CHAPTER 10

International Development: Systemic Change Over Time

10.1 Agricultural Transformation: Demography, Urbanization and Farm Size

10.1.1 Motivation and Guiding Questions

Where does economic growth come from? Why do some countries have so much more stuff—a larger quantity of more diverse goods and services—than other populations? And how does change in the country's entire economy relate to its agriculture, food systems, nutrition and health?

In the previous chapter we introduced how economists measure and understand each country's economy, and now we turn to the factors that drive expansion of economic activity over time, using natural and human resources to supply goods and services. Environmental sustainability, social inclusion and living conditions all depend on both the total size of each population and activity per person. What drives change in the number of people, and how does that demographic change relate to economic activities, dietary patterns and disease?

The dynamics of population size and age structure, together with resource constraints and demand for different types of goods and services, cause economic growth to trace out somewhat consistent patterns of change over time and differences across countries. These patterns involve the rise and fall of variables such as the number of children per adult, or the number and size of family farms. Other variables keep rising but their composition changes, for example as national incomes grow but shift from resource-using to resource-saving activities. Similarity in the rise-and-fall dynamics of some variables, and the way that activities change as they grow, results from aspects of economic

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life that remain mostly unchanged, such as the fact that most farms remain family enterprises.

Taken together, the changes in society we observe to be associated with economic growth are developments in some ways like human development more generally. Like the development of each person, change occurs gradually in unique ways and is not predetermined but is shaped by the environment in ways that allow us to steer growth towards more desirable outcomes.

By the end of this section, you will be able to:

1. Describe how accumulation of capital from investment in physical and human resources enables growth of income and expenditure over time;
2. Describe Preston curves, and explain how innovation enables people to obtain more longevity or other nonmarket goals at each level of national income;
3. Use the available data on demographic transition to explain and describe the rise then fall in population growth rates, size and age structure of the population; and
4. Use the available data on structural transformation and urbanization to explain and compare the rise then fall in rural populations in countries and regions around the world.

10.1.2 Analytical Tools

This chapter concerns the process of economic growth and change over time. Because growth occurs gradually, from different starting points at different speeds, many aspects of growth over time are also visible in comparisons across countries. The patterns of development traced out in one country over time are not quite the same as cross-country differences associated with higher incomes, but observing both changes and differences helps us understand underlying causes and make the choices needed for more sustainable and inclusive economic development.

The patterns we observe in changes over time and differences between countries are caused by underlying similarities, with unique features and obstacles in each case. Centuries of observation and decades of modern research on economic development have characterized stylized trajectories of change. These patterns often involve a shift from one condition to another, or a rise and then fall in some variable, explained to some degree by structural models of underlying interactions.

Our focus in this half of the book is data visualization. Each chart or table aims to include all available observations for the variables shown, to limit selection effects from choosing only some countries or time periods. The notes and text around each chart or table introduce what was observed, and how the many underlying observations were transformed into a meaningful variable. We aim to draw each kind of data from the most authoritative organization responsible for monitoring that aspect of economic development, reproducing their own charts where possible. Each chart typically has either years or income along the horizontal axis. Outcomes on the vertical axis often trace out trajectories for individual countries that cover some of the range seen across countries, allowing to see both similarities and differences.

For income and economic activity, the underlying driver of change identified by economics research is *capital accumulation*. This refers to capital in all its forms, also known as *factors of production*, starting with natural resources especially land, water and air, complemented by physical capital such as public infrastructure or buildings and equipment, and human resources including health and education. The productivity of all those factors, in terms of goods and services produced with the limited quantity of resources available, is determined by how resources are used to make things. Each population's income and economic activities, including its sustainability given planetary boundaries, is therefore driven by both the accumulation of capital and innovation in how resources are used.

Each country's limited land and other natural resources, the dynamics of population growth as each person ages from one life stage to another, and similarities among people in our needs and demand for food, all combine to make capital accumulation and innovation trace out common paths of development followed by many but not all societies around the world. These patterns include a *demographic transition* in population size and age structure, a *structural transformation* in and between sectors of the economy, a *food system transformation* in how food is made and delivered and a *nutrition transition* in diet quality and health outcomes associated with what we all eat.

Capital Accumulation: Innovation and Investment in Physical and Human Resources

The foundation of every country's economy is its land and natural resources. For most of human history that's almost all there was, as people hunted and gathered and then grew the foods they needed. Population growth was slow, and most people had very few things, but migration gradually led to settlement of almost all places around the world, and civilizations emerged under a wide variety of circumstances.

The process of economic development is most simply described as accumulation or buildup of capital in all its forms, complementing a country's natural resources with public and private investment in both physical and human resources. Those investments are closely tied to innovations, meaning the invention or development of a new technology or institutional arrangement. Innovations lead people to invest in new ways of doing things, using the available land and natural resources in a new way that produces more goods and services, some of which is saved and reinvested in additional capital.

Economic models of capital formation and growth begin with a formulation devised by Robert Solow in the 1950s, for which he was awarded a Nobel prize in 1987. Solow's approach was simultaneously also developed by an Australian economist, Trevor Swan, and Solow was awarded the prize in large part for how he and others used the Solow-Swan model to guide research and public investment in education and new technologies, in ways that help raise long-run incomes given fixed natural resources.

The Solow-Swan model itself has no role for innovation. In its simplest form, the model specifies that capital investments offer a rate of return which depends on how much capital has been accumulated, so people save and invest until additional investments are no longer worthwhile. At that point the economy has reached its highest attainable level of income per person. It might take many decades to reach that steady state outcome, but in the simplest Solow-Swan model each person would eventually have all the education and health care as well as tools and equipment known to exist. They would then save and invest just enough each year to replace the capital that depreciates or is lost over time, and thereby use the available land and natural resources in a sustainable manner.

The Solow-Swan approach captured many observed facts about the world and accurately predicted some aspects of global economic development in later decades, but it was most important for what was left out of the model and came to be a later focus of additional research. The main prediction that proved correct is how low-income countries with little capital per person could potentially grow very fast with high returns on new investment, catching up to high-income countries who would typically experience a growth slowdown as their capital stock grew towards its steady-state maximum.

The puzzling aspects of economic growth that could not be explained from within the Solow-Swan model included why some countries started their growth process earlier or later than others, and what determined their pace of growth and ultimate level of income per person. Those factors were the real subject of Robert Solow's research. In statistical tests of the model, each population's income could be explained by their accumulated education as well as physical capital and natural resources available to them, plus or minus variation in the productivity with which those factors of production are turned into income. That overall factor productivity differs by country and varies over time and is actually measured as the residual between observed income and what would be predicted based only on observed capital and natural resources. Robert Solow memorably referred to this residual as 'a measure of our ignorance' about what determines the technologies and institutions in each country, and hence the productivity of new investments that would influence their growth path.

In the decades after publication and use of the Solow-Swan model, economists focused their attention on what factors influenced the productivity of available technologies, and what institutional arrangements facilitate investment in the most productive technologies to achieve sustainable economic growth. A wide range of influences were discovered, including important roles for geography and proximity to places with complementary resources, as well as politics and incentives for governments to invest in public goods and services that complement what the private sector can provide.

A major step forward in the study of economic development has been the large-scale use of field trials, with randomized assignment of interventions in real-world settings around the world. Theoretical predictions can then be compared to observed outcomes, yielding a much richer set of data than could be obtained from naturally occurring variation in human circumstances. The use of randomized trials to test interventions in low-income settings was pioneered in the 1990s by a group of economists led by Abhijit Banerjee, Esther Duflo and Michael Kremer, for which they were awarded the Nobel prize in 2019.

Modern growth theory, and its real-world use to guide public and private investments in both low- and high-income settings, is designed around two sides of the same question: how to help low-income people escape poverty, and how to help high-income people use resources sustainably. The two questions are intertwined because the frontier of available technologies in the world, ranging from crop seeds to solar panels and everything else, drives the ability of both low- and high-income people to use the world's natural resources in more efficient and productive ways. For most of the twentieth century, technologies made increasing use of fossil fuels, and now the twenty-first century innovation is focused on electrification powered by renewables. Within agriculture and food systems, twentieth century innovation focused on increasing quantities of dietary energy and whatever kinds of food people wanted to buy, while twenty-first-century innovation is focused on improving diet quality for health and longevity. The many twists and turns of history can be studied in infinite detail but can also be seen in stylized form as patterns of transition in a few summary variables over time.

Patterns in Development: Four Transitions Associated with Economic Growth

Research on changes during economic growth has identified many different trends and transitions, each described in slightly different terms for different audiences. The most important of these for the food sector are summarized in Table 10.1.

The four transitions listed in Table 10.1 are discussed in turn throughout the remainder of this book. Each has been documented and described in different ways by different researchers, for different purposes. The table itself mentions only some aspects of each transition and is not intended to be a complete list of all changes associated with economic growth.

Here we summarize the four transitions very broadly, in ways that are most useful for food economics. Our focus is on how these transitions relate to economic growth, which itself occurs with very different timing and speed in different countries. Some populations experience rapid economic growth and capital accumulation, while others experience no income growth at all for decades or even centuries, and some have negative growth and destruction of

Table 10.1 Four transitions associated with economic growth and capital accumulation

Domains of change	Typical shifts, with varied speed and timing across countries
Demographic transition	*Rise then fall in population growth rates*
mortality & epidemiology	improved child health, shift to chronic and acute disease at older ages
dependency & ages	rise then fall in child population, rise in older population
fertility & birth timing	fewer births per woman, later first birth and wider spacing
Structural transformation	*Urbanization, shifts in location and composition of economic activity*
Employment	rise in manufacturing and services, greater specialization
agriculture & farm size	fall in farm share of population and income; rise then fall in number of farmers
Education	rise in primary, secondary, higher education and preschool enrollment
Food system transformation	*Diversification of diets, specialization and intensification in production*
crop and livestock systems	more intensive use of inputs, more (then less?) animal source foods
dietary transition	more packaged and processed foods, more meals away from home
nonfood use, loss & waste	more feed and industrial uses, less supply chain loss, more consumer waste
Nutrition transition	*From undernutrition to higher and lower-quality diets*
anthropometric status	taller children and adults, more overweight and obesity
micronutrient deficiencies	more needs met by new dietary patterns, some supplementation & fortification
diet-related disease	more burden of diabetes, hypertension, some cancers; less frequent infection

their existing capital stock. Also, for a given speed of economic growth, the pace and nature of changes in the four dimensions listed in Table 10.1 can vary greatly around the global average pattern of transition, revealing the important role for policy choice in determining the trajectory of each population and the world.

The first change in Table 10.1 is the *demographic transition*, regarding the composition and size of a country's population. Our ancestors emerged several million years ago in Africa, and populations then spread around the world with very slow, gradual increases in the total number of people. For most of human history, population growth was well below 0.1% per year, meaning that it took several years for a community of 1000 to add one more surviving child. The demographic transition began just a few hundred years ago, at different times for different populations, when the number of surviving children began to grow, and they had children of their own.

The start of demographic transition is triggered by improvements in child health, whose survival to have children of their own leads to a rise in the number of children per adult, and an accelerating rate of growth in the total population over time. During this phase, a community's population growth rate could rise to as fast as 4% per year, and for the world, that rate peaked at around 2% in the 1960s. By the time that peak is reached, many communities have already delayed and reduced the number of births per woman, which after the 1960s was facilitated by use of modern contraception. As the birth rate declines, the average age of the population rises and the burden of disease shifts to illnesses experienced primarily by older people, and the total size of the population eventually peaks and then declines if deaths outnumber births. For the world, the UN projects that peak population will occur in the 2080s, which is within lifetime of some people reading this book.

The second change in Table 10.1 is the *structural transformation* of each economy, consisting of urbanization and shifts in the composition of economic activity from primarily food to a wider variety of goods and services. Agriculture's share of employment and income declines, but the rising number of young adults caused by demographic transition typically outpaces the number of new nonfarm opportunities for many decades. For example, if a population with 3% annual growth in the number of adult workers has very rapid capital accumulation (including education) leading to an 6% annual growth in the number of nonfarm jobs, it experiences a rapid shift into nonfarm employment, but the number of farmers continues to grow until the share of workers already in nonfarm jobs reaches more than 50% of the workforces. The natural resource base for each population is limited, so any increase in the number of farmers implies a reduction in land area and natural resources per farmer. That population growth and shrinking land per person causes impoverishment, unless productivity per farm rises, or growth of nonfarm employment allows a decline in the number of farms and a corresponding increase in land area and water or other resources per farm.

The process of structural transformation into activities that use less land per person is driven by the speed of economic growth per person, interacting with the demographic transition and the size of the nonfarm employment at each point in time. Historically, the U.S. reached its peak number of farmers and smallest average farm size around 1914, then experienced accelerating change to a peak annual rate of decline in the number and rise in size of farms in the 1950s, followed by a slowing rate of change to almost no further decline in the national total number and average size of farms since the 1990s. Other countries have experienced similar transition with very different speeds and timing. The world has probably already reached its peak number of farmers, with declining numbers in many regions and continued increases only in Africa, where the peak number of farmers is unlikely to be reached until well past the 2050s.

The third change in Table 10.1 is a *food system transformation*, defining the 'food system' as all activities relating to food, including the supply of farm inputs and availability of land or other natural resources for farmers as well as postharvest transformation, distribution and marketing of food to consumers. As societies accumulate capital and earn more income from a greater variety of things, the food system uses those as inputs to food production both on and off the farm. For agriculture itself, the process of intensification complements the natural resource base of land, water and biodiversity with increasingly capital- and knowledge-intensive methods, initially to raise yields (total food output per acre or hectare), especially when available area per farmer is falling so the labor to land ratio is rising, and then to focus on mechanization when the number of farmers begins to decline so each can operate over land previously farmed by their neighbors. Innovation also gradually shifts towards more of the outputs that higher-income consumers seek, produced in ways that cause less environment harm and provide other benefits sought by higher-income communities.

