Japan; that is, the former is slightly higher. The composition ratios of value-added by the sector part induced by the final demand of China and Japan significantly differ. The value-added induced for the MM part of the home country is 27.5% in China and 8.8% in Japan. However, the value-added induced for the domestic information service (SIS and PIS) parts is 21.3% in China and 40.3% in Japan. It is also interesting to compare the value-added composition ratio that the final demand of each country induces in the other country. The composition ratio that China's final

[9] See the appendix for the specific calculation formula.

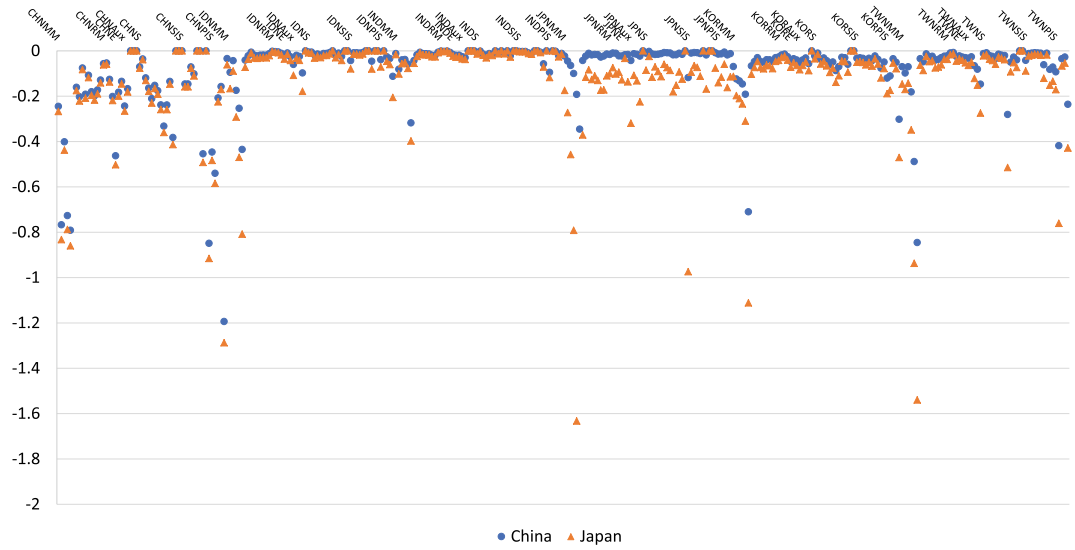

Fig. 10.9 Impacts of increased productivity in the "manufacture of computer, electronic, and optical products" sector in China and Japan on the manufacturing cost of each sector in other countries[10]

demand induces in Japan is only 0.98%, while the composition ratio that Japan's final demand induces in China is 3.1%. Upon considering the extent to which one country's production activity is affected by the final demand of another, it is observed that Japan's impact on China is higher than the other way around.

Figures 10.9 and 10.10 show the results of an analysis of the cost reduction effects of improved labor productivity in the information-related sectors of China and Japan on the production sectors of each country in the Asian region. Figure 10.9 shows how much the production cost of each sector in the Asian countries (China, Indonesia, India, Japan, Korea, and Taiwan) featured in the WIOD will decrease when labor productivity increases by 30% in the "manufacture of computer, electronic, and optical products" sector of the MM part in China and Japan. If a sector in a country has a "manufacture of computer, electronic, and optical products" sector in China or Japan involved in its supply chain, the production cost of that sector is expected to drop significantly. Figure 10.9 shows that the increase in labor productivity in the "manufacture of computer, electronic, and optical products" sector in Japan and China affects the manufacturing unit price of sectors of the information service part as well as sectors of the MM part in Asian countries. In particular, price declines in various sectors of China are significant. China's sectors are more affected by the productivity gains of Japan's "manufacture of computer, electronic, and optical products" sector than by the productivity gains of the same sector in China. This tendency is the same in other countries. It can be inferred that Japan's "manufacture of computer, electronic, and optical products" sector is deeply involved in the supply chains of many sectors in Asian countries.

Figure 10.10 shows how much the production cost of each sector of the Asian countries (China, Indonesia, India, Japan, Korea, and Taiwan) featured in the WIOD will decrease when labor

[10] The abbreviations on the horizontal axis consist of country and sector part names. The abbreviations for country names are as follows: China (CHN), Indonesia (IDN), India (IND), Japan (JPN), Korea (KOR), and Taiwan (TWN). The abbreviations for sector part names are the same as those in Table 10.2.

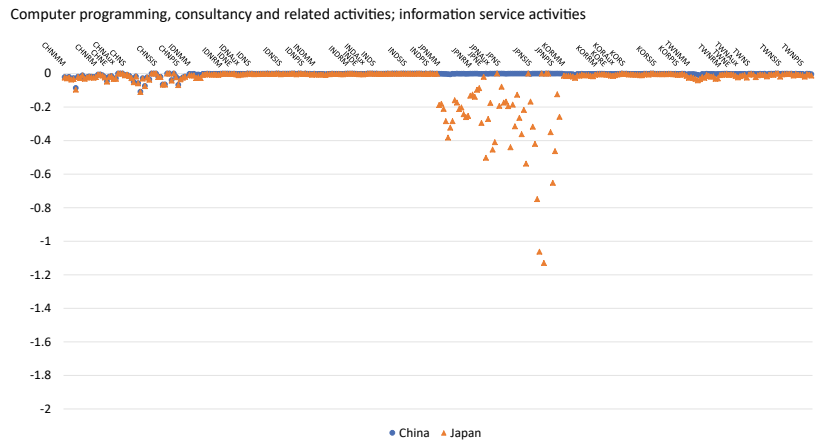

Fig. 10.10 Impacts of increased productivity in the "computer programming, consultancy, and related activities; information service activities" sector in China and Japan on the manufacturing cost of each sector in other countries[11]

productivity increases by 30% in the "computer programming, consultancy, and related activities; information service activities" sector of the PIS part in China and Japan. The increase in productivity in this sector in Japan has a considerable impact on the production prices of the service and manufacturing sectors in Japan. However, its impact on other Asian countries, including China, is not as high as in the case of increased productivity in the "manufacture of computer, electronic, and optical products" sector. Increasing labor productivity in the same sector in China has a minor impact on Asian countries. The impact of increased productivity in this sector in China on the production prices of each industry in China is approximately the same as the impact on them by this sector in Japan.

In short, Japan is more informatized than China. Japan's information goods manufacturing sector influences the supply chains of various Asian sectors. The productivity improvement of the information service sector in Japan will spread to the supply chains of Asian countries, but the extent will be minor compared to the effect of the information goods manufacturing sector. However, the scope of the production sector, which is affected by productivity improvements in the information service sector, seems to be broader.

10.6 Concluding Remarks

In this chapter, based on the recognition that the analysis of the effects of ICT use requires an analytical framework that integrates various sectors and regions, using the input–output framework, we explain the structure of development in a smart society utilizing ICT.

This chapter first clarified the structure of development theory of industrial society, developed by Leontief and extended by Ozaki. Subsequently, it was suggested that the structure of development mechanism of the industrialized society has major drawbacks: When the final demand for industrial products at the end of the supply chain disappears, it becomes dysfunctional.

Next, we considered how the structure of development theory would be extended in a smart society using ICT. Previous studies have pointed out that the effect of using ICT is greater than the effect of producing ICT materials and investing in ICT infrastructure, and that ICT creates values that exceed the economic value captured by means of conventional statistical indicators. Based on these points, we have rearranged the relationship between the information

[11] The abbreviations on the horizontal axis are the same as in Fig. 10.9.

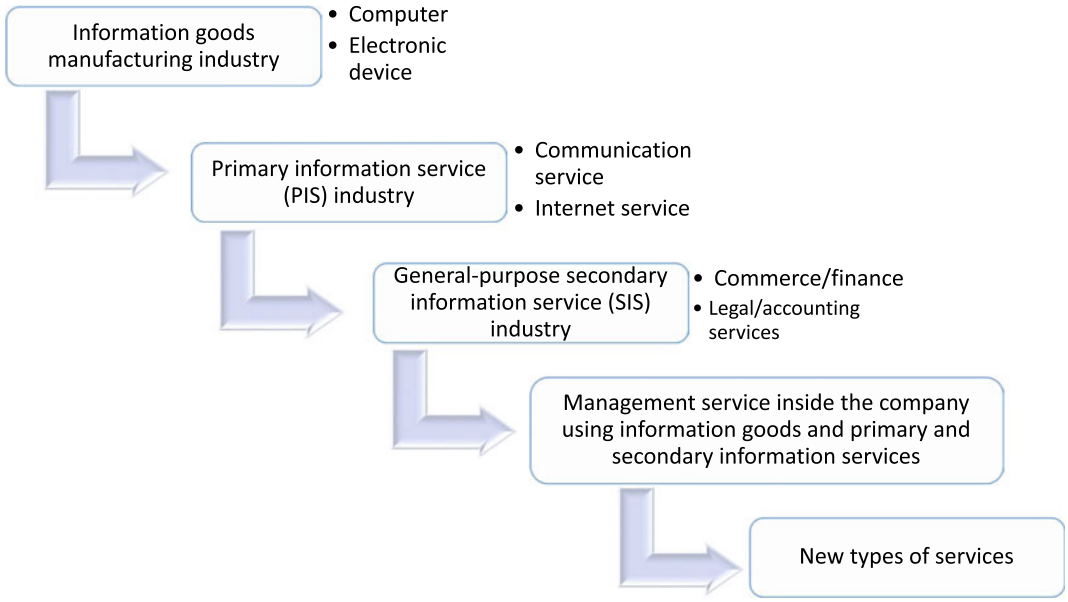

Fig. 10.11 Relationship between information goods manufacturing sector and information service sector

goods manufacturing sector and the information service sector, as shown in Fig. 10.11.

Specifically, the products produced in the information goods manufacturing sector of the MM part are input into the service industry of the PIS part that produces primary information services (e.g., communication services). At this time, economies of scale operate in the production process of the primary information services. Furthermore, the service industries in the SIS part use the primary information services produced in the PIS part to generate more customized secondary information services (e.g., legal and accounting services). The management department inside each industry (including the manufacturing industry of the MM part) creates efficient management services by combining information goods, primary information services, and secondary information services. The management service within each industry eliminates the waste in various supply chains and greatly contributes to improving the efficiency of the entire industrial structure. Furthermore, it creates new types of services (e.g., sharing services) which did not exist before the smart society and contributes to people's welfare.

Based on the inter-industry relationships in Fig. 10.11, we rearranged the input–output table and presented the structure of development mechanism of a smart society. Here, the continuous final demand for smart services makes it easier to maintain an economic cycle and avoid dysfunction.

Finally, using the WIOD, we analyze the current state of interdependence in the Asian region regarding the ICT material manufacturing sector and the ICT use sector. Consequently, it is shown that Japan is an informatized economy in the Asian region. Japan's information manufacturing sector has influenced the supply chains of various sectors in Asian countries. The productivity improvement of the information service sector in Japan also affects the supply chains of Asian countries, but the extent is minor compared to the effect of the information goods manufacturing sector. However, the range of production sectors affected by productivity improvements in the information service sector is wider.

This chapter analyzes the input–output effects of the smartening of society through technological innovations in ICT directly related to SDG9.

However, ICT advances have spillover effects that cannot be discussed under this topic alone. For example, it is necessary to build smart energy management systems to more efficiently utilize renewable energy sources, which are variable and decentralized. Therefore, this chapter is also related to SDG7. Similarly, advances in ICT have made it possible to strengthen the management of production systems and ensure improvements in resource efficiency (SDG8). They have also contributed to the realization of sustainable consumption by making it possible to replace the consumption of people's "things" with the consumption of "services" produced by things (sharing services, etc.) (SDG12). Advanced utilization of renewable energy, improvements in resource efficiency, and the construction of sustainable production and consumption systems are indispensable means of reducing greenhouse gas emissions (SDG13). Advances in ICT are also useful for solving various other social issues. For example, they can contribute to community development that is favorable for the elderly and people with disabilities through the provision of appropriate smart transportation services (SDG 11) and will streamline food production and contribute to addressing the problems of hunger and poverty through the development of smart agricultural machinery and precision agriculture technology (SDG2). Furthermore, it has been pointed out that improved ICT will increase employment opportunities for women and empower them, thereby contributing to gender equality (SDG5). Thus, this chapter is not only directly related to SDG9, but also to SDGs 2, 5, 7, 8, 11, 12, and 13.

Appendix

This appendix shows the formula for the analysis in Sect. 10.5 using the WIOD in 2014. The formula for Table 10.2 is as follows: Eq. (10.4) is for calculating the amount of production that the final demand in a specific region r induces in all regions. This formula calculates all the production inducements that individual goods in the final demand in region r cause worldwide through the supply chains.

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{F^r} \tag{10.4}$$

$\mathbf{x}$: vector of the production induced in all sectors in all regions

$\mathbf{F^r}$: vector of final demand in region $r(r = 1, \ldots, k)$

$\mathbf{A}$: inter-regional input coefficients matrix of the WIOD

By using the calculation results of Eq. (10.4), the value-added (income) induced by the final demand in region r in all regions is calculated using Eq. (10.5).

$$\mathbf{VA} = \mathbf{v}'x \tag{10.5}$$

$\mathbf{VA}$: vector of the gross value-added induced in all sectors in all regions

$\mathbf{v}' = \left(v_j^r\right)'$: vector of the gross value-added ratio of all sectors in all regions

$v_j^r = {VA_j^r}/{X_j^r}$ VA_j^r: the gross value-added of sector j in region r in the WIOD

X_j^r: control total of sector j in region r in the WIOD

In Sect. 10.5, the case of r = China, Japan is calculated.

The method of calculating the cost reduction effect of improving labor productivity in the information-related sectors of China and Japan on the production sectors of Asian countries is presented as follows: The production unit price p by country/sector is calculated by the following Eq. (10.6) using the traditional equilibrium price model of input–output analysis:

$$\mathbf{p} = (\mathbf{I} - \mathbf{A}')^{-1}\mathbf{v} \tag{10.6}$$

Here, $\mathbf{p}$ is the price vector by country/sector, $\mathbf{I}$ is the identity matrix, $\mathbf{A'}$ is the transposed matrix of the input coefficients matrix of WIOD, and $\mathbf{v}$ is the vector of gross value-added ratio by country/sector.

We assume that labor costs, which are components of value-added, will decrease and the

value-added coefficient will decrease through the increase in labor productivity in the information goods manufacturing sector or information service sector in China or Japan. In the text, the analysis is performed based on the assumption that the rate of decrease in the value-added coefficient is 30%. That is, the value-added coefficient v of the information-related sector in China or Japan is reduced by 30%, and the change in manufacturing unit price p by country/sector is calculated.

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Trade-Investment Nexus and Economic Growth in East Asia

11

Shujiro Urata

Abstract

SDG 8's goal is to promote sustained, inclusive, and sustainable economic growth; full and productive employment; and decent work for all. This chapter examines the experiences of East Asian developing countries in achieving rapid and inclusive economic growth by focusing on the role of international trade and foreign direct investment nexus created through global value chains (GVCs) by multinational corporations (MNCs). GVCs enabled participating companies and countries to improve productivity, contributing to economic growth. The factors attributable to the participation in GVCs include high competitiveness of local companies and open business environment created by the Asian government. Moreover, construction and maintaining well-functioning soft (e.g., education and legal systems) and hard (e.g., transportation and communication systems) infrastructure by the government and international donors contributed to the creation of business-friendly environment. Faced with growing protectionism and the threats of growing US-China rivalry, infectious diseases, climate change, etc., maintaining an open and transparent rules-based business environment is crucially important to further achieving sustained, inclusive, and sustainable economic growth. In the light of absence of effective global economic order, exemplified by ineffectiveness of the World Trade Organization in trade liberalization as well as dispute settlement, regional economic frameworks such as the CPTPP and RCEP in the Asia and Pacific region would be proven to be effective to achieve the goal.

Keywords

Global value chains · Free trade agreements · Infrastructure

11.1 Introduction: Asia's Rapid Economic Growth

Among the United Nations' 17 sustainable development goals (SDGs), the objective of SDG 8 is to "promote sustained, inclusive, and sustainable economic growth; full and productive employment; and decent work for all." Among the world's developing countries and economies, those in East Asia have been relatively successful in achieving some of these objectives. The most

SDG 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all.

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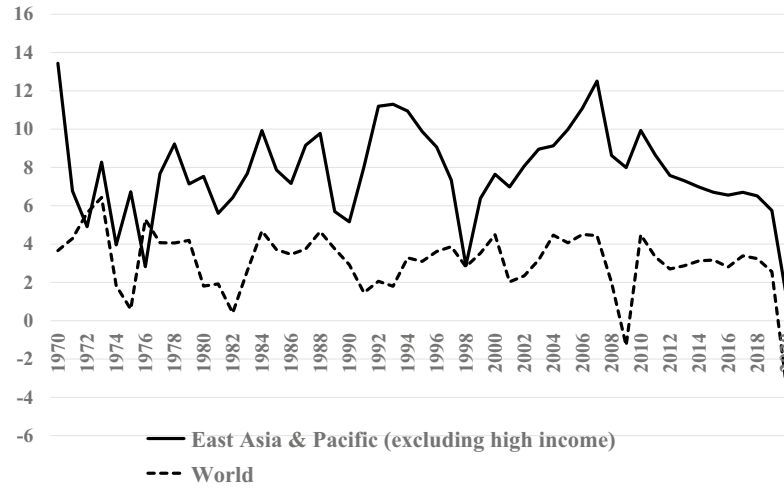

Fig. 11.1 GDP growth rates for East Asia and the world (%).[2] *Source* World Bank, World Development Indicators online

obvious indication of their success is that many of these countries have achieved high, sustained economic growth for several decades. This chapter examines how East Asian countries[1] are achieving the objectives outlined in SDG 8 and attempts to provide guidance for other countries that are eager to achieve stronger economic growth. In our analysis, we focus on the roles of international trade and foreign direct investment (FDI), which have contributed significantly to development in East Asian countries.

We begin by presenting some facts about East Asia's rapid economic growth, and in the following sections, we analyze the role of foreign trade and FDI in achieving that growth.

East Asia has been an engine of economic growth for the world economy since the end of World War II although the main drivers of that growth have changed over time, shifting from Japan to the Newly Industrializing Economies, namely South Korea, Taiwan, Hong Kong, and Singapore, then to China, and the several member countries of the Association of Southeast Asian Nations (ASEAN), including Indonesia, Malaysia, Thailand, Vietnam, and the Philippines. As shown in Fig. 11.1, economic growth measured by the annual growth rate of gross domestic product (GDP) for East Asia has been higher than the rest of the world in the post-war period.

Rapid economic growth in developing East Asian countries has been accompanied by an improved quality of life. The number of people in poverty has declined significantly, based on declines in the percentage of people living below the poverty line for the East Asian countries for which data are available: China 66.3% (1990) to 0.5% (2016), Indonesia 68.5% (1984) to 2.7% (2019), Lao PDR 31.1% (1992) to 10% (2018), and Vietnam 52.3% (1992) to 1.8% (2018).[3] From 1960 to 2020, GDP per capita in current US dollars for East Asian developing countries increased approximately 90 times, and the gap in GDP per capita in USD between East Asian developing countries and high-income countries declined sharply from 46 times in 1990 to 5.3 times in 2020. A large number of job opportunities were generated over the period from 1991 to 2019, with the number of employed workers increasing from 1.22 billion to 1.37 billion before declining to 1.34 billion in 2020 due to the

[1] In this chapter, the term "East Asian countries" refers to developing countries in East Asia, specifically China, South Korea, and the members of the ASEAN: Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. It excludes Japan unless otherwise noted. Due to data availability, in some cases countries in the Pacific region are included.

[2] East Asia includes developing countries in East Asia and the Pacific.

[3] Data used in this paragraph are obtained from the World Bank's World Development Indicators online. Poverty here is defined as people living on less than US$1.9 a day in 2011 purchasing power parity USD.

COVID-19 pandemic. Life expectancy at birth rose from 45 in 1960 to 75 in 2019, while the infant mortality rate declined from 45 per 1000 births in 1990 to 12 in 2019.

Various factors have been identified as drivers of the rapid economic growth in East Asia,[4] including high savings and investment, sound macroeconomic policies, highly educated and dedicated workers, a well-functioning infrastructure, and others. Among these, outward-oriented development strategies such as import liberalization and export promotion, which are discussed later in this chapter, played an important role in achieving rapid economic growth.

Despite sharing the common characteristic of rapid economic development and growth, the East Asia region is a collection of diverse countries not only in economic terms but also in noneconomic aspects. The countries are diverse in size (measured in terms of GDP, population, and land area), level of economic development, and endowment of natural resources. Among East Asian countries, China has the largest population, GDP, and land area, while Brunei has the smallest population (3/10,000th the size of China) and GDP (8/10,000 as large as China), and Singapore is the smallest in terms of land area (8/100,000th of China). Among East Asian countries, Singapore has the highest income per capita and Myanmar has the lowest (1/50th of Singapore). Similarly, there is diversity with respect to noneconomic aspects such as religion, culture, and political system. It should be noted that the diverse economic characteristics found in East Asia have led to an interesting and unique economic development pattern, which we discuss later in this chapter.

The remainder of this chapter is structured as follows. Section 11.2 discusses the role of foreign trade and FDI in achieving rapid economic development and growth, with a focus on global value chains (GVCs) created through FDI by multinational corporations (MNCs). Section 11.3 examines the changing environment with respect to trade and investment policy in East Asia, which has seen an emergence of free trade agreements (FTAs). Section 11.4 concludes and provides several policy implications that would be helpful for other developing countries seeking to achieve economic development and growth. It also discusses challenges for East Asia to achieve inclusive growth.

11.2 Nexus of Trade and Investment and Global Value Chains

One of the notable characteristics of the economic growth pattern in East Asia is the rapid expansion of trade and FDI during the period of high economic growth. According to Fig. 11.2, the ratio of trade (exports and imports) to GDP rose from 50% in 1980 to a high of 78% in 2006 before starting to decline, reaching 42% in 2020. This decline is mainly due to China's influence, which expanded domestic production and sales substantially as a result of its rapid economic growth. Somewhat in contrast to the pattern observed for the trade-to-GDP ratio, the ratio of inward FDI stock to GDP increased throughout the period 1980–2020, with some fluctuations, rising from 3% in 1980 to 26% in 2020. As we discuss more in detail later, trade and FDI increased more or less in tandem by interacting with each other.

11.2.1 Expansion of Intra-regional and Machinery Parts Trade

International trade in East Asia has experienced several notable structural changes. First, intra-regional trade, which refers to trade among East Asian countries, has expanded rapidly. The ratio of intra-regional trade to overall trade for East Asia increased from 25.7% in 1985 to 37.2% in 2012 and then declined slightly to 34.9% in 2019 (Fig. 11.3).[5] Within East Asia, China has become an important source of import and a significant export destination for many East Asian countries. For China, the importance of

[4] See, for example, the World Bank (1993) and Asian Development Bank (2020).

[5] In Fig. 11.3, East Asia includes Japan.

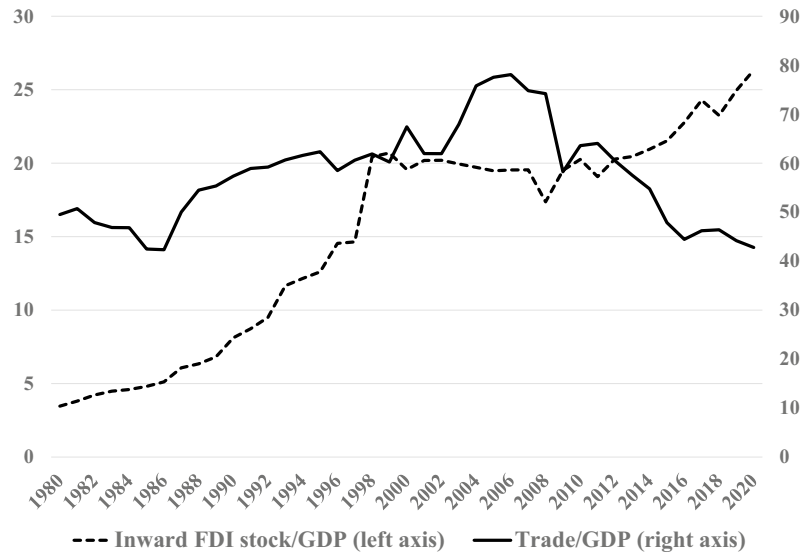

Fig. 11.2 Trade and inward FDI (% of GDP). *Source* World Bank, World Development Indicators online, UNCTAD, UNCTADstat online

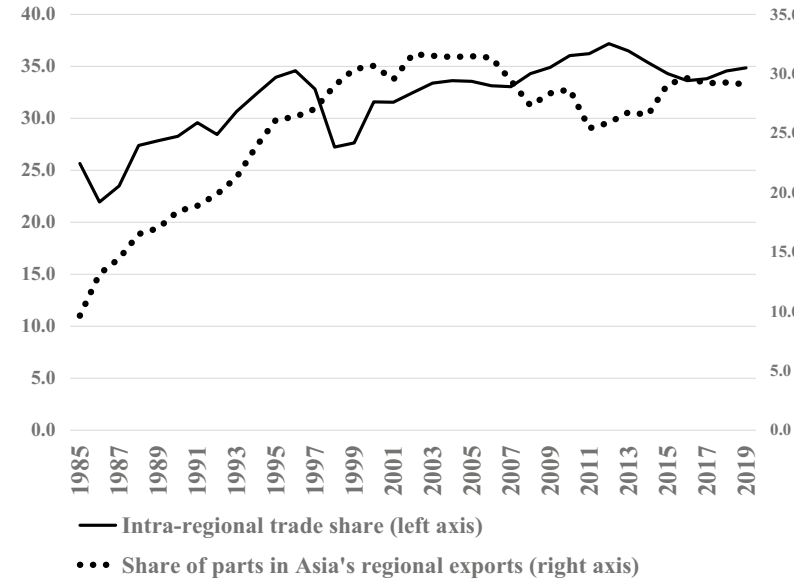

Fig. 11.3 Intra-regional trade and parts trade as shares in total trade in East Asia (%). *Source* Computed from RIETI-TID database

countries outside of East Asia, such as the US and the European Union (EU), has also increased. This rapid expansion of intra-regional trade can be explained mainly by the rapid economic growth of East Asian countries. It is natural for a rapidly growing country to increase its demand for imports and its ability to supply exports, leading to an expansion of trade. However, it should also be noted that GVCs in East Asia, formed through FDI by multinational corporations (MNCs), also contributed to an expansion of intra-regional trade, as will be discussed later in this chapter.

