13 Global Food Security, and Economic and Agricultural Development

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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

$$\text{Demand on Food} = \text{Population} \times \text{per capita demand}$$

Change in demand = Change in Population

+ Change in per capita Demand

Determinants

$$\begin{cases} \text{1. Income Change} \\ \text{2. Price Change} \end{cases}$$

$$= \text{Change in Population}$$
$$+ (\eta_I \times \text{Change in per capita Income})$$
$$+ (\eta_p \times \text{Change in Price})$$

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.

$$\overbrace{\frac{\Delta D}{D} \times 100}^{\text{Change in food demand (\%)}} = \overbrace{\frac{\Delta N}{N} \times 100}^{\text{Change in population (\%)}}$$

$$\frac{D_t - D_{t-1}}{D_{t-1}} \times 100$$

$$+ \overbrace{\eta_I \frac{\Delta\left(\frac{I}{N}\right)}{\left(\frac{I}{N}\right)} \times 100 + \eta_p \frac{\Delta P}{P} \times 100}^{\text{Change in per capita food demand (\%)}}$$

Change in per capita income (%) Change in price (%)

$$\frac{\left(\frac{Y}{N}\right)_t - \left(\frac{Y}{N}\right)_{t-1}}{\left(\frac{Y}{N}\right)_{t-1}} \times 100 \qquad \frac{P_t - P_{t-1}}{P_{t-1}}$$

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

$$\overbrace{\frac{\Delta D}{D} \times 100}^{\text{Change in food demand (\%)}} = \overbrace{\frac{\Delta N}{N} \times 100}^{\text{Change in population (\%)}}$$

$$+ \overbrace{\eta_I \frac{\Delta\left(\frac{I}{N}\right)}{\left(\frac{I}{N}\right)} \times 100 + \eta_p \frac{\Delta P}{P} \times 100}^{\text{Change in per capita food demand (\%)}}$$

Change in per capita income Change in price

$$= 0.8\% + (-1.8) \times (-1\%) + (-1\%) + (-0.1) \times (-1\%)$$
$$= 2.7\%$$
$$\Rightarrow = 0.027(\times \text{Ratio taking 1 as base})$$
$$D_{2021} = 1.50 \text{ (million tons)}$$
$$D_{2022} = D_{2021} \times (1 + 0.027) = 1.50 \times 1.027$$
$$= 1.54(1.5405) \text{ (million tons)}$$
$$D_{2023} = D_{2021} \times (1 + 0.027)^2 = 1.50 \times (1.027)^2$$
$$= 1.58(1.5821) \text{ (million tons)}$$

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 $\alpha_1 = wL/PY$ and $\alpha_2 = rK/PY$ 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

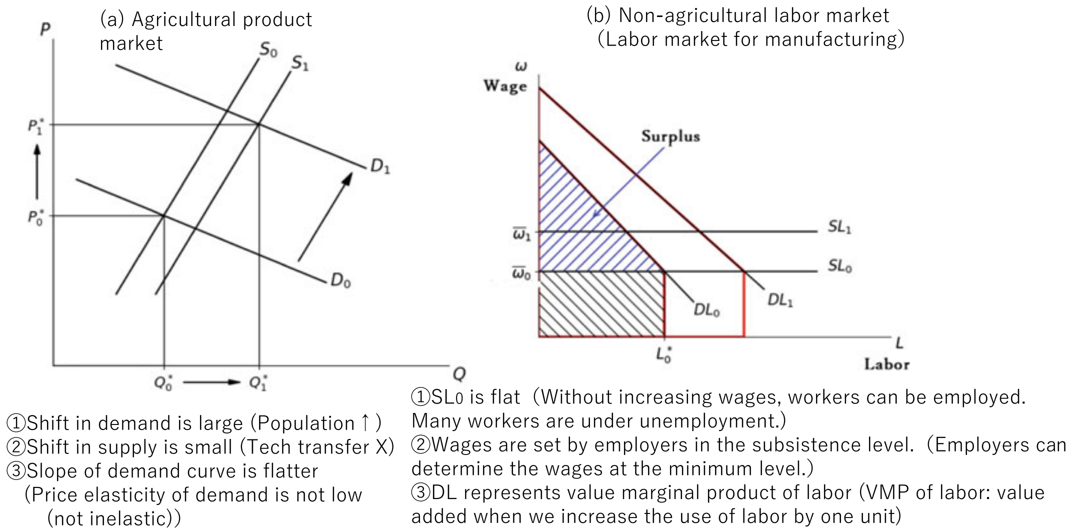

Fig. 13.1 Dual-sector model in economic development. *Note* The author has been benefitted from Hayami and Goda (2002) and Hayami (1986) regarding their debates on agricultural development using the dual-sector model of economic development developed by Lewis (1954)

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

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

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.

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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