Each country's food system transformation changes not only how agricultural products are made, but also a *dietary transition* in what is consumed. This transition in dietary patterns involves both the share of dietary energy from each major food group such as starchy staples or dairy, and food attributes such as whole versus refined grains and fermenting or adding sugar to dairy. At the lowest observed levels of income, people get almost all their dietary energy from the very least expensive foods per calorie. For most of history that was starchy staples, but in the twentieth century the cost per calorie of vegetable oil and sugar fell to be about the same as starchy staples. For survival people also need additional protein and micronutrients, for which the least cost sources are beans and lentils or other legumes and pulses, and very low-income people also consume small amounts of vegetables and fruits when they are in season. As incomes rise from the lowest levels we observe, most populations have a high-income elasticity of demand for meat and other animal source foods (dairy, eggs and fish), and especially for fried foods and items with added sugar and salt, as well as refined grains and other processed or packaged foods, and meals away from home.

The food system transition and dietary transition are two sides of the same phenomenon, involving supply and demand for each food attribute. For each type of food, the quantity sold equals the quantity purchased, but not all food produced is eaten by people. During the transition, nonfood uses of farm products are of growing importance. An increasing share of land and other natural resources is used to sustain livestock, and some crops are used for fuel and other industrial uses. Of the food that is intended for people, losses due to spoilage and breakage on the farm or in supply chains decline due to increasing speed and precision of handling, while kitchen and plate waste by consumers increases due to the cost of food ingredients being a smaller fraction of total meal costs, even for meals prepared at home. There is also a rise in the quantity of food consumed by household pets, especially in societies with large numbers of relatively large dogs. In addition, most people are concerned about the welfare of livestock and wild animals and have a variety of health and environmental concerns about their food as well as different preferences and aspirations. All these factors lead to a variety of dietary patterns in the population, supplied by a continuous flow of new food items in retail shops and new kinds of restaurants and food delivery services.

A fourth category of change in Table 10.1 is known as the *nutrition transition* in diet-related health outcomes. This transition in a population's nutritional status is both cause and consequence of the demographic and epidemiological transition described in the first row of the table. Nutritional variables are commonly categorized using an ABCD list to aid memory, starting with *A*nthropometry such as measured heights and weights, then *B*iomarkers which include blood and urine samples tested for micronutrient levels, *C*linical signs and symptoms of disease, and *D*ietary assessment of individual intake relating to those diseases. During the nutrition transition, children born in each successive generation can gain height very quickly relative to their parents, converging over several generations to the heights of healthful people from almost anywhere in the world. Attained heights are mostly determined in the first thousand days after conception, in utero and infancy up to two years of age and driven by exposure to disease as well as dietary intake. The nutrition transition also involves children and adults gaining weight relative to height, sometimes during relatively brief episodes of weight gain over a few months or years of stress and other contributing factors, causing a change in body composition that is difficult to reverse.

The nutrition transition in terms of biomarkers or clinical signs and symptoms typically involves gradual elimination of specific micronutrient deficiencies, such as vitamin A deficiency that can cause night blindness, or iron deficiency that can cause anemia. The micronutrient deficiencies observed at lower incomes can potentially be eliminated by dietary diversification to the extent that people move towards a balanced diet with higher levels of vegetables, fruits, dairy, fish and other nutrient-rich foods, but even in high-income countries many populations have some remaining deficiencies that are most cost-effectively filled by supplementation or fortification with individual nutrients. Fortification refers to adding nutrients to a food for the general population, such as folate (vitamin B9) that has been added to U.S. flour supplies as folic acid since 1998 to prevent neural tube defects in pregnancy, following an earlier U.S. program advocating that pregnant women take folate supplements. The switch from a supplements-only policy to fortification for everyone was done to reach more women before they know they are pregnant, on the grounds that other people might not need the additional folate but are not harmed by it. Gradually eliminating all major deficiencies in specific nutrients then shifts the burden of diet-related disease to cardiometabolic conditions such as diabetes, hypertension and some cancers, as well as food safety concerns from contaminants and water- or airborne diseases. That epidemiological transition in the timing and composition of disease burdens is partly due to rising exposure to some risk factors, and partly due to reductions in competing risks that were previously a more likely cause of death.

Preston Curves: Changes Associated with Income Can Shift Over Time
The summary Table 10.1 listing four major transitions associated with economic growth describes a global average trajectory over time and pattern across countries. As we will see there is substantial variation around that global average, and systematic shifts in how the transition takes place due to new technologies and policy changes. These shifts are known as Preston curves, after the demographer Samuel Preston who first observed the relationships illustrated in Fig. 10.1.

The type of curve shown in Fig. 10.1 was first published by Samuel Preston in 1975, and the version here was first created by economist Max Roser in 2013 as one of the initial charts in an online data-visualization project called Our World in Data. The pictures shown in this chapter begin here because Preston curves are a natural starting point for understanding international development, and because the specific chart reproduced in Fig. 10.1 is due to a Swedish physician named Hans Rosling who championed the use of data

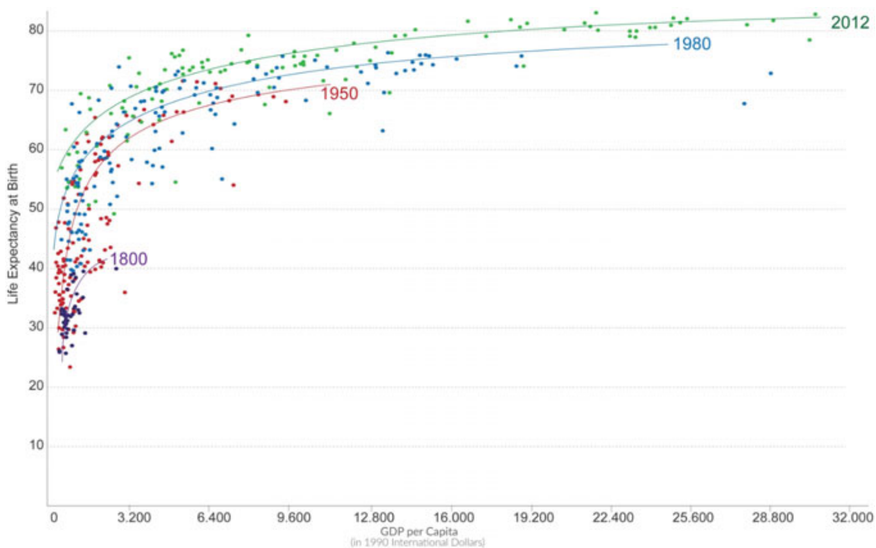

Fig. 10.1 Preston curves of life expectancy at each level of GDP, 1800–2012 *Source*: Reproduced from Max Roser, Esteban Ortiz-Ospina and Hannah Ritchie [2019], Our World in Data: Life Expectancy [https://ourworldindata.org/life-expectancy], using life expectancy data compiled from various sources by Gapminder [https://www.gapminder.org/data] and GDP estimates from the Maddison project at University of Groningen [https://www.rug.nl/ggdc/historicaldevelopment]

visualization to build intuition about large-scale changes we would otherwise not be able to see. Most data visualizations in this chapter are from national governments and international organizations because those are the most authoritative sources of the original observations, but in some cases like these Preston curves we use images compiled from multiple sources such as the work of Our World in Data.

Preston curves have real national income on the horizontal axis. In Fig. 10.1 and most other visualizations, income is shown in logarithmic terms to capture the exponential nature of growth and change. Values are shown at 1990 prices. Conversion to more recent terms would require multiplying by about 1.9 to convert obtain purchasing power parity dollars at 2017 prices, meaning that the horizontal axis labels range from about $6000 to $60,000 per person in each year.

Life expectancy shown on the vertical axis of Fig. 10.1 is the starting point for this chapter in part because survival is the most fundamental of human development goals, and the epidemiological transition towards longer lifespans relates to income in ways that also characterizes other transitions. Increases in life expectancy begin with improved child survival, which is the first step of all growth processes listed in Table 10.1.

Preston curves combine a scatterplot of individual country observations with a best-fit line through those points collected for four specific years. In 1800 all countries for which data was available were poor by modern standards, with incomes per person below $3200 in 1990 dollars, and less than 40 years of life expectancy due primarily to high infant and child mortality. By 2012 there were still some countries with incomes like those observed in 1800, but most of those had more than 60 years of life expectancy due mainly to improved child health. Also, by 2012 some countries had experienced over two hundred years of economic growth leading to ten times more goods and services per person, with the highest income countries reaching above 80 years of life expectancy.

The upward shift in the Preston curves for 1800 and then 1950 primarily involved cleaner water and sanitation, plus improved nutrition. There were very few modern medicines before 1950. The first globally successful antibiotic, penicillin, was discovered in 1928 and not deployed worldwide until the late 1940s, and the first globally effective vaccines were developed in the 1930s, first against airborne viruses that cause influenza, and then against the mosquito-borne virus that causes yellow fever. As those and other interventions were rolled out, from 1950 to 1980 the worldwide Preston Curve rose by over 10 years in the poorest countries, and by about 5 years in the richest countries. A similar and even larger shift occurred from 1980 to 2012.

Successive upward shifts in the Preston curve over the late 20th and early twenty-first centuries were caused by many different new technologies for both prevention and treatment, such as the use of oral rehydration therapy for recovery from cholera and other diarrheal diseases that was disseminated worldwide starting in the late 1970s. Some techniques spread faster than others depending on their ease of adoption and the pace of institutional innovation as well as political willingness to invest in public health services. Adoption often involves non-governmental organizations founded for specific purposes, such as Helen Keller International which initially aimed to assist blind people, then led global vitamin A supplementation campaigns starting in the 1970s to prevent blindness that also reduced child mortality, working together with government services led by the World Health Organization of the United Nations.

The Preston curves shown in Fig. 10.1 are all steepest at the lowest incomes, with a flatter slope at higher incomes and nearly horizontal line among the highest income countries today. That pattern of diminishing returns to income reflects how with some investments offer high impacts at low cost per person that can readily be adopted in low-income countries. These include many things that households do for themselves without scientific knowledge or intervention, such as seeking cleaner air and water, often with the help of collective action and government programs such as local water and sanitation improvements. Other interventions require more administrative effort based on scientific guidance, such as vaccination or supplementation campaigns.

Scatterplots around each year's Preston curve typically show more variation at lower incomes than at higher incomes. This reflects how countries can have low average incomes per person for different reasons under a wide range of environmental or other circumstances that influence life expectancy, while almost all countries with high national income invest in the technologies needed to approach the global frontier of survival and longevity. That pattern of convergence towards more similar outcomes at higher income levels applies primarily to goals that all societies have in common, such as life expectancy, but even for such a universal human objective each country has its own unique history and trajectory of life expectancy over time.

Country Trajectories: Life Expectancy and National Income in Four Example Countries

The data compilations and visualizations created for Our World in Data provide new and informative ways of seeing how transitions occur. Some of the variation we observe is measurement error, but the very wide range of experiences shown in the available data reveal both similarities and differences in how different populations have experienced economic development as shown in Fig. 10.2.

The background of Fig. 10.2 has trajectories in gray for 178 countries and territories, of which the highlighted examples are Ethiopia and Nigeria (the two largest countries in Africa), China and India (the two largest in Asia) and the U.S. Many other examples would be similarly revealing. The data for Ethiopia and Nigeria begin in 1950, partly because systematic data collection for many countries did not begin until formation of the UN in 1945, while

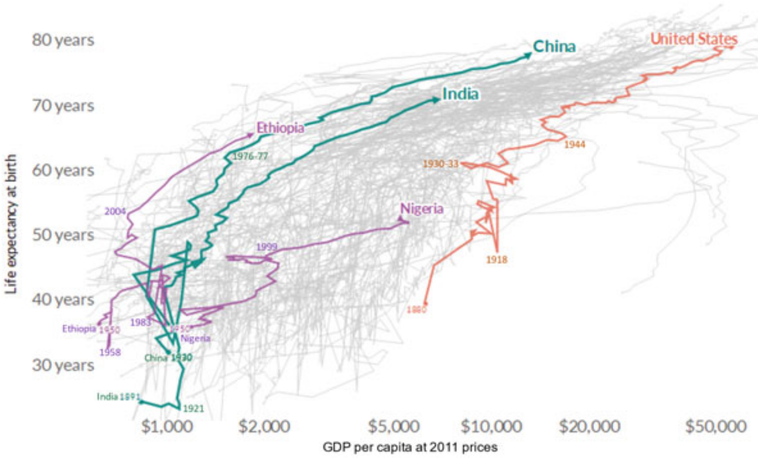

Fig. 10.2 Examples of growth and change in national income and life expectancy, 1880–2018 *Source*: Reproduced from Max Roser, Esteban Ortiz-Ospina and Hannah Ritchie [2019], Our World in Data: Life Expectancy, using data from diverse sources. Other countries can be shown by modifying https://ourworldindata.org/grapher/life-expectancy-vs-gdp-per-capita

the data for India and the U.S. begin in 1891 and 1880 respectively, and data for China begins in 1930.

Ethiopian data for 1950 shows a life expectancy around 36 years and average income of $622. Their trajectory was initially diagonal, upwards and to the right following the global pattern, but was interrupted by a severe famine in 1958, another in 1973, and an even more extreme famine in 1983–1985 followed by an income decline which lasted for a decade after 1993. When economic growth resumed in 2004, within four years the country had returned to the income levels of the 1970s and proceeded diagonally from there to a life expectancy in 2018 around 65 years at an income of $1838.

Nigeria data begin in 1950 with a similar life expectancy as Ethiopia at 36 years, but twice its national income level at $1200 per person. The country proceeded diagonally until a civil war caused famine in the province of Biafra during 1968–1970 marked an end to those improvements, with a decade of income decline starting in the late 1970s followed by a decade of no further change until income grow resumed in the late 1990s. Nigeria then returned to a diagonal path but at a much flatter slope than most other countries, with less gain of life expectancy than other countries achieved, to a life expectancy in 2018 around 53 years at an income of $5238.