Second, the product composition of trade for East Asian countries changed significantly. Specifically, the importance of manufactured products increased significantly for many countries in the region, which is attributable to successful industrialization. Specifically, the share of manufactured exports to total merchandise exports for East Asia's developing countries increased sharply from 27% in 1985 to 85% in

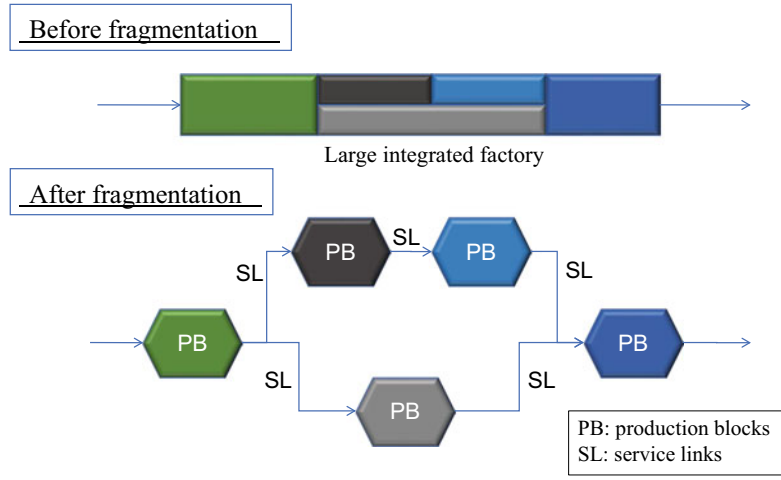

Fig. 11.4 Fragmentation strategy. *Source* Kimura et al. (2010)

2005 and remained at that level through 2020. Among manufactured exports, exports of machinery products, particularly electric and electronic machinery and their parts, expanded markedly (Fig. 11.3).

These two notable developments regarding international trade in East Asia, namely increases in intra-regional trade and parts and components trade, are the result of regional production networks known as GVCs, created by MNCs.

11.2.2 Formation of Global Value Chains

Japanese MNCs that use a large number of parts and components began to establish factories in East Asia, in the early 1980s, undertaking FDI to take an advantage of low production costs. This process of internationalizing production was accelerated by a sharp appreciation in the Japanese yen in the mid-1980s, which increased the cost of Japanese products in foreign markets. Many Japanese MNCs implemented a fragmentation strategy, in which an integrated production system is fragmented into a number of production blocks. Each block specializes in producing one or a few specific parts, and the production blocks are connected by service links (Fig. 11.4), creating GVCs. MNCs in South Korea and Taiwan followed Japan's MNCs in implementing a fragmentation strategy as those countries' currencies appreciated. In implementing a fragmentation strategy, MNCs set up factories for part production in countries where those parts can be produced at a low cost. Through these GVCs, MNCs can achieve efficient production systems, in which production factors, such as labor, capital, and technology, are allocated and used efficiently.

Next, we examine how deeply East Asian countries are involved in GVCs. There are several ways to measure the extent of a firm's or county's participation in GVCs. One is to use information about a firm's transaction pattern. If a firm imports inputs and exports outputs, it is considered a participant in one or more GVCs. Another approach is to use information on international trade and production at sector level. More specifically, data on value-added trade constructed from world input–output tables are used to measure the extent of GVC participation by country.[6] In this approach, GVC participation is generally assessed by two approaches, namely backward and forward participation. Backward participation refers to the ratio of the "foreign value-added content of exports" to the country's total gross exports.[7] This is the "buyer" perspective or sourcing side of GVCs, in which a country imports intermediate

[6] See, for example, the World Bank (2020) for useful information about GVCs with respect to economic development.

[7] Adopted from WTO (2016).

inputs to produce its exports. Forward participation refers to the ratio of the "domestic value-added sent to other countries relative to the country's total gross exports. It captures the domestic value-added contained in inputs sent to other countries for further processing and exporting through various value chains. This is the "seller" perspective or the supply side of GVCs. Total GVC participation is the sum of backward and forward participation.

Figure 11.5 shows GVC participation rates for ASEAN countries, China, Japan, and Korea (ASEAN+3 countries) in 1980 and 2018. Many countries increased the level of GVC participation, although there are some countries that experienced a decline in GVC participation. Singapore, Malaysia, and the Philippines show very high GVC participation rate, while Cambodia, Lao PDR, and Myanmar exhibit low GVC participation rate. Magnitude of backward and forward GVC participation rates reveals interesting patterns of GVC participation of a country. Countries with relatively high share of backward participation such as Singapore and Malaysia engage in assembling final products by importing intermediate goods. We may divide countries with relatively high share of forward participation into two groups. One group of countries includes Brunei, Indonesia, Lao PDR, and Myanmar, while the other group consists of China and Japan (1980). Countries in the first group mainly export raw materials, while those in the second group mainly export manufactured or processed intermediate goods such as parts and components. One cannot make judgment a priori as to which type of participation, high share of backward participation or forward participation, contributes more to economic growth. Having said this, one may observe that countries with high share of manufacturing tend to grow fast compared to those with high share of raw materials sector.

11.2.3 Benefits of GVC Participation

In the early stages, GVCs were formed by MNCs to involve their foreign subsidiaries; over time, they expanded to include local companies. GVCs have brought many benefits to their participating companies and the countries in which they operate.[8] By participating in GVCs, local firms are able to import high-quality raw materials and components, which they use to produce and export their products. This export expansion not only increases production and employment, but also improves production efficiency and strengthens competitiveness. It is particularly important that superior technologies and management know-how owned by MNCs are transferred to the participating local companies through these GVCs. To make this technology transfer possible, it is essential that local companies that participate in GVCs have capable employees with technological knowledge and managers who understand the importance of technology.

Another benefit of participating in GVCs is that their robustness and resilience limits damage to the production system that may be caused by various factors. Crises caused by natural disasters, such as the Great East Japan Earthquake and the floods in Thailand in 2011, and the COVID-19 pandemic in 2020–2021, disrupted GVCs and suspended the production of parts and final products, causing economic damage to many companies and countries. In such situations, GVCs' vulnerability and the way in which these negative effects propagate were considered problematic. However, experience shows that most GVCs were not greatly damaged and in fact are quite robust. Furthermore, when GVCs were seriously damaged, they recovered rapidly and rebuilt, and their resilience was recognized. To contend with the risk of GVC fragmentation, rather than retreating to integrated production, system diversification is considered to be an effective countermeasure. As deepening and expanding GVCs are seen as important for promoting future economic growth in East Asia and Japan, this issue will be discussed later.

[8] On the benefits of GVC participation, see, for example, World Bank (2020) and Urata and Baek (2021).

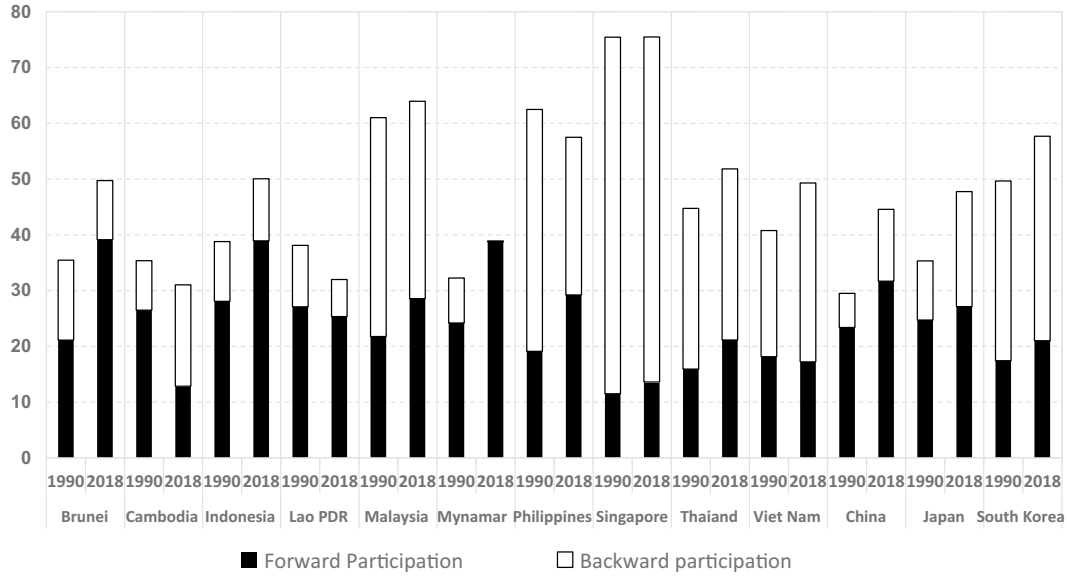

Fig. 11.5 GVC participation in selected East Asian countries. *Source* UNCTAD, GVC Database

11.2.4 Factors Leading to the Formation of GVCs

The factors that led to the formation of many GVCs by MNCs in East Asia may be classified into two groups. The first group consists of supply-side factors from the perspective of MNCs, and the other contains demand-side factors from the standpoint of the East Asian countries that hosted them. As noted above, a major realignment in foreign exchange rates encouraged MNCs to relocate production from their home countries (e.g., Japan and South Korea) to developing countries in East Asia, to achieve low-cost production. Accumulated international business experience in exporting and importing businesses contributed to MNCs' ability to create and manage GVCs. In addition, major reductions in the cost of communication and transportation services, attributable to technological innovations such as the development and the propagation of the Internet in the telecommunications arena and the development of large ships for transportation, as well as deregulation in both of those sectors, played an important role.

Turning to demand-side factors, we consider two types: those pertaining to local firms participating in GVCs and those originating in GVCs' host countries. Starting with the factors related to local firms, the number of local firms with technical and managerial capabilities in East Asia has been increasing. In their study of GVC participation by firms in Asia, Urata and Baek (2020) find that competitive local firms can successfully participate in GVCs. However, many firms are not able to handle the processes or complete the tasks within the GVC network needed to produce the products to be exported to foreign countries. Competitiveness among local firms reflects various factors such as the high labor productivity, uniqueness or high quality of their product or task, low-cost production capabilities, and others. To possess competitiveness, firms need educated, trained, and high-skilled workers; capable and ambitious managers; high-quality technology; and imported inputs. Having links to MNCs, access to technology, capital, and information about foreign markets helps firms to improve their competitiveness. Local firms' competitiveness is reflected by international certifications such as ISO. As such, possessing international certifications facilitates firms' participation in GVCs.

Regarding the factors concerning the GVCs' host countries, Urata (2021) found that compared to other developing countries, many East Asian

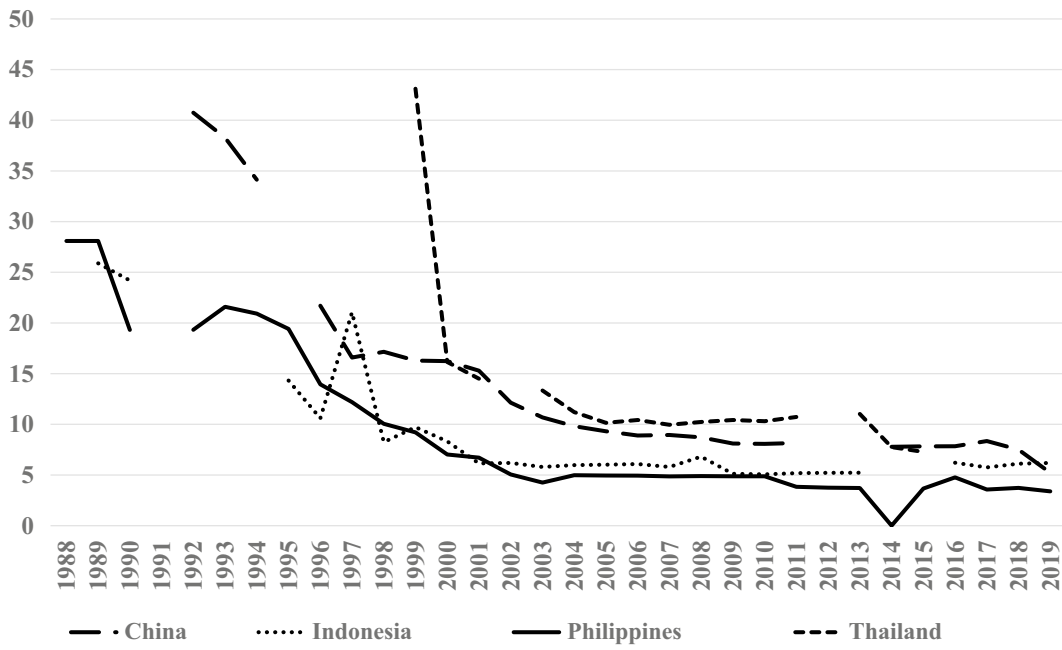

Fig. 11.6 Changes in tariff rates (%). *Source* World Bank, World Development Indicators online

countries have established a business environment that is open to trade and FDI inflows, with an abundance of educated and disciplined workers, financial resources, technology and information with respect to foreign markets, and a well-developed infrastructure. Figure 11.6 shows tariff rates on manufacturers have declined for selected East Asian countries, reflecting the trade liberalization policies they have adopted. Infrastructure, which plays an important role in promoting economic activity, is a rather broad concept that may be divided into soft and hard infrastructures. Soft infrastructure includes educational, regulatory, and legal systems, while hard infrastructure includes transportation and communication systems. Having an efficient public sector refers to government and business associations that facilitate firms' participation in GVCs.

These findings reinforce the importance of government policies in promoting GVC participation. Governments can help local firms participate in GVCs in various ways, including technical and financial support that helps firms upgrade their technology and marketing support that disseminates information on foreign markets to the firms. Governments are also advised to establish a business-friendly environment, characterized as open, fair, transparent, and rules-based with respect to trade and FDI. One effective way for governments to achieve this objective is to join FTAs, which we discuss in the next section. Governments can also play an important role in building soft and hard infrastructure that can contribute not only to attracting MNCs to involve local firms in their GVCs, but also to provide the building blocks that are fundamental to achieving economic growth. To the extent possible, governments should leverage economic assistance provided by foreign donor countries, international organizations, and other sources to supplement their own efforts.

11.3 Regional Economic Integration in East Asia[9]

East Asia witnessed a rapid expansion of intra-regional trade during the late 1980s and 1990s, resulting in de facto regional economic integration.

[9] This section updates and modifies Urata (2019, 2022). See also Urata (2014) on regional integration in East Asia.

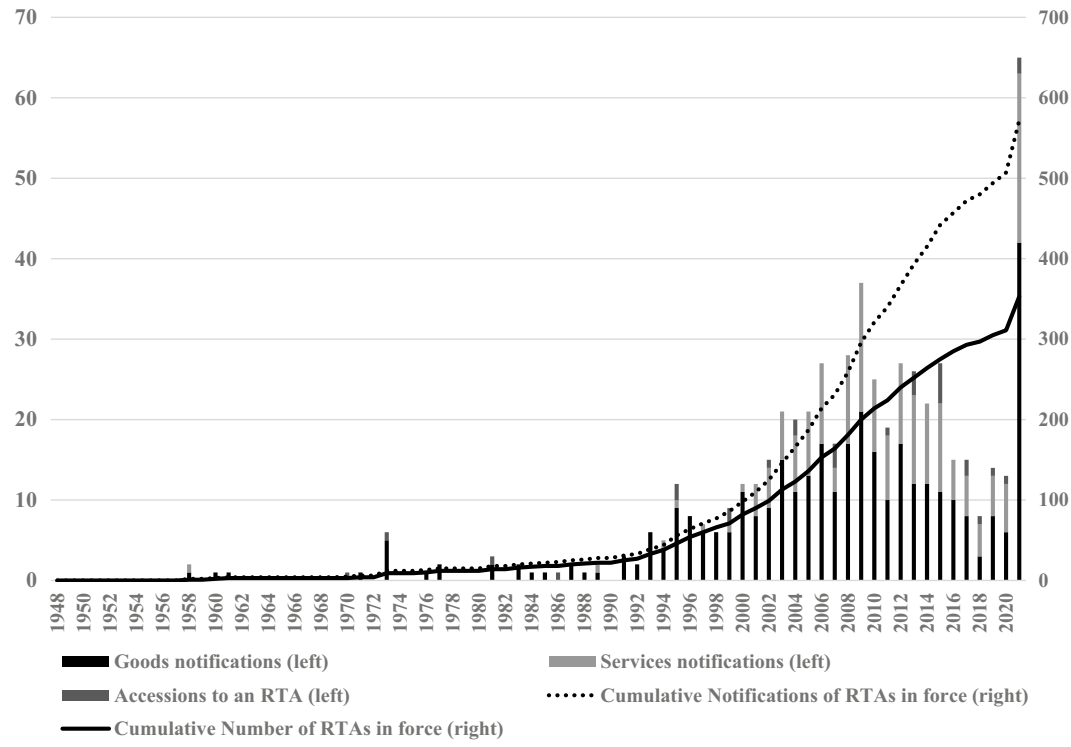

Fig. 11.7 Regional trade agreements (RTAs) in the world.[12] *Source* World Trade Organization, RTA database

As discussed in the previous section, the formation of regional production networks or GVCs by MNCs drove this integration. The development of GVCs contributed to economic growth, which in turn further liberalized trade and FDI policies, resulting in greater and deeper regional economic integration. Because of the increased importance of market forces in forming regional economic integration, which results from allowing more open trade and FDI policies, such integration is characterized as market-driven regional economic integration.[10]

In the latter half of the 1980s, the movement toward institutionalized regional economic integration (institution-driven regional economic integration) gained momentum in various regions of the world (Fig. 11.7). In Europe, the movement that started in the 1950s accelerated: The European Single Market was established in 1992, the EU in 1993, the European Central Bank in 1998, and the single currency, the euro, was introduced in 1999. In North America, the US-Canada Free Trade Agreement came into effect in 1989, followed by the North American Free Trade Agreement between the US, Canada, and Mexico in 1994. One important reason for this institution-driven economic integration was the slow progress in trade liberalization negotiations that were part of the General Agreement on Tariffs and Trade (GATT) under the so-called Uruguay Round, which began in 1986.[11] Faced with stalled negotiations for GATT, countries interested in trade liberalization to promote economic growth opted to sign FTA with like-minded countries, which promoted regional economic integration.

[10] See Urata (2004) for discussions on market-driven and institution-driven regional economic integration in East Asia.

[11] The Uruguay Round began in 1986 with the goal of completing negotiations in four years. However, the negotiations involved many difficult issues and agreement was not reached until 1994.

[12] Regional trade agreements (RTAs) include FTAs and customs unions.

Compared to other regions of the world, East Asia has been slow to develop institution-driven regional economic integration.[13] The first major regional economic integration in East Asia was the ASEAN Free Trade Area (AFTA), created by the ASEAN member countries (Brunei, Indonesia, Malaysia, the Philippines, Singapore, and Thailand) in 1993. Two external factors prompted AFTA's formation: the development of regional economic integration in other parts of the world and the rise of China. These forces had reduced ASEAN's importance as an investment destination and were negatively impacting its economic development. The ASEAN countries sought to improve the region's attractiveness as an investment destination by integrating their markets through AFTA, which was completed by 2015. ASEAN then created the ASEAN Economic Community to deepen economic integration in the region.[14]

In the latter half of the 1990s, support for regional economic integration on an institutional level that would encompass the countries of the East Asia region emerged. This movement developed along two tracks: one by the East Asian countries and the other by the Asia–Pacific countries. In the remaining sections, we present an overview of the developments along each track and examine the possible impacts of regional economic integration on an institutional level on economic growth in East Asian countries.

11.3.1 East Asia Track

In the early 1990s, then Malaysian Prime Minister Mahathir proposed the formation of a regional economic integration that would encompass the countries of East Asia. The idea was inspired by movements toward regional economic integration in Europe and North America, but it was not until the beginning of the twenty-first century that the effort began in earnest. Here, we review the development of bilateral or plurilateral FTAs in East Asia and then analyze the trends in regional FTAs in the region.

At the start of the twenty-first century, a number of bilateral FTAs were established by East Asian countries, starting with the Japan-Singapore FTA that came into effect in 2002. Singapore, Japan, and South Korea began to actively engage in FTAs but China showed no interest in participating. After China joined the World Trade Organization (WTO) in 2001 and secured access to the world market, it began to use FTAs to advance its regional presence in Asia. China's FTA policy was different from those of other countries. First, while Japan and South Korea began their FTA participation through bilateral FTAs, China chose all ASEAN countries as its first FTA partners. Second, the China-ASEAN FTA included content that was not included in other FTAs. For example, China offered preferential treatment, including economic cooperation, to the new member countries of ASEAN, namely Cambodia, Lao PDR, Myanmar, and Vietnam, which were lagging in their economic development compared to the original AFTA members. China's FTA strategy included both economic objectives, such as expanded trade, and political objectives such as building friendly relations with neighboring countries. The China-ASEAN FTA came into effect in 2005, generating a domino effect; by 2010, Japan, South Korea, Australia, New Zealand, and India had individually ratified FTAs with ASEAN (the so-called ASEAN+1 FTA).

The movement toward forming regional economic integration within the East Asian region was triggered by the Asian currency crisis that occurred in 1997 and 1998. East Asian countries that suffered serious economic consequences from the currency crisis recognized the need for regional economic cooperation to recover and to avoid a recurrence and considered an East Asia FTA (EAFTA) with ASEAN, China, Japan, and South Korea (ASEAN+3) as one form of regional economic cooperation. The idea of regional

[12] Regional trade agreements (RTAs) include FTAs and customs unions.

[13] See Urata (2014, 2016) on regional economic integration in East Asia.

[14] See ERIA (2014) for a detailed analysis of ASEAN's economic integration.

economic integration in East Asia was accelerated by the growth of regional economic integration in the rest of the world. The plans for EAFTA began in 2005, with China taking the lead. In 2006, Japan proposed the Comprehensive Economic Partnership in East Asia (CEPEA), which would consist of ASEAN+6, namely ASEAN+3 countries, Australia, New Zealand, and India. It was clear that the backdrop to EAFTA and CEPEA was the rivalry between Japan and China for regional economic integration in East Asia.

The feasibility studies for EAFTA and CEPEA were conducted in parallel until 2011, when Japan and China proposed establishing a joint working group to accelerate the discussions. Underlying the proposal to establish the joint working group made by Japan and China, which had been battling for leadership in establishing a regional FTA, was China's desire to create an East Asian regional FTA that excluded the US without being bogged down in debates about EAFTA versus CEPEA while the Trans-Pacific Partnership (TPP) negotiations, as discussed in the next section, progressed. The joint proposal from China and Japan created a sense of crisis for the ASEAN countries, which had a strong interest in playing a central role in regional integration in East Asia. ASEAN proposed the Regional Comprehensive Economic Partnership (RCEP) in 2011 to counter the move by Japan and China. RCEP is an ASEAN-centered framework, in which any country that has concluded an FTA with ASEAN can participate, rather than a framework that fixes the member countries as in EAFTA and CEPEA.

Although ASEAN+6 declared the start of RCEP negotiations in November 2012, the actual negotiations did not begin until May 2013. RCEP members realized the need to start their negotiations after Japan formally announced it would join the TPP negotiations in March 2013. The RCEP negotiations were contentious, and the target date for agreement was repeatedly pushed back. India withdrew from the final stage, and the agreement was reached in November 2020. Several reasons for India's withdrawal have been offered. One is that India feared that trade liberalization through RCEP would not only increase its trade deficit with China, but it would also be a major blow to India's manufacturing sector, given the country's large trade deficit due to its large volume of Chinese manufactured product imports. Another is the concern about a negative impact on India's agriculture sector, as low-priced agricultural products from Australia and New Zealand would increase substantially. RCEP is scheduled to enter into force on January 1, 2022, now that the requirements for enactment have been fulfilled. RCEP faces several challenges, including monitoring to ensure that the members comply with the agreement and their commitments. Another is to improve the quality of the agreement, as discussed in Sect. 11.3.3.

11.3.2 Asia–Pacific Track

Discussions on the formation of a framework for economic integration that would encompass the Asia–Pacific region began in the 1990s with some countries participating in the Asia–Pacific Economic Cooperation forum (APEC). Established in 1989 by the economies[15] located in the Asia–Pacific region, its main objective is to achieve economic growth by promoting regional economic integration through trade and investment liberalization. Due to differences in the approaches and priorities of the various economies involved, movement toward liberalization of trade and investment did not progress as hoped. Therefore, Chile, Singapore, New Zealand, and Brunei, all of whom were interested in a high degree of trade and investment liberalization, established the Trans-Pacific Strategic Economic Partnership Agreement (P4) in 2006. The purpose of P4 is to create a free and open business environment and to help realize APEC's goal of achieving a free and open environment for trade and FDI. The founding members hoped

[15] The word "economies" is used to describe APEC members because the APEC cooperative process is predominantly concerned with trade and economic issues, with members engaging with one another as economic entities.

that by accepting new members, P4 would become the basis for a larger regional FTA.

In March 2008, the P4 members began negotiations to expand the scope of the agreement to include financial services. P4 was described as a living agreement because it was open to amendments based on the demands and wishes of businesses in its member countries even after it entered into force. The US, which had a strong interest in liberalizing cross-border activities in the financial services sector, decided to participate in the expanded P4 negotiations in September 2009. Following the announcement by the US, Australia, Peru, and Vietnam also announced their intention to participate in the negotiations. During this period, P4 was renamed as the TPP. It has been said that the US participated in TPP negotiations to avoid being excluded from East Asia, whose economies were projected to grow rapidly and were increasingly moving toward regional integration on an institutional level.

In the 2010s, the move toward regional economic integration on the institutional level gained momentum. Negotiations for an expanded TPP that included eight countries—Brunei, Chile, New Zealand, Singapore, Australia, Peru, the US, and Vietnam—began in March 2010. Four more countries joined after the start of negotiations: Malaysia (in October 2010), Canada and Mexico (in 2012), and Japan (in 2013). It is unusual for new countries to join after negotiations have begun, and this indicated the importance of the TPP. The negotiations took five years and seven months, culminating in an agreement in October 2015. The TPP agreement was signed by the negotiating parties in February 2016, and the 12 countries involved began the process of ratifying the agreement. However, the conditions for the agreement to enter into force were abrogated when US President Trump took office in 2017 and withdrew from the TPP. As a result, the agreement is no longer in effect.

Although the US withdrew from the TPP, the remaining TPP countries decided to establish TPP11 without the US. Negotiations were completed in a short period of time, and the agreement was signed in March 2018. TPP11 entered into force in December 2018 as the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP). To date (December 2021), the agreement has been ratified by all signatories except Malaysia, Brunei, and Chile. There are a number of possible reasons the TPP11 members promoted the agreement. First, as a continuation of the original TPP (see the next section), the CPTPP includes comprehensive sectoral rule-building and a high degree of trade and investment liberalization, and its members expect it to stimulate economic activity that will promote economic growth. Second, the CPTPP is a high-level, comprehensive FTA that will serve as a model for future FTAs. Third, the CPTPP is expected to curb and reverse the protectionism that has emerged since the 2007–2008 global financial crisis. Fourth, as there is a possibility that the US will seek to return to the TPP in the future, the CPTPP must be brought into force to prepare for such a situation. The CPTPP is attracting considerable attention, as evidenced by the UK's application for membership in February 2021, followed by applications from China and Taiwan in September 2021.