The differences between Ethiopia and Nigeria are stunning, and clearly demonstrate how national income is not the sole determinant of life expectancy or any other aspect of economic development. In the 1950s, Ethiopia had one of the lowest levels of average income ever recorded, and it experienced some periods of improvement from there but did not begin its trajectory of consistent economic growth until 2004. In contrast, Nigeria entered the 1950s with higher income and began modern growth around 1999 but has not ever experienced the sharp rise in life expectancy achieved by Ethiopia.

The development trajectories of individual countries defy easy explanation. Entire books have been written about the development of even a single village, and whole libraries are devoted to the history of Africa. One of William's favorite expressions about international development is that we can learn so much from actually visiting each place: from a week of interviews, we could write a whole article, and from a year of study we could write a book, but if we stay long enough we usually learn that those partial truths can be misleading and much of what we see remains surprising. Both William and Amelia were able to live in various countries for multiple years, and William was able to return in the 2010s to places he'd lived in Zimbabwe, Haiti and Colombia more than 25 years earlier. With deeper immersion and a longer time frame, we find more unexpected aspects of how each place develops, just as we might from returning to our own childhood homes. Deep scholarship about individual people, places and communities is therefore essential to understanding their specific circumstances, while zooming out to longer time frames and large sample sizes is essential to understanding broad patterns of development for entire populations and the world as a whole.

India data in Fig. 10.2 begin with 1891, when India had a life expectancy of 24 years at an income level of $843 per year. India then had 20 years of unchanged or declining life expectancy and slightly rising income to one of the world's lowest recorded life expectancies at 23 years and an income of $1100 in 1911, at which point the country's life expectancy began a gradual rise. That rise occurred much more steadily than Ethiopia and Nigeria, despite famines in some regions of India during 1943 and 1972–1973. For the first 30 years of rising life expectancy, however, India was still under British rule and experienced no increase in national income at all. Independence came in 1948, when the country's national income was about the same level as 50 years earlier. India's income growth did not begin until 1951 and accelerated gradually, to reaching a life expectancy in 2018 of 71 years at an income of $6800 per year.

China data beginning in 1930 starts at a point very similar to where India was at that time, with a life expectancy of 32 years and an income of $1012 per year. Life expectancy then improved greatly to 49 years in 1958 but plummeted during a massive famine in 1959–1961 before recovering and continuing its rise. From 1930 to the mid-1960s China had no income growth at all, and income only gradually began to increase in the late 1960s and 1970s, accelerating particularly after a brief reversal in 1976–1977. At the start of China's modern period of growth in 1978, the country had slightly higher income than India ($1744 vs. $1540) and much high life expectancy (63.2 vs. 52.5). By the end of the period in 2018, China had much higher income ($13,100 vs. $6800) and only somewhat higher life expectancy (78 vs. 71 years).

U.S. data in this chart begin in 1880, with a life expectancy of 39 years at an income of $6256. Life expectancy then grew gradually except for a sharp drop during the flu epidemic of 1918, and income also grew gradually except for the large reversal in the great depression of 1930–1933, and the anomalously large expansion of GDP for World War II military spending that peaked in 1944. The relatively long and sustained period of economic growth led the U.S. to a life expectancy in 2018 of 79 years at an income of $55,300 per year.

The cloud of all countries' data in Fig. 10.2 allows us to see each country's trajectory in the global context. Ethiopia started and still remains at the left edge and upper edge of the cloud, meaning that it has unusually high life expectancy for its level of income. Ethiopia, Nigeria, India and China all had multiple large setbacks prior to their modern era of economic development, but then grew quickly along a diagonal path. China has consistently had greater life expectancy than India at each level of income. Nigeria has followed a development path with much less increase in life expectancy as its income rose, moving it from the center towards the right of the data cloud, towards the United States which is consistently on the right and lower edge of the cloud with low life expectancy for its level of income.

The purpose of showing five trajectories in detail is to demonstrate that the systematic patterns of development described in Table 10.1 are the result of broad social forces only when development advances. Economic growth can easily stall or go into reverse. It is only when growth occurs at all that additional income can be spent on child survival as shown in Figs. 10.1 and 10.2, with innovations that systematically improve outcomes at each level of income in the Preston Curves, as well as differences in the speed and direction of change in each development trajectory. In the following sections we examine the four major transitions of Table 10.1 in turn, using a variety of data sources and visualization techniques.

Demographic Transition, Population Size and Age Structure

The first major shift associated with economic development is the demographic transition, triggered by improvements in child survival and reduced mortality that are measured by overall life expectancy in the previous two figures, followed by lower fertility and a smaller number of children per woman. The speed and timing of these trends can best be seen in terms of a population's overall rate of births and deaths per thousand people, as shown with actual historical data for two example countries in Fig. 10.3.

The data in Fig. 10.3 show Sweden because it has recordkeeping available to us of births and deaths from the mid-1700s, and Mauritius because it is the only African country with similar recordkeeping from the late 1800s. These are each country's 'crude' rates in the sense of aggregate totals, shown per thousand people to avoid the decimals needed to show each as a percentage

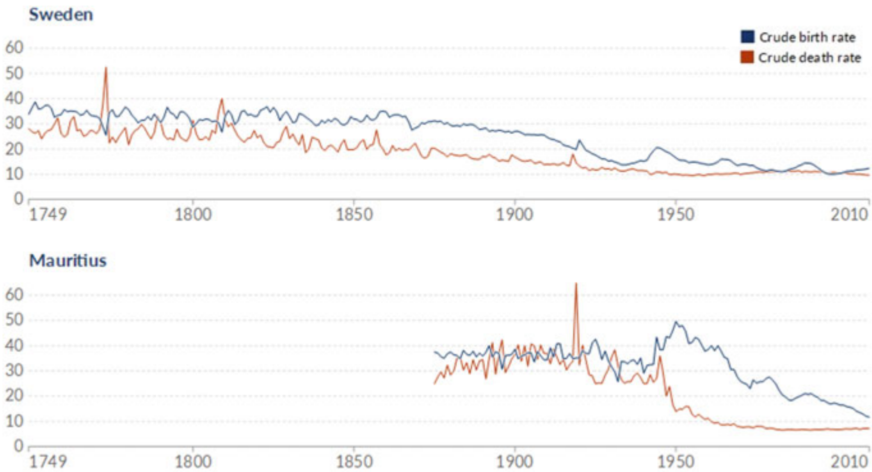

Fig. 10.3 The demographic transition in Sweden and Mauritius *Source*: Reproduced from Hannah Ritchie et al. [2023], Our World in Data: Population Growth, using data compiled by Brian Mitchell for the International Historical Statistics project at https://www.eui.eu/Research/Library/ResearchGuides/Economics/Statistics/DataPortal/IHS. Other countries can be chosen at https://ourworldindata.org/grapher/demographic-transition-sweden

of the population. One feature of these charts is that the country's population growth rate in each year is the gap between deaths and births, seen by counting the dotted horizontal lines between the two curves that trace intervals of 10 per thousand, or 1% annual growth in the population when births outnumber deaths.

These data show how Sweden's death rate was highly variable with no trend from 1749 to the 1820s, then began to decline and have smaller fluctuations until about 1880 when it declined faster and had very few fluctuations until the spike from the 1918 flu epidemic. The timing reveals how death rates fell long before any modern medicines were known, with very large year-to-year variation in population health that were also reflected in birth rates. During the early period from 1749 through the 1820s, the birth rate rose when deaths fell, and fell when deaths rose, as waves of infectious disease both raised mortality and limited fertility, followed a 'baby boom' of births when health conditions improved. After 1820 the birth rate generally stayed above 30 and declined only after 1870, opening a gap of around 10 more births than deaths per thousand people. Decline in birth rates happened long before any modern contraceptives were available, due only to social changes such as delaying marriage. That decline in fertility happened at about the same pace as the decline in mortality, leading to population growth of about 1% per year for over a century. It was only in the 1920s that birth rates started to fall faster than death rates, ultimately catching up to reach near zero population growth in the early 2000s.

The data for Mauritius show a very different story, with deaths fluctuating along a rising trend from 1875 to the 1910s, so the country had no population growth at all. There were then even larger fluctuations in both births and deaths, followed by a period after World War II when death rates plummeted, and birth rates spiked. In Mauritius from 1945 to 1950 birth rates rose in response to better health, as births had in Sweden during the 1749–1820 period, before people reduced their birth rates from 1950 onwards. Birth rates fell must faster than they had in Sweden, but death rates had dropped even faster, opening a population growth rate of over 3% per year until death rates stopped falling in the 1980s while birth rates continued to decline.

Each country's population growth begins with child survival, and in some cases a brief baby boom period of replacement fertility after periods of hardship and high mortality, followed by a sustained decline in birth rates. The timing and speed of change depends on the circumstances for each country. Countries like Mauritius that had increasing child survival in the mid to late twentieth century created a broad base of children who then grew up to form families of their own. That creates population 'momentum' from a larger size of each successive generation, and then population aging after the fertility rates of each generation have fallen.

The absolute number of people and age distribution of each country's population follows from their unique speed and timing of change in birth and death rates, but the synchronized rapid worldwide improvements in child survival and life expectancy after 1950 created a distinctive global demographic transition illustrated by Fig. 10.4.

The population pyramids shown in Fig. 10.4 are compiled by statisticians at the United Nations from country census data, using demographic models to infer the number of people at each age in each year for places with few observations in the top row for 1950, 1975 and 2000, and then to project forward for 2025, 2050 and 2075. These UN population projections continue to 2100, with variants shown in degrees of shading at the bottom of each pyramid in the second row. The lightest and widest shading shows the UN's 95% prediction interval, implying that only 5% of demographic scenarios would exceed that range, and the intermediate shading shows an 80% prediction interval. The primary estimate shown is the UN's median projection.

Population pyramids are constructed using the same data and techniques as life expectancy for each cohort of infants, based on demographic models known as life tables. A population's life table for a given year is based on mortality rates for people of each age and sex observed in the previous year, which provides the probability that a person of each age and sex will survive into the following year. Demographers then use the previous year's fertility rates for women at each age to calculate the number of infants likely to be born in the following year. The number of births each year depends not only on the average number of births per woman over their lifetime, known as the

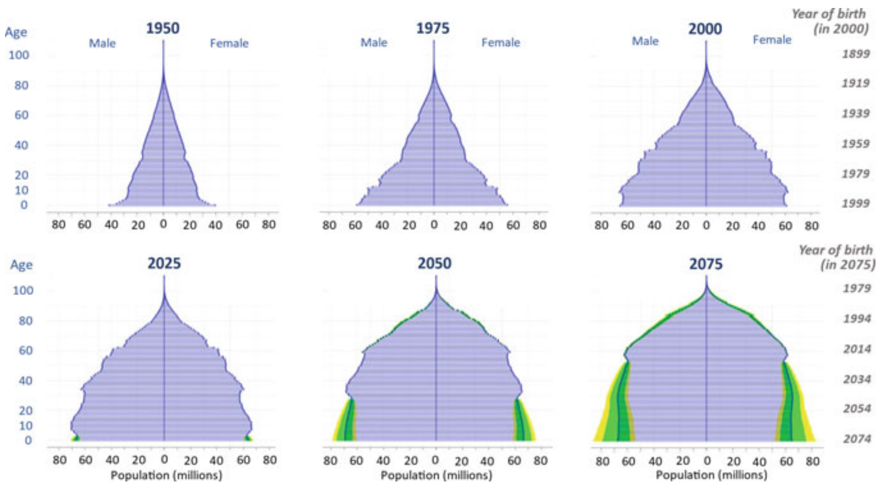

Fig. 10.4 The demographic transition worldwide: population pyramids from 1950 to 2075 *Source*: Authors' composite image of population pyramids reproduced from the UN Department of Economic and Social Affairs, Population Division [2022], World Population Prospects 2022 [https://population.un.org]. Population pyramids, growth rates and other data for individual countries and regions can be drawn at https://population.un.org/wpp/Graphs/DemographicProfiles/Pyramid

total fertility rate, but also the size of each cohort of women at each age and their birth timing. Delayed first births and spacing between births can greatly slow the rate of population growth, even if there is no change in the total number of children per woman.

The global demographic transition shown in Fig. 10.4 drives many of the changes in agriculture, food systems and nutrition described in Table 10.1. The global total is the sum of all countries, driving change worldwide based on each country starting the transition when their child mortality begins to fall, proceeding at different speeds with occasionally reversals. Some countries such as Sweden already experienced most of their historical transition prior to 1950, but most of the world population is experiencing a transition whose timing is more like Mauritius, with most of their decline in child mortality occurring after 1950.

Demographic transition can be described as a shift from population pyramids to columns with similar numbers of people in each age group. In the pyramid stage, the population at each age has a larger cohort of people younger than them. Each community has many newborns and young children per young adult, parents are caring for children throughout their adult lives, and older adults form a small share of the total population. Such pyramids can persist for decades or centuries with little or no and even negative population growth. When a larger fraction of children survives, as they did after 1950, the result is population growth and transition as shown in Fig. 10.1. The world-wide pyramid grew larger from 1950 to 1975 and 2000, with fewer newborns per adult but a growing share of the population who are school-aged children and young adults.

The age structure of the population can be as important as its total size, as shown in Table 10.2.

The magnitudes of change and growth provided in Table 10.2 summarize the global population pyramids in age groups that are especially relevant for economic development, growth and equity. Children aged 0–4 constituted 14% of the entire world population in 1950, dropping slightly to 13% in 1975. In most contexts those infants and preschoolers are cared for primarily by older girls and women, both in the home and as care providers in the community, severely limiting the ability of women to do any other kinds of work.

Table 10.2 Distribution and growth of the global population by age group, 1950–2100

	1950 (in %)	*1975 (in %)*	*2000 (in %)*	*2025 (in %)*	*2050 (in %)*	*2075 (in %)*	*2100 (in %)*
Dependency rates and size of the workforce							
Age 0–4 (infancy and preschool)	14	13	10	8	7	6	5
Age 5–14 (school-aged children)	21	24	20	17	14	12	11
Age 15–64 (youth and midlife, or working age)	60	57	63	65	63	61	59
Age 65 + (older adults)	5	6	7	10	17	21	24
Age 80 + (octogenarian and older)	*0.6*	*0.7*	*1.2*	*2.1*	*4.7*	*7.2*	*9.3*
Cohort growth or shrinkage over 25 years							
Age 0–4 (infancy and preschool)		+60	+13	+5	+3	−7	−11
Age 5–14 (school-aged children)		+83	+29	+9	−1	−6	−9
Age 15–64 (youth and midlife, or working age)		+70	+41	+10	−2	−4	−8
Age 65 + (older adults)		+55	+66	+38	+14	+4	−3
Age 80 + (octogenarian and older)		+77	+87	+103	+87	+35	+15

Source: Authors' summary of data from United Nations, Department of Economic and Social Affairs, Population Division (2022). *World Population Prospects: The 2022 Revision*. Updates and other variables are available at https://population.un.org/wpp. Data on family planning and contraceptive use are at https://www.un.org/development/desa/pd/data/family-planning-indicators

When the child dependency rate declines as shown in the top row of Table 10.2, women's time is freed to do many other things thereby contributing to growth of the economy. Claudia Goldin was awarded the Nobel prize in 2023 for pioneering work on this topic. Goldin's findings included how delayed births played a causal role in decision-making about women's education and careers, including the sharp rise in women's schooling and paid employment in the U.S. from the 1970s through the 1990s seen in Fig. 9.11 of the previous chapter. Goldin's work shows how delayed and declining birth rates allowed women to reach higher levels of schooling, often beyond that of men, even as their remaining childcare obligations then limit their professional advancement. This work helps explain how women's wages rose towards convergence with men's earnings into the 1990s as shown in Fig. 9.12 of the previous chapter, and identifies the need for assistance with childcare to permit continued convergence as shown for some other countries in Fig. 7.10 of our chapter on inequity.

The share of the world's population aged 15–64 plays an important role in economic development, as people in that age range are often increasingly experienced and productive at their work. From 1950 to 1975 that group declined from 60 to 57% of the world's population, limiting the world's ability to have a rising share of all people participating in the workforce. Then from 1975 to 2000 and 2025 the world population's share in that age range rose rapidly from 57 to 63 and 65%, contributing a 'demographic dividend' through greater labor force participation. From 2025 onwards the world will return to the 'demographic drag' experienced earlier as the share of working age declines.

The share of the population that is 65 or older, and even 80 or older, will continue to grow at an increasing rate. As shown by Table 10.2, the fraction of people who are 65+ grew from 5 to 7% in the half-century from 1950 to 2000 but will more than double from 7 to 17% from 2000 to 2050. As dependency shifts from children to older adults, including especially those 80 or older, the cost shifts from childcare to elder care, and from schooling to medical services. A disproportionate fraction of both childcare and elder care is done by women, but the time burden and cost of care arises somewhat later in each person's adult life and might be less likely to interrupt their initial work experience.

Cohort growth and shrinkage over 25 years, from one generation to the next, drive change in employment prospects especially in the food system. For the world as a whole the number of school-age children from 5 to 14 grew by 9% from 2000 to 2025 but is projected to decline by about 1% over the next 25 years to 2050. The number of young and working adults will also fall, even as the older population grows.

The demographic transition affects food and nutrition not only through the number of people, but also epidemiological shifts in the burden of disease, and changes in gendered time use as shown in Table 10.3.

Table 10.3 Vital statistics for the global population, 1950–2100

	1950	*1975*	*2000*	*2025*	*2050*	*2075*	*2100*
Population size and growth							
Total population (billions)	2.50	4.07	6.15	8.19	9.71	10.37	10.35
Growth rate (percent per year)	1.7%	1.8%	1.3%	0.9%	0.5%	0.1%	−0.1%
Crude birth rate (births per thousand people)	37	30	22	16	14	12	11
Crude death rate (deaths per thousand people)	20	12	8	8	9	11	12
Life expectancy and age-specific mortality							
Life expectancy at birth (years)	46.5	58.3	66.5	73.8	77.2	79.8	82.1
Infant mortality rate (deaths per thousand, age 0–1)	143	91	53	26	17	12	9
Under-five mortality rate (deaths per thousand aged 0–5)	224	133	76	36	24	17	13
Youth and midlife mortality (deaths per thousand aged 15–60)	379	251	183	130	109	93	75
Fertility and family planning							
Total fertility rate (births per woman)	4.9	4.1	2.7	2.3	2.1	2.0	1.8
Mean age of childbearing (all births)	29	28	27	28	29	30	30
Estimated demand for family planning (pct of women aged 15–49)		58.9	73.9	75.9			
Contraceptive use, any modern method (percent of women aged 15–49)		28.0	55.0	59.1			
Contraceptive use, any traditional method (pct of women aged 15–49)		10.5	6.8	6.2			
Sex-specific mortality and gender bias							
Sex ratio at birth (males per thousand females)	1054	1056	1075	1054	1047	1046	1045
Sex ratio of the total population (males per thousand females)	993	1004	1011	1009	1000	994	987

Source: Authors' summary of data from United Nations, Department of Economic and Social Affairs, Population Division (2022). *World Population Prospects: The 2022 Revision*. Updates and other variables are available at https://population.un.org/wpp. Data on family planning and contraceptive use are at https://www.un.org/development/desa/pd/data/family-planning-indicators

The demographic transition caused the world population to double over the 50 years from 1975 to 2025, from 4.07 to 8.19 billion as shown in the first line of Table 10.3. In so doing the percentage rate of growth from year to year has been cut in half, from 1.8 to 0.9% as shown in the second line. African countries such as Mauritius have experienced this change much faster and later in time than the world, but the pattern in terms of life expectancy and the epidemiological transition, fertility and birth timing mentioned in Table 10.1 occurs along similar lines.

The epidemiological aspect of demographic transition can be seen in the sharp fall in infant, child and youth or midlife mortality, shifting the burden of disease to chronic and noncommunicable diseases caused by risk factors whose impact is cumulative over time. The onset of cardio-metabolic diseases such as diabetes and hypertension most often occur in adulthood and is closely related to diet and other modifiable risks that are themselves associated with economic growth and development, as discussed in the next section of this chapter.

The timing of births as shown in the middle sector of Table 10.3 is a central aspect of social and economic development, greatly influencing women's participation in the economy. From 1950 to 2000 the total fertility rate fell from 4.9 to 2.7 births per woman, but much of that came from wider spacing and an earlier end of childbearing in the mother's adult life, so the average age at which mothers gave birth went down from 29 to 27 years of age. As fertility continues to fall to below replacement levels, postponing that first and second child is driving the average age of childbearing back up to 29 and then 30 in the decades ahead. Control over the timing of births is closely related to demand for and use of contraception. The fraction of women survey respondents worldwide who say they want to use family planning is estimated to have risen from about 60 to 76% from 1975 to 2025, with a doubling of the fraction of all women who use any modern method from 28 to 60%, and a decline from 11 to 6% in the fraction who use a traditional method.

Sex-specific behavior and gender roles underlie many aspects of the demographic transition, with two of the most important kinds of variation shown in Table 10.3. For humans and most other mammals, under normal conditions biological factors lead to a slightly larger number of males than females at births, and higher mortality for males in infancy, childhood and as adults. That gap is reflected in the sex ratios observed in 1950, when there were 1054 male births for every thousand female births, and the surviving population had only 993 males per thousand females. The UN projects that the world will eventually return to those same ratios in the future, but in the meantime, there has been a large swing towards more male births and more male survival.

The sex ratio changes shown in the last two rows of Table 10.3 reveal that from 1950 to 1975 there was almost no change in the sex ratio at birth, but a greater increase in male than female survival so the sex ratio of the population rose to 1004 males per thousand females. Over the next 25 years to 2000, the sex ratio at birth rose from 1056 to 1075 males per thousand females, and survival also continued to grow faster for males than females leading to the sex ratio of the whole population rising from 1004 to 1011. The mechanisms behind these changes include both gender bias and sex-specific mortality. There is evidence that a preference for sons contributes to neglect and even infanticide of girls in many settings, leading to millions of 'missing women' highlighted in the early 1990s by the economic philosopher Amartya Sen, whose many contributions led to his being awarded the economics Nobel prize in 1998. At the same time, biological factors leading to high child mortality affect boys more than girls, so reducing those harms has the opposite effect.

The changes in gender roles and other aspects of human development shown in Table 10.3 have profound consequences for agriculture and food systems. Economic principles can help us understand those changes and improve outcomes, for example by recognizing how decisions to change time use and household activities are often made in response to changes in opportunity costs. When differences between groups in access to schooling and earning opportunities are reduced or removed, people will reallocate their time to take advantage of those opportunities. Lifting barriers to participation reduces inequity and drives growth of the economy, creating a further round of new opportunities from economic expansion especially in agriculture and the food system.

Agricultural Transformation, Urbanization and the Food System

Economic growth is driven by accumulation of physical capital and human resources, interacting with demographic transition, allowing a country's people to use its land and natural resources in new and different ways. Many activities deplete or degrade natural resources at first, until the increasing scarcity and value of ecosystem services and other environmental attributes drives individual and collective action towards land-saving, nature-enhancing innovations. The most fundamental of these shifts is the transition from extraction and cultivation or production of physical goods in general towards more knowledge-intensive services.

The *structural transformation* of economic activity is generally defined as the switch from agriculture to manufacturing and services, as illustrated for the U.S. in Fig. 10.5.

The left panel of Fig. 10.5 shows how economic development in the U.S. drew workers first into manufacturing, which rose from 15 to 20 and then 26% of jobs from 1840 to 1860 and then the 1880s. Manufacturing employment fluctuated between 28 and 34% of jobs from 1900 to 1980, then fell to 15% by 2015. Employment in services fluctuated between 21 and 27% of employment from 1840 through the 1890s, but then grew continuously to 84% where it remained during the 2011–2015 period. Service employment fluctuated briefly during World War II, but otherwise grew consistently from year to year to the entire twentieth century, from 1900 to 2011.

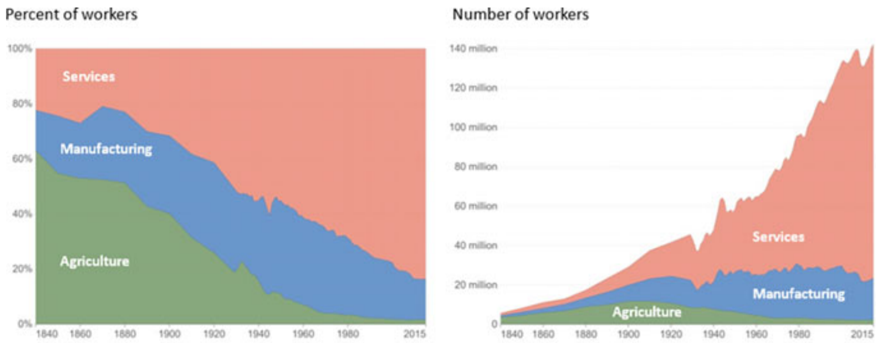

Fig. 10.5 The structural transformation of the United States, 1840–2015 *Source*: Reproduced from Our World in Data, updating data described in B. Herrendorf, R. Rogerson and A. Valentinyi [2014], 'Growth and Structural Transformation' in Handbook of Economic Growth Vol. 2B [Elsevier]. Data for other countries are at https://ourworldindata.org/structural-transformation-and-deindustrialization-evidence-from-todays-rich-countries

As shown at the left of the chart, farming was the principal occupation for 60% of Americans in 1840. The structural transformation then reduced the share of workers who are farmers almost continuously, except for a rise during the great depression (1930–1933) and during World War II. The pace of decline slowed in the 1990s when the share fell below 3%. Since 1996, the share of workers who are farmers has fluctuated between 1.5 and 2%.

A surprising aspect of structural transformation is how agriculture's declining share of employment interacts with demographic transition and changes in the total number of people entering the workforce each year, as shown in the right panel of the chart. The total number of U.S. workers in 1840 was 5.7 million, of whom 3.6 million were farmers. Because the total number of workers was rising quickly, in part due to immigration, the number of farmers kept rising for the next 70 years, to a peak around 12 million in 1910–1915. From the end of World War I in 1918 the number of farmers then fell steadily, with the fastest pace of decline between 1950 and 1970, before flattening in the 1990s. Since 1996, the number of farmers has fluctuated between 2 and 2.5 million.

The pattern seen in the U.S. is unusual primarily due to expansion of the country's geographic borders, primarily through conquest and displacement of native people as well as treaties to buy land from France, Spain and other colonial powers. The U.S. also had unusually high levels of immigration, and a long well documented experience of almost uninterrupted economic growth. To compare the 175-year history of the U.S. shown in Fig. 10.5 with structural transformation elsewhere, we can use the more recent and very rapid transformation of the economy in South Korea shown in Fig. 10.6.