11.3.3 CPTPP and RCEP

Both the CPTPP and RCEP contain comprehensive content aimed at promoting regional integration and achieving economic growth through increased trade and investment, with a particular emphasis on expanding GVCs. An important benefit of both agreements is that common rules will be applied to trade and investment for many of the participating countries, thereby avoiding the "spaghetti bowl" effect of restraining trade that results from a mix of FTAs between two countries that have different rules, or have a small number of participating countries. This emphasizes that RCEP is much more than just a combination of four ASEAN+1 FTAs and ASEAN's FTAs with China, Japan, South Korea, and Australia-New Zealand, in one framework.

While the CPTPP and RCEP share a common goal of economic growth, there are important

differences: The RCEP focuses on economic development, not just economic growth; the CPTPP emphasizes the importance of active private sector involvement in achieving economic growth, while the RCEP emphasizes the importance of economic cooperation in achieving equitable and inclusive economic development. The RCEP includes countries in the early stages of development, such as Cambodia, Lao PDR, and Myanmar, and emphasizes economic cooperation because economic development in these countries is important for the region's sustainable development and social stability. Specifically, the RCEP allows for preferential treatment of countries in the early stages of development, while the CPTPP treats all members equally and does not allow for special treatment.

Both the CPTPP and RCEP are more comprehensive than the WTO (Table 11.1); however, they differ in the items they cover. The agreements cover many common issues, such as market access for trade in goods and services, trade facilitation, and intellectual property rights, but they differ on important issues. Important items addressed in the CPTPP but not the RCEP are state-owned enterprises and designated monopolies, labor, environment, regulatory coherence, transparency, and anti-corruption. While these aspects of the CPTPP are important to developed countries such as Japan and Australia in order to maintain a level playing field across firms and achieve sustainable economic growth, developing countries find them difficult to accept. For example, the regulations do not allow preferential policies for state-owned enterprises, which is difficult for developing countries where government involvement in the economy is significant. Importantly, the CPTPP includes rules that protect and promote workers' rights: requiring freedom of association and collective bargaining, forbidding child labor, forced or compulsory labor, and discrimination in employment and occupations, helping to achieve some of the goals of SDG 8, namely to promote productive employment and decent work.

Some items are common to both agreements but differ in content and degree of discipline. One clear example of this is in the liberalization of trade in goods (market access), where the CPTPP eliminates almost all tariffs on all products (100% tariff elimination rate), with a few exceptions. In the RCEP, tariff elimination varies among countries and the average rate is roughly 90%, lower than in the CPTPP. There is also a major difference in the area of e-commerce, which is attracting attention as it regulates the international movement of data that is becoming increasingly important in the global economy. The CPTPP includes the following three principles of the TPP: (1) ensuring freedom of cross-border transfer of information by electronic means, (2) prohibiting requests to install and/or use computer-related equipment, and (3) prohibiting the transfer of and requests for access to source code, with the aim of ensuring the free movement of data. In contrast, items (1) and (2) are included in the RCEP, but (3) is excluded. In addition, the content of (1) and (2) is less rigid in the RCEP, not only because exceptions are allowed for national security and other reasons, but also because they are not subject to dispute settlement procedures.

Some believe that the CPTPP and RCEP are competitors because the US took the lead in negotiating the CPTPP's predecessor, the TPP, and showed a strong desire to exclude China, while the RCEP includes China but not the US. However, as there are considerable differences between the two agreements in content and the degree of discipline, they are considered to be complementary, rather than conflicting or competing. The two agreements can be viewed as presenting a phased opportunity for countries that cannot join the CPTPP due to its high level of discipline to first join the RCEP and then join the CPTPP when the higher level of discipline imposed by the CPTPP becomes acceptable. Beyond the RCEP and CPTPP, the Free Trade Area of the Asia–Pacific (FTAAP), which encompasses the Asia–Pacific region, was agreed upon at the APEC summit in Yokohama, Japan, in 2010 as the ultimate goal of regional integration in the Asia–Pacific region.

Table 11.1 CPTPP, RCEP, and WTO

	CPTPP	RCEP	WTO
Market access for goods	●	●	●
Rules of origin and origin procedures	●	●	●
Textiles and apparel	●	●	●
Customs administration and trade facilitation	●	●	●
Trade remedies	●	●	●
Sanitary and phytosanitary measures	●	●	●
Technical barriers to trade	●	●	●
Investment	●	●	▲
Cross-border trade in services	●	●	●
Financial services	●	●	●
Temporary entry for business persons	●	●	▲
Telecommunications	●	●	●
Electronic commerce	●	●	
Government procurement	●	●	▲
Competition policy	●	●	
State-owned enterprises and designated monopolies	●		
Intellectual property	●	●	●
Labor	●		
Environment	●		
Cooperation and capacity building	●	●	
Competitiveness and business facilitation	●		
Development	●		
Small and medium-sized enterprises	●	●	
Regulatory coherence	●		
Transparency and anti-corruption	●		
Administrative and institutional provisions	●	●	
Dispute settlement	●	●	●

Note ● indicates the issue is covered, and ▲ is partially covered
Sources CPTPP and RCEP texts

11.3.4 Economic Impacts of Regional Economic Integration

Regional economic integration in the form of FTAs affects economic activity for both member and nonmember countries, mainly through its impacts on trade and investment. Here, we examine the economic impacts of FTAs, first from a theoretical perspective and then based on empirical analyses.

We can think of the effects of FTAs as static and dynamic.[16] Beginning with static effects, FTAs promote trade among FTA members (the trade creation effect), as tariffs on bilateral trade decline, and tend to reduce trade between members and nonmembers (the trade diversion effect), as some of their bilateral trade activities are likely to be replaced by trade among FTA members. FTAs give rise to these trade creation and

[16] For more detailed explanation, see textbooks on international economics such as Appleyard and Field (2017).

diversion effects because they give preferential access to the FTA partners' markets. A nonmember's economic welfare will decline because of the reduction in exports, while it is not known a priori whether the member country's economy will gain or lose. The member country gains from an expansion of trade, but loses from the reduction in tariff revenue. If the gain exceeds the loss, a member gains overall, but loses otherwise.

Turning to dynamic effects, FTAs may promote economic growth because expanded trade is likely to increase productivity through economies of scale and greater competition. An FTA member could gain from increased investment that may occur because the member country's future economic prospects are expected to improve. An FTA member may also expect an increase in FDI because many FTAs, including the CPTPP and RCEP, liberalize FDI policies. Expanded FDI inflows would lead to economic growth for FDI recipient countries.

With this theoretical understanding of the economic impacts of FTAs, we turn to an empirical analysis. Researchers conduct an ex-ante analysis of FTAs before they are enacted using a simulation based on economic models. The most popular model for analyzing FTAs is the computable general economic (CGE) model, which mimics a real economy based on market mechanisms by considering consumers, producers, and governments. A typical CGE model covers all sectors of an economy (typically represented by 15–30 sectors) and the world (generally represented by 20–50 countries and regions). An ex-post analysis is conducted after FTAs are enacted to examine their impact on trade. A typical approach is to apply the gravity model, which attempts to explain the magnitude of bilateral trade using the economic size of two countries and the geographical distance between them. The name comes from physics, specifically Newton's Law of Gravity, which states that the gravitational force between two bodies is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. We first consider studies that examine the economic impacts of the CPTPP and RCEP using a CGE model and then review studies that examine the trade creation and diversion effects of AFTA using a gravity model.

Petri and Plummer (2020) simulate the economic impacts of the CPTPP and RCEP by projecting economic conditions in 2030 that reflect commitments required by those agreements, such as tariff reductions. The results of their analysis with respect to national income are shown in Table 11.2, with the figures for member countries shown in bold. Consistent with theoretical expectations, national income for members of the CPTPP and RCEP increases but declines for many nonmembers. The increases in national income are mainly due to the trade creation effect, while decline is primarily caused by the trade diversion effect. In the case of the CPTPP, Japan gains the most in absolute terms and China loses the most. With the RCEP, China gains the most while India (not shown in the table) loses the most. These opposite impacts for China clearly indicate that a country benefits from being a member of an FTA. Impacts on the US are very small.

The impacts are quite different when we consider the percentage change in national income, rather than the absolute change. With the CPTPP, Malaysia gains the most, and Japan and South Korea gain the most with the RCEP. One important factor that determines the gain for a given country is the tariff reduction that the country experiences for its exports, i.e., tariff reductions in its export destination countries. For example, the large gain that Japan obtains from membership in the RCEP is mainly due to a reduction of tariffs on its exports to China and South Korea, with whom free trade is established under the RCEP. For the same reason, ASEAN members see relatively small gains because they have already established free trade with other RCEP members such as China, Japan, and Korea under the ASEAN+1 FTA frameworks. It should be noted that the world as a whole gains from both the CPTPP and RCEP.

Turning to studies on the impacts of FTAs on trade using the gravity model estimation method, there are no comparable studies to those reviewed above that use the CGE model because the gravity model applies to ex-post data,

Table 11.2 Effects on real income, 2030 (USD billion, %)

	Incremental change		Incremental percent change	
	CPTPP	RCEP	CPTPP	RCEP
Asia	69	164	0.1	0.3
Brunei	**1**	**0**	2.6	**0.5**
China	−10	**85**	0.0	**0.3**
Indonesia	−1	**3**	−0.1	**0.1**
Japan	**46**	**48**	**0.9**	**1.0**
South Korea	−3	**23**	−0.1	**1.0**
Malaysia	**21**	**4**	**3.1**	**0.6**
Philippines	0	**2**	0.0	**0.3**
Singapore	**13**	**0**	**2.7**	**0.0**
Taiwan	0	−3	0.0	−0.4
Thailand	−5	**4**	−0.6	**0.5**
Vietnam	**11**	**3**	**2.2**	**0.5**
Oceania	**15**	**1**	**0.5**	**0.0**
America	49	2	0.1	0.0
United States	−2	1	0.0	0.0
Europe	12	13	0.0	0.1
World	147	186	0.1	0.1

Note Figures of the CPTPP/RCEP members are shown in bold letters
Source Petri and Plummer (2020)

whereas the CGE model is used in ex-ante studies. The CPTPP entered into force in December 2018, and the RCEP has yet to be enacted; therefore, there is not yet sufficient data for a gravity model analysis of these FTAs. As a result, our discussion of gravity model studies is rather general. A large number of studies that use the gravity model have analyzed the impacts of FTAs on trade. The results are mixed in that some studies found positive impacts, i.e., the trade creation effect, while others did not.

Bair and Bergstrand (2007) conducted a rigorous analysis by addressing econometric problems encountered in earlier studies and found that on average the bilateral trade between two members under an FTA approximately doubles after 10 years. Okabe and Urata (2014) conducted one of the few studies on FTAs in Asia by analyzing the impact of the AFTA. They found the trade creation effect for a wide range of products and that such trade creation effects are relatively small for the newer ASEAN members compared to the original members. Based on these results, they claim that AFTA was successful in promoting intra-ASEAN trade. In their study of the trade creation and trade diversion effects of FTAs covering 20 products, Urata and Okabe (2013) found that FTAs among developed countries generate trade creation effects for many products, while the trade diversion effect was not found except for medical and pharmaceutical products. In contrast, FTAs among developing countries generate trade creation effects in fewer products but give rise to trade diversion for many more products when compared with FTAs among developed countries. They also found that plurilateral FTAs give rise to trade creation for many more products compared to bilateral FTAs.

Empirical studies of the economic impacts of FTAs have shown that FTA members tend to benefit in terms of increased trade and economic growth, while nonmembers are likely to lose in both respects. These findings indicate that countries should join FTAs to help them achieve

economic growth; however, this is not an optimal situation for the world economy as a whole, because FTAs give rise to trade diversion. The optimal situation would be free trade among all countries. Since achieving free trade around the world is unlikely in the current environment where the WTO is not functioning effectively to liberalize trade, the second-best policy may be to expand the membership of existing mega-FTAs such as the CPTPP and RCEP, with the goal of eventually covering all countries, thereby achieving global free trade.

11.4 Conclusions: Achieving Inclusive Economic Growth

This chapter examined the roles of foreign trade and FDI in achieving high economic growth in East Asia, in order to draw lessons for achieving sustainable economic growth (SDG 8). We noted the formation of GVCs through FDI by multinational corporations (MNCs) as a special characteristic of rapid economic growth in East Asia. Participation in GVCs has provided opportunities for East Asian countries to expand their foreign trade and obtain new technology, helping them to increase productivity and achieve strong economic growth. We emphasized the importance to East Asian countries of pursuing trade and FDI liberalization and constructing and managing hard and soft infrastructure to realize economic growth based upon participation in GVCs. To promote further economic growth and achieve higher levels of economic development, East Asian countries are advised to participate in mega-FTAs such as the CPTPP and RCEP to improve their business environment, which would expand and intensify GVCs.

Although East Asian countries have been successful in achieving rapid economic growth and improving the standard of living for their people, they face a number of challenges, including growing inequality, a deteriorating environment due to climate change, worsening relations between the US and China, a growing probability of infectious disease, and others. Here, we focus on the issue of inequality because it has been argued that the rapid expansion of trade and FDI—in other words, the globalization of economic activity—has significantly increased inequality. It is important to realize that greater inequality would deter economic growth as it would likely lead to political and social instability.

In discussing globalization and inequality, we need to differentiate between developed and developing countries, and this section takes the perspective of developing countries.[17] For many East Asian countries, growing income/asset inequality is a rather recent phenomenon. Indeed, for many decades expanding trade and FDI helped to reduce inequality in East Asia. From the 1980s through the early 2000s, East Asian countries increased exports of unskilled labor-intensive products such as clothing in large quantities, which generated a high demand for unskilled labor. This in turn led to a rise in wages for these workers, reducing the wage inequality between unskilled and skilled labor. The situation changed when MNCs began to undertake FDI in sectors such as electric and electronic machinery and transport equipment. MNCs brought technologies that require skilled labor, and introducing such technologies increased demand and therefore raising wages for skilled labor, widening the wage and income gap in East Asia.

Large FDI inflows resulted in a different kind of inequality problem, namely inequality between large firms and small and medium-sized enterprises (SMEs). MNCs are typically large firms that tend to have advantage over SMEs in terms of financial and human resources. This resource gap between large firms and SMEs not only leads to differences in their performance, but it also increases the wage/income gap between those working for large firms and those working for SMEs.

This growing income inequality must be addressed, and inclusive growth has to be achieved to realize the political and social stabilities necessary for sustainable economic

[17] See, for example, Urata and Narjoko (2017) for a detailed discussion on this issue.

growth (SDG 10, reducing inequality). This will require SMEs to improve the capabilities of their unskilled workers to stay competitive, which calls for more education and training. Public institutions/governments should provide education and training with respect to general skills and knowledge, while specialized skills and knowledge should be developed by specialized institutions or through on-the-job training. To improve SMEs' competitiveness, public institutions/governments should provide technical, financial, and marketing assistance. Furthermore, a policy to promote competitiveness for SMEs to address the risk of dominance of large firms over SMEs should be considered, to level the playing field. We emphasize that governments, as providers of assistance, must have capable personnel to identify the need of those who seek to benefit from that assistance and to apply appropriate measures so that various forms of assistance can be effective. It should be noted that assistance can be effective if it is provided in cooperation with the private sector. Finally, governments' own efforts are of utmost importance, but they should seek international cooperation with donors and international organizations.

Finally, we would like to reiterate the importance of constructing, maintaining, and managing soft and hard infrastructure (SDG 9), not only for the developing countries to participate in GVCs, but also for building the foundations for economic growth, more specifically, inclusive and sustainable economic growth.

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12 BoP Businesses of Multinational Corporations and Sustainability

Shinji Hasegawa

Abstract

Pessimism about the effects of official development assistance (ODA) on the poorest countries (base of the pyramid; BoP) has raised expectations of social business by multinational corporations (MNCs) since the end of the twentieth century. First, this chapter summarizes the historical developments focused on the role of MNCs in alleviating poverty at the BoP (Sustainable Development Goals [SDGs] 1, 3, and 6) through delivery of affordable products and services, following activities of non-governmental organizations, growing awareness of corporate social responsibility, and framing of development goals by United Nations agencies. Next, it discusses BoP's shift from its role as a marketplace to a production base or source of innovation, as MNCs have established global production networks. We argue that this has changed the BoP business toward contributing to the achievement of SDGs 5, 8, and 9. Finally, MNCs are required to address not only social challenges at the BoP, but also environmental challenges (SDGs 13) in both emerging and developed countries. To balance these overall SDG-related challenges with MNCs' own interests, BoP business is further evolving into SDG business management, and MNCs will be increasingly required to redefine their role from a sustainability perspective.

Keywords

Base/bottom of the pyramid (BoP) · Inclusive business · Multinational corporation (MNC) · Triple bottom line

12.1 Introduction

This chapter discusses the role that multinational corporations (MNCs) can play in addressing the social challenges faced by the poor in developing countries. Initially, MNCs' businesses with the poor started as targeting poverty alleviation by delivering products and services to them that they could afford: of the 17 Sustainable Development Goals (SDGs), Goals 1 (no poverty), 3 (good health and well-being), and 6 (clean water and sanitation) were their direct targets. Subsequently, however, there was a growing realization that other goals were also important social agendas for the poor, such as Goals 5 (gender equality), 8 (decent work and economic growth), and 9 (industry, innovation, and infrastructure), and that pursuing them would also serve MNCs' interests. This led to significant changes in MNCs' businesses in those countries. More recently, their businesses have even embraced

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environmental challenges, including Goals 13 (climate action), and are now developing into ambitious initiatives that encompass the broad areas of the SDGs on a global scale, including developed as well as developing countries.

12.2 What is the BoP Business?

The bottom of the pyramid (BoP) refers to those people who are regarded as the poorest in the socioeconomic strata, and the business activities of companies, particularly MNCs, targeting such people are called BoP businesses. Prahalad and Hart (1999, 2002) first introduced the term BoP, which placed the poorest people at the bottom of a pyramid structure based on socioeconomic stratification by income. Although the term BoP itself has not changed, the term "bottom" is considered to carry discriminatory overtones, and consequently, "base" is used more frequently instead. More recently, the United Nations (UN) and other international organizations have tended to prefer the term "inclusive business" instead of BoP business, arguing that using the term "base" or "bottom" to distinguish a business is not the way to solve related social problems.[1]

Specifically, the BoP is defined as a population group with an annual per capita consumption expenditure (or income) of less than $3000 in purchasing power parity (PPP) in 2002 (Hammond et al. 2007).[2] As Fig. 12.1 shows, there are 4 billion people at the BoP, representing 71.7% of the 5.575 billion people recorded by available national household surveys worldwide,[3] with an overall market size estimated to reach $5 trillion. At the middle of the pyramid (MoP), there are 1.4 billion people with income between $3000 and $20,000, representing 25.1% of the survey population. The top of the pyramid (ToP) comprises mature markets, mainly in the developed countries, with annual per capita income of over $20,000 and a population of 0.18 billion, or only 3.1% of the total surveyed. The area of each segment in the figure is shown according to its actual share, making it easier to understand how the BoP group accounts for a large part of the total, whereas the ToP is a tiny part.

Figure 12.2, which presents a bar chart showing the distribution of the population arranged according to actual income level (established from Free data from Gapminder.org: gapm.io/d_incm_v2), does not have a neat shape compared to the pyramid in Fig. 12.1. The upper part of the distribution is narrow due to the lowest number of high-income earners, and the lowest part is wide due to the highest number of low-income earners, with the population increasing at a non-proportional rate as it approaches the bottom. The vertical axis could be set much higher; however, it is limited to $100 a day in the interest of convenience and clarity.

Typically, a corporate BoP business is regarded as the business activity of a company that simultaneously satisfies the following three conditions:

1. People belonging to the BoP segment play one or more of the following roles: consumer, supplier, worker, producer, seller, or manager.
2. Business activities improve one or more of the social or environmental challenges faced by the BoP.
3. A private company or its subsidiaries carry out business activities to increase profits.

In other words, the corporate BoP business represents a form of "creative capitalism" (Kinsley and Clarke 2008), wherein business is

[1] According to UNDP, an inclusive business (model) is defined as "including the poor into a company's supply chains as employees, producers and business owners or develop affordable goods and services needed by the poor" (UNDP 2010).

[2] PPP is a ratio of currencies calculated so that the purchasing power (quantity of goods and services that can be purchased) of each currency is equal. An income of $3000 in PPP terms in 2002 means people with an income amount that would allow them to go to the USA in 2002 and make $3000 worth of purchases. This definition was given in a report prepared jointly by the World Bank Group's International Finance Corporation (IFC) and the World Resource Institute.

[3] Data are derived from national income and consumption surveys conducted by national statistics offices in 110 countries. See Appendix A in Hammond et al. (2007).

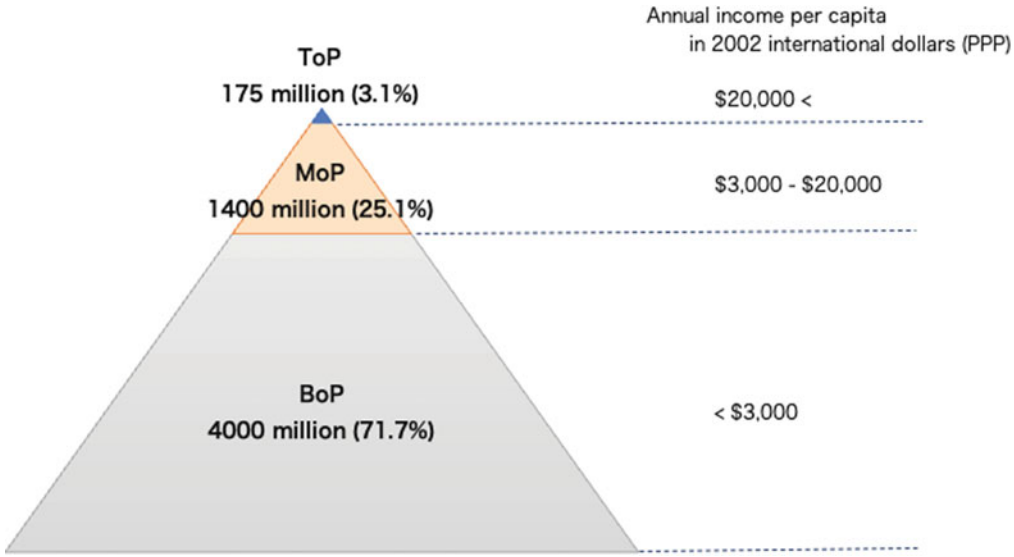

Fig. 12.1 Pyramid of the world's population by income group

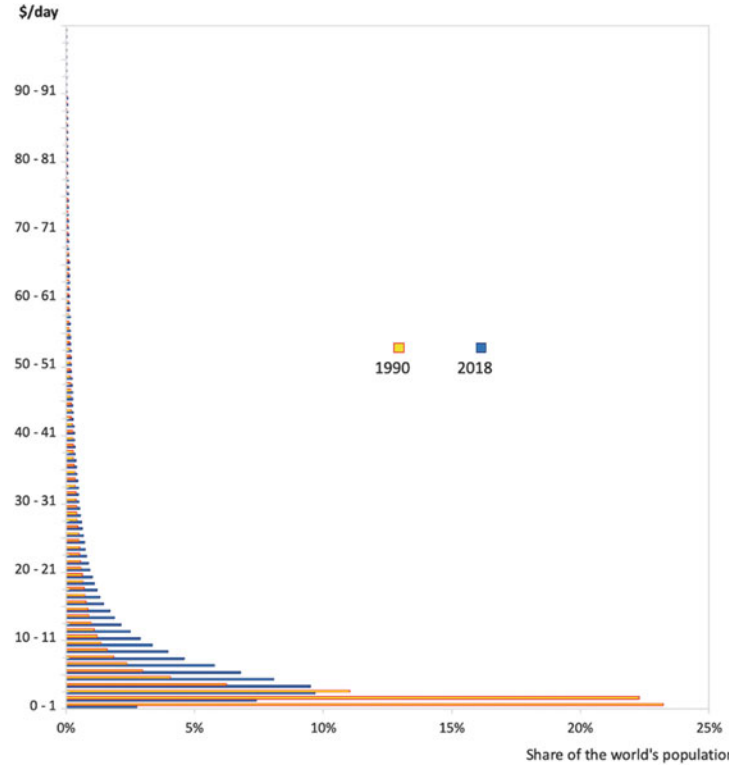

Fig. 12.2 Percentage of the world's population in different income groups in 2018 and 1990

conducted with the dual intention of pursuing economic outcomes by opening up new high-growth markets and social outcomes by solving critical social problems in those markets.

As mentioned previously, the most commonly used quantitative definition of BoP is an annual income of less than $3000; dividing this number by 365, we obtain the daily income of people in

the BoP as less than $8.2. Therefore, in Fig. 12.2, the bottom nine bars, that is, the area below the red-dotted line, roughly correspond to the BoP.[4] This shows that in 2018, the BoP group accounted for 58.6% of the world's population (yellow bars) compared to 75.6% in 1990 (blue bars) and that the volume zone moved up slightly from the bottom. In particular, the number of people living in "extreme poverty"—those earning less than $1.9 per day (World Bank 2016), or the bottom two bars—has fallen dramatically in the three decades since 1990. Although a large proportion of the population still belongs to this segment, part of this upward shift in the volume zone can be considered to be a result of BoP businesses.

12.3 Birth of the BoP Business

During the post-war period to the 1970s, when the "Global North and Global South" were raised, there was criticism that the expansion of MNCs from developed to developing countries would lead to the exploitation of the poor. A growing trend of resource nationalism has emerged among the newly independent countries to reclaim for themselves the natural resources that MNCs had once controlled during the new imperialist era, which came into conflict with the interests of MNCs. In 1962, the UN General Assembly explicitly declared the Permanent Sovereignty over Natural Resources, which led to the nationalization of extraction facilities of MNCs in many developing countries in the Middle East and South America. In 1964, the UN Conference on Trade and Development (UNCTAD) was established to redress the North–South divide through the promotion of economic development of developing countries; at the same time, the Group of 77 (G77), a coalition to increase the voice of developing countries, was founded, and various cartels were formed by producer countries in oil, copper, bauxite, and other resources. The Declaration for the Establishment of a New International Economic Order (NIEO), adopted in 1974 by the UN Sixth Special Session of the General Assembly on Raw Materials and Development, included the right of host countries to regulate and supervise the activities of MNCs. In the 1980s, when it was widely recognized that foreign direct investment (FDI) could contribute to the economic development of developing countries, many of these countries turned their stance toward accepting FDI, and shortly afterward, some emerging countries became even more welcoming. However, MNCs continued to operate with an imperialist mindset, viewing developing countries as places to sell their old products or squeeze profits out of their sunset technologies (Prahalad and Lieberthal 2003).

During this period, various social challenges faced by low-income groups, including poverty, were addressed through grant aid, preferential loans, technical assistance, provision of relief supplies, donations, or volunteer activities by public bodies such as governments of developed countries, UN agencies, the World Bank, the Asian Development Bank (ADB), the African Development Bank (AfDB), and other non-governmental organizations (NGOs). In the 1990s, however, after years of official development assistance (ODA) failed to produce the desired results in poverty alleviation while breeding graft and corruption, developed countries experienced "aid fatigue," and key members of the OECD Development Assistance Committee (DAC) began to reduce their ODA spending. Concurrently, the concept of private finance initiatives (PFI) took root as Western countries sought to move toward smaller governments, raising the expectation that the private sector could finance public services to a greater extent. This trend was reflected in development aid to developing countries, wherein the importance of public–private partnerships (P3) was emphasized. Moreover, as the development needs of developing countries diversify from dealing with debt crises and structural economic reforms to

[4] Since the Gapminder income data set is calculated using PPP for the benchmark year 2011, there will be some discrepancies in the definition of BoP when measured in PPP terms in 2002. This means that the number and share of people belonging to the BoP group estimated here may be somewhat underestimated.

broader social issues, such as poverty, hunger, health, the environment, education, and human rights, it is increasingly recognized that the administrative approach of governments and international organizations is limited. In other words, the prevailing view is that development projects can be conducted more efficiently by using private finance and technology, particularly with the help of MNCs.

Since the late 1990s, there has been growing momentum for corporate social responsibility (CSR), which posits that companies have a responsibility to return profits from their business to have a positive (or avoid a negative) impact on the environment and all stakeholders, including consumers, employees, investors, and local communities. CSR used to be regarded as self-regulatory and voluntary decisions at the individual firm level, although its interpretation and evaluation varied between countries and regions. However, CSR has evolved to include mandatory schemes at national, regional, and international levels as national governments and international organizations have pushed companies to develop sustainable practices, laws, and regulations, and stakeholders have increasingly demanded it. Some examples of these programs are the following. First was the ISO 14000 series of environmental management standards issued in 1996 in response to the Earth Summit of 1992; second, the widespread adoption of the concept of the triple bottom line (TBL) (i.e., the social [people], environmental [planet], and economic [profit] bottom lines) in accounting and auditing procedures; and third, the Global Reporting Initiative (GRI), an NGO launched in 1997 to develop international standard guidelines for sustainability reporting by companies and other organizations.

The UN "Global Compact" (UNGC), a non-binding charter announced by the then-UN Secretary-General at the World Economic Forum in 1999 and launched in July 2000 with the signature of 7,700 companies from 130 countries, required companies to act in a socially, environmentally, and ethically responsible manner. Signatories were requested to integrate the ten principles outlined in the UNGC in four areas, namely human rights, labor, environment, and anti-corruption.[5] Private companies, recognized as an essential force in achieving the development goals set by the UN for developing countries, were expected to act as catalysts through their actions in support of these goals. In September 2000, with the enactment of the UN Millennium Development Goals (MDGs), eight international goals were set with specific targets to be achieved by 2015 to solve the problems of developing countries. One of these targets was to reduce the number of people suffering from extreme poverty and hunger by half compared to 1990. To achieve these challenging development goals on time, the traditional approach of relying on ODA from developed countries or support and donations from international organizations and NGOs was insufficient, and expectations of the role that business activities could play had become increasingly important. In response, MNCs and entrepreneurs sought to address poverty reduction from a business perspective by providing products and services that meet the needs of developing countries. This led to the emergence of BoP businesses.

12.4 First-Generation BoP Strategies—BoP 1.0

The BoP businesses that emerged in the early years were essentially attempts by MNCs to modify existing goods and services and offer them at lower prices so that people in the BoP markets could afford them. Poverty was defined as the deprivation of basic needs such as food and water, clothing, shelter, sanitation, health, and electricity. Accordingly, poverty-stricken people were regarded as suffering from various disadvantages known as the "BoP penalty" (Prahalad 2010), which referred to higher costs of living due to poverty, including transport, utilities, food, and medicine, among others.

Thus, the role of the BoP business was considered as elimination of the BoP penalty to

[5] As of February 23, 2022, the number of signatories has grown to 19,616 companies and organizations in 164 countries. For more information, see UNGC (2022).

enable people to meet their basic needs. To this end, modifications of existing business models, such as the small packaging strategy, were suggested to eliminate the BoP penalty and achieve the 3As—affordability, access, and availability (Prahalad 2010). The idea is that this will create a fair market for the poor, improve the standard of living of the BoP, raise their income, and, consequently, help them move to the next volume zone (Hammond et al. 2007), opening up new market opportunities for MNCs. Thus, the BoP business can be considered a sustainable strategy for companies. As the "base" part of the pyramid shifts upward, it may no longer be a pyramid structure but a diamond-shaped structure with a thicker mid-layer. This approach to the BoP market, which seeks to reduce poverty through consumption, was later coined as BoP 1.0 by Simanis et al. (2008).

At the time, MNCs from developed countries did not have much business experience in developing countries, excluding their former resource development and procurement activities. Moreover, MNCs were not accustomed to doing business in the developing areas of the world, where markets—a network in which buyers and sellers interact to exchange goods and services for money—were essentially nonexistent or poorly functioning compared to those of developed countries with well-functioning market mechanisms. Therefore, MNCs often choose to work with NGOs and entrepreneurs acting on the ground. They believed that without partnerships with this third sector—the civil sector, which is neither public nor private—an approach to the BoP segment, wherein simple aid is ineffective, and markets do not function well, would be infeasible.

Accordingly, BoP 1.0 comprised the following three steps:

1. To identify the BoP segment as potential customers and listen to them deeply to understand their specific needs and wants.
2. To develop promising solutions for the BoP by lowering prices, narrowing down features, redesigning packaging, exploring new distribution channels, and meeting previously unreachable customers' needs.
3. To partner with local NGOs/NPOs as mediators in implementing BoP solutions.

One well-known example of BoP 1.0 is the purified water business of Procter and Gamble (P&G). As a BoP initiative, P&G launched the Children's Safe Drinking Water (CSDW) program in 2004.[6] It provides safe drinking water for children aged 0–13 years in developing countries. P&G worked with the US Center for Disease Control and Prevention (CDC) to invent a water purification powder and provide sachets of "Purifier of Water" (PUR) to children in rural villages and refugee camps. Sachets were used because the poor could not afford the cost of buying products in bulk. With just 4 g of powder, a bucket, a spoon, and a cloth, 10 L of dirty water could be turned into clean drinkable water in 30 min. P&G did not simply sell the product through its usual distribution network but worked with around 70 organizations, including international organizations such as the Red Cross and UNICEF (United Nations International Children's Emergency Fund), as well as local NGOs.

Another example is Unilever's soap business in India. In 2002, Hindustan Lever Limited (HLL), Unilever's subsidiary in India,[7] launched a 5-year health and hygiene education campaign, "Swasthya Chetna" ('Health Awakening'), to promote Unilever's " Lifebuoy" brand of hygiene products.[8] The program was launched in eight states of India with the objective of educating around 200 million people in rural and urban areas on the importance of health and hygiene

[6] See P&G (2022).

[7] Unilever set up its first production subsidiary in India, Hindustan Vanaspati Manufacturing Co., in 1931, a year after the merger of the British company Lever Brothers and the Dutch company Margarine Unie to form Unilever. At the time, India was a British colony before gaining independence in 1947. This subsidiary changed its name to Hindustan Lever Limited (HLL) in 1956 and to Hindustan Unilever Limited (HUL) in 2007.

[8] Lifebuoy is a world-leading brand of their hygiene products launched by Lever Brothers in 1895, which includes soap, hand wash, body wash, sanitizer, deodorant, and other products. Although it is no longer seen in developed countries, it is highly recognized in developing countries, and products produced in India are exported to the Asian region.

(Fernando and Purkayastha 2006). Through demonstrations, interactive visuals, and drama workshops, mainly in primary schools, HLL educated children about the effectiveness of washing hands with soap to prevent diseases. The children would go home and tell their parents about it, who would, in turn, tell their neighbors, relatives, and colleagues. Through this word-of-mouth communication, the concept of sanitation took root in Indian society. Through social marketing, Unilever aimed to cause a behavioral change in two ways: attracting consumers who never used soap and convincing people to use soap more frequently, thus creating more users for its brand. Resultingly, Unilever succeeded in expanding the market for the company's Lifebuoy products, which had been introduced in India long ago but had only been recognized by a small group of wealthy people, while solving a social problem wherein many people were suffering from poor health due to lack of hygiene habits.

12.5 Transformation of BoP Business

12.5.1 Lack of Success of BoP 1.0

Despite many attempts, BoP 1.0 was not as successful as expected. Many businesses were unable to scale or generate satisfactory returns or failed to address the development challenges of the poor adequately. Many others continue to suffer from low profits, small market size, and slow growth, including Grameen Danone's nutritious yogurt development in Bangladesh, Nike's World Shoe project in China, P&G's Nutri Delight (a fortified orange powdered drink) in the Philippines, and Monsanto's sale of genetically modified seeds; some of which have been discontinued. Some assessments suggest that even P&G's PUR and Unilever's soap business, mentioned above, have not performed as expected (Simanis et al. 2008).

The graph in Fig. 12.3 illustrates the relationships between business and social agenda and helps to understand the background of the poor performance of BoP 1.0 for both companies and society and provides some hints on how to address it. It attempts to capture corporate BoP businesses in a box diagram measured by two dimensions: corporate profit on the vertical axis and development impact on the horizontal axis. Given the trade-off between the two challenges, the strategy a company can adopt lies in the area inside (lower left) the frontier curve, shown by the main diagonal, with the optimal strategy lying at any point on the frontier. If a company, located in the top left corner as a profit-seeking entity, tries to engage in the BoP business, it can achieve development benefits by sliding down along the frontier line from the upper left position, that is, by sacrificing some of its corporate profits. When the BoP1.0 venture does not yield satisfactory profits, it means that the company has moved below point A at the intersection of the frontier line with an acceptable profit level p^*. Further, if the BoP business is unsatisfactory in meeting the development challenge, it means that it has not moved beyond B at the intersection with the expected level of development at d^*. In short, unsuccessful BoP businesses are located somewhere on the line segment AB.

As aforementioned, CSR, UNGC, and the MDGs are the background factors that have encouraged MNCs to engage in BoP business; however, an increase of these exogenous pressures shifts the vertical line set at s^* to the right, such that, ceteris paribus, line segment AB will become even longer, increasing the likelihood that BoP businesses will create only unsatisfactory results.

There is a common feature underlying these unsatisfactory results of many BoP 1.0 ventures: They were outside-in initiatives to increase consumption in the BoP segment by modifying and applying existing products and business models created in developed countries. This was based on the mindset of approaching the unmet needs of poorer people. (Simanis et al. 2008; Cañeque and Hart 2015).

However, several serious problems are associated with this approach. First, people in the BoP segment were viewed as target customers instead of targets of certain development goals.

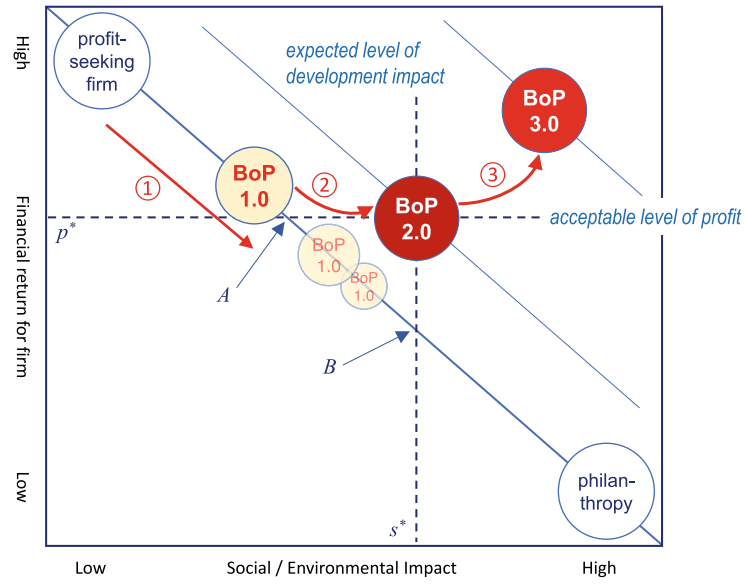

Fig. 12.3 Relationship between business and social agendas

On the MNCs' side, the BoP business created a boom at the turn of the twenty-first century, with the illusion that it would open up unlimited sales opportunities in markets with huge populations; however, the civil and public sectors, as well as the poor themselves, have sometimes criticized the BoP business as nothing more than a strategy for selling to the poor.

Second, with no existing product market that served as a benchmark, neither firms nor prospective BoP customers had a reference point from which to assess whether a given product or service was "needed" (Simanis et al. 2008). This is why the usual market strategy of understanding potential needs through listening to prospective customers, identifying the market segments to play in, and gaining a competitive advantage could not be applied. While P&G's PUR business initially saw an enormous potential need to solve the social challenge of preventing infectious diseases with clean water, the actual demand generated was so small for the company that the CSDW project had to shift to a philanthropic model of health-related social marketing campaigns in partnership with a global health NPO (Simanis et al. 2008).

Lastly, outside-in initiatives contain paternalistic attitudes and cultural imperialism elements, which sometimes mean a devaluation of tradition and culture in the target country. This is likely to provoke a backlash from non-profit and grassroots organizations, as well as from poor people themselves. In the past, NGOs have often monitored the subsidiaries of MNCs and led boycotts of their products in protests against environmental degradation and child labor in developing countries. With such a history of adversarial relations, the basic needs approach, relying on an outside-in strategy, does not make it easy to forge partnerships with NGOs, which are crucial to the success of the BoP business.

12.5.2 Advent of BoP 2.0

Reflecting on the modest success of BoP 1.0, the next generation of BoP strategies emerged: BoP 2.0. A key feature of BoP 2.0 is a radically new approach involving the "co-creation" of products and value propositions by partnering with people from underserved communities (London and Hart 2010). Co-creation refers to working together with local companies, low-income communities, and other actors to create a fortune with the BoP, which enables a deep process of social transformation (Nahi 2016). BoP 2.0 not only aims to focus on markets that previously existed but were unrecognized and to turn poor people

into customers for its products, as in BoP 1.0 but also encompasses the following three elements:

1. Involving BoP people in the global value chain as producers, suppliers, and distributors and working with them to "co-create" entirely new markets and business models.
2. Providing employment opportunities for the poor to increase their consumption through higher incomes and enhance their human capital and empower them through labor participation, training, and education.
3. Engaging BoP people in creative activities that can generate bottom-up innovation, enabling the development of environmentally sustainable technologies with leapfrogging, and implementing "reverse innovation" (Govindarajan and Trimble 2012), wherein innovative products from the BoP flow back to developed countries.

Thus, theoretically, BoP 2.0 would engender culturally embedded, socially and environmentally sustainable, profitable, and more "inclusive" businesses[9] which is what the BoP people want.

Thus, BoP 2.0, which seeks to commit the poor to the supply chains and innovative activities of MNCs, has been driven by the international fragmentation of production—the pursuit of offshoring strategies by splitting a production process into different steps—and the establishment of global production networks (Ernst and Kim 2002; Jones et al. 2005; Coe et al. 2008). As a result, the role of the BoP has shifted from being a mere marketplace to a production base and even a source of innovation.

Unilever's Indian subsidiary, HLL's project "Shakti" (meaning empowerment), is often described as the next-generation BoP initiative (Prahalad 2010). Although not yet fully successful in terms of profitability, probably due to Unilever's heavy financial burden and high turnover, the project is considered a BoP 2.0 scheme as it involves "innovation for the last mile"—the penetration of the company's products into traditionally unreachable rural India through direct sales using local women's channels—while simultaneously contributing to society by spreading the concept of hygiene, and thereby, improving health, creating employment, improving human capital, empowering people, and making women more self-reliant and socially empowered.

HLL set up a sales and distribution organization that contracts women, called "Shakti Amma," as self-employed traders who buy and sell Unilever products on consignment and receive a success fee. This enabled Unilever to penetrate rural areas, where two-thirds of India's population lives, at a cost more than 10% less than traditional sales agents, and promote Unilever products through word of mouth (Rangan and Rajan 2005). In particular, the expansion of sales of "Annapurna Salt," an iodized salt developed by Unilever in 1995, has had a breakthrough effect in preventing iodine deficiency disorder, which may cause mental retardation in children, and considerably contributed to reducing the health problems of India's low-income population, who do not have access to a balanced diet. Shakti Amma, now comprising more than one million women, has become not only Unilever's favorite customer by enhancing women's and their family's livelihoods by enabling them to earn the same level of income as men ($60–150/month), but also an entrepreneurial venture that develops women's skills through training and on-site practice in product knowledge, revenue and logistics management, and contractual concepts, helping women to become spiritually independent through increased financial independence and dignity. Additionally, HLL has played a complementary role in microfinance by making Shakti Amma a self-help group with joint savings and loans among its members, which, in turn, induces bank loans and new business start-ups. In collaboration with local government agencies and NGOs, the project has effectively recruited and nurtured talented women with local knowledge and a desire to lift themselves out of poverty and become self-reliant.

[9] There is no uniform definition of inclusive business, and people sometimes interpret it differently, but common features are adopting the principle of nondiscrimination, to focus on creating new economic opportunities for low-income populations rather than maximizing corporate profits. See Likoko and Kini (2017) for more details.

Figure 12.3 illustrates the logic behind BoP 2.0, which is realized when a company can further enhance its economic profits or social benefits without sacrificing either. The social contributions brought about by Shakti Amma at Unilever's expense, such as increased employment, poverty alleviation, spread of market-based economy, improved health and sanitation, and women's empowerment, among others, will not necessarily undermine the company's financial bottom line because it will lead to a reduction in distributor commissions, increased productivity through enhanced human capital of Shakti Amma, and increased sales through higher incomes for low-income groups. This means that, as shown in Fig. 12.3, when starting from BoP 1.0, indicated by the large circle, and seeking further to increase the social benefits on the horizontal axis, companies do not need to slide down along the frontier curve (arrow ①), but can reach BoP 2.0, while maintaining corporate profit level p^* on the vertical axis (arrow ②). In BoP 2.0, both the acceptable level, p^*, for corporate profit, and the expected level, s^*, of social benefit are met, making the business sustainable. Therefore, BoP 2.0 is about internalizing the positive production externalities to create social value through business model innovation, rather than relying on absolute altruism, as in philanthropy, to achieve the same results.

The transition to BoP 2.0 was driven by not only companies' efforts to overcome the flawed BoP 1.0, but also institutional pressures on MNCs to put emphasis on social and environmental aspects. In particular, as Table 12.1 shows, the P3 initiatives in development, successively launched by various international organizations, acted as a "focal point" to encourage companies to be more proactive in fulfilling their social responsibilities owing to their rational choices. Additionally, they helped the private sector find solutions to reconcile its profitability with social development at a higher level in difficult market conditions with high poverty levels by providing specific policy recommendations and illustrating other companies' initiatives as best practices. For example, the 2004 report of the UN Commission on the Private Sector and Development, "*Unleashing Entrepreneurship: Making Business Work for the Poor*," outlined recommendations for building the capacity of the private sector to advance the development process set out in the MDGs, with particular emphasis on providing opportunities for income generation through decent work. The growing inclusive markets (GIM) initiative launched by the United Nations

Table 12.1 Key institutional pressures to engage the private companies in BoP business

1987	UN	Brundtland report
		Sustainable development was first defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"
1996	NGO	ISO 14000 series
		International standards related to environmental management for organizations to minimize the negative impact of their operations on the environment
1997	NGO/UNEP	Global reporting initiative (GRI)
		An international standards organization to support sustainability reporting by companies and organizations, through developing the GRI guidelines, was first published in 2000 and updated in 2002, 2006, and 2013
1999	NGO/UN	United Nations Global Compact (UNGC)
		A non-binding UN pact to encourage companies to adopt sustainable and socially responsible policies and report on their implementation, calling for compliance with 10 principles on human rights, labor rights, the environment, and anti-corruption
2000	UN	Millennium development goals (MDGs)
		Eight international development goals for 2015 that had been established following the Millennium Summit of the UN in 2000

(continued)

Table 12.1 (continued)

2004	UN	Report: "unleashing entrepreneurship: making business work for the poor"
		The UN commission on private sector and development proposed how companies can create value for the poor in difficult market conditions with high levels of poverty. Recommendations to enhance the private sector's ability to advance the development process outlined in the MDGs
2006	UNDP	Growing inclusive markets (GIM) initiative
		Presentation of an inclusive business model that brings the poor into the value chain as consumers, producers, employers, or workers
	NGO/UNEP	Principles for responsible investment (PRI) initiative
		A UN-supported network of institutional investors encouraging signatory investors to incorporate ESG issues into their investment practices and require their investees to disclose ESG information based on six non-binding voluntary principles
2007	UNDP	Inclusive market development (IMD) approach
		Providing support for the development of product and service markets and labor markets to provide choices and opportunities for poor people as producers, consumers, and workers
2008	UNDP	Business call to action (BCtA)
		Exploring and promoting business models that can achieve commercial and development objectives simultaneously through membership networks among relevant players (e.g., companies, governments, and development assistance periods)
	NGO	Global impact investing network (GIIN)
		A global network created by the Rockefeller Foundation and other investors to stimulate impact investing by standardizing the social and environmental impact assessment indicators
	UNDP	GIM report: "Creating Value for All: Strategies for Doing Business with the Poor"
		The report identifies constraints and solution strategies for inclusive business models based on 50 case studies
2010	NGO	ISO26000
		The international standard provides guidance for businesses and organizations committed to operating in a socially responsible way and comprises seven aspects: organizational governance, human rights, labor practices, environment, fair business practices, consumer issues, and community involvement and development
2015	UN	Sustainable development goals (SDGs)
		Seventeen global goals designed to be a "blueprint to achieve a better and more sustainable future for all" were set up in 2015 and are intended to be achieved by 2030. The SDGs were developed to succeed the MDGs, which ended in 2015
	NGO/UN	SDG compass
		A five-step action guideline that provides tools and knowledge for companies to place the SDGs at the center of their corporate strategy, published by the UNGC GRI and the world business council for sustainable development (WBCSD)
2016	NPO/UNEP	Global reporting initiative (GRI) standards
		New sustainability reporting standards to replace the previous GRI guidelines
2022	UNDP	SDG impact
		Criteria for assessing the extent to which an investment object has an impact on achieving the SDGs

Development Programme (UNDP) in 2006, and its report, *Creating Value for All*, published in 2008, highlighted the importance of inclusive business, which involves poor populations in global value chains as consumers, producers, employers, and workers, and provided many different examples of good practices in such business. Similarly, other UNDP-led strategies, such as inclusive market development (IMD) in 2007 and business call to action (BCtA) in 2008, have sought to promote private sector engagement in the BoP development process, with recommendations on how to build business models that achieve commercial and development objectives simultaneously. Similar efforts to get companies and NGOs to focus more on development issues at the BoP can be seen in other UN agencies, such as Food and Agriculture Organization (FAO), World Food Programme (WFP), World Health Organization (WHO), and United Nations International Children's Emergency Fund (UNICEF), with each working in its own area of expertise. Thus, all these efforts from international organizations have served as a catalyst for private sector companies to take a more active role in BoP business while maintaining their interests.

12.6 Future of the BoP Business

BoP businesses need to and will evolve further to more effectively address the social challenges faced by the BoP while concurrently ensuring corporate profitability. Against this background, the "BoP 3.0" was recently proposed (Cañeque and Hart 2015). Although this initiative is still in an embryonic stage and the real picture has not yet become clear, some directions can be discerned.

12.6.1 Open Innovation and Frugal Innovation

One such direction is to facilitate further "co-creation," as implemented in BoP 2.0, and move toward "open innovation." As aforementioned, co-creation involves working with local companies and other actors to develop new business models that create value for local communities at the BoP. Furthermore, open innovation is a distributed innovation process based on purposively managed knowledge flows across organizational boundaries (Chesbrough et al. 2014). In contrast, traditional "closed innovation," which is pursued in-house or through vertical integration, is when companies seek to build competitive advantages based on proprietary technology through speeding up new product development. However, increasing silos of technology have made it increasingly difficult to create innovation through in-house research and development (R&D). The boundaries between a firm and its external environment have become more permeable due to lower transaction costs in the marketplace and advances in information and communication technology (ICT). Increasing the transfer of technology and ideas inward and outward between organizations and individuals can be expected to stimulate innovation within the organization, which, in turn, will extend outside the organization (Chesbrough 2003). Technology and ideas should not be confined within an organization but allowed to flow freely to stimulate innovation. Compared to the co-creation emphasized in BoP 2.0, which was a bottom-up innovation that was undertaken with the help of BoP people, open innovation is a more participatory grassroots innovation that harnesses the knowledge of the "cloud" distributed across different sectors and actors—private, government or citizens, or formal or informal—to create solutions that were previously unforeseeable (Cañeque and Hart 2015).

As an extension of this open innovation, "frugal innovation" has attracted growing attention in recent years (Zeschky et al. 2011; Bhatti and Ventresca 2013). It is called "frugal" as it is a way of developing products and services that are more affordable and easily accessible by only implementing necessary features. It is frugal because it meets the basic needs of the BoP in a lean way, thus conserving resources and making societies and the planet more sustainable. Frugal innovation is a locally adaptive solution that

develops and provides products and services that are "good enough" and affordable to meet the needs of consumers under severe financial, technological, material, and other resource constraints (Bhatti and Ventresca 2013), meeting the needs of BoP people who would otherwise be unable to afford existing products and services. Frugal innovation is a model of the social contribution that emphasizes the reduction of the global environmental footprint by providing products and services in a resource-saving manner. In other words, frugal innovation reduces public bads (negative externalities), whereas the conventional BoP business aimed to contribute to society by expanding public goods (positive externalities), that is, by alleviating poverty through delivering products and services to the poor.

However, this may not be an easy task for MNCs from developed countries as their business models and organizations are traditionally designed to develop advanced products for the few affluent people at the ToP. To overcome such strategic and organizational barriers and achieve frugal innovation, it is necessary to provide a substantial degree of autonomy to local subsidiaries of MNCs to enable them to deploy open innovation (Zeschky et al. 2011).

12.6.2 Business Ecosystem

The second direction for BoP 3.0 is to use the business ecosystem. A business ecosystem is an economic community comprising many loosely interconnected participants (Clarysse et al. 2014). These participants, organizations or individuals, come together in such a community "in a partially intentional, highly self-organizing, and even somewhat accidental manner" (Moore 1998, p.169). These participants include customers, suppliers, workers, competitors, and other stakeholders, such as financial institutions, trade associations, standards bodies, labor unions, and governmental and quasi-governmental institutions (Moore 1998). In the context of BoP, human resource cultivators, supply chain players, technology and microfinance providers, and even neighboring residents, are constituents of the business ecosystem. Their relationships could be cooperative or competitive, with each participant specializing in a particular activity and depending on each other for their mutual performance. In other words, the collective efforts of many participants create value, but individual efforts have no value outside of the collective effort (Clarysse et al. 2014). Unlike conventional inter-firm networks, which tend to be geographically dense, business ecosystems form value networks distributed globally.