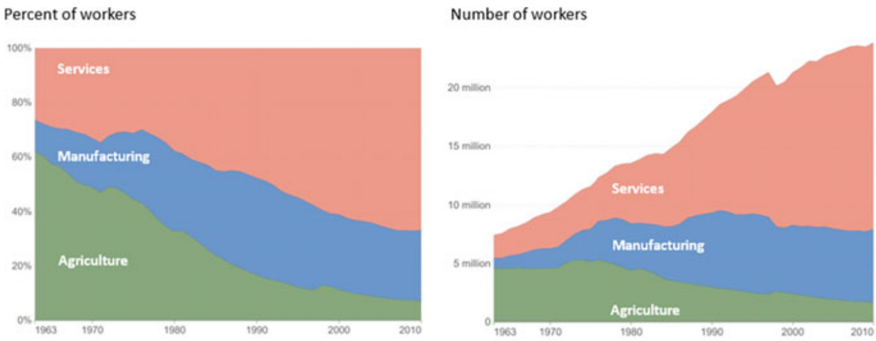

Fig. 10.6 The structural transformation of South Korea, 1963–2010 *Source*: Reproduced from Our World in Data, updating data described in B. Herrendorf, R. Rogerson and A. Valentinyi [2014], 'Growth and Structural Transformation' in Handbook of Economic Growth Vol. 2B [Elsevier]. Data for other countries are at https://ourworldindata.org/structural-transformation-and-deindustrialization-evidence-from-todays-rich-countries

The structural transformation of South Korea shown in Fig. 10.6 is like patterns observed in the U.S. and almost any other country experiencing economic growth, except that South Korea's transformation was unusually rapid. The growth trajectory of South Korea, when drawn in terms of national income and life expectancy, is like that of China in Fig. 10.2. The first available data for those variables in South Korea is around 1913, when the country had among the lowest incomes and shortest life expectancy ever recorded for any country.

Korea was ruled by Japan as a colony from 1910 to 1945 and entered the 1950s with the same very low level of income (around \$3 per person per day in 2017 dollars) and very low life expectancy (under 25 years) as it had in 1910. By 1963, at the start of Fig. 10.6, South Korea's national income and health had begun to rise, leading into one of the world's fastest periods of sustained economic growth ever recorded. Over the 47 years from 1963 to 2010, South Korea's income rose from \$5 to over \$90 per person per day at purchasing power parity prices of 2017, and life expectancy rose from 56 to 81 years.

South Korea's structural transformation from agriculture to manufacturing and services was unique primarily in terms of its speed. From 1963 to 1976 the fraction of workers who were farmers dropped from 62 to 43%, and the fraction in manufacturing more than doubled from 12 to 27%. The country's demographic transition led to such rapid growth of the entire workforce that the number of farmers kept rising throughout this period, growing from 4.6 to a peak of 5.3 million farmers, before the absolute number of farmers began its sustained decline since 1976. The share of workers in manufacturing peaked at 36% in 1991, and by 2010 the country's workforce was 67% in services, 26% in manufacturing and 7% in agriculture.

Economic Growth and Transformation in Sources of GDP

To compare development trajectories for the world it is helpful to use aggregate data for major geographic regions. The primary source of such data is the World Bank, which lends to governments in low- and middle-income countries and tracks a wide range of economic development indicators. Countries differ in whether and how they collect each type of data, but the most basic national accounting of GDP is available for almost all populations and is shown for selected global regions in Fig. 10.7.

The national income data underlying Fig. 10.7 were collected in each country's local currency, then converted to U.S. dollars at market exchange rates in each year and adjusted for inflation in the United States to show values in 2015 dollars. This provides the longest time frame over which consistent data are available for all low- and middle-income countries, revealing the main stylized facts of their economic growth and development since 1960.

The top line shows GDP per person for the world, rising steadily except for brief global downturns in 1974–1975, 1981–1982, 2008–2009 and then 2020. These synchronized downturns reflect the many linkages between countries through international markets and other conditions such as the global

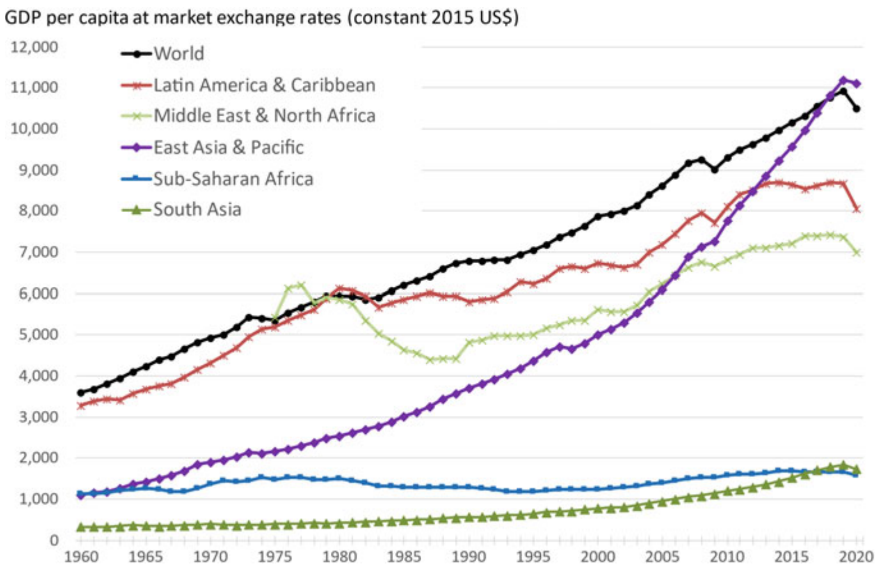

Fig. 10.7 Economic growth in selected regions and worldwide, 1960–2020 *Source*: Authors' chart of data from the World Bank, World Development Indicators. Updated values of these and related indicators are available from https://databank.worldbank.org/MacroDataBySector-AgTransformation/id/eb58207

COVID pandemic in 2020. Latin America and the Caribbean was close to the global average through 1980 but experienced three years of decline then no growth until expansion resumed from the early 1990s to 2014 when growth again stopped, ahead of the 2020 recession. The Middle East and North Africa experienced an even greater decline in the 1980s but resumed growth after 1990.

The three regions with low incomes in 1960 experienced very different trajectories. East Asia and the Pacific and Sub-Saharan Africa had similar incomes at first, but Africa grew only slowly through the 1960s and 1970s and experienced a lengthy period of decline from 1980 to the mid-1990s, before experiencing growth from 1999 to around 2015. In contrast, East Asia and the Pacific converged to surpass the world average income.

To measure a population's experience of economic development it is helpful to recognize that their income is used to buy goods and services locally, and international comparisons at market exchange rates may not reflect the quantity of things they can buy within their own country. For that kind of comparison, we would need prices for the same things in multiple countries, averaged over all items to construct purchasing power parity (PPP) exchange rates that account for differences in the price level between countries, just like a country's own consumer price index (CPI) accounts for changes over time. These PPP exchange rates were introduced in Chapter 7 to compute global poverty rates in Figs. 7.6 and 7.7, and are used here to compare national income in Fig. 10.8.

The PPP conversion factors that account for the difference between Figs. 10.7 and 10.8 are available only since 1990 and are shown here on the same axes for ease of comparison. Using local prices to compare real incomes reveals how populations in the Middle East and North Africa as well as Latin America and the Caribbean had purchasing power in their countries that are above the global average, instead of below it as suggested when using market exchange rates, but trends for them and for East Asia and the Pacific are unaffected by the difference.

Where currency conversions make a bigger difference to understanding economic growth is when comparing Sub-Saharan Africa and South Asia. Local prices for similar things turn out to be much higher in Africa, so a dollar at market exchange rates can buy larger quantities of goods and services in South Asia than in Africa. Comparing countries in terms of purchasing power reveals that total real income of South Asians caught up to that of Africans in 2005 and has since grown to average incomes per person that are about one-third higher in South Asia than in Africa, at $6000 in contrast to $4000 per person in 2017 U.S. dollars.

Structural transformation from agriculture to manufacturing and services is more difficult to measure than total GDP, but the World Bank's compilation of national accounts shows the share of value added produced in agriculture in Fig. 10.9.

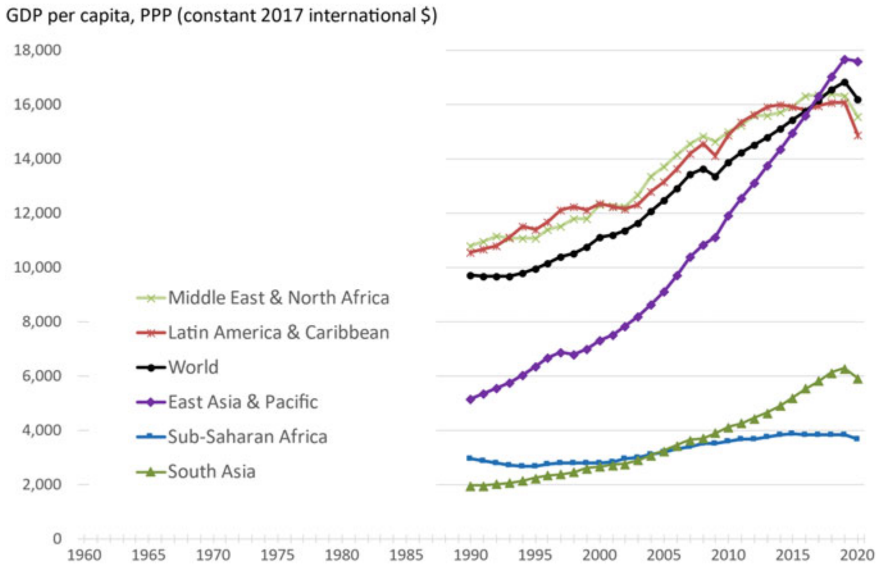

Fig. 10.8 Economic growth by region at purchasing power parity prices, 1990–2020
Source: Authors' chart of data from the World Bank, World Development Indicators. Updated values of these and related indicators are available from https://databank.worldbank.org/MacroDataBySector-AgTransformation/id/eb58207

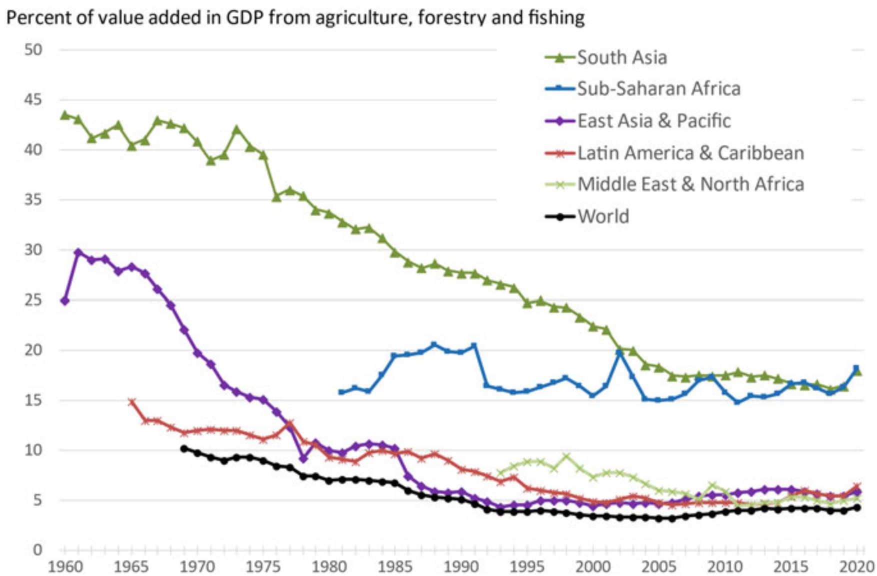

Fig. 10.9 Structural transformation in sources of income by region, 1960–2020
Source: Authors' chart of data from the World Bank, World Development Indicators. Updated values of these and related indicators are available from https://databank.worldbank.org/MacroDataBySector-AgTransformation/id/eb58207

These charts show structural transformation of the economy in terms of income sources before we turn to changes in employment. The data in Fig. 10.9 reveal how South Asia had been much more dependent on agriculture for its income than Africa or other regions, consistent with its lower level of resources and income per person but was able to increase its share of earnings from other sectors. In contrast Africa had much more mineral wealth, including oil and gas, so its share of earnings from agriculture was lower and has changed little since 1980, while the other regions converged to around 5% of GDP from agriculture.

The earlier comparison of structural transformation the U.S. and South Korea was in employment terms, and it is useful here to consider how Korean agriculture changed as a share of GDP, compared to several other countries in Asia and Sub-Saharan Africa using Fig. 10.10.

The trajectories shown in Fig. 10.10 reveal how individual countries can experience sustained reversals in their structural transformation out of agriculture, but also remarkably fast transition once they begin to accumulate the physical capital and human resources needed to expand nonfarm activity. Starting from the top left we see that the population of Bangladesh was dependent on agriculture for more than 50% of total national income through the 1960s to its independence from Pakistan in 1971. A series of crises led to a massive famine in 1974, after which policy reforms drove the sustained transition to only 12% of GDP from agriculture in 2020. Bangladesh's transformation after 1975 is similar and parallel to that of China, South Korea.

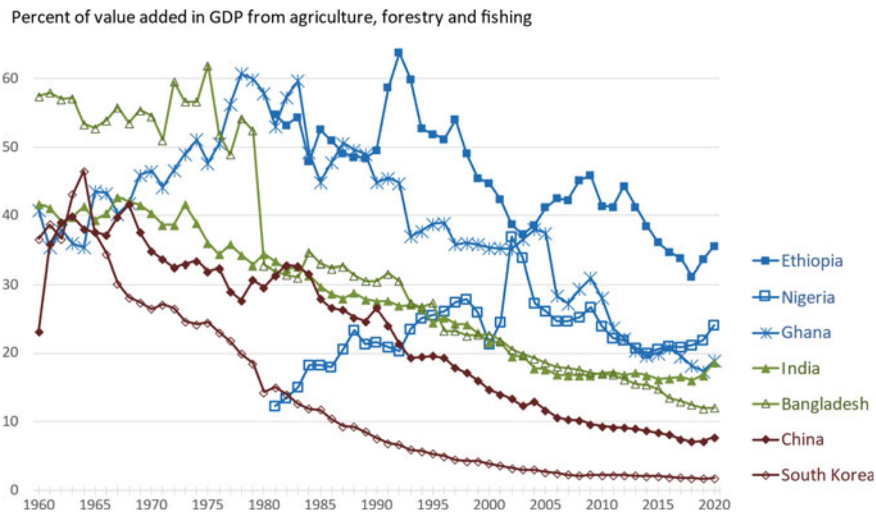

Fig. 10.10 Structural transformation in sources of income for selected countries, 1960–2020 *Source*: Authors' chart of data from the World Bank, World Development Indicators. Updated values of these and related indicators are available from https://databank.worldbank.org/MacroDataBySector-AgTransformation/id/eb58207

India also followed a similar path up to 2005 when further transformation stalled, and India also had a significant reversal back towards agriculture in 2019 and 2020.

Ghana, Nigeria and Ethiopia all had periods of reversed or paused structural transformation, in addition to the high variability in their agricultural shares of GDP due to both climatic variation and political instability in the decades since 1960. Starting at the left of the chart, Ghana was the first African nation to win independence from colonial rule, gaining control of its own government in 1957. From the 1960s to the early 1980s agriculture's share of Ghanaian income rose from around 40 to 60%, until a series of political and economic crises led to a change of direction in 1983 that brought rapid transition to below 20% in 2020. The data for Nigeria start in 1981, after which it also experienced a long period of reverse transformation until 2002. From 1981 to 2002, agriculture's share of Nigeria's national income rose from 12% to a peak of 37%, before falling back to around 20% in the 2010s. Ethiopian data on income shares begin with its period of famine in 1983–1985 and continued crisis until a new government took power in 1991, a year of peak reliance on agriculture at over 60% of GDP. Policy changes then put structural transformation in motion, driving down agriculture's share of GDP at about the same average rate as Ghana, to a low of just over 30% in 2018.

The structural transformation of income shares out of agriculture is closely related to growth of the economy, with some notable variation as shown in Fig. 10.11.

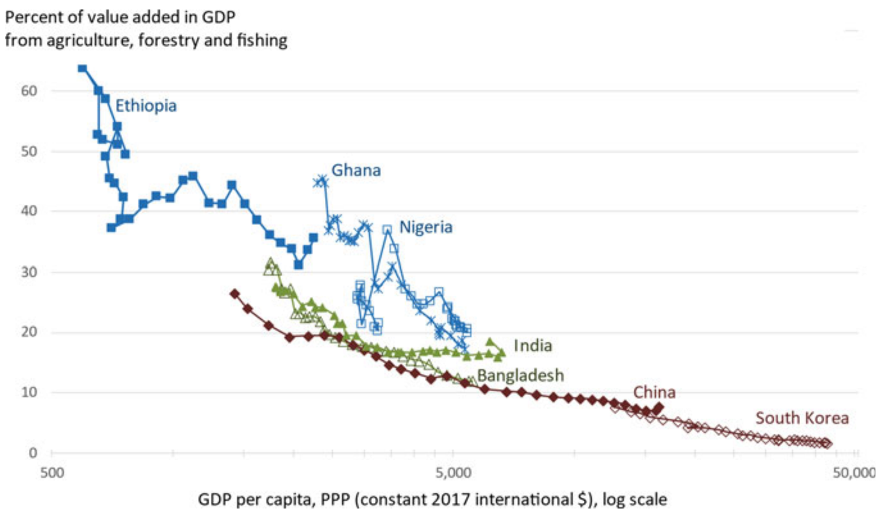

Fig. 10.11 Selected trajectories of growth and structural transformation, 1990–2020
Source: Authors' chart of data from the World Bank, World Development Indicators. Updated values of these and related indicators are available from https://databank.worldbank.org/MacroDataBySector-AgTransformation/id/eb58207

The vertical axis of Fig. 10.11 shows the same data as the previous chart, but instead of time along the horizontal axis we show GDP per person at purchasing power parity prices, in US dollars of 2017. The very wide range of incomes and the exponential nature of economic growth leads us to show that variable on a logarithmic scale, as we did for Fig. 7.9 showing inequality across countries in Chapter 7 on poverty and inequity.

Scatterplots with income on the horizontal axis are used for many aspects of economic development, and with the small number of countries in Fig. 10.11 we can connect the dots to show country trajectories over time as in Fig. 10.10. The trajectories reveal occasional reversals as in Ethiopia and Nigeria, and the distance between years reveals the speed of growth and transition, shown for example as the slowdown in China and South Korea's progression towards the bottom right of the chart. Comparing countries in a chart like Fig. 10.11 reveals both similarities and differences in paths of growth and transformation. As countries experience growth, they typically expand nonfarm activities faster than agricultural output at about the same rate, moving in parallel to lower share of income from agriculture as national income grows to the right.

One difference in development paths shown in Fig. 10.11 is that the African countries have notably higher agricultural shares of GDP at each income level than the Asian countries. That greater reliance on agriculture in Africa than in Asia could reflect Africa's relative abundance of agricultural land, with lower population densities and other factors that raise the relative cost and reduces the quantity of manufacturing and services at each level of income. Even so, to the extent that African countries have overcome these barriers to expand their economies, they have shifted resources into other sectors at about the same rate as other countries.

The seven countries shown on Fig. 10.11 are extremely different from each other in physical geography as well as social, cultural and political structures, and yet their growth follows a parallel path towards more non-agricultural activity. What forces drive investment and activity to expand other activities faster than agriculture expands?

Explaining Change in the Sources of Income: Inelastic Demand and a Fixed Land Area

Structural transformation of income sources away from agriculture when societies become wealthier could be caused by multiple factors, each operating differently at each place and time. The shifts revealed by agriculture's share of income shown in our charts occur gradually and are visible only when economic statistics are collected and compared, revealing deep commonalities in the underlying structure of agriculture and the food system.

One factor that contributes to structural shifts away from agriculture is Engel's Law, as consumer preferences lead to a low-income elasticity of demand. Engel's Law says that at higher incomes, demand for non-food items grows faster than demand for food. Among foods, Bennett's Law tells us that demand shifts to more expensive sources of dietary energy, including animal source foods and other products with high value added on the farm. That can help increase farm value added as national income rises, but much of the increased spending involves work after harvest that is not counted in the agricultural sector.

Another factor that contributes to structural shifts is low price elasticity of demand. Total dietary intake of all foods is almost completely inelastic with respect to both price and income when measured in energy terms. When food prices fall or rise there is substitution among foods towards more or less expensive sources of dietary energy, and changes in the nonfood use or loss and waste of farm products, but total calories consumed is driven by metabolic needs and other factors with little effect of price or income. Quantity in terms of weight or volume can grow as people buy more beverages and fresh foods with more water weight, but even non-caloric beverages have price-inelastic demand at quantities determined by preferences, convenience and aspirations.

Consumers' inelasticity of demand with respect to price could potentially imply that, when farmers adopt innovations and invest in increased production, the resulting outward shift in supply leads to more price reduction than quantity increase. That relationship holds for the entire aggregate supply and demand of all food in the world as a whole, and holds for the entire supply of foods that are too perishable and bulky to be traded internationally. In those markets, increased supply causes price to fall, so consumers can shift their spending to other things. But when foods are traded internationally, prices received by farmers are determined by the whole world's supply and demand, and by their own transport costs to and from their trading partners.

For foods that are traded with a large rest of the world, production at each place is determined by supply conditions, even if local consumers have inelastic demand. That separability of production from consumption makes Engel's Law relevant to structural transformation only for bulky, perishable products or for all products in the world as a whole. For products that can be stored and traded, a country that produces only a small fraction of the whole world's consumption can expand its production with very little impact on prices. In that case production is not limited by demand, but by the country's underlying land and resource constraints.

Explanations for structural transformation based on price effects are often known as Cochrane's technology treadmill. In the 1950s, an agricultural economist named Willard Cochrane noted how use of output-increasing innovations might be profitable only for the early adopters, whose increase in quantity sold drove price reductions that forced other producers to adopt the same technology but only for cost reduction. For example, a new seed that raises yield per acre would be used by early adopters on unchanged or even expanded area in ways that increase their farm income, but as that technology spreads to other farmers the price received by all growers of that product would fall, reducing their income unless they also adopt the new seed or cut back on resources used in farming.

Cochrane used the term 'treadmill' as part of an argument on behalf of farmers that government policies should restrict supply or at least slow its expansion to keep prices high. His book popularizing the treadmill idea appeared in 1958, at a time of rapid economic growth and unprecedented decline in the number of U.S. farmers shown in Fig. 10.5. Farm exits are painful, as the families that experienced the most financial hardship are often those most likely to stop farming. Cochrane argued that the declining number of farmers was due to insufficiently high prices for farm output, but subsequent evidence shows that prices mostly affect the value of farmland and have little influence on the number of farmers. Change in the number of farmers is mostly driven by changes in total rural population relative to the number of attractive new nonfarm jobs.

Experience with structural transformation since the 1960s shows that Cochrane's view of farmers on a treadmill, running to adopt new techniques just so they could stay in business, could more helpfully be reframed as Cochrane's flywheel. A flywheel is a mechanism which, once put in motion, sustains and distributes that energy to other parts of an interconnected system. In the U.S. and internationally, evidence since Cochrane's book shows how public and private investment in agricultural innovation accelerates the circular flow of economic activity, helping farmers make the most of limited farmland and driving growth in nonfarm activity. Places with lower farm production growth keep more farmers on the land only to the extent that they create fewer nonfarm jobs, and their lower farm productivity also raises the total land area and other resources used for food.

Cochrane's treadmill—reframed as a flywheel—explains how the spread of cost-reducing, output-enhancing innovations in agriculture helps drive economic development and environmental sustainability. For internationally traded products, higher productivity raises national income through net exports, and for nontraded goods higher productivity raises income through lower prices and less need to use natural resources and other inputs in farm production.

The decline in the number of farmers observed by Willard Cochrane in the 1950s turned out to be halfway through the eighty-year U.S. transition shown in Fig. 10.5. In the U.S. after the 1910s, as in South Korea after 1976, the declining number of farmers allows those who remain to adopt larger, faster machines and equipment with which to plant and harvest more area, including land rented or sold to them by neighbors who left farming. Mechanization generally does not increase total output, because its principal function is to cover more area in each day of work. Output of the farm sector depends mainly on yield increases and intensification of input use per acre. In the U.S. most crop yields had little increase until the 1940s, when new seeds raised returns to more intensive crop management that triggered an upward trend that continues into the 2020s. In contrast South Korea had experienced yield increases much earlier in time, including through labor-intensive investments in irrigated rice production.

In summary, the changing number of farmers is mostly caused by demographic factors and changes in the nonfarm sector. Mechanization to cover more land with less labor is often a response to that, while intensification to raise yields is driven by public and private investment in innovative ways to do more with less. The flywheel of economic growth can be accelerated and sustained by innovation and investments in new techniques anywhere in the circular flow of goods and services. In low-income settings, innovation in agriculture is especially important for economywide growth and sustainability because of its large size at the start of structural transformation, and its large environmental footprint that can be reduced by more efficient use of land and other natural resources. Agricultural productivity also matters greatly for equity and inclusion, because lowering the real cost of food allows low-income people to buy other things instead, and because farmers in low-income countries have incomes below their national average. All of these factors drive structural transformation and interact with the demographic transition to cause each year's change in the total number of farmers.

The Farm–Nonfarm Employment Transition: Why the Number of Farmers Rises and Then Falls

The number of farmers in each country is the country's workforce, minus those with solely nonfarm employment. Similarly, each year's change in the number of farmers is the change in the country's total workforce, minus the change in the number with nonfarm employment. Those facts by themselves are accounting definitions with no predictive power, but in low- and middle-income countries there are many young people entering the workforce each year, and few nonfarm job openings. Those nonfarm jobs typically offer higher incomes than a life of farming, but many young people who seek a nonfarm jobs cannot get one and become farmers out of necessity.

The gap in earnings and living standards between farmers and otherwise similar nonfarmers is largest in the lowest income countries. Farm incomes can catch up to nonfarm earnings but typically remain below the national average in most countries of the world. In the U.S., average farm incomes were less than half of average nonfarm incomes in the 1930s, then caught up and have exceeded nonfarm incomes since the mid-1990s. Convergence was possible in part because enough farmers left agriculture each year from the 1940s through the 1980s that the remaining farmers could often rent or buy land to expand their own operations. Those remaining farmers could both mechanize to cover the larger area per farm, and use more inputs to increase revenue per acre, thereby raising their income and wealth very quickly from year to year. By the late 1990s, most U.S. farmers had incomes above the national median and the pace of exits slowed to almost zero, as shown in the right panel of Fig. 10.5.

Countries often have a wide distribution of farm sizes and farmer incomes. Even in a country where most farmers have very low-incomes, some might control a lot of land or livestock and consequently have high-incomes. Survey data usually confirms that some farmers have incomes above many non-farmers, but that is complicated by the fact that the few higher-income farmers also often have non-farm income. The total income available per farmer in contrast to workers in other sectors is more easily seen with national income data, as shown in Fig. 10.12.

The data in Fig. 10.12 are the same shares of national income as Fig. 10.8 in the four lower lines, contrasted with the four upper lines for each region's estimated share of the workforce who are farmers. The shares of income are in terms of value added, which is defined in Chapter 9 with a numerical example in Table 9.2. Income from value added includes not just compensation for labor, but also the value of land and water or other natural resources used in farming, as well as the value of all buildings, equipment and livestock on the farm. Differentiating between a farmer's labor earnings and the returns to their land and other assets is often impossible because the farm family's efforts are embodied in the farm itself. The value added shares shown here are the best available estimate for each region or country as a whole.