BoP 2.0 emphasized the need to engage people from the BoP community in the local activities of MNCs to promote bottom-up innovation. However, since an ecosystem is a network of actors with many horizontal (Moore 1996) as well as vertical relationships, many of its members fall outside the traditional value chain, which is formed by a linear process from upstream to downstream (Iansiti and Levien 2004). Thus, the innovation model of BoP 2.0 will be unable to tap into the diversity of species inhabiting the ecosystem. For BoP businesses to evolve further, it is necessary to incorporate companies as part of a larger ecosystem (Cañeque and Hart 2015). It is not about involving the BoP people in their global value chain but about the MNCs themselves becoming part of the business ecosystem, locally embedded and extending beyond regional boundaries. Therefore, it is essential to view the business ecosystem as a foundation for innovation to exploit the potential of open innovation discussed above fully.

Innovation in business ecosystems focuses on the customer (demand) side rather than on technological activities; in other words, it aims to generate value for the customer rather than new knowledge (Clarysse et al. 2014). Firms can collaborate with other participants in the business ecosystem to create solutions and deliver value that customers alone cannot create (Moore 1993). Such innovations may involve the creation of new markets and are well suited to the relatively small and poorly defined commercial opportunities that need to be pursued (Clarysse et al. 2014); therefore, it is a suitable model for innovation at the BoP.

At the BoP, the market economy—a network of buyers and sellers interacting to trade goods and

services—does not function as it does in developed countries; the participants in the ecosystem include not only companies but a wide range of actors, seamlessly and intricately linked together to form a single business sphere. It is not based on market principles but on the dominant principles of a community—a group whose ties are based on trust through profound human interactions, such as bonds, blood relations, geographical ties, camaraderie, and ethnic cohesion, which are maintained through implicit contracts. Many poor people are engaged in the informal sector and deprived of legal ownership, property rights, and education rights, among others, which are largely beyond the reach of normal means of distribution, credit transactions, and communication.

Therefore, it is essential for MNCs to network with these non-traditional actors, especially if they want to create non-economic and social value. The strength of MNCs is that they can reorganize their ecosystems in a way that is not solely based on customary mechanisms, as in the past, by bringing in transparent market mechanisms. For this purpose, ICT can be used, as it helps to eliminate opportunistic behavior (Williamson 1985)—selfish actions, such as cheating or shirking, which will undermine the potential of the transactions—by reducing information asymmetries between buyers and sellers, thus allowing the market mechanism to function and realize fair trade. Further, ICT can enable joint tasks between organizations and individuals within the business ecosystem through Internet-based technologies in conjunction with face-to-face interaction (Corallo et al. 2007), thus connecting companies and individuals in the same ecosystem across traditional industry sectors and national boundaries. By evolving business ecosystems into digital business ecosystems, each company or individual will be able to exchange digital knowledge with other members and add one or more aspects of product or service value to the value created by the ecosystem (Tapscott et al. 2000), enabling the provision of customized solutions to people at the BoP.

However, the process of building relationships and creating business ecosystems with many different stakeholders is lengthy and path dependent. Moreover, companies need to play a pivotal role in the ecosystem to orchestrate the coordination of interests, conceive a business model that satisfies social needs, and secure their own profits, which can be a daunting task. However, this is precisely why it can be a source of sustained competitive advantage by accumulating resources that are difficult to imitate and prevent others from entering (Barney 1991).

In this respect, solving social problems and pursuing economic interests, which were once thought to be opposites, can now be perfectly aligned. Reflecting on Fig. 12.3, we understand that this situation, wherein companies can increase their economic profits, or rather their sources of competitive advantage, by addressing these social challenges, can be illustrated by the shift of the frontier curve, which shows the feasible combination of the two trade-offs, to the upper right, and the corresponding shift of BoP business to BoP 3.0 (arrow ③). Such a leap can be made through open innovation, which leverages the widely distributed knowledge across BoP communities; frugal innovation, which is resource conserving and genuinely meets the basic needs of BoP people; and inclusive innovation, which comes from embedding companies in ecosystems and building truly inclusive businesses.

12.6.3 Sustainable Development

The third direction for BoP 3.0 is to broaden the perspective of the challenges faced by the BoP, from poverty reduction to sustainable development. Initially, BoP businesses' motivation was focused on alleviating poverty by leveraging the resources and capabilities of the private sector, especially MNCs, to deliver products and services affordable to the BoP population (BoP 1.0), and then providing them with the means to earn a living (BoP 2.0). However, it is becoming increasingly important to consider TBL and incorporate other development challenges such as environmental sustainability.

The SDGs, adopted at the UN Summit in September 2015, set 169 specific targets in 17 areas of development goals for 2016–2030. They were introduced as successors to the MDGs,

which expired in 2015 and comprised eight set goals. In addition to poverty, hunger, and health, which were emphasized in the MDGs, the SDGs encompass a wider range of environmental issues, including climate change, energy, and ecological system, as well as other social issues such as human development, decent work, women's empowerment, and inequality. The BoP faces all of these challenges, and overcoming them is defined as an essential condition for sustainability. Hence, the SDGs have a high affinity with the BoP business, and as the SDGs gain ground, companies are likely to become more proactive about engaging in "SDG business management" and incorporating those goals into BoP businesses.

Recently, there has been increasing pressure from investors to enable companies to adopt SDGs in their business. Table 12.1 summarizes some of the major developments. This pressure originally started as socially responsible investing (SRI), an investment practice that requires investee companies to manage their businesses in a CSR-oriented manner. After the manifestation of environmental problems on a global scale since the late 1980s and the spread of the TBL concept in the 1990s, SRI has become more active. Companies have been evaluated in terms of the environment (environmental impact such as global warming and resource destruction) and society (impact on social stakeholders, poverty alleviation, and reduction of inequality), as well as corporate profitability, and investors' decisions have been made based on these three aspects. In 2006, the UN announced the principles for responsible investment (PRI).[10] The subsequent increase in the number of institutional investors signing up to the PRI accelerated the trend toward incorporating an assessment of G (governance: appropriateness of corporate management processes) into their investment decisions, in addition to those on TBL (financial, environmental, and social bottom lines), which has come to be known as "ESG investing"—prioritizing optimal environmental, social, and governance factors or outcomes. In the aftermath of the 2008 financial crisis, ESG investing expanded rapidly (Global Sustainable Investment Alliance 2021) in response to the criticism that excessive capitalism and overstressing short-term returns caused instability in financial markets. More recently, "impact investing," which places greater emphasis on the impact of social and environmental issues (Brest and Born 2013), has grown even faster than ESG investing. These ESGs and impact investment decisions require investee companies, particularly MNCs, to internalize the positive and negative social externalities they generate as a cost of capital. Concurrently, they are known to place high demands on the financial profitability of investees.[11] In Fig. 12.3, such changes in investors' behavior mean that while maintaining (or even shifting upward) the acceptable level of profitability, p^*, the expected level of development impact, s^*, will shift further to the right. Unless the BoP business model is further evolved by integrating it with SDG business management, it will be difficult to achieve a balance between corporate profits and social contribution.

12.7 Concluding Remarks: Sustainable Societies and MNCs

The development challenges contained in the SDGs are not just for the poor, but many of them need to be addressed by the international community as a whole, including those belonging to the ToP and MoP in developed and emerging countries. As SDGs emphasize the importance of multi-stakeholder partnerships, the resources and capabilities of the private sector, especially those of MNCs, are expected to play a major role in addressing these challenges. In SDG business

[10] As of the end of 2021, the PRI has 4679 signatories in more than 80 countries around the world, up from 81 signatories in 2006. For more information, see PRI (2022).

[11] In 2018, in an effort to attract more private capital into the SDGs, UNDP began developing the SDG impact, a set of criteria for assessing the extent to which an investment object has an impact on achieving the SDGs, which is expected to be operational by the end of 2022. Additionally, in 2020, UNEP FI (UN Environment Programme Finance Initiative) launched a tool for banks to measure the impact of their loan portfolios.

management, as in BoP business, the essential question is how to reconcile social and economic interests. Therefore, an effective approach to SDG business management is to advance the "analytic generalization" (Yin 2017), which describes the logic of the BoP business as a relationship between abstracted key variables and to increase the generalizability of the model in SDG business management. Additionally, it will be possible to provide valuable implications for the BoP business based on the findings of the SDG management analyses.

For example, frugal innovation, which was initially focused on BoP customers, could be applied as a concept to address issues, such as environmental (e.g., global warming, ocean pollution, deforestation), demographic (e.g., aging population, population decline, and explosion), and socioeconomic changes (e.g., widening inequality, increasing cross-border migrations), on a global level (Agarwal and Brem 2017). Moreover, the growing interest in resource-conscious and minimalist consumption in developed countries suggests that the concept of "frugality" may also be applied in these markets. Such application to markets other than BoP may enable the generalization of the theory of frugal innovation beyond just "cheap" innovations to the creation of sustainable innovations that are more "resource efficient" (minimizing the use of resources such as water, electricity, and time) and have a higher value proposition (i.e., better quality, ease of availability). The same holds true for reverse innovation as well. Reverse innovation, which initially emerged as a product of BoP business practices, served as a useful business model in the recovery process in Japan, where the tsunami caused by the Great East Japan Earthquake in March 2011 devastated lifelines (Cañeque and Hart 2015).

A report released by the UN in 2019 warns that while progress toward SDGs has been made in some areas, overall, countries are significantly off track with respect to achieving the goals within the target timeframe (UN 2019). The COVID-19 pandemic, which began in early 2020, has further delayed these efforts, and progress toward these goals has stalled or even regressed in many areas, including poverty, hunger, health care, education, and inequality. However, the pandemic has provided a great opportunity for countries to change the course of this current trend and build recovery plans to change consumption and production patterns for a more sustainable future. In other words, countries should avoid returning to the ways of the pre-pandemic world and redesign their economies and societies to be more sustainable and resilient to build a better world. In the "with COVID-19" period, or toward the "after COVID-19" era, how can we balance business with social challenges such as ensuring public health, establishing a new normal in response to workplace and lifestyle changes, and ensuring equitable distribution among stakeholders? How are we to restore global supply chains disrupted by border blockades and the contagion of economic shocks? (Baldwin and Freeman 2020; Hasegawa 2021) Furthermore, how should we go about developing business continuity planning (BCP)? These are pressing issues for companies globally, and MNCs need to redefine their role in rebuilding their global production network from SDG perspectives.

Shortly after BoP businesses garnered attention, the concept of "creating shared value" (CSV) was proposed as a way for companies to combine the pursuit of economic profit with social contribution (Porter and Kramer 2011). CSV implies that when a company creates social value by addressing social issues and problems, it also creates economic value. Unlike CSR, which is based on the premise that solving social problems and pursuing economic profit are incompatible, and companies must sacrifice profits in the spirit of philanthropy, CSV aims to integrate social contribution and business. According to Porter, CSV is a strategy that allows companies to gain a competitive advantage over their rivals in a differentiated way (Porter and Kramer 2011). By boldly challenging social needs, which were previously left to public bodies or the not-for-profit sector, or abandoned altogether, and meeting those needs in the marketplace, companies can create economic value that their competitors never could. Thus, rather than looking for a compromise between economic and social interests, CSV focuses on creating synergies between the two in a mutually enhancing relationship, which is quite similar to the BoP 3.0 concept.

If the seeds of CSV business lie in unmet social needs (Kramer and Pfitzer 2016), such needs are

inexhaustible at the BoP of developing countries and in other regions, including developed countries and emerging economies. Many developed countries are facing social problems such as aging population with declining birthrate, population decline, and increases in cross-border migrations. Issues such as gender inequalities, social disparities, human capital degradation, and lack of decent living are common challenges globally, not just in the BoP market. On a planetary scale, meeting the needs of the world's population, which is expected to reach 9 billion by 2050, while achieving growth without exceeding the available resources (e.g., food, water, and energy) or causing environmental devastation, is an extremely difficult agenda for humanity. CSV, BoP 3.0, and SDG businesses aim to make this possible.

Companies must take the initiative to solve social challenges and gain a competitive advantage. This is what the "new capitalism" based on CSV is all about, and the same is true for BoP 3.0 and SDG business management. If realized, new capitalism will be far more powerful and effective than traditional capitalism, comprising profit-maximizing businesses and wealth-redistributing governments, and will be the engine that drives social change toward sustainability. The question of how to reconcile economic and social interests by integrating findings and insights that have been conceived under different terms and concepts, such as BoP business, SDG business management, CSV, social businesses, and inclusive businesses, among others, is a key issue for business practitioners, scholars, and policymakers and will become increasingly relevant in the coming years.

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Part IV
For Peace (SDG 2)

Global Food Security, and Economic and Agricultural Development

13

Masahiko Gemma

Abstract

This chapter aims to present factors affecting global food demand and supply conditions and to find potential solutions to global food security problems. First, the factors determining the supply and demand conditions of food are detailed in relation to the linkages among food, agriculture, and rural development. Second, Japan's success in securing food in the early stage of economic growth as a developing country is presented as example. Discussions on supply and demand determinants in the first part are needed to understand the reasons for success in achieving Japan's food security objectives. Policy implications are derived for developing countries that struggle to ensure global food security. Reading this chapter will assist the readers in discussing potential solutions to global food security problems. Climate change issues are also discussed in relation to global food and energy security. We examine the effectiveness of crop-based energy production and potential conflicts with food production using examples from Japan and the United States of America.

Keywords

Global food security · Developing countries · Agricultural and economic development · Food problem

Global food security issues are discussed in relation to economic and agricultural development in this chapter.

13.1 Introduction

Zero hunger of Goal 2 in SDGs aims to end hunger and to achieve food security and improved nutrition and promote sustainable agriculture. This chapter directly considers the means to avoid hunger and malnutrition and to foster sustainable agriculture in both developing and developed countries.

This chapter is also related to other SDGs. No poverty of Goal 1 can be debated in terms of the changes in social welfare. Social welfare is defined as the sum of consumer surplus, producer surplus, and government surplus in welfare economics. The process of economic development is considered as the procedure of the enhancement of these three surpluses. Income distribution is considered as divisions of social welfare among consumers, producers, and the government.

Goal 7 of access to affordable, reliable, sustainable, and modern energy for all can be also

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discussed using an example of biomass-based renewable energy generation by the agricultural and food sector.

Sustainable consumption and production patterns of agricultural and food products are discussed in this chapter for Goal 12. This chapter also talks about multi-functionality of agriculture. Agriculture is the only industry that can positively contribute to climate change challenges (Goal 13) through photosynthesis in crop production. Greenhouse gases are emitted in animal production. Life on land is also considered important in agriculture related to Goal 15 within the framework of multi-functionality of agricultural land and rural areas.

We start with what we should know about food security. On the occasion of "World Food Summit" in 2006, it was confirmed that "food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life." Food security has four interrelated elements: availability, access, utilization, and stability as summarized by Australian International Food Security Research Centre (2014) in the below.

Availability is about food supply and trade, not just quantity but also the quality and diversity of food. Improving availability requires sustainable productive farming systems, well-managed natural resources, and policies to enhance productivity.

Access covers economic and physical access to food. Improving access requires better market access for smallholders allowing them to generate more income from cash crops, livestock products, and other enterprises.

Utilization is about how the body uses the various nutrients in food. A person's health, feeding practices, food preparation, and diversity of their diet and intra-household distribution of food all affect a person's nutrition status. Improving utilization requires improving nutrition and food safety, increasing diversity in diets, reducing post-harvest loss, and adding value to food.

Stability is about being food secure at all times. Food insecurity can be transitory with short term shocks as a result of a bad season, a change in employment status, or a rise in food prices. When prices rise, it is the poor who are most at risk because they spend a much higher portion of their income on food. Social nets can play an important role in supporting people through transitory food insecurity.

Food security is still at risk even in the globalized world. According to FAO et al. (2000), "prior to the COVID-19 pandemic, almost 690 million people, or 8.9% of the global population, were undernourished." This number is in increase. The number of undernourished people is expected to exceed 840 million by 2030 if the current trend continues. Achieving Goal 2 of zero hunger in SDGs is not feasible without improved actions.

We would like to understand demand and supply determinants for food in Sect. 13.2 before discussing food problem in developing countries in Sect. 13.3. Shortage of agricultural products not only dangers food security, but also jeopardizes the process of economic development in developing countries. This is understood as food problem. Lessons learned from the Japanese experiences in overcoming food problem are discussed in Sect. 13.4. Policy implications are derived in Sect. 13.5.

13.2 Demand and Supply Determinants for Food and Agricultural Products

In microeconomics, demand is considered as a function of income and prices. Changes in per capita demand on food and agricultural products are determined by the sum of the changes coming from income and the changes originating from prices. The national-level demand can be also influenced by the changes in national population. The relations can be summarized in the below.

National Level

$$\text{Demand on Food} = \text{Population} \times \text{per capita demand}$$

$$\text{Change in demand} = \text{Change in Population} + \text{Change in per capita Demand}$$

Determinants
1. Income Change
2. Price Change

$$= \text{Change in Population} + (\eta_I \times \text{Change in per capita Income}) + (\eta_p \times \text{Change in Price})$$

η_{I} Income elasticity of demandChange in per capita demand (%) when per capita income increases by 1%.

η_{p} Price elasticity of demandChange in per capita demand (%) when price increases by 1%.

Since income elasticity of demand is larger in the absolute value than price elasticity for agricultural and food products, per capita income and population are the critical determinants for the national-level demand in developing countries. When income elasticity of demand is negative, the item is called as inferior good. For the estimation of the future changes in demand, an important macroeconomic indicator of economic growth rate is typically utilized as proxy for the rate of change in per capita income. The information on per capita income is not easy to obtain even from the household survey. It is not often accurate as respondents tend to keep the private information such as revenue information secrete.

$$\overbrace{\frac{\Delta D}{D} \times 100}^{\text{Change in food demand (\%)}} = \overbrace{\frac{\Delta N}{N} \times 100}^{\text{Change in population (\%)}} + \overbrace{\eta_I \frac{\Delta\left(\frac{I}{N}\right)}{\left(\frac{I}{N}\right)} \times 100 + \eta_p \frac{\Delta P}{P} \times 100}^{\text{Change in per capita food demand (\%)}}$$

$$\frac{D_t - D_{t-1}}{D_{t-1}} \times 100 = \frac{\Delta N}{N} \times 100 + \eta_I \frac{\Delta\left(\frac{I}{N}\right)}{\left(\frac{I}{N}\right)} \times 100 + \eta_p \frac{\Delta P}{P} \times 100$$

$$+ \underbrace{\frac{\left(\frac{Y}{N}\right)_t - \left(\frac{Y}{N}\right)_{t-1}}{\left(\frac{Y}{N}\right)_{t-1}} \times 100}_{\text{Change in per capita income (\%)}} \quad \underbrace{\frac{P_t - P_{t-1}}{P_{t-1}}}_{\text{Change in price (\%)}}$$

N Population.

I National income.

P Price.

η_{I} Income elasticity of demand (% change in demand divided by 1% change in income) Change in per capita demand (%) when per capita income increases by 1%.

η_{p} Price elasticity of demand (% Change in demand divided by 1% change in price) Change in per capita demand (%) when price increases by 1%.

Let me explain how the demand estimate can be made using a numerical example.

Example of demand predictions

$$\overbrace{\frac{\Delta D}{D} \times 100}^{\text{Change in food demand (\%)}} = \overbrace{\frac{\Delta N}{N} \times 100}^{\text{Change in population (\%)}} + \overbrace{\eta_I \frac{\Delta\left(\frac{I}{N}\right)}{\left(\frac{I}{N}\right)} \times 100 + \eta_p \frac{\Delta P}{P} \times 100}^{\text{Change in per capita food demand (\%)}}$$

$$+ \underbrace{\qquad}_{\text{Change in per capita income}} \quad \underbrace{\qquad}_{\text{Change in price}}$$

$$= 0.8\% + (-1.8) \times (-1\%) + (-1\%) + (-0.1) \times (-1\%)$$

$$= 2.7\%$$

$$\Rightarrow \quad = 0.027(\times \text{Ratio taking 1 as base})$$

$$D_{2021} = 1.50 \text{ (million tons)}$$

$$D_{2022} = D_{2021} \times (1 + 0.027) = 1.50 \times 1.027 = 1.54(1.5405) \text{ (million tons)}$$

$$D_{2023} = D_{2021} \times (1 + 0.027)^2 = 1.50 \times (1.027)^2 = 1.58(1.5821) \text{ (million tons)}$$

The following is a set of assumptions to characterize the rice economy in Taiwan. Assuming the rice demand in 2021 was 1.50 million metric tons, we attempt to predict the rice demand for the following two years (2022 and 2023).

Population growth rate: $\Delta N/N \times 100 = 0.8\%$

Change in national income: $\Delta(I/N)/((I/N)) 100 = -1\%$ (Economic growth rate is often used as proxy).

Rate of price change: $\Delta P/P \times 100 = -1\%$ (With advancement in trade liberalization, domestic prices tend to decline.)

η_{I}: Income elasticity of demand (% change in demand divided by the % change in per capita

income) = −1.8 (This food item is considered as inferior good).

η_p: Price elasticity of demand (% change in demand divided by the % change in price) = −0.1 (All the food items are normal goods. Every η_p is negative).

As for supply determinants, there are two ways to increase agricultural production (supply of products): ① increase in input use and ② improvement in total factor productivity (TFP). TFP can be improved through (a) technical change and (b) improvement in production efficiency. This analytical framework can apply to all products including agricultural and food products.

How does (b) work? If incentives to work hard function, or education and training are implemented, production efficiency improves relative to the peer producers with best practice. TFP will be improved, then production goes up.

Assuming Y is output and I is total input (aggregated figure for all the inputs),

Y: Output ΔY: Output change $\frac{\Delta Y}{Y}$: Rate of change in output.

I: Total input.

$\frac{Y}{I}$: Total factor productivity (TFP).

We can derive the relationship among the change in output, the change in total input and the change in TFP on the right-hand side from the numerical relations among output, total input, and TFP on the left side.

$$Y = I \cdot \frac{Y}{I} \Rightarrow \frac{\Delta Y}{Y} \times 100 = \frac{\Delta I}{I} \times 100 + \frac{\Delta\left(\frac{Y}{I}\right)}{\frac{Y}{I}} \times 100$$

We utilize the equation on the right-hand side in the above to conduct growth accounting studies to examine the sources of output growth.

Why do we use rates of change for empirical analyses? This is because we can be free from problems with aggregation of inputs measured in different units by using rates of changes in showing the relationship between output and the sources to influence the output (inputs and productivity).

The rate of change in total input can be measured by the following equation.

$$\Delta I/I * 100 = 0.6 * \Delta L/L * 100 + 0.4 * \Delta K/K * 100$$

0.6 and 0.4 are the weights measured in cost shares. Cost shares become the weights in the calculation of total input for a Cobb–Douglas type production function. We assume that the production function is a Cobb–Douglas type of $Y = \alpha_0 L^{\alpha 1} K^{\alpha 2}$, where $\alpha_1 = wL/\text{PY}$ and $\alpha_2 = rK/\text{PY}$ under the profit maximization principle for the behavior of producer.

Which approach is preferred to increase output?

① increases in input use or ② improvement in total factor productivity (TFP)?

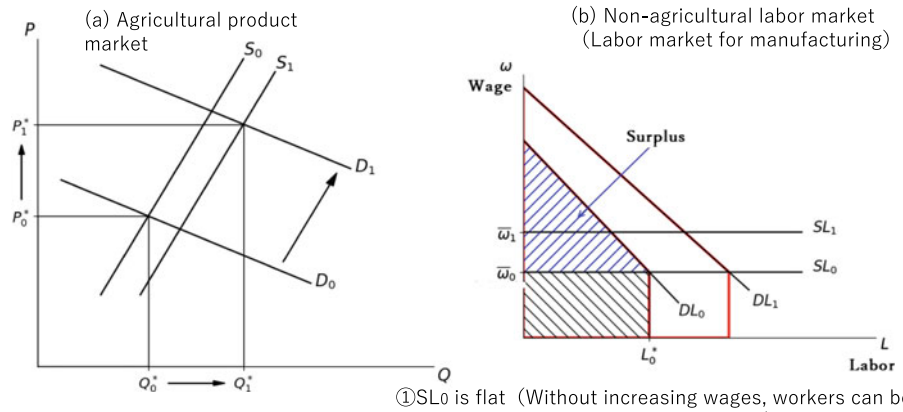
② is preferred to ①. This is because ② can save costs and maximizes profit. ② is also a sustainable approach. This leads to environmental conservation.

Historically speaking, ② improvement in total factor productivity (TFP) explains approximately 70% of output growth for Japanese agriculture over the past 120 years.

For most developing countries, because of lack of (a) "technical change" and (b) "improvement in production efficiency", ① "increasing use of total input" is the dominant determinant for output increase. Developing countries need to move to Approach ②. We will discuss the approach by Japanese agriculture in Sect. 13.4 and policy implications in Sect. 13.6.

13.3 Food Problem in Developing Countries

In the process of economic development, the speed of increase in demand on agricultural products exceeds the speed of increase in the supply of agricultural products. This results in increase in the prices of agricultural products. The nominal wages in non-agricultural sectors need to be raised. This slows down the speed of economic development (through slowdown of



①Shift in demand is large (Population ↑)
②Shift in supply is small (Tech transfer X)
③Slope of demand curve is flatter
(Price elasticity of demand is not low (not inelastic))

①SL_0 is flat (Without increasing wages, workers can be employed. Many workers are under unemployment.)
②Wages are set by employers in the subsistence level. (Employers can determine the wages at the minimum level.)
③DL represents value marginal product of labor (VMP of labor: value added when we increase the use of labor by one unit)

Fig. 13.1 Dual-sector model in economic development. *Note* The author has been benefitted from Hayami and Goda (2002) and Hayami (1986) regarding their debates on agricultural development using the dual-sector model of economic development developed by Lewis (1954)

enlargement of non-agricultural sector activities mainly in the manufacturing sector). We call this challenge in economic development as food problem. We would like to discuss how food problem happens first. We will then consider the short-run and long-run solutions to food problem using Fig. 13.1.

In our economic development model for developing countries, we assume the following in the agricultural product market and the labor market in the non-agricultural (manufacturing) sector.

①Industrial development is a key for economic development. In the history of economic development in Japan, the manufacturing sector developed about 15 times faster than the agricultural sector for 1880–1980. Other industrialized countries followed the same path as Japan.

②The wage is set at the lowest for survival (in the subsistence level) in the non- agricultural sector. We assume that labor supply exceeds labor demand. (A large proportion of the workers is under unemployment.)

③Food (agricultural products) is a wage good. (The share in the total expenditure is high so that the nominal wage is influenced by the price level of food (agricultural products).) The food price is an important determinant of the nominal wage in the non-agricultural sector. Even powerful employers need to agree to a pay raise in the nominal term to avoid a decline in labor productivity.

Here is the explanation of the labor market in the manufacturing sector shown in (b) of Fig. 13.1.