To see how value added is distributed in the population we would need household surveys, but those are scarce and have limited coverage. Most countries rarely if ever conduct a complete census of agricultural enterprises, and they only occasionally conduct nationally representative household surveys. Household surveys are designed to represent the population in general, so they may miss important categories of farms, livestock operations and fisheries. The limited available data on farm operations globally is introduced in

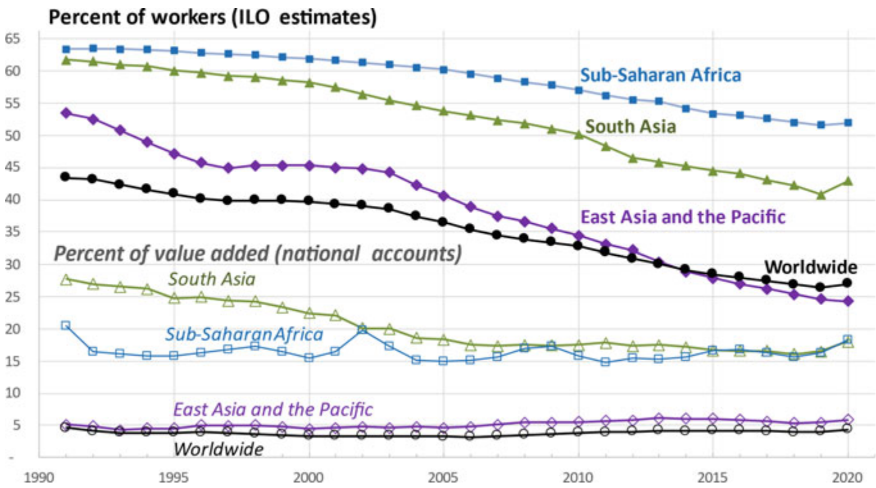

Fig. 10.12 Agriculture's share of employment and earnings in selected regions, 1991–2020 *Source*: Authors' visualization of data from the World Bank, World Development Indicators. Updated values of these and related indicators are available from https://databank.worldbank.org/MacroDataBySector-AgTransformation/id/eb58207

the next chapter. Historical data on farming as a share of the workforce is also scarce, which is why the data on employment changes shown earlier are just for the U.S. in Fig. 10.5 and for South Korea in Fig. 10.6. The estimates shown in Fig. 10.12 are produced by the International Labor Organization (ILO) of the United Nations by combining occasional surveys of principal occupation from 189 different countries, matched to the UN population projections by age and sex reported in Fig. 10.4 and Table 10.2, and then smoothed to infer values for missing countries and years.

The top line shows that Sub-Saharan Africa's workforce in the early 1990s was around 63% farmers, declining gradually to around 52% in 2019, rising slightly due to the loss of nonfarm jobs during COVID in 2020. The lower line shows that together those workers earned around 20% of total available income in 1990, which declined to just above 15% of all income in most years since then. South Asia and East Asia had somewhat faster shifts of the labor force out of agriculture, but in all cases including the world as a whole, farmers' share of income is much smaller than their share of employment, implying a much smaller pool of income per worker in agriculture than in services or manufacturing.

In Africa during the 1990s, having over 60% of workers who are farmers earn under 20% of total available income implies that average farm income was less than one-third of the national average. The value added produced per farmer in Africa was less than one-sixth that of non-farm workers. This enormous gap shrunk only slowly, so that by 2020 the 52% of workers earning 18% of income in 2020 had average farm incomes that were 35% of the national average, and one-fifth the value added produced per nonfarm worker. Like any average, these regional totals hide all the variation between and within countries, but they do mean that in any place where some farmers have above-average incomes, typically from controlling above-average land area, the remaining farmers must have even less than the national average earnings from agriculture.

The gap between farm and nonfarm incomes shown in Fig. 10.12, which is largest for Africa but also big in Asia and worldwide, implies that many people who are farmers would prefer to have a nonfarm job. Indeed, there is a continuous flow of people moving between farm and nonfarm employment, often within rural areas and small towns as well as migration to cities. Much of the flow from farm to nonfarm work is part-time activity or seasonal employment and circular migration, by which members of farm families try to gain nonfarm income while still living on and maintaining the family farm. Migration is also often exploratory, in which young people leave the farm to seek a nonfarm job and may return to the family farm out of necessity if they do not succeed. Migration routes of that type can be internal or international, linking a low-income farming community to far away destinations, as each wave of migrants help the next wave make the move if they can.

The flow of migrants from farm to nonfarm work takes many different forms in different places. In some countries, especially in Asia, rural households doing agricultural work may not actually own the land they farm. When the rural poor are landless in that sense, they may be tenant farmers who rent fields from a landlord, for either fixed price per year or a share of the output. Sharecropping and cash rents are used throughout the world, even by operators of large farms in the U.S. who rent parcels of land from neighbors. When tenants or even owners of small plots have low wealth, however, a series of bad years can push them into bankruptcy and drive them out of farming entirely, at which point they may go into nonfarm employment as low-wage workers. In other settings, including much of Africa, access to land is more egalitarian. In African history, many farm communities could simply expand into nearby areas formerly used for grazing and forests, and newly formed households would be granted land to start their own farms. That kind of area expansion has now ended in much of Africa, and in some countries, there are wealthy landowners attempting to control very large areas, thereby forcing other farmers onto smaller plots or out of agriculture as low-wage workers. Even so, the children of farmers who go into nonfarm work are often not the poorest. Migration itself can be costly, so those who migrate are those who can afford to search for a nonfarm job, and higher-wage positions often require formal education that the lowest-income youth may not have.

Rural education is an important aspect of economic transformation and agricultural development not only because it facilitates migration to higher earnings, but also because it facilitates innovation and adoption of new methods within agriculture, as well as growth of rural nonfarm activities that complement farming. Countries can often reach nearly universal literacy, numeracy and completion of primary education even at quite low incomes, but universal secondary schooling is much more difficult especially for farm families whose children at those ages are often needed on the farm. The growth of higher education and higher preschool enrollments is also important for agriculture and the food system and is increasingly widespread at higher levels of national income when more people have completed secondary school, and more people work outside the home.

The various kinds of farm to nonfarm migration make it difficult to quantify the magnitude movement in terms of labor hours or individual workers. For international comparisons, the best available measure is comparing the entire population living in areas of each country that are classified as either rural or urban. These classifications differ by country, so areas with a similar density of population might be classified as rural in one place and urban in another. Towns and cities also expand geographically, so a given home might be classified as rural for decades until it is reclassified as urban.

The rural–urban distinction corresponds only roughly to employment and earnings. Some people living in rural areas have no agricultural earnings at all, and those who are farming typically also earn income from nonfarm sources, including remittances from migration. Surveys of urban households also reveal significant levels of farming activity, sometimes on small plots within the urban area, and sometimes from land held elsewhere. Production and earnings from urban agriculture is visible and important, but small in magnitude relative to farming activity on the vast expanse of rural land. Within those rural areas, nonfarm activity is a necessary complement to agriculture for almost all farm families. Counting rural and urban people is not the same as the farm–nonfarm distinction, but for global monitoring it is the only kind of data available. The rural–urban distinction is also useful beyond just agriculture: each country's rural population provides a rough upper bound on the number of people using large areas of land for their lives and livelihoods, while urban people have a smaller geographic footprint per person.

Tracking the interaction between urbanization and population size can be done using the same demographic data that underlies population pyramids and projections based on life tables, adding data on the probability of migration at each age. Historical data and projections for the world as a whole are computed by the United Nations Population Division, as shown in Fig. 10.13.

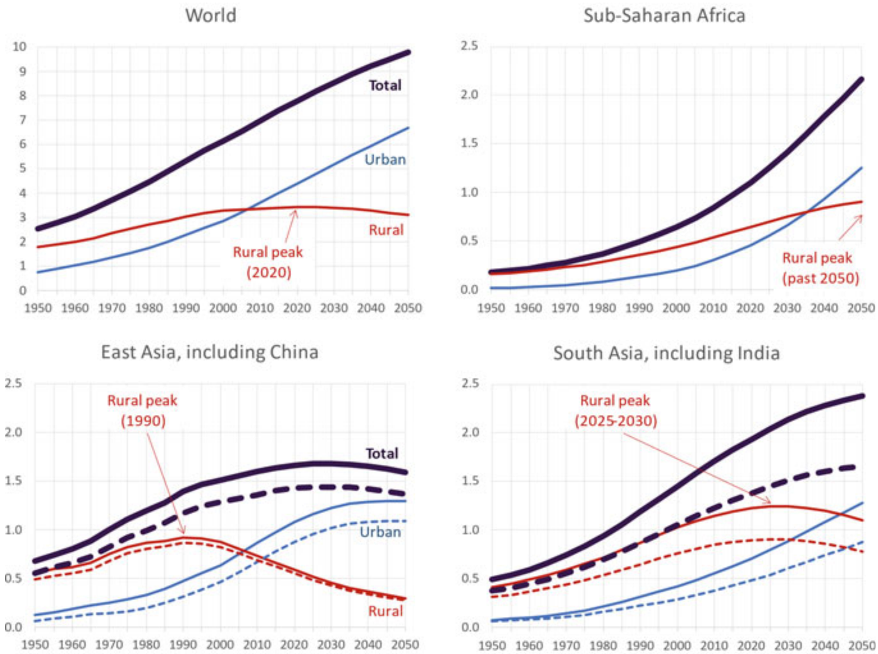

Fig. 10.13 Rural and urban population in selected regions and countries, 1950–2050 *Source*: Authors' chart of data from the United Nations, Department of Economic and Social Affairs, Population Division [2018]. *World Urbanization Prospects: The 2018 Revision*. Data shown are at five year intervals. Updated estimates will be available at https://population.un.org/wup/DataQuery

The top left panel of Fig. 10.13 shows the same world total as the population pyramids in Fig. 10.4, growing through the 1950s and 1960s at an accelerating annual rate that peaked in the 1970s then slowed. By these counts the world as a whole reached 50% urban around 2008 and is projected to reach 68% urban by 2050. Despite towns and cities growing much faster than population, urbanization was not fast enough to absorb all rural population growth until around 2020. The 2020s are in the middle of a long period of roughly constant rural population in the world total, so all the world as whole's population growth is in towns and cities.

The top right panel shows a similar dynamic at work in Africa, but with very different timing. Africa entered the 1950s with only 11% of its population classified as urban. Africa's urban population grew at around 5% per year in the 1950s, more than twice as fast as its total population growth of around 2%, but the urban share was so small that Africa's rural population grew at around 1.7%, almost as fast as its total population. Africa's total population growth rate then accelerated into the demographic transition, peaking at 2.8% in the 1980s, by which point about 25% of the population was urban. African cities were expanding at among the world's fastest rates, growing at around 4.8%, but they were still too small to absorb all of the continent's population growth so Africa's rural population expanded at over 2% per year. Africa is projected to reach 50% urban in the 2030s, and not reach its peak rural population until well past the 2050s.

Africa's low level of initial urbanization and the delayed start to its demographic transition have deep historical origins and powerful, long-lasting effects through the coming decades. Focusing just on the 2020s, Africa's urban areas are growing at twice the global average, and faster than cities in any other major world region. But Africa's rural areas are still growing at around 1.5% per year, while the rest of the world's rural population is already shrinking. That rural population growth rate means that a village of 1000 people must accommodate an average of 15 more people, for example because of 20 more births than deaths, and net out-migration of only 5 people. Their neighboring villages are also growing, and the total available land, water and other natural resources remains fixed or is worsening due to climate change, deforestation and water depletion.

Within Africa's rural areas, nonfarm activities can grow rapidly, perhaps even grow at some of the world's fastest rates like African cities do. But even so, the area of land and other natural resources available for each rural family across Africa is shrinking by about 1.5% per year in the 2020s. Productivity per acre or hectare must rise by at least 1.5% per year just to keep up.

In contrast to Africa's experience, East Asia's rural population (in the solid line of the bottom left) China peaked around 1990, and South Asia's rural population (in the solid line at the bottom right) is projected to peak in the late 2020s. The population of those regions is dominated by China and India, shown in the dashed lines. Throughout this period Africa's cities have grown faster than China's cities, and much faster than India's cities, but

Africa's total population growth is faster, and its initial urbanization is lower. In other words, despite Africa's world-record speed of urbanization, Africa's rural population will continue to grow for many decades, shrinking the land available per rural household, even as the rest of the world moves into an era of falling rural populations and increasing area per rural household.

10.1.3 Conclusion

This section on how agriculture changes during economic growth builds on our introduction to macroeconomics in the previous chapter, showing how all parts of a country are interconnected. Once we see economic activity as a circular flow of goods and services within the country, with international trade and capital flows to and from other countries, we can see how the linkages between agriculture and other sectors influence the evolution of agriculture over time and differences across countries.

One central finding concerns the role of innovation and investment in new ways of doing more with less, within agriculture and in other sectors. Economic growth can be sparked by innovation and investment in any sector, but in low-income countries the agricultural sector is especially important because it is large, employs relatively low-income people, and uses a disproportionate share of land and other natural resources.

A second core finding concerns the farm-to-nonfarm transition, and the demographic factors that drive an increase in the number of rural people and hence the number of farm families, shrinking the land available per rural household, for many decades until cities and the nonfarm sector are large enough to absorb all the region's rural population growth. All kinds of innovation are helpful, but during the period of rising rural populations, agricultural intensification for higher yields is the priority due to falling land area per worker, whereas after the rural population begins to fall yield improvement is less urgent for rural incomes, and the remaining farmers can take over their neighbors' land and mechanization becomes a higher priority.

The chapter began with Table 10.1 listing a set of four major transitions associated with economic growth. This first section addressed the demographic and structural changes affecting farm production, and the following section turns to transitions in the food system and nutrition.

10.2 Food Systems and Dietary Transition: From Inadequacy to Excess and Health

10.2.1 Motivation and Guiding Questions

What people eat is changing fast. This section continues our exploration of global and U.S. data by focusing on food system transformation and the nutrition transition, as summarized at the start of the chapter in Table 10.1. How are dietary patterns changing, and how do these choices relate to nutritional status and health?

The *food system* refers to all activities involved in the production, processing, packaging, transportation, storage, and marketing of food to end-users. In this section we focus on systemic changes in diet composition, and the following chapters return to the supply of food regarding international trade and policy in Chapter 11, and the institutional arrangements around agriculture and value chains in Chapter 12.

The *food system transformation* associated with economic growth involves a changing mix of foods produced by increasingly specialized suppliers who make more intensive use of physical capital and human resources. Innovation and investment allow producers to do more with less, giving each consumer access to more diverse foods from a wider variety of sources. Higher incomes allow consumers to acquire more expensive foods, but each item's nutritional impact on our future health is often unknown and sometimes misunderstood, making food one of the few expenditure categories for which increased spending can actually worsen health outcomes.

Changes in the health-related attributes of dietary patterns are known as the *nutrition transition*. With increased spending some aspects of dietary intake become more health promoting over time, reaching towards nutritional adequacy of attributes that are known to be desirable, while other aspects of newly consumed foods turn out to be harmful. Those harms may eventually be discovered and addressed, potentially leading consumers to converge on balanced diets that achieve adequacy without excess.

By the end of this section, you will be able to:

1. Use the available data on global consumption by food group to describe how income elasticities and other changes have altered the mix of foods consumed worldwide;
2. Use the available data on packaged foods and meals away from home to describe the dietary transition in how farm products are transformed for final consumption;
3. Describe how health researchers use anthropometric, biological, clinical and dietary data to measure nutritional status; and
4. Describe the nutritional and epidemiological transitions in risk factors associated with disease and premature mortality around the world.

10.2.2 Analytical Tools

Changes in global food systems, dietary intake and nutritional status pose enormous challenges for human health. New ingredients and new ways of producing and processing foods are introduced and consumed on a massive scale, altering nutrition in ways that may go unnoticed or misunderstood for years. Impacts on health are often cumulative and depend on interaction with other aspects of dietary intake, so they appear slowly over time in any individual and vary widely across a population.

In this section we describe how the world's dietary and nutrition transitions are measured and understood in the health sciences. The most widely used metrics reflect a scientific consensus about the attributes of a benchmark diet that would minimize disease risk over time. Actual diets differ from that benchmark, sometimes because people can afford only the least expensive sources of dietary energy that lack the nutritional attributes needed for health, and because food choice is driven by many other goals in addition to health.

As economic growth proceeds, food choices trace out each population's income elasticities of demand introduced in Section 3.2, including the patterns described there as Engel's law and Bennett's law. With higher incomes, people are able to buy a wider range of foods. Dietary diversification often helps reduce or eliminate deficiencies of individual nutrients, but also often involves excess intake of some foods and ingredients. Preventing those excesses takes time, so observed changes often transition from inadequacy to excess and only later to just-right nutrition. The nutrition transition involves food system changes in both the mix of farm or fish products produced in agriculture, and the post-harvest transformation of those products into food items and meals for consumption. Some nutritional attributes of foods needed for health are intrinsic to the agricultural product, and classified into nutritional food groups that may differ from other classification schemes. For example, the 'vegetable' food group includes tomatoes which are botanically fruits and excludes white potatoes because white potatoes are a starchy staple. Other nutritional attributes depend on how the item is processed and used in meal preparation, for example by removing the germ from whole grains to make refined flour or adding other ingredients such as salt or sugar. To describe the nutrition transition, we begin with change in agricultural supply and consumption by food group, and then turn to postharvest transformation of those foods.

Dietary Transition in Consumption by Food Group

Nutrition researchers have proposed many different food classification schemes, often associated with diet quality metrics. For example, the U.S. Healthy Eating Index (HEI) measures how closely an observed diet adheres to the Dietary Guidelines for Americans. The most recent HEI scoring system published in 2023 rates diet quality in terms of 13 nutritional attributes per thousand calories of dietary energy. Some of those attributes reflect an entire food group, such as total quantity of all fruits, all vegetables, or any dairy product, but most are individual nutrients like total sodium, or an aspect of processing like whole versus refined grains. The 13 attributes scored in the HEI are the U.S. government's official definition of a healthy diet, developed jointly by the USDA and the Department of Health and Human Services.

For international comparisons, in July of 2022 the five UN agencies mandated to monitor food security and nutrition around the world adopted a new approach for measuring food access, using the least expensive locally available items balanced across six food groups. The results of that approach, known as the cost and affordability of healthy diets (CoAHD), were shown at the end of our chapter on poverty and risk in Fig. 7.17. The use of least-cost diets by food group had been piloted in the FAO, IFAD, UNICEF, WFP and WHO annual report on the State of Food Security and Nutrition in the World for 2020, then modified and adopted for annual monitoring in their 2022 report. Monitoring food access in this way is done by FAO jointly with the World Bank, based on healthy diet basket (HDB) targets of total energy from each of six mutually exclusive food groups shown in Table 10.4.

The HDB targets shown in Table 10.4 are designed to reflect commonalities in dietary guidelines adopted by governments around the world. The HDB's purpose is to help UN agencies and national governments monitor global and national food systems for access to a balanced diet. It is not itself a dietary recommendation, in part because actual guidelines also specify attributes related to food processing and meal preparation and may specify slightly different food groups. For example, the U.S. HEI scores designed to capture the Dietary Guidelines for Americans has a specific recommendation for dairy, and a specific recommendation for seafood or plant proteins, in addition to limits on specific kinds of fatty acids that are often present in animal foods. Most other countries accomplish similar goals by combining dairy with meat and eggs, and sometimes grouping that with fish. Since the HDB aims to provide a minimalist lower bound on requirements to meet national guidelines, it combines all the animal source food recommendations into a single category.

HDB targets are designed to measure costs per day for a representative person and are specified in terms of the number of items for diversity within food groups, and the total calories from each food group needed to meet energy requirements with a balanced diet. Dietary guidelines are aimed at communicating with the public, so they choose locally representative foods and recommend quantities in terms of weight, volume or number of servings per day. Diet quality scores like the HEI then convert those to grams, cups or servings per thousand calories, so that the score can scale up or down with the total energy needed by each person given their height, weight and physical activity. The HDB directly targets the calories of food from each group to allow for substitution between items with different water weight, for example to substitute between large tomatoes, small tomatoes, tomato concentrate, and tomato paste and obtain the same quantity of tomato solids, and similarly to substitute between liquid milk, yogurt, soft cheese or hard cheese and obtain the same quantity of milk solids.

As shown in Table 10.4, high-moisture food groups like vegetables and fruits provide a small share of energy but a large and variable share of total weight in the HBD targets. These data focus on calories and weights for use in comparing healthy diet targets to quantities bought and sold. Dietary guidelines often also use areas on a plate for the prepared forms of each

Table 10.4 Healthy diet basket targets used for monitoring food access worldwide

Food group	*Dietary diversity (items)*	*Dietary energy targets (kcal)*	*Energy shares (pct of total) (in %)*	*Weight shares of example foods (as dry products) (in %)*	*Example foods and typical weights*
Starchy staples	2	1160	50	24–28	322 g of dry rice, or other cereals and root crops
Vegetables	3	110	5	23–30	270–400 g of carrots, onions, tomatoes, leafy greens etc.
Fruits	2	160	7	20–22	230–300 g of bananas, apples, oranges etc
Animal source foods	2	300	13	16–18	210 g of egg, or equivalent weight of dairy, meat or fish
Legumes, nuts and seeds	1	300	13	6–7	85 g of dry beans, or other legumes, nuts or seeds
Oils and fats	1	300	13	3	34 g of vegetable oil, or other oil or fat
Total	11	2330	100	100	1151–1351 g

Source: Food Prices for Nutrition project, for the World Bank DataHub on Food Prices for Nutrition (https://worldbank.org/foodpricesfornutrition) and the FAOSTAT domain on Cost and Affordability of Healthy Diets (https://www.fao.org/faostat/en/#data/CAHD). Methods used to obtain these data are detailed in journal articles and background papers by Anna Herforth and others at https://sites.tufts.edu/foodpricesfornutrition

food, typically calling for something like half the plate to be high-moisture, high-fiber fruits and vegetables, while a quarter or more of the plate is high-moisture, high-fiber starchy staples, and a quarter or less of the plate to be high-protein items which are either animal source foods or legumes, nuts and seeds.

Dietary transition in terms of food groups can be tracked relative to HDB targets, revealing whether supply-demand balances in national, regional and global systems are approaching or exceeding the minimal quantities per person that would be needed to support human health. The total quantity of each agricultural product available for consumption is estimated by the FAO using food balance sheets (FBS) for every country in the world, adding up total production plus imports minus exports, nonfood uses and losses along the supply chain to final sale. That estimate of quantity available for consumption is an upper bound on dietary intake because some of it would be kitchen and plate waste or destined for nonfood uses within the home.

Food Balance Sheet quantities per person are national averages, and to track its distribution in the population we would need household consumption and expenditure surveys (HCES) that typically ask about foods consumed over the previous 30 days or an entire year. Then to identify intake by individuals, we would need dietary recall surveys that typically as about foods eaten over the previous 24 hours. HCES are typically done only every five or so years, and 24HR dietary recall surveys are even more expensive and less frequently done. In contrast, FBS estimates of total consumption are available for every country in all years, from 1961 to the present.

Results comparing quantities available for consumption to the HDB targets for each food group, plus a seventh discretionary food group of caloric sweeteners, are in Fig. 10.14.

Figure 10.14 provides a unified picture of global dietary transition in terms of food groups, with the entire world average in dark black, and data for each of the major world regions above and below that global average. Panels for each food group are aligned and scaled so that total supply-demand balances range from zero up to the healthy diet basket target at the same point on each vertical axis. The HDB targets themselves are requirements for a healthy diet, and while the horizontal dashed line for sugar is the World Health Organization guideline that sugar intake be limited to 10% or less of total daily energy.

The pattern of dietary transition over time and between regions reveals how some food groups, especially legumes, nuts and seeds and to a lesser extent fruits, remain far below HDB targets even in high-income regions in recent years, while vegetables reach and surpass HDB targets only in East Asia. From the top left, the only region with below-target levels of starchy staples is North America, which the other panels reveal is due to displacement by high levels of animal source foods, oils and fats, and sugars. The next highest level of animal source foods and oils and fats is Europe and Central Asia, followed by Latin America and the Caribbean which has an even higher level of sugar than Europe and Central Asia.

The fastest changes shown in Fig. 10.14 are in East Asia and the Pacific, where animal source foods rose from lowest in the world in 1961 to just below Latin America and the Caribbean in the 2010s, and vegetables for which East Asia and the Pacific has had a uniquely rapid increase in quantities available for consumption since 1980. The food group with greatest uniformity in trends across regions is oils and fats, which has increased at roughly

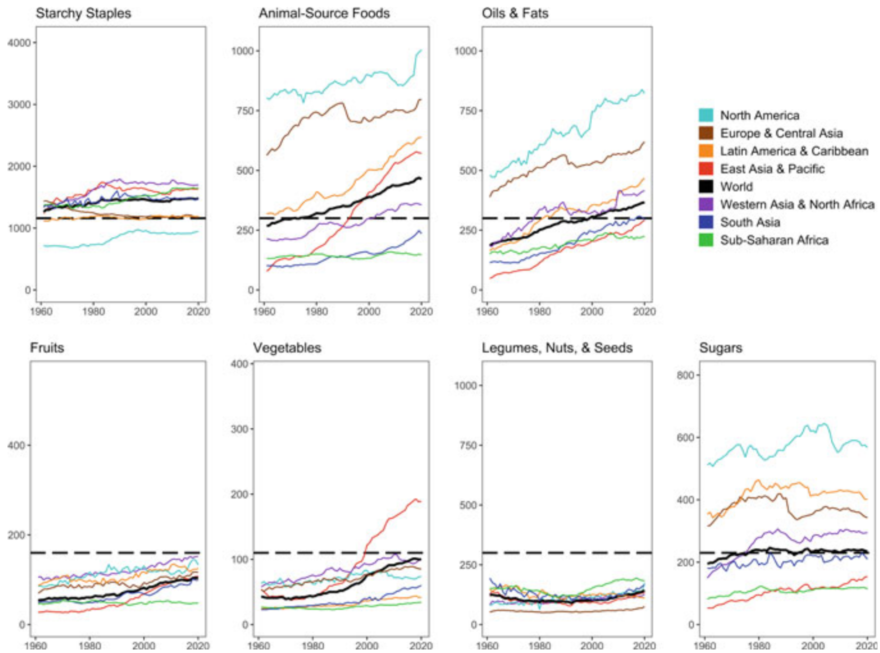

Fig. 10.14 The food system transition by food group in major world regions, 1961–2020 *Source*: Data visualization by Leah Costlow, showing kilocalories per person per day available for food consumption in each region using historical and current estimates from FAO Food Balance Sheets at https://www.fao.org/faostat. Panels are aligned with horizontal guidelines showing energy balance from each food group in the Healthy Diet Basket reference targets used by FAO to measure the cost and affordability of healthy diets, https://www.fao.org/faostat/en/#data/CAHD

similar rates everywhere over the entire period from 1961 to 2020. In contrast, sugar consumption has fallen or stayed constant in most regions, with the only exception being East Asia and the Pacific where it has risen steadily from the world's lowest level below Sub-Saharan Africa to slightly above Africa.

Returning to our description of food system transitions in Table 10.1, the central difference among regions and changes over time involve the very high level of animal source food consumption in North America and in Europe and Central Asia, and the sharp rise in Asia including South Asia that rose from below to well above the total for Sub-Saharan Africa which has barely risen since 1961. The future demand for animal source products is a central concern regarding the environmental footprint of the food system and for animal welfare. For health, having animal source foods as well as oils and fats above the HDB targets is not itself strongly associated with severe harms, unless the specific items consumed have high levels of saturated fats which is associated with cardiovascular disease. Having above-target levels of those food groups is harmful to health mostly by displacing other food groups whose attributes are needed, including especially the potential for future substitution into plant-based high protein foods from the legume, nuts and seeds group that is consistently under-consumed in all regions.

The fact that dietary guidelines and hence the HDB call for quantities of fruits, vegetables and legumes, nuts or seeds that are so consistently above what is actually consumed by most people is a puzzle for economists, because it implies that nutritional standards for health are beyond the range of variation typically observed. In fact, there is significant cross-sectional variation within societies in these food groups, and epidemiological evidence suggests that those who consume those higher levels do in fact have lower disease risk and greater longevity. Part of that could be a displacement effect from consuming less of the other foods that might be harmful, especially