1. We assume that the manufacturing sector is labor intensive.
2. Supply curve of labor (SL_0) is flat in developing countries. The wage level is constant.
3. W_0 is the subsistence level of wage, which is the minimum level of wage for survival. This is the minimum level of wage to keep workers' basic health conditions to continue working.
4. Since SL_0 is flat, even if demand for labor (DL_0) shifts to a higher level of (DL_1), the minimum or subsistence wage stays at the same level of W_0.
5. The blue and black line areas (the shaded areas) are the total revenue, which is equivalent to the producer's willingness to pay for wages (value marginal product of labor (MP_L * P).
6. The black area is the total wages paid to the workers.

7. The difference between the producer's willingness to pay (revenue) and the wages they pay is the producer's surplus (profit) which can be used for reinvestment in the next year.
8. Reinvestment can shift DL_0 to the right (like to the location of DL_1) to make the surplus even larger in the next year. This reinvestment cycle in the manufacturing sector can lead to economic development. (The GDP share in production is large for the manufacturing sector.)
9. Land is not such a limiting constraint for the manufacturing sector as the agriculture sector.

When increase in agricultural product prices happens, the following will be observed in developing countries.

1. The Engel Index of 60–70% is a typical range of the share for food and beverages in the total household expenditure in developing countries.
2. The engine for economic growth is not the agriculture sector, but the manufacturing sector. Land is not such a limiting constraint for the manufacturing sector as for the agriculture sector.
3. The increase in agricultural products (food) prices has a negative impact on the manufacturing sector's growth because it would necessitate an increase in nominal wages to at least keep real wages constant. Nominal wage raise would become necessary by employers in the manufacturing sector because the nominal wages were in the subsistence (minimum) level. Labor productivity would decline if employers do not raise nominal wages.
4. The surplus (profit) that the producer in the manufacturing sector enjoys becomes smaller. The speed of the growth in the national economy as well as the manufacturing sector will slow down.

The solution to food problem in the long run is to shift the supply curve to the right by reducing the cost of production through technical change. This can be achieved through technology transfer from developed countries.

Since successful technology transfer requires human resource development and improvement in agriculture and rural infrastructure, it is a time-consuming process to overcome food problem in developing countries. In the short run, the country can, assuming lower international prices, choose to import the difference between Q_1' and Q_0. However, the import necessitates domestic reserve in foreign currencies to import.

Alternatively, food aid from bilateral and multilateral donors can be another shot-run solution for the developing countries. What we observe most is cheap food policy. The governments often intervene to the agricultural product market to keep the prices low. The governments exclusively buy at the price of P_1 and sell at P_0 where $P_0 < P_1$. $< P_1$*. Food rationing is frequently present. Many relied on this third option in Africa. However, this approach called "cheap food policy" has a structural problem. Incentives for agricultural producers to produce more remain low. The supply curve will not significantly shift to the right.

13.4 Japanese Experiences for Overcoming Food Problem

Japan overcame food problem by shifting the supply curve of agricultural products to the right. We would like to learn lessons from the experiences of Japan. Agricultural product prices were kept low to avoid the hike in real wages in non-agriculture. We study the history of agricultural development in Japan in relation to economic development to understand what is needed to shift the supply curve. Policy implications are derived for the countries which are still struggling for food problem.

The agriculture sector subsidized the manufacturing sector in the early stage of economic development in the Meiji period. A new land tax scheme was introduced. Feudal tax (in kind) levied in proportion to quantities was replaced by a cash tax system. This (land tax) source of revenue accounted for 70% of the Meiji government revenue. Modernization of the Japanese economy was made possible using the government revenue from land tax.

The tax rates were determined in relation to the land value. 3% of land value was annually imposed as land tax. Many small-scale farmers failed to pay for the land tax and had to give up land ownership. Disparities in land asset ownership and income enhanced among rural households as a result.

Technologies imported from Europe and North America did not work for agriculture. The agricultural technology suited for large-scale production in dry areas was not useful for Japanese agriculture in wet areas. Instead, improvement of indigenous rono (veteran farmers) techniques through the application of modern science was set as means for agricultural development. Technology developed was intended to increase land productivity and was biased toward land saving. Scarcity of agricultural land represented the major constrain on agricultural development in Japan. New technology has been induced to develop for saving a scarce factor of production following the induced innovation hypothesis (Hayami and Ruttan 1985).

In terms of sources of growth (supply determinants), the contribution of total factor productivity (TFP) has been dominant in Japanese agriculture. When Japanese agriculture was rapidly expanding its production in 1880–1920 in order to conquer food problem, the growth in TFP accounted for 67% of the output growth as shown in Table 13.1. Domestic technology transfer of land saving technology was encouraged by the government to localize high yielding rice varieties from Southern and Western Japan in Northern and Eastern Japan.

The Japanese government helped the process of domestic technology transfer with the policies listed in Table 13.2. Rice yields (land productivity) increased significantly because of (1) development of a nationwide network of research, experimental, and extension stations, (2) improvement in land infrastructure, and (3) increase in availability of chemical fertilizer. High yielding rice varieties are heavy in grains. The height of rice plants should be short to stand firm even in rainstorms. Better water control became required for the high yielding rice varieties. Land improvement efforts to install irrigation and drainage facilities in rural areas have been made. The government assisted the efforts by local land improvement associations with easier decision-making rules and formal legal status of the land improvement associations and financial supports through the newly created public financial institution which was able to provide long-term soft loans.

Table 13.1 Sources of growth in Japanese agriculture

	Annual growth rate in output (%)	Annual growth rate in total input (%)	Annual growth rate in TFP (%)
1880–1900	1.5	0.3	1.2
1900–1920	1.8	0.8	1.0
1920–1935	0.9	0.5	0.4
1935–1945	−1.8	-1.1	-0.8
1945–1955	3,3	2.2	1.1
1955–1965	3.2	0.4	2.8
1965–1980	0.3	-1.1	1.4
1980–1995	−0.6	-2.1	1.5

Source Adapted from Hayami and Godo (2002), Table 4.4 on Page 99

13.5 Conflicts Between Energy Security and Food Security Goals

Securing natural resources for energy use has been always a challenge for natural resourceless countries like Japan. The use of biomass resources was thought to be a good idea when crude oil and other natural resource prices were record high in the 2000s before the economic crisis happened in 2008.

In the USA, a promotional policy to produce bioethanol from maize started. This created a conflict between energy crop and food crop in land use. The agricultural product prices as well as land prices soared. Biofuels came out from agricultural land, competed with food and thus endangered food security.

Table 13.2 Government policies for agricultural development in Japan

• *1887—Japan Hypothec Bank was established*
This bank aimed to extend long-term credit for land infrastructure investments
• *1888—Establishment of the Tokyo Artificial Fertilizer Company*
Commercial production of superphosphate began
• *1893—National Agricultural Experiment Station*
This was created to counteract the request to reduce land tax
Despite its meager (insubstantial) resources, it was able to work on indigenous technological potential
• *1894—National Agricultural Association*
A larger and more systematic organization was required for promoting agricultural interests, one that could exercise political influence
• *1899—Fertilizer Control Law*
This ensured quality of fertilizer being sold to the farmers
• *1899—Arable Land Reallotment Law*
With this law, the participation in a land improvement project became compulsory upon the consent of more than 2/3 of the landowners in the region concerned owning more than 2/3 of the arable land
Legal person status was given to the land improvement associations so they can receive credit from financial institutions such as Japan Hypothec Bank

Source Chapter 2, Hayami and Yamada (1991)

As land stays scarce in Japan, promotion of energy crop production is not desirable. Use of the second-generation (more efficient) technology is an option. High cost of production is a problem. Direct use of local forest resources such as wood chips is becoming popular in the local level in Japan. There is no significant development of bioethanol production beyond pilot cases.

Problems exist related to bioethanol production and use in the local communities in Japan. First, legal problems occurred in getting permissions to sell biofuels to others, getting permissions to blend bioethanol with gasoline, and getting permissions to modify vehicles to use blended gasoline. Technical problems are high cost of production and low-energy efficiency. Biofuels use renewable resources when produced, but still emit greenhouse gasses when used. If more energy is used to produce and emit lots of greenhouse gasses, it would not be sustainable to utilize biofuels.

Promotional policy of bioethanol production has implications on alternative energy production, food security, climate change problems, agricultural and industrial development, and rural and community development. Political decisions need to be made.

Unless we use by-products from agricultural and forest production or use marginal land for energy crop production, we will face conflict with food security. Improvement in energy efficiency is another technological challenge.

13.6 Concluding Remarks

Policy implications for developing countries are discussed related to global food security and related to SDGs.

Production increase in agriculture has come from the improvement in productivity in Japan. Increasing use of inputs has been playing a minor role with the exception of the food shortage period of the late 1940s and the 1950s. Zero hunger (Goal 2 of SDGs) and zero poverty (Goal 1 of SDGs) were achieved in Japan thanks to the efforts for technical change over time.

Production increase in agriculture for the rest of Asia had been observed based on the increasing use of inputs. However, in recent decades, productivity improvement has become

important, especially in Korea, China, and ASEAN countries.

Governments can play significant roles for promoting productivity growth-based output growth for securing the availability for food security in developing countries. Like Japanese agriculture was helped, the governments can develop research and extension networks. Direction of technical change should be the direction to save a scarce factor of production for economic and sustainability reasons. The scarce factor in Japanese agriculture was initially land in the Meiji period. Later, in the post-World War II period, labor has become scarcer than land. Biological technology of high yielding rice variety was developed with scarcity in land. Mechanical technology has been developed in recent years. Researchers and policy decision makers might have to carefully observe the scarcity of individual inputs. Improvement in agricultural and rural infrastructure such as irrigation and drainage systems would be quite critical. High yielding rice varieties have been more effectively adapted to the new agricultural and rural environment in the new locations with better control on water in the paddy field in Japan.

As for other functions of agricultural and rural development like energy security and mitigation of climate change, many governments are still struggling with what to do locally. The national-level global goals including SDGs have been set by the governments in developed as well as developing countries. There exist conflicts between different SDGs as we discussed the example of energy security and food security in this chapter. We hope to collect the cases of good practice from local stakeholders and widely share the lessons learned from them for the globalized world.

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Part V
For Peace (SDG 16)

Designing Allocation Rules in Economic Problems

14

Yoichi Kasajima

Abstract

How should we divide a resource among a group of agents who have conflicting claims for it? A typical example is the bankruptcy problem: The liquidation value of a bankrupt firm must be divided among creditors. An alternative example with the same mathematical structure is the taxation problem: The cost of some public projects must be collected by a government through taxing incomes. An awards vector determines the division of the resource among the agents. An allocation rule, or simply a rule, is a function that associates an awards vector to each problem of this kind. Our goal is to construct "good" rules. By that, we intend to learn how to achieve one of the Sustainable Development Goals (SDGs) (Goal 16: Peace, Justice and Strong Institutions). In our study of rules, we follow the axiomatic approach. That is, we (i) formulate rules (mathematically), (ii) introduce "desirable" properties of rules (called axioms), and (iii) study those implications (e.g., identify rules that satisfy those properties). We present some well-known characterization results based on the properties analyzed.

Keywords

Economic problems · Claims problems · Allocation rules · Axiomatic approach

14.1 Introduction

The problem of allocating scarce resources among agents is called an "economic problem." The resource could be a variety of goods, including natural resources, foods, clothes, houses, etc. It could also be economic services, money, time, or human resources. An "allocation rule," or simply a rule, is a systematic way to determine an answer (or a recommendation) to such an economic problem. More precisely, it is a mapping that associates an allocation with each economic problem. Our goal is to study how to design "good" rules. By that, we intend to learn how to achieve Goal 16 (Peace, Justice and Strong Institutions) of the Sustainable Development Goals (SDGs). Designing good rules for economic problems makes each nation wealthy and achieves world peace. Fairness (equity) is the key to designing good rules in this chapter. However, how can we construct a fair rule? How can we evaluate whether a rule is fair? We adopt an axiomatic approach. That is, we (i) formulate rules (mathematically), (ii) introduce "desirable" properties of rules (called axioms), and (iii) study

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those implications (e.g., identify rules that satisfy those properties).

The value of the designed rule depends on the types of economic problems that we face. Among the many economic problems, we consider one of the simplest economic problems called the "claims problem" (O'Neill 1982), described as follows.[1] There are a set of agents and a resource to divide among them. Each agent has a claim over the resource, but the quantity of the resource is not sufficient to cover all claims. We assume that the resource and each agent's claim are non-negative real numbers. The question is how to allocate the resource to the agents. For instance, suppose that there are three agents: agents 1, 2, and 3. Let $c_1 = 100$, $c_2 = 200$, $c_3 = 300$ be the claims of agent 1, agent 2, and agent 3, respectively, and $E = 250$ be a resource to divide. As $c_1 + c_2 + c_3 > E$, the resource is clearly not sufficient to cover all claims. However, we still have to divide $E = 250$ among the agents. A typical example of this is bankruptcy: The liquidation value of a bankrupt firm has to be divided among creditors. Another example with the same mathematical structure is taxation, where the cost of some public projects must be collected by a government through taxing incomes. Here, each agent's claim is considered the agent's pre-tax income, while the resource corresponds to the amount of money needed to implement the project. However, we will use language based on the bankruptcy interpretation.

When we allocate a resource to the agents, we require that each agent receives a non-negative amount that is at most as large as their claim. Additionally, the resource is entirely divided among the agents (i.e., the total amount that agents receive is equal to the resource). In our previous three-agent example, let x_1, x_2, and x_3 be the amounts agents 1, 2, and 3 receive, respectively. Then, the above requirements can be expressed as $0 \leq x_1 \leq c_1, 0 \leq x_2 \leq c_2$, $0 \leq x_3 \leq c_3$ and $x_1 + x_2 + x_3 = E$. We call such (x_1, x_2, x_3) an awards vector. A rule is a function that associates with each claims problem an awards vector. As mentioned before, we adopt an axiomatic approach to analyze the rules. We study the implications of several important properties of rules and present some well-known characterization results based on these properties.

[1] See Thomson (2003, 2015, 2019) for an extensive survey on this subject.

14.2 Model

Here, we introduce a formal model. There is an infinite set of "potential" agents indexed by the natural numbers $\mathbb{N}$. For each case, a finite number of them are present. Let $\mathcal{N}$ be a set of finite subsets of $\mathbb{N}$. The set $N \in \mathcal{N}$ is called the **set of agents**. For instance, $N = \{1, 2, 3, 4\}$. There is a **resource** $E \in \mathbb{R}_+$ that needs to be divided among agents.[2] Each agent $i \in N$ has a **claim** over the resource. Let $c_i \in \mathbb{R}_+$ be the claim of agent i. Let $c = (c_i)_{i \in N}$ be the claims vector. If $N = \{1, 2, 3, 4\}$, $c = (c_1, c_2, c_3, c_4)$. We assume that the resource is not sufficient to honor all claims, that is, $\sum_{i \in N} c_i \geq E$.[3] We allow the equality $\sum_{i \in N} c_i = E$ for convenience. A claims problem, or simply a **problem**, with agent set $N \in \mathcal{N}$ is a pair $(c, E) \in \mathbb{R}_+^N \times \mathbb{R}_+$ such that $\sum_{i \in N} c_i \geq E$.[4] Let $\mathcal{C}^N$ be the set of all claims problems. If $N = \{1, 2, 3, 4\}$, $c = (5, 10, 20, 30)$, and $E = 50$, then $(c, E) = (5, 10, 20, 30; 50) \in \mathcal{C}^N$ since $\sum_{i \in N} c_i \geq E$. On the other hand, given the same N and c, if $E = 70$, then $(c, E) = (5, 10, 20, 30; 70) \notin \mathcal{C}^N$ since $\sum_{i \in N} c_i < E$.

We impose the following restrictions on the amount that the agents can receive: Each agent should not receive a negative amount; each agent should not receive more than their claim; and the total amount that agents receive should be equal to the resource. A list of amounts satisfying these requirements is called an awards vector. Formally, an **awards vector** for $(c, E) \in \mathcal{C}^N$ is a

[2] By $\mathbb{R}_+$, we mean the set of non-negative real numbers.

[3] If $N = \{1, 2, 3, 4\}$, $\sum_{i \in N} c_i = c_1 + c_2 + c_3 + c_4$.

[4] By $\mathbb{R}_+^N$, we mean the Cartesian product of $|N|$ copies of $\mathbb{R}_+$ indexed by the members of N.

vector $x = (x_i)_{i \in N} \in \mathbb{R}^N$ such that (i) for each $i \in N$, $0 \leq x_i \leq c_i$ and (ii) $\sum_{i \in N} x_i = E$.[5] Let $X(c, E)$ be the set of awards vectors for $(c, E) \in \mathcal{C}^N$. If $N = \{1, 2, 3, 4\}$, $c = (5, 10, 20, 30)$, $E = 50$, and $x = (3, 7, 13, 27)$, then $x \in X(c, E)$. On the other hand, under the same N, c, and E, if $x = (3, 12, 15, 20)$, then $x \notin X(c, E)$ since agent 2 receives more than her claim ($x_2 > c_2$). Again, under the same N, c, and E, if $x = (3, 7, 10, 15)$, then $x \notin X(c, E)$ since the resource is not entirely allocated ($\sum_{i \in N} x_i < E$). A **rule**, denoted generically φ, is a function defined on $\bigcup_{N \in \mathcal{N}} \mathcal{C}^N$, which associates with each $N \in \mathcal{N}$ and each $(c, E) \in \mathcal{C}^N$ a vector $x \in X(c, E)$. We introduce several examples of these rules in the next section.

The **bankruptcy problem** is a typical application of the situation we have considered. Suppose that a firm goes bankrupt. Let N be the set of creditors of that firm, c_i be creditor i's amount of claim, and E be the liquidation value of the firm. Naturally, $\sum_{i \in N} c_i \geq E$. Then, a rule determines how to allocate the liquidation value to the creditors. Another application with the same mathematical structure is the **taxation problem**. Consider the case in which a government has to collect money from the people in the nation by taxing their incomes. Let N be the set of people in the nation, c_i be the person i's pre-tax income, and E be the amount of money the government has to collect. Since the government cannot ask for more than the total pre-tax income, it is natural to assume that $\sum_{i \in N} c_i \geq E$. Then, a rule determines how to tax income.

We also refer to two problems that appear in the Talmud. One is the **marriage contract problem** (Thomson 2019). This is described as follows:

> If a man who was married to three wives died and the kethubah of one was a maneh (100 zuz), of the other two hundred zuz, and of the third three hundred zuz, and the estate (was worth) only one maneh (one hundred zuz), the (the sum) is divided equally. If the estate (was worth) two hundred zuz (the claimant) of the maneh (one hundred zuz) receives fifty zuz (and the claimants respectively) of the two hundred and the three hundred zuz (receive each) three gold denarii (seventy-five zuz). If the estate (was worth) three hundred zuz (the claimant) of the maneh receives fifty zuz and (the claimant) of the two hundred zuz (receives) a maneh (one hundred zuz) while (the claimant) of the three hundred zuz (receives) six gold denarii (one hundred and fifty zuz). Similarly if three persons contributed to a joint fund and they had made a loss or a profit they share in the same manner.
>
> (O'Neill 1982, p. 370)

The above problem can be described using our notations as follows. Let N be the set of wives, c_i be the claim of each wife $i \in N$, and E be the worth of the estate. In addition, let x_i be the amount that wife $i \in N$ receives. This problem comprises three situations. For each situation, $N = \{1, 2, 3\}$, $c_1 = 100$, $c_2 = 200$, and $c_3 = 300$. For the first situation, $E = 100$, and the Talmud suggests $x_1 = x_2 = x_3 = 33\frac{1}{3}$. For the second situation, $E = 200$, and the recommendation is $x_1 = 50$ and $x_2 = x_3 = 75$. For the third situation, $E = 300$, $x_1 = 50$, $x_2 = 100$, and $x_3 = 150$.

The other problem is called the **contested garment problem** (Thomson 2019), which is described as follows:

> Two hold a garment… if one of them says, "It is all mine" and the other says, "Half of it is mine",… the former then receives three quarters and the latter receives one quarter.
>
> (O'Neill 1982, page 346)

Let the worth of the garment be 100. Then, we can describe the above problem by $N = \{1, 2\}$, $c_1 = 50$, $c_2 = 100$, and $E = 100$. The Talmud suggests $x_1 = 25$ and $x_2 = 75$, where x_i denotes the amount that agent $i \in N$ receives.

Table 14.1 summarizes examples that appear in the marriage contract and contested garment problems. What kind of rule will generate numbers that the Talmud recommends for each problem in Table 14.1? The answer does not seem to be straightforward. For instance, in (A), the Talmud seems to suggest "equal division," while in (C), it seems to insist on "proportional division." In the next section, we answer the

[5] By $\mathbb{R}$, we mean the set of real numbers. We define $\mathbb{R}^N$ similar to footnote 4.

above question by exploring examples of rules. Hereafter, unless specified, we use language based on bankruptcy application.

14.3 Rules

14.3.1 CEA Rule

We introduce four central rules proposed in the literature. In our first rule, we try to divide a resource equally among the agents. However, if we simply divide the resource equally, some agents may receive more than their claims. Thus, we divide the resource equally, subject to no agent receiving more than their claim. For instance, let $N = \{1, 2, 3, 4\}$, $c = (20, 30, 50, 60)$, and $E = 140$. If we divide E equally among the four agents, agents 1 and 2 will receive more than their claims. In that case, we first determine that agent 1 (who has the smallest claim) receives 20. Next, we divide the rest $140 - 20 = 120$ to agents 2, 3, and 4. Now, if we divide the rest equally among them, agent 2 will receive more than her claim. Thus, we decide to give 30 to agent 2. The rest is $120 - 30 = 90$. We can divide this amount equally to agents 3 and 4 because neither of them receives more than their claim. Thus, each agent obtains 45. The formal definition is as follows:

Constrained Equal Awards rule (CEA rule): For each $N \in \mathcal{N}$, each $(c, E) \in \mathcal{C}^N$, and each $i \in N$, $\mathrm{CEA}_i(c, E) = \min\{c_i, \lambda\}$, where $\lambda \in \mathbb{R}$ is chosen such that $\sum_{i \in N} \min\{c_i, \lambda\} = E$.

Example 14.1 Let $N = \{1, 2, 3\}$, $c = (50, 80, 100)$, and $E = 170$. Then, $\mathrm{CEA}(c, E) = (50, 60, 60)$. ◀

Example 14.2 Let $N = \{1, 2, 3, 4, 5\}$, $c = (20, 40, 40, 70, 90)$, and $E = 200$. Then, $\mathrm{CEA}(c, E) = (20, 40, 40, 50, 50)$. ◀

The reader can check that $\lambda = 60$ and $\lambda = 50$ in Examples 14.1 and 14.2, respectively. In Table 14.1, the CEA rule generates the numbers recommended by the Talmud only in problem (A). Under the CEA rule, even an agent with a small claim can receive some amount. In this sense, smaller claimants favor this rule.

14.3.2 CEL Rule

The next rule focuses on the losses that agents face and the total loss (the difference $\sum_{i \in N} c_i - E$). We try to divide the total loss equally among agents so that each agent bears the same loss. However, some agents may receive a negative amount if we do so. Thus, we divide the total loss equally, subject to no agent receiving a negative amount. For instance, let $N = \{1, 2, 3, 4\}$, $c = (20, 35, 55, 60)$, and $E = 40$. Then, the total loss is $(20 + 35 + 55 + 60) - 40 = 130$. If we divide this amount equally among the four agents $(130/4 = 32.5)$ and ask each agent to give up that amount, agent 1 ends up receiving a negative amount. Then, we determine that agent 1 receives 0 (we ask agent 1 only to give up 20). Note that the final awards vector is not $(0, 35 - 32.5, 55 - 32.5, 60 - 32.5) = (0, 2.5, 22.5, 27.5)$ because the total award is not equal to $E = 40$. Thus, the total loss must be revised. Since agent 1 only gave up 20, the revised total loss among the remaining agents 2, 3, and 4 is $130 - 20 = 110$. If we divide this amount equally among them, agent 2 receives a negative amount. Thus, we set agent 2 to receive 0 (agent 2 only gives up 35). The revised total loss among agents 3 and 4 is now $110 - 35 = 75$. We can ask each of them to give up $75/2 = 37.5$ since neither of them ends up receiving a negative amount. This results in agents 3 and 4 receiving 17.5 and 22.5, respectively. Thus, the formal definition is as follows:

Constrained Equal Losses rule (CEL rule): For each $N \in \mathcal{N}$, each $(c, E) \in \mathcal{C}^N$, and each $i \in N$, $\mathrm{CEL}_i(c, E) = \max\{0, c_i - \lambda\}$, where $\lambda \in \mathbb{R}$ is chosen such that $\sum_{i \in N} \max\{0, c_i - \lambda\} = E$.

Example 14.3 Let $N = \{1, 2, 3\}$, $c = (50, 80, 100)$, and $E = 50$. Then, $\mathrm{CEL}(c, E) = (0, 15, 35)$. ◀

Table 14.1 Examples in the Talmud

Problem in the Talmud	Recommendation by the Talmud
(A) $c_1 = 100, c_2 = 200, c_3 = 300, E = 100$	$x_1 = 33\frac{1}{3}, x_2 = 33\frac{1}{3}, x_3 = 33\frac{1}{3}$
(B) $c_1 = 100, c_2 = 200, c_3 = 300, E = 200$	$x_1 = 50, x_2 = 75, x_3 = 75$
(C) $c_1 = 100, c_2 = 200, c_3 = 300, E = 300$	$x_1 = 50, x_2 = 100, x_3 = 150$
(D) $c_1 = 50, c_2 = 100, E = 100$	$x_1 = 25, x_2 = 75$

Example 14.4 Let $N = \{1, 2, 3, 4, 5\}$, $c = (20, 40, 40, 70, 90)$, and $E = 70$. Then, $\text{CEL}(c, E) = (0, 0, 0, 25, 45)$. ◀

The reader can verify that $\lambda = 65$ in Example 14.3. Thus, all agents either give up "their entire claim" (if their individual claim is less than λ) or "λ" (if their individual claim is at least as large as λ). Similarly, $\lambda = 45$ in Example 14.4. In Table 14.1, the CEL rule generates recommendations by the Talmud only in problem (D). Under the CEL rule, an agent with a small claim can easily receive nothing. Since each agent, regardless of the claim size, is asked to give up the same amount (or the entire claim), an agent with a larger claim gives up a relatively small part of their claim. In this sense, larger claimants are more likely to favor this rule.[6]

14.3.3 Proportional Rule

The next rule divides the resource proportional to the claims. Let $N = \{1, 2, 3, 4\}$, $c = (10, 30, 50, 60)$, and $E = 120$. Then, for instance, agents 1 and 2 receive $\frac{10}{10+30+50+60} \times 120 = 8$ and $\frac{30}{10+30+50+60} \times 120 = 24$, respectively. Note that

$$\frac{10}{10+30+50+60} \times 120 = 10 \times \frac{120}{10+30+50+60} = 10 \times \frac{4}{5} = 8 \text{ and}$$
$$\frac{30}{10+30+50+60} \times 120 = 30 \times \frac{120}{10+30+50+60} = 30 \times \frac{4}{5} = 24.$$

Thus, agents 1 and 2 receive $\frac{4}{5}$ of their individual claims. A similar calculation can also be performed for agents 3 and 4. Therefore, we can claim that each agent obtains the same "ratio" of their claim under this rule. This is denoted by λ in the following formal definition:

Proportional rule: For each $N \in \mathcal{N}$, each $(c, E) \in \mathcal{C}^N$, and each $i \in N$, $P_i(c, E) = \lambda c_i$, where $\lambda \in \mathbb{R}$ is chosen such that $\sum_{i \in N} \lambda c_i = E$.

Example 14.5 Let $N = \{1, 2, 3\}$, $c = (20, 40, 60)$, and $E = 90$. Then, $P(c, E) = (15, 30, 45)$. ◀

Example 14.6 Let $N = \{1, 2, 3, 4, 5\}$, $c = (20, 40, 40, 70, 70)$, and $E = 60$. Then, $P(c, E) = (5, 10, 10, 17.5, 17.5)$. ◀

The reader can check that $\lambda = \frac{3}{4}$ and $\lambda = \frac{1}{4}$ in Examples 14.5 and 14.6, respectively. In Table 14.1, the proportional rule gives the same recommendation as the Talmud only in problem (C).

14.3.4 Talmud Rule

The final rule generates numbers recommended by the Talmud for each problem in Table 14.1 (Aumann and Maschler 1985). The rule is described as follows. We distinguish two cases: when the quantity of the resource is less than or equal to the half-sum of the claims ($\sum_{i \in N} \frac{c_i}{2} \geq E$); and when the resource is more than the half-sum of the claims ($\sum_{i \in N} \frac{c_i}{2} < E$). In the first case, we apply the CEA rule to the problem $\left(\frac{c}{2}, E\right)$. We reduce each agent's claim by half since even if each agent only claims half of their claim, the

[6] The CEA and CEL rules are called "dual" rules. See Aumann and Maschler (1985), Herrero (2003), and Thomson and Yeh (2008) for details regarding the notion of duality in this context.

resource is not sufficient (except for the case when $\sum_{i\in N}\frac{c_i}{2}=E$). In the second case, we first give each agent half of their individual claim. After that, we still have the amount $E-\sum_{i\in N}\frac{c_i}{2}$ left to divide. We then apply the CEL rule to divide this amount. Since the agents have already given half of their claims, we let them assert only half of their claims when applying the CEL rule. To summarize, after giving each agent half of their claim, we use the CEL rule to the problem $\left(\frac{c}{2},E-\sum_{i\in N}\frac{c_i}{2}\right)$. For example, let $N=\{1,2,3,4\}$, $c=(20,30,40,60)$, and $E=65$. Since $\sum_{i\in N}\frac{c_i}{2}=\frac{1}{2}(20+30+40+60)=75>E=65$, we apply the CEA rule to the problem $\left(\frac{c}{2},E\right)$. Thus, the awards vector is $\mathrm{CEA}\left(\frac{c}{2},E\right)=\mathrm{CEA}(10,15,20,30;65)=(10,15,20,20)$. Next, under the same N and c, let $E=90$. Since $\sum_{i\in N}\frac{c_i}{2}=\frac{1}{2}(20+30+40+60)=75<E=90$, we give each agent half of their claim and apply the CEL rule to divide the rest $E-\sum_{i\in N}\frac{c_i}{2}=90-75=15$ under the claims vector $\frac{c}{2}=(10,15,20,30)$. Thus, the awards vector is $\frac{c}{2}+\mathrm{CEL}\left(\frac{c}{2},E-\sum_{i\in N}\frac{c_i}{2}\right)=(10,15,20,30)+\mathrm{CEL}(10,15,20,30;15)=(10,15,20,30)+(0,0,2.5,12.5)=(10,15,22.5,42.5)$. One can say that this rule is a "well-balanced" rule in the sense that it mixes the CEA rule (favored by smaller claimants) and the CEL rule (favored by larger claimants). The formal definition of this rule is as follows:

Talmud rule: For each $N\in\mathcal{N}$ and $(c,E)\in\mathcal{C}^N$,

$$\mathrm{Tal}(c,E)=\begin{cases}\mathrm{CEA}\left(\frac{c}{2},E\right)\text{if}\sum_{i\in N}\frac{c_i}{2}\geq E\\ \frac{c}{2}+\mathrm{CEL}\left(\frac{c}{2},E-\sum_{i\in N}\frac{c_i}{2}\right)\text{if}\ \sum_{i\in N}\frac{c_i}{2}<E.\end{cases}$$ ◀

Example 14.7 Let $N=\{1,2,3,4,5\}$, $c=(10,30,40,80,100)$, and $E=100$. Note that $\sum_{i\in N}\frac{c_i}{2}=\frac{1}{2}(10+30+40+80+100)=130>E=100$. Thus, we have $\mathrm{Tal}(c,E)=\mathrm{CEA}\left(\frac{c}{2},E\right)=\mathrm{CEA}(5,15,20,40,50;100)=(5,15,20,30,30)$. ◀

Example 14.8 Let $N=\{1,2,3,4,5\}$, $c=(10,30,40,80,100)$, and $E=170$. Note that $\sum_{i\in N}\frac{c_i}{2}=\frac{1}{2}(10+30+40+80+100)=130<E=170$. Thus, we have

$$\begin{aligned}\mathrm{Tal}(c,E)&=\frac{c}{2}+\mathrm{CEL}\left(\frac{c}{2},E-\sum_{i\in N}\frac{c_i}{2}\right)\\&=(5,15,20,40,50)+CEL(5,15,20,40,50;170-130)\\&=(5,15,20,40,50)+(0,0,0,15,25)\\&=(5,15,20,55,75).\end{aligned}$$

◀

Example 14.9 (Examples in Table 14.1): (A) Note, $\sum_{i\in N}\frac{c_i}{2}=\frac{1}{2}(100+200+300)=300>E=100$. Thus, $\mathrm{Tal}(c,E)=\mathrm{CEA}\left(\frac{c}{2},E\right)=\mathrm{CEA}(50,100,150;100)=\left(33\frac{1}{3},33\frac{1}{3},33\frac{1}{3}\right)$.

(B) Note, $\sum_{i\in N}\frac{c_i}{2}=\frac{1}{2}(100+200+300)=300>E=200$. Thus, $\mathrm{Tal}(c,E)=\mathrm{CEA}\left(\frac{c}{2},E\right)=\mathrm{CEA}(50,100,150;200)=(50,75,75)$.

(C) Note, $\sum_{i\in N}\frac{c_i}{2}=\frac{1}{2}(100+200+300)=300\geq E=300$. Thus, $\mathrm{Tal}(c,E)=\mathrm{CEA}\left(\frac{c}{2},E\right)=\mathrm{CEA}(50,100,150;300)=(50,100,150)$.

(D) Note, $\sum_{i\in N}\frac{c_i}{2}=\frac{1}{2}(50+100)=75<E=100$. Thus,

$$\begin{aligned}\mathrm{Tal}(c,E)&=\frac{c}{2}+\mathrm{CEL}\left(\frac{c}{2},E-\sum_{i\in N}\frac{c_i}{2}\right)\\&=(25,50)+CEL(25,50;100-75)\\&=(25,50)+(0,25)=(25,75).\end{aligned}$$

14.4 Axioms (Properties of Rules)

14.4.1 Equal Treatment of Equals

As previously mentioned, we adopt an axiomatic approach to evaluate the rules. We introduce the properties of rules, called **axioms**, and see whether the rules defined in the previous section satisfy those properties. Our first axiom is basic. We require agents with the same claim to receive the same amount. More precisely, given $N \in \mathcal{N}$ and $(c,E) \in \mathcal{C}^N$, if two agents $\{i,j\} \subseteq N$ have the same claim ($c_i = c_j$), then, this axiom states that awards given to agents i and j under the rule φ ($\varphi_i(c,E)$ and $\varphi_j(c,E)$, respectively) should be the same. Thus, the formal definition is as follows:

Equal treatment of equals (ete): For each $N \in \mathcal{N}$, $(c,E) \in \mathcal{C}^N$, and each $\{i,j\} \subseteq N$, if $c_i = c_j$, then $\varphi_i(c,E) = \varphi_j(c,E)$.

All four rules that have appeared in the previous section satisfy this axiom.

14.4.2 Minimal Rights First

Our next axiom is more demanding. First, we consider the minimal amount that each agent should receive. Let $N = \{1,2,3\}$, $c = (10,30,40)$, and $E = 60$. In the case of agent 2, even if agents 1 and 3 are fully compensated, there is an amount of $E - (c_1 + c_3) = 60 - (10+40) = 10$ left to divide. Thus, we can say that agent 2 should receive at least 10. Similarly, as $E - (c_1 + c_2) = 60 - (10+30) = 20$, agent 3 should receive at least 20. However, if agents 2 and 3 are fully compensated, agent 1 receives a negative amount ($E - (c_2 + c_3) = 60 - (30+40) = -10$). In that case, agent 1's minimal amount is 0 (recall that each agent should end up receiving a nonnegative amount). Thus, this is formally described as follows:

For each $N \in \mathcal{N}$, each $(c,E) \in \mathcal{C}^N$, and each $i \in N$, let $m_i(c,E) = \max\left\{E - \sum_{j \in N \setminus \{i\}} c_j, 0\right\}$ be **agent *i*'s minimal right** (minimal amount). Further, let $m(c,E) = (m_i(c,E))_{i \in N}$ be the **minimal rights vector**.

In our previous example, $m_1(c,E) = 0$, $m_2(c,E) = 10$, $m_3(c,E) = 20$, and $m(c,E) = (0,10,20)$. Now we identify each agent's minimal right in $(c,E) \in \mathcal{C}^N$. Next, consider dividing the resource E in two steps: first, give each agent their minimal right; second, divide the rest $E - \sum_{i \in N} m_i(c,E)$ under the claims vector $c - m(c,E)$. We use the claims vector $c - m(c,E)$ in the second step because the agents have been given their minimal rights in the first step. The next axiom requires that the awards vector chosen by the rule for $(c,E) \in \mathcal{C}^N$ is the same as that obtained by dividing E in the two steps described above. Thus, the formal definition is as follows:

Minimal rights first (mrf): For each $N \in \mathcal{N}$ and each $(c,E) \in \mathcal{C}^N$, $\varphi(c,E) = m(c,E) + \varphi(c - m(c,E), E - \sum_{i \in N} m_i(c,E))$.

The CEL and Talmud rules satisfy *minimal rights first*. For instance, consider the CEL rule. Let $N = \{1,2,3\}$, $c = (5,20,35)$, and $E = 40$. Then, $CEL(c,E) = (0,12.5,27.5)$ (we choose "$\lambda = 7.5$" to calculate $CEL(c,E)$). Note that $m_1(c,E) = \max\{40 - (20+35), 0\} = 0$, $m_2(c,E) = \max\{40 - (5+35), 0\} = 0$, and $m_3(c,E) = \max\{40 - (5+20), 0\} = 15$. Thus, $m(c,E) = (0,0,15)$. If we first assign agents their minimal rights and apply the CEL rule to the remaining problem, the awards vector becomes

$$\begin{aligned} &m(c,E) + \mathrm{CEL}\left(c - m(c,E), E - \sum_{i \in N} m_i(c,E)\right) \\ &= (0,0,15) + \mathrm{CEL}(5-0, 20-0, 35-15; 40-(0+0+15)) \\ &= (0,0,15) + (0,12.5,12.5) = (0,12.5,27.5). \end{aligned}$$

(Note that we choose "$\lambda = 7.5$" again when we calculate $\mathrm{CEL}(c - m(c,E), E - \sum_{i \in N} m_i(c,E))$.) Thus, $\mathrm{CEL}(c,E) = m(c,E) + \mathrm{CEL}(c - m(c,E), E - \sum_{i \in N} m_i(c,E))$ under this example. In fact, this equality holds for each $N \in \mathcal{N}$ and each $(c,E) \in \mathcal{C}^N$.

However, neither the CEA rule nor the proportional rule satisfies this axiom, as shown below.

Proposition 14.1 The CEA rule does not satisfy *minimal rights first*.

Proof Let $N = \{1, 2, 3\}$, $c = (10, 30, 40)$, and $E = 60$. Then, $\mathrm{CEA}(c, E) = (10, 25, 25)$. On the other hand,

$$m(c,E) + \mathrm{CEA}\left(c - m(c,E), E - \sum_{i \in N} m_i(c,E)\right)$$
$$= (0, 10, 20) + \mathrm{CEA}$$
$$(10 - 0, 30 - 10, 40 - 20; 60 - (0 + 10 + 20))$$
$$= (0, 10, 20) + (10, 10, 10) = (10, 20, 30).$$

Thus, $\mathrm{CEA}(c, E) \neq m(c, E) + \mathrm{CEA}(c - m(c, E), E - \sum_{i \in N} m_i(c, E))$, in violation of *minimal rights first*. ∎

Proposition 14.2 The proportional rule does not satisfy *minimal rights first*.

Proof Let $N = \{1, 2\}$, $c = (40, 60)$, and $E = 50$. Then, $P(c, E) = (20, 30)$. Also,

$$m(c,E) + P\left(c - m(c,E), E - \sum_{i \in N} m_i(c,E)\right)$$
$$= (0, 10) + P(40 - 0, 60 - 10; 50 - (0 + 10))$$
$$= (0, 10) + \left(\frac{160}{9}, \frac{200}{9}\right) = \left(\frac{160}{9}, \frac{290}{9}\right).$$

Thus, $P(c, E) \neq m(c, E) + P(c - m(c, E), E - \sum_{i \in N} m_i(c, E))$, in violation of *minimal rights first*. ∎

14.4.3 Claims Truncation Invariance

Next, we consider truncating some claims. For example, let $N = \{1, 2, 3\}$, $c = (10, 30, 40)$, and $E = 25$. For agent 2, the claim is greater than the resource ($c_2 = 30 > 25 = E$). In this case, we truncate agent 2's claim by the resource amount (implying that agent 2's "relevant" claim is 25). Similarly, since agent 3's claim is also greater than the resource ($c_3 = 40 > 25 = E$), we truncate this claim by the resource amount too (agent 3's relevant claim is 25). Since agent 1's claim does not exceed the resource quantity ($c_1 = 10 < 25 = E$), there is no need to truncate the claim (agent 1's relevant claim is 10). Thus, this is formally described as follows.

For each $N \in \mathcal{N}$, each $(c, E) \in \mathcal{C}^N$, and each $i \in N$, let $t_i(c, E) = \min\{c_i, E\}$ be **agent *i*'s truncated claim**. Further, let $t(c, E) = (t_i(c, E))_{i \in N}$ be the **truncated claims vector**.

In our previous example, $t_1(c, E) = 10$, $t_2(c, E) = 25$, $t_3(c, E) = 25$, and $t(c, E) = (10, 25, 25)$. The following axiom requires that the awards vector given by applying the rule to $(c, E) \in \mathcal{C}^N$ is the same as that obtained by using the truncated claims vector. Thus, the formal definition is as follows:

Claims truncation invariance (ctinv):

For each $N \in \mathcal{N}$ and each $(c, E) \in \mathcal{C}^N$, $\varphi(c, E) = \varphi(t(c, E), E)$.

The CEA and Talmud rules satisfy *claims truncation invariance*. For instance, consider the CEA rule. Let $N = \{1, 2, 3\}$, $c = (5, 20, 35)$, and $E = 25$. Then, $\mathrm{CEA}(c, E) = (5, 10, 10)$ (we choose "$\lambda = 10$" to calculate $CEA(c, E)$). Note that $t_1(c, E) = \min\{5, 25\} = 5$, $t_2(c, E) = \min\{20, 25\} = 20$, $t_3(c, E) = \min\{35, 25\} = 25$, and $t(c, E) = (5, 20, 25)$. If we apply the CEA rule under the truncated claims vector to divide $E = 25$, the awards vector becomes $\mathrm{CEA}(t(c, E), E) = \mathrm{CEA}(5, 20, 25; 25) = (5, 10, 10)$ (we choose "$\lambda = 10$" again when we calculate $\mathrm{CEA}(t(c, E), E)$). Thus, $\mathrm{CEA}(c, E) = \mathrm{CEA}(t(c, E), E)$ under this example. In fact, this equality holds for each $N \in \mathcal{N}$ and $(c, E) \in \mathcal{C}^N$.

However, the CEL and proportional rules do not satisfy this axiom, as shown below.

Proposition 14.3 The CEL rule does not satisfy *claims truncation invariance*.

Proof Let $N = \{1, 2, 3\}$, $c = (10, 30, 40)$, and $E = 25$. Then, $\mathrm{CEL}(c, E) = (0, 7.5, 17.5)$ and

$\mathrm{CEL}(t(c,E),E) = \mathrm{CEL}(10,25,25;25) = (0,12.5,12.5)$. Thus, $\mathrm{CEL}(c,E) \neq \mathrm{CEL}(t(c,E),E)$, in violation of *claims truncation invariance*. ∎

Proposition 14.4 The proportional rule does not satisfy *claims truncation invariance*.

Proof Let $N = \{1,2,3\}$, $c = (20,30)$, and $E = 25$. Then, $P(c,E) = (10,15)$ and $P(t(c,E),E) = P(20,25;25) = \left(\frac{100}{9},\frac{125}{9}\right)$, in violation of *claims truncation invariance*. ∎

14.4.4 Consistency

Next, we introduce an axiom broadly used in the context of resource allocation. Given $N \in \mathcal{N}$, $(c,E) \in \mathcal{C}^N$, and the awards vector $x = \varphi(c,E)$ chosen by the rule φ, suppose that some agents leave the scene with their awards. The reduced problem consists of the remaining agents $N' \subset N$, their claims $c_{N'}$, and the resource reduced by the awards given to the leaving agents, $E - \sum_{i \in N \setminus N'} x_i$.[7] For instance, let $N = \{1,2,3,4,5\}$. Suppose that agents 2 and 4 leave with their awards x_2 and x_4, respectively. Then, the reduced problem consists of agents $N' = \{1,3,5\}$, claims vector $c_{N'} = (c_1,c_3,c_5)$, and the resource $E - (x_2 + x_4)$. The axiom requires that starting with the awards vector chosen by the rule, if some agents leave the situation with their awards and apply the rule to the reduced problem, each remaining agent still receives the same amount as before. In our previous example, this means that $(x_1,x_3,x_5) = \varphi(c_1,c_3,c_5;E-(x_2+x_4))$. The formal definition is as follows[8]:

Consistency (cons): For each $N \in \mathcal{N}$, each $(c,E) \in \mathcal{C}^N$, and each $N' \subset N$, if $x = \varphi(c,E)$, then $x_{N'} = \varphi\left(c_{N'}, E - \sum_{i \in N \setminus N'} x_i\right)$.[9]

All four rules defined in the previous section satisfy *consistency*.[10] In fact, for each of the four rules, the same "λ" (appearing in their definition) is chosen in both the initial and reduced problems.[11] For example, let $N = \{1,2,3,4,5\}$, $c = (10,20,40,60,70)$, and $E = 120$. Let us consider the CEA rule. Then, we choose $\lambda = 30$ to obtain $\mathrm{CEA}(c,E) = (10,20,30,30,30)$. Now suppose that agents 2 and 4 leave with their awards. Let $N' = \{1,3,5\}$. Then, the reduced problem is $\left(c_{N'}, E - \sum_{i \in N \setminus N'} x_i\right) = (10,40,70;120-20-30)$. If we apply the CEA rule to this reduced problem, we again choose $\lambda = 30$ to obtain $CEA(10,40,70;70) = (10,30,30)$. Since we choose the same λ in both initial and reduced problems, the awards given to the remaining agents do not change.

Table 14.2 summarizes the findings from this section. This also includes other results that we study in Sect. 14.5.2. The abbreviations "ete," "mrf," "ctinv," "cons," "cp-up," "cp-down," and "nat" stand for "*equal treatment of equals*," "*minimal rights first*," "*claims truncation invariance*," "*consistency*," "*composition up*," "*composition down*," and "*no advantageous transfer*," respectively. The symbol "+" (respectively, "−") means the corresponding rule satisfies (respectively, does not satisfy) the corresponding axiom.

14.5 Characterizations

14.5.1 Characterization of the Talmud Rule

We provide characterizations of the rules based on the properties (axioms) studied in the previous section. Before that, we introduce the following

[7] We denote by $c_{N'}$ the restriction of c to N'.

[8] See Thomson (2011a) for a survey regarding this axiom. Also, see Thomson (2012) for interpreting this axiom.

[9] The notation $x_{N'}$ means the restriction of x to N'.

[10] See Young (1987) for a wide family of rules satisfying *consistency*.

[11] For the Talmud rule, we chose λ when we calculate $\mathrm{CEA}\left(\frac{c}{2},E\right)$ or $\mathrm{CEL}\left(\frac{c}{2},E-\sum_{i\in N}\frac{c_i}{2}\right)$.

Table 14.2 Rules which satisfy the axioms

Rules	Axioms						
	ete	mrf	ctinv	cons	cp-up	cp-down	nat
CEA	+	−	+	+	+	+	−
CEL	+	+	−	+	+	+	−
Proportional	+	−	−	+	+	+	+
Talmud	+	+	+	+	−	−	−

lemma that describes the awards vector given by the Talmud rule for the two-agent case.

Lemma 14.1 Let $N = \{1, 2\}$ and $(c, E) \in \mathcal{C}^N$ be such that $c_1 < c_2$. Then,

$$\mathrm{Tal}(c,E) = \begin{cases} \left(\frac{E}{2}, \frac{E}{2}\right) & \text{if } 0 \le E \le c_1 \\ \left(\frac{c_1}{2}, E - \frac{c_1}{2}\right) & \text{if } c_1 < E < c_2 \\ \left(\frac{c_1 - c_2 + E}{2}, \frac{-c_1 + c_2 + E}{2}\right) & \text{if } c_2 \le E \le c_1 + c_2. \end{cases}$$

The reader can verify this lemma by applying the definition of the Talmud rule provided in Sect. 14.3.4. For instance, if $c_2 \le E \le c_1 + c_2$, since $c_1 < c_2$, we have $\frac{c_1}{2} + \frac{c_2}{2} < \frac{c_2}{2} + \frac{c_2}{2} = c_2 \le E$. Thus, the awards vector is given by $\left(\frac{c_1}{2}, \frac{c_2}{2}\right) + CEL\left(\frac{c_1}{2}, \frac{c_2}{2}; E - \frac{c_1}{2} - \frac{c_2}{2}\right)$. The total loss in the problem $\left(\frac{c_1}{2}, \frac{c_2}{2}; E - \frac{c_1}{2} - \frac{c_2}{2}\right)$ is $\frac{c_1}{2} + \frac{c_2}{2} - \left(E - \frac{c_1}{2} - \frac{c_2}{2}\right) = c_1 + c_2 - E$. Half of the total loss is $\frac{c_1 + c_2 - E}{2} \le \frac{c_1}{2}$ (where the inequality holds by $c_2 \le E$). Thus, $CEL\left(\frac{c_1}{2}, \frac{c_2}{2}; E - \frac{c_1}{2} - \frac{c_2}{2}\right) = \left(\frac{c_1}{2} - \frac{c_1 + c_2 - E}{2}, \frac{c_2}{2} - \frac{c_1 + c_2 - E}{2}\right)$. This leads to the desired conclusion.

Suppose we want a rule to satisfy *equal treatment of equals*, *minimal rights first*, and *claims truncation invariance*. Among the four rules studied in the previous section, only the Talmud rule satisfies all of them. The following theorem states that, among any rules, the Talmud rule is the only one that satisfies the three axioms for the two-agent case.

Theorem 14.1 (Dagan 1996): Let $N \in \mathcal{N}$ with $|N| = 2$. The Talmud rule is the only rule satisfying *equal treatment of equals*, *minimal rights first*, and *claims truncation invariance*.

Proof We prove only the uniqueness. Let $N = \{1, 2\}$ and $(c, E) \in \mathcal{C}^N$. Let φ be a rule that satisfies the three axioms listed in the theorem. We want to show that $\varphi(c, E) = Tal(c, E)$. If $c_1 = c_2$, because both φ and the Talmud rule satisfy *equal treatment of equals*, $\varphi(c, E) = Tal(c, E) = \left(\frac{E}{2}, \frac{E}{2}\right)$. Without loss of generality, let $c_1 < c_2$. We distinguish the three cases.

Case 1: $0 \le E \le c_1$.

Note that $t(c, E) = (E, E)$. Since φ satisfies *claims truncation invariance*,

$$\varphi(c, E) = \varphi(t(c, E), E) = \varphi(E, E; E). \quad (14.1)$$

Since φ satisfies *equal treatment of equals*,

$$\varphi(E, E, E) = \left(\frac{E}{2}, \frac{E}{2}\right). \quad (14.2)$$

By (14.1) and (14.2), $\varphi(c, E) = \left(\frac{E}{2}, \frac{E}{2}\right)$.

Case 2: $c_1 < E < c_2$.

Note that $m(c, E) = (0, E - c_1)$. Since φ satisfies *minimal rights first*,

$$\begin{aligned} \varphi(c,E) &= m(c,E) + \varphi\left(c - m(c,E), E - \sum_{i \in N} m_i(c,E)\right) \\ &= (0, E - c_1) + \varphi(c_1 - 0, c_2 - (E - c_1); E - 0 - (E - c_1)) \\ &= (0, E - c_1) + \varphi(c_1, c_1 + c_2 - E; c_1). \end{aligned} \quad (14.3)$$

Since $c_2 - E > 0$, $c_1 + c_2 - E > c_1$. In addition, because φ satisfies *claims truncation invariance* (corresponding to the first equality below) and *equal treatment of equals* (corresponding to the second equality below),

$$\varphi(c_1, c_1 + c_2 - E; c_1) = \varphi(c_1, c_1; c_1) = \left(\frac{c_1}{2}, \frac{c_1}{2}\right). \quad (14.4)$$

By (14.3) and (14.4), $\varphi(c, E) = (0, E - c_1) + \left(\frac{c_1}{2}, \frac{c_1}{2}\right) = \left(\frac{c_1}{2}, E - \frac{c_1}{2}\right)$.

Case 3: $c_2 \leq E \leq c_1 + c_2$.

Note that $m(c, E) = (E - c_2, E - c_1)$. Since φ satisfies *minimal rights first*,

$$\begin{aligned}\varphi(c, E) &= (E - c_2, E - c_1) \\ &\quad + \varphi(c_1 - (E - c_2), c_2 - (E - c_1); \\ &\quad E - (E - c_2) - (E - c_1)) \\ &= (E - c_2, E - c_1) + \varphi(c_1 + c_2 - E, \\ &\quad c_1 + c_2 - E; c_1 + c_2 - E)\end{aligned} \quad (14.5)$$

Since φ satisfies *equal treatment of equals*,

$$\varphi(c_1 + c_2 - E, c_1 + c_2 - E; c_1 + c_2 - E) = \left(\frac{c_1 + c_2 - E}{2}, \frac{c_1 + c_2 - E}{2}\right) \quad (14.6)$$

By (14.5) and (14.6),

$$\begin{aligned}\varphi(c, E) &= (E - c_2, E - c_1) \\ &\quad + \left(\frac{c_1 + c_2 - E}{2}, \frac{c_1 + c_2 - E}{2}\right) \\ &= \left(\frac{c_1 - c_2 + E}{2}, \frac{-c_1 + c_2 + E}{2}\right).\end{aligned}$$

In each cases, by Lemma 14.1, we have $\varphi(c, E) = Tal(c, E)$. ∎

For more than two agents, the Talmud rule is not the only the rule satisfying *equal treatment of equals*, *minimal rights first*, and *claims truncation invariance*. However, if we additionally require a rule to be *consistent*, then the Talmud rule becomes the only one.

Theorem 14.2 (Aumann and Maschler 1985; Dagan 1996): The Talmud rule is the only rule satisfying *equal treatment of equals*, *minimal rights first*, *claims truncation invariance*, and *consistency*.

We provide a sketch of the proof of Theorem 14.2. Before doing so, we introduce two lemmata. The first lemma, known as the "Elevator Lemma," relates the result obtained in the two-agent case to more than two agents by applying two axioms: *consistency* and "converse consistency."[12]

Lemma 14.2 (The Elevator Lemma) (Thomson 2011a): Let φ and $\overline{\varphi}$ be two rules. If (i) φ coincides with $\overline{\varphi}$ in the two-agent cases, (ii) φ is *consistent*, and (iii) $\overline{\varphi}$ is *conversely consistent*, then φ coincides with $\overline{\varphi}$ for any number of agents.[13]

The second lemma states that if a rule is *consistent* and satisfies a fundamental requirement called "resource monotonicity," the rule is *conversely consistent*.[14]

Lemma 14.3 (Chun 1999): *Resource monotonicity* and *consistency* together imply *converse consistency*.

Now, we explain a sketch of the proof of Theorem 14.2. We show only the uniqueness part. Let rule φ satisfy *equal treatment of equals*,

[12] A rule φ satisfies *converse consistency* if for each $N \in \mathcal{N}$ with $|N| \geq 3$, each $(c, E) \in \mathcal{C}^N$, and each $x \in \mathbb{R}^N_+$ such that $\sum_{i \in N} x_i = E$, if for each $N' \subset N$ with $|N'| = 2$, we have $x_{N'} = \varphi(c_{N'}, \sum_{i \in N'} x_i)$, then $x = \varphi(c, E)$. In words, *converse consistency* requires the following. Let $N \in \mathcal{N}$ with $|N| \geq 3$ and $(c, E) \in \mathcal{C}^N$ be given. Suppose that there is an awards vector $x = (x_i)_{i \in N}$ for (c, E) such that for each two-agent group $N' \subset N$, the restriction of x to the group N' is chosen by the rule φ for the problem of dividing $\sum_{i \in N'} x_i$ (the total awards of the group N') under the claims vector $c_{N'} = (c_i)_{i \in N'}$ (claims of agents in the group N'), that is, $x_{N'} = \varphi\left(c_{N'}, \sum_{i \in N'} x_i\right)$. Then, x should be chosen by φ for (c, E).

[13] In fact, the Elevator Lemma holds in many other economic problems. See Thomson (2011a) for details.

[14] A rule φ satisfies *resource monotonicity* if for each $N \in \mathcal{N}$, each $(c, E) \in \mathcal{C}^N$, each $i \in N$, and each $E' > E$ such that $\sum_{i \in N} c_i \geq E'$, we have $\varphi_i(c, E') \geq \varphi_i(c, E)$. In words, *resource monotonicity* requires that if the amount to divide increases, no agent receives less than before. Thus, each agent becomes at least as well off as before by the increment of the resource (if each agent prefers to receive more).

minimal rights first, *claims truncation invariance*, and *consistency*. Let rule $\overline{\varphi}$ be the Talmud rule. We want to show that φ coincides with $\overline{\varphi}$ for any number of agents. According to Theorem 14.1, φ coincides with $\overline{\varphi}$ in the two-agent cases. Based on the assumption, φ is *consistent*. It is easy to see that the Talmud rule satisfies *resource monotonicity*. Then, $\overline{\varphi}$ is *resource monotonic* and *consistent*. By Lemma 14.3, $\overline{\varphi}$ is *conversely consistent*. Therefore, by Lemma 14.2, we obtain the desired conclusion.

14.5.2 Other Characterizations

14.5.2.1 Characterization of the CEA Rule

We introduce other axioms and provide other characterizations. Consider the following situation. Given $N \in \mathcal{N}$ and $(c, E) \in \mathcal{C}^N$, suppose, we initially obtain the awards vector $\varphi(c, E)$ by applying rule φ. However, following this, we found that there is more of the resource to divide. In our bankruptcy application, this could happen after re-evaluating the bankrupt firm's assets. Let $E' \in \mathbb{R}_+$ be the new resource $(E' > E)$. We assume that $\sum_{i \in N} c_i \geq E'$. Now we have to divide E' among the agents. There may be two ways to achieve this. One way is to forget about the initial awards given to the agents and apply rule φ directly to the new problem (c, E'). Thus, the resulting awards vector becomes $\varphi(c, E')$. Another way is to give each agent their initial award and divide the increment $E' - E$ under the claims vector $c - \varphi(c, E)$ (we reduce each agent's claim by their initial award). The resulting awards vector is $\varphi(c, E) + \varphi(c - \varphi(c, E), E' - E)$. The reader can verify that $\sum_{i \in N} c_i - \sum_{i\ N} \varphi_i(c, E) \geq E' - E$. Thus, the problem $(c - \varphi(c, E), E' - E)$ is well defined. The following axiom requires that both methods yield the same awards vector. This solves any disagreement among agents regarding the way to choose. The formal definition is as follows:

Composition up (cp-up): For each $N \in \mathcal{N}$, each $(c, E) \in \mathcal{C}^N$, and each $E' > E$ such that $\sum_{i \in N} c_i \geq E'$, we have $\varphi(c, E') = \varphi(c, E) + \varphi(c - \varphi(c, E), E' - E)$.

The CEA, CEL, and proportional rules satisfy *composition up*. For instance, consider the CEL rule. Let $N = \{1, 2, 3\}$, $c = (5, 20, 35)$, and $E = 40$. Then, $\mathrm{CEL}(c, E) = (0, 12.5, 27.5)$. Suppose, after re-evaluating the resource, the resource becomes larger. Let the new resource be $E' = 51$. If we forget about the initial awards and apply the CEL rule to the new problem, we have $\mathrm{CEL}(c, E') = \mathrm{CEL}(5, 20, 35; 51) = (2, 17, 32)$ (note that we choose "$\lambda = 3$" to calculate $\mathrm{CEL}\left(c, E^{'}\right)$). On the other hand, if we first assign agents their initial awards for $E = 40$ and divide the remaining $E' - E = 51 - 40 = 11$ under the claims vector where each agent's claim is reduced by their initial award, we have

$$\begin{aligned}
&\mathrm{CEL}(c, E) + \mathrm{CEL}(c - \mathit{CEL}(c, E), E' - E) \\
&= \mathrm{CEL}(5, 20, 35; 40) \\
&\quad + \mathrm{CEL}((5, 20, 35) - \mathrm{CEL}(5, 20, 35; 40), 51 - 40) \\
&= (0, 12.5, 27.5) + \mathrm{CEL}((5, 7.5, 7.5), 11) \\
&= (0, 12.5, 27.5) + (2, 4.5, 4.5) = (2, 17, 32).
\end{aligned}$$

(Note that we choose "$\lambda = 3$" again to calculate $\mathrm{CEL}(c - \mathrm{CEL}(C, E), E' - E)$). Thus, $\mathrm{CEL}(c, E')$ $= \mathrm{CEL}(c, E) + \mathrm{CEL}(c - \mathrm{CEL}(c, E), E' - E)$ for this example. In fact, for each $N \in \mathcal{N}$, each $(c, E) \in \mathcal{C}^N$, and each $E' > E$ such that $\sum_{i \in N} c_i \geq E'$, we obtain the above equality.

However, the Talmud rule does not satisfy *composition up*, as shown below.

Proposition 14.5 The Talmud rule does not satisfy *composition up*.

Proof Let $N = \{1, 2\}$, $c = (20, 30)$, $E = 20$, and $E' = 30$. Then, $\mathrm{Tal}(c, E') = (10, 15) +$ $\mathrm{CEL}(10, 15; 30 - 25) = (10, 15) + (0, 5) = (10,$ $20)$. Note that $\mathrm{Tal}(c, E) = \mathrm{CEA}(10, 15; 20)$ $= (10, 10)$. Thus, $\mathrm{Tal}(c, E) + \mathrm{Tal}(c - \mathrm{Tal}$ $(c, E), E' - E) = (10, 10) + \mathrm{Tal}(20 - 10, 30 - 10;$ $10) = (10, 10) + \mathrm{CEA}(5, 10; 10) = (10, 10) +$

$(5,5) = (15,15)$. Therefore, $\text{Tal}(c,E') \neq \text{Tal}(c,E) + \text{Tal}(c - \text{Tal}(c,E), E' - E)$, in violation of *composition up*. ∎

If we want a rule to satisfy *equal treatment of equal*, *claims truncation invariance*, and *composition up*, the next theorem states that there is only one rule that does so.

Theorem 14.3 (Dagan 1996): The CEA rule is the only rule satisfying *equal treatment of equals*, *claims truncation invariance*, and *composition up*.

We will not prove Theorem 14.3, but see how the three axioms listed in the theorem identify the awards vector for some problem. Let $N = \{1,2,3\}$, $c = (36,44,50)$, and $E = 75$. Let a rule φ satisfy *equal treatment of equals*, *claims truncation invariance*, and *composition up*. We cannot identify $\varphi(c,E)$ by directly applying these three axioms. However, as φ satisfies *equal treatment of equals* and *claims truncation invariance*, we know how to divide $\hat{E} = 36$ $(= \min\{c_1,c_2,c_3\})$ under c, that is, $\varphi(c,\hat{E}) = \varphi(36,44,50;36) = \varphi(36,36,36;36) = (12,12,12)$. Suppose that initially, the resource was $\hat{E} = 36$, but after re-evaluating the resource, the resource becomes $E = 75$. Since φ satisfies *composition up*,

$$\begin{aligned}\varphi(c,E) &= \varphi(c,\hat{E}) + \varphi(c - \varphi(c,\hat{E}), E - \hat{E})\\ &= \varphi(36,44,50;36)\\ &\quad + \varphi((36,44,50) - \varphi(36,44,50;36); 75 - 36)\\ &= (12,12,12) + \varphi(24,32,38;39).\end{aligned}$$

Again, we cannot identify $\varphi(24,32,38;39)$ directly, but as φ satisfies *equal treatment of equals* and *claims truncation invariance*, we know how to divide $\tilde{E} = 24$ $(= \min\{24,32,38\})$ under the claims vector $(24,32,38)$, that is, $\varphi(24,32,38;24) = \varphi(24,24,24;24) = (8,8,8)$. Now suppose that after re-evaluating the resource, the resource increases from $\tilde{E} = 24$ to $E - \hat{E} = 39$. As φ satisfies *composition up*,

$$\begin{aligned}\varphi(24,32,38;39) &= \varphi(24,32,38;24)\\ &\quad + \varphi((24,32,38) - \varphi(24,32,38;24);\\ &\quad 39 - 24)\\ &= (8,8,8) + \varphi(16,24,30;15).\end{aligned}$$

As φ satisfies *equal treatment of equals* and *claims truncation invariance*, $\varphi(16,24,30;15) = \varphi(15,15,15;15) = (5,5,5)$. Overall, $\varphi(c,E) = (12,12,12) + (8,8,8) + (5,5,5) = (25,25,25)$. Thus, $\varphi(c,E) = \text{CEA}(c,E)$ under this example.

14.5.2.2 Characterization of the CEL Rule

Let $N \in \mathcal{N}$, $(c,E) \in \mathcal{C}^N$, and the awards vector $\varphi(c,E)$ obtained by applying rule φ be given. Suppose that, in contrast to the situation in the previous axiom, after re-evaluating E, we find that there is less of the resource to divide. Let $E' \in \mathbb{R}_+$ be the new resource $(E' < E)$. There may be two ways to divide E'. One way is to forget about the initial awards given to the agents and apply rule φ to the new problem (c,E'). Thus, the resulting awards vector is $\varphi(c,E')$. Another way is to think that each agent claims the initial award and apply rule φ to divide E'. The resulting awards vector is $\varphi(\varphi(c,E),E')$. Since $\sum_{i\in N} \varphi_i(c,E) > E'$, the problem $(\varphi(c,E),E')$ is well defined. The following axiom requires (as with the previous axiom) that each agent receives the same amount in both ways. The formal definition is as follows:

Composition down (cp-down): For each $N \in \mathcal{N}$, each $(c,E) \in \mathcal{C}^N$, and each $E' < E$ such that $0 \leq E'$, we have $\varphi(c,E') = \varphi(\varphi(c,E),E')$.

The CEA, CEL, and proportional rules satisfy *composition down*. For instance, consider the CEA rule. Let $N = \{1,2,3\}$, $c = (5,20,35)$, and $E = 40$. Then, $\text{CEA}(c,E) = (5,17.5,17.5)$. Suppose, after re-evaluating the resource, it becomes $E' = 30$. If we apply the CEA rule to (c,E'), we have $\text{CEA}(c,E') = CEA(5,20,35;30) = (5,12.5,12.5)$ (note that we choose

$\lambda = 12.5$ to calculate $\mathrm{CEA}(c, E'))$. On the other hand, if we think that each agent's claim is their initial award and apply the CEA rule to divide E', we have $\mathrm{CEA}(\mathrm{CEA}(c, E), E') = \mathrm{CEA}(5, 17.5, 17, 5; 30) = (5, 12.5, 12.5)$ (note that we choose $\lambda = 12.5$ again to calculate CEA $(\mathrm{CEA}(c, E), E'))$. Thus, $\mathrm{CEA}(c, E') = \mathrm{CEA}(\mathrm{CEA}\ (c, E), E')$ under this example. In fact, this equality holds for each $N \in \mathcal{N}$, each $(c, E) \in \mathcal{C}^N$, and each $E' < E$ such that $0 \leq E'$.

The Talmud rule, however, violates *composition down*, as shown below.

Proposition 14.6 The Talmud rule does not satisfy *composition down*.

Proof Let $N = \{1, 2\}$, $c = (20, 30)$, $E = 30$ and $E' = 20$. Then, $\mathrm{Tal}(c, E') = \mathrm{CEA}(10, 15; 20) = (10, 10)$. Note that $\mathrm{Tal}(c, E) = (10, 15) + \mathrm{CEL}(10, 15; 30 - 25) = (10, 15) + (0, 5) = (10, 20)$. Thus, $\mathrm{Tal}(\mathrm{Tal}(c, E), E') = \mathrm{Tal}(\mathrm{Tal}(20, 30; 30), 20) = \mathrm{Tal}(10, 20; 20) = (5, 10) + \mathrm{CEL}(5, 10; 20 - 15) = (5, 10) + (0, 5) = (5, 15)$. Thus, $\mathrm{Tal}(c, E') \neq \mathrm{Tal}(\mathrm{Tal}(c, E), E')$, in violation of *composition down*. ∎

The following theorem states that only one rule satisfies *equal treatment of equals*, *minimal rights first*, and *composition down*.

Theorem 14.4 (Herrero 2003): The CEL rule is the only rule satisfying *equal treatment of equals*, *minimal rights first*, and *composition down*.

As for the previous theorem, we will not prove Theorem 14.4 but explain how the axioms listed in the theorem determine the awards vector for some problem. Let $N = \{1, 2, 3\}$, $c = (36, 44, 50)$, and $E = 55$. Let φ be a rule that satisfies *equal treatment of equals*, *minimal rights first*, and *composition down*. Note that $m(c, E) = (0, 0, 0)$. Thus, we cannot identify $\varphi(c, E)$ directly by applying the above three axioms. However, if we consider dividing $\hat{E} = 94$ $(= c_2 + c_3)$ under c, the minimal rights vector is $m(c, \hat{E}) = (0, 8, 14)$. As φ satisfies *equal treatment of equals* and *minimal rights first*,

$$\begin{aligned}\varphi(c, \hat{E}) &= m(c, \hat{E}) + \varphi\left(c - m(c, \hat{E}), \hat{E} - \sum_{i \in N} m_i(c, \hat{E})\right) \\ &= (0, 8, 14) + \varphi(36, 36, 36; 72) \\ &= (0, 8, 14) + (24, 24, 24) = (24, 32, 38).\end{aligned}$$

Suppose that initially, the resource was $\hat{E} = 94$, but after re-evaluating the resource, it becomes $E = 55$. As φ satisfies *composition down*,

$$\varphi(c, E) = \varphi\big(\varphi(c, \hat{E}), E\big) = \varphi(24, 32, 38; 55).$$

Note that $m(24, 32, 38; 55) = (0, 0, 0)$. Thus, we cannot identify $\varphi(24, 32, 38; 55)$ directly by applying the three axioms. But if we consider dividing $\tilde{E} = 70$ $(= 32 + 38)$ under the claims vector $(24, 32, 38)$, we have $m(24, 32, 38; 70) = (0, 8, 14)$. As φ satisfies *equal treatment of equals* and *minimal rights first*,

$$\begin{aligned}\varphi(24, 32, 38; 70) &= (0, 8, 14) + \varphi(24, 24, 24; 48) \\ &= (0, 8, 14) + (16, 16, 16) \\ &= (16, 24, 30).\end{aligned}$$

Now, suppose that after re-evaluating the resource, it decreases from $\tilde{E} = 70$ to $E = 55$. As φ satisfies *composition down*,

$$\begin{aligned}\varphi(24, 32, 38; 55) &= \varphi(\varphi(24, 32, 38; 70); 55) \\ &= \varphi(16, 24, 30; 55).\end{aligned}$$

Note that $m(16, 24, 30; 55) = (1, 9, 15)$. As φ satisfies *equal treatment of equals* and *minimal rights first*,

$$\begin{aligned}\varphi(16, 24, 30; 55) &= (1, 9, 15) + \varphi(15, 15, 15; 30) \\ &= (1, 9, 15) + (10, 10, 10) \\ &= (11, 19, 25).\end{aligned}$$

Overall, $\varphi(c, E) = \varphi(24, 32, 38; 55) = \varphi(16, 24, 30; 55) = (11, 19, 25)$. Thus, $\varphi(c, E) = \mathrm{CEL}(c, E)$ under this example.

14.5.2.3 Characterization of the Proportional Rule

Suppose that some agents transfer their claims among group members. For instance, let $N = \{1,2,3,4,5\}$, $c = (10,20,50,60,80)$, and $E = 160$. Consider the group $M = \{2,3,5\} \subset N$. Suppose, agent 3 transfers 10 units of her claim to agent 2 and 5 units of her claim to agent 5. Then, the new claims vector is $c' = (10,30,35,60,85)$. Note that $\sum_{i\in M} c_i = 20+50+80 = \sum_{i\in M} c_i' = 30+35+85 = 150$.

Thus, the claims are transferred among agents in M. The next axiom requires no group of agents to benefit from transferring their claims. More precisely, it says that the total amount given to agents who transfer the claims among themselves does not change. Thus, it intends to avoid this kind of strategic behavior caused by a group of agents. In our previous example, under the rule φ, it means that $\sum_{i\in M} \varphi_i(c,E) = \sum_{i\in M} \varphi_i(c',E)$, or $\varphi_2(c,E)+\varphi_3(c,E)+\varphi_5(c,E) = \varphi_2(c',E)+\varphi_3(c',E)+\varphi_5(c',E)$. The formal definition is as follows:

No advantageous transfer (nat): For each $N \in \mathcal{N}$, each $(c,E) \in \mathcal{C}^N$, each $M \subset N$, and each $(c_i')_{i\in M} \in \mathbb{R}_+^M$, if $\sum_{i\in M} c_i = \sum_{i\in M} c_i'$, then $\sum_{i\in M} \varphi_i(c,E) = \sum_{i\in M} \varphi_i(c',E)$ where $c' = \left((c_i')_{i\in M}, c_{N\setminus M}\right)$.

As shown below, none of the CEA, CEL, and Talmud rules satisfy this property.

Proposition 14.7 The CEA rule does not satisfy *no advantageous transfer*.

Proof Let $N = \{1,2,3\}$, $c = (10,30,40)$, and $E = 36$. Then, $\mathrm{CEA}(c,E) = (10,13,13)$. Consider the group $M = \{1,2\} \subset N$. If agent 2 transfers 10 units of her claim to agent 1, the new claims vector will be $c' = (20,20,40)$. Note that $c_1 + c_2 = c_1' + c_2' = 40$. Since $\mathrm{CEA}(c',E) = (12,12,12)$, group M benefits by transferring their claims, that is, $\mathrm{CEA}_1(c,E) + \mathrm{CEA}_2(c,E) = 23 < \mathrm{CEA}_1(c',E) + \mathrm{CEA}_2(c',E) = 24$. ∎

Proposition 14.8 The CEL rule does not satisfy *no advantageous transfer*.

Proof Let $N = \{1,2,3\}$, $c = (10,30,40)$, and $E = 30$. Then, $\mathrm{CEL}(c,E) = (0,10,20)$. Consider the group $M = \{1,2\} \subset N$. If agent 1 transfers 10 units of her claim to agent 2, the new claims vector will be $c' = (0,40,40)$. Note that $c_1 + c_2 = c_1' + c_2' = 40$. Since $\mathrm{CEL}(c',E) = (0,15,15)$, the group M benefits by transferring their claims, that is, $\mathrm{CEL}_1(c,E) + \mathrm{CEL}_2(c,E) = 10 < \mathrm{CEL}_1(c',E) + \mathrm{CEL}_2(c',E) = 15$. ∎

Proposition 14.9 The Talmud rule does not satisfy *no advantageous transfer*.

Proof Let $N = \{1,2,3\}$, $c = (10,50,70)$, and $E = 45$. Then, $\mathrm{Tal}(c,E) = (5,20,20)$. Let $M = \{1,2\} \subset N$ and $c' = (30,30,70)$. Note that $c_1 + c_2 = c_1' + c_2' = 60$. Since $\mathrm{Tal}(c',E) = (15,15,15)$, the group M benefits by transferring their claims, that is, $\mathrm{Tal}_1(c,E) + \mathrm{Tal}_2(c,E) = 25 < \mathrm{Tal}_1(c',E) + \mathrm{Tal}_2(c',E) = 30$. ∎

However, the proportional rule satisfies *no advantageous transfer*. For instance, let $N = \{1,2,3,4,5\}$, $c = (c_1,c_2,c_3,c_4,c_5) \in \mathbb{R}_+^5$, and $E \in \mathbb{R}_+$ with $\sum_{i\in N} c_i \geq E$. Consider the group $M = \{2,3,5\}$. Under the proportional rule, this group in total receives

$$P_2(c,E) + P_3(c,E) + P_5(c,E) = \frac{c_2}{\sum_{i\in N} c_i} \times E + \frac{c_3}{\sum_{i\in N} c_i} \times E + \frac{c_5}{\sum_{i\in N} c_i} \times E = \frac{c_2+c_3+c_5}{\sum_{i\in N} c_i} \times E.$$

Now suppose that agents in the group M transfer claims among themselves. Let $c_M' = (c_2', c_3', c_5') \in \mathbb{R}_+^3$ be their claims. Note that $c_2 + c_3 + c_5 = c_2' + c_3' + c_5'$. Let $c' = (c_1, c_2', c_3', c_4, c_5')$. Then, after agents in the group M transfer their claims, this group in total receives

$$P_2(c',E)+P_3(c',E)+P_5(c',E)$$
$$=\frac{c_2'}{\sum_{i\in N}c_i'}\times E+\frac{c_3'}{\sum_{i\in N}c_i'}\times E+\frac{c_5'}{\sum_{i\in N}c_i'}\times E$$
$$=\frac{c_2'+c_3'+c_5'}{\sum_{i\in N}c_i'}\times E.$$

Since $c_2+c_3+c_5=c_2'+c_3'+c_5'$ and $\sum_{i\in N}c_i=\sum_{i\in N}c_i'$, $P_2(c,E)+P_3(c,E)+P_5(c,E)=P_2(c',E)+P_3(c',E)+P_5(c',E)$. Thus, the group M cannot receive more by transferring their claims under the proportional rule. A similar analysis can be made for each $N\in\mathcal{N}$, each $(c,E)\in\mathcal{C}^N$, each $M\subset N$, and each $(c_i')_{i\in M}\in\mathbb{R}_+^M$ such that $\sum_{i\in M}c_i=\sum_{i\in M}c_i'$ (unless $\sum_{i\in N}c_i=0$). Thus, the proportional rule satisfies *no advantageous transfer*.

The following theorem states that the proportional rule is the only one that satisfies this axiom for more than two agents.

Theorem 14.5 (Moulin 1985a, b; Chun 1988; Ju et al. 2007): The proportional rule is the only rule satisfying *no advantageous transfer* for more than two agents.

14.6 Concluding Remarks

This chapter studies the basics of designing a good (fair) allocation rule in economic problems by analyzing the so-called claims problems. In Sect. 14.5.1, we learn that the Talmud rule is the only rule satisfying *equal treatment of equals*, *minimal rights first*, *claims truncation invariance*, and *consistency*. Thus, if society agrees with the above four properties of rules (axioms), we can recommend adopting the Talmud rule. However, some other societies may disagree with one or more of these properties. Alternatively, these properties may be deemed acceptable or not depending on the situation (application) they face. Thus, providing other characterizations as in Sect. 14.5.2 would be very meaningful for selecting a good rule. This logic applies not only to claims problems but also to other economic problems. In fact, extensive studies (providing characterizations) have been conducted in the literature.[15]

To achieve Goal 16 (Peace, Justice and Strong Institutions) of the SDGs, especially when designing rules for economic problems, it becomes necessary to have this kind of precise analysis (mathematical analysis). As mentioned in Sect. 14.2, the problem studied in this chapter can also be interpreted as a taxation problem. In view of constructing a desirable tax system or correcting inequalities among people in other economic systems, our analysis in this chapter is related to Goal 10 (Reduced Inequalities) of the SDGs. Further, since our focus is on economic problems, our analysis is also closely related to Goal 8 (Decent Work and Economic Growth) of the SDGs. When we try to design good rules in economic problems, it is crucial to take into account a variety of strategic behaviors carried out by people. We studied one such behavior in Sect. 14.5.2 (recall the axiom of *no advantageous transfer*). In fact, extensive analyses have been performed in the literature.[16] If we successfully design an economic system that is immune to strategic behavior, such a system would motivate people to work and promote the nation's economic growth.

When constructing a building, we draw a plan in detail. The same thing must be done when designing a rule for economic problems (as we did for the claims problem in this chapter). By doing so, we may achieve several goals in the SDGs and make the world better in the future.

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[15] See Thomson (2011b).

[16] A pioneering study is given by Gibbard (1973) and Satterthwaite (1975). See Barbera (2011) for a survey.

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Index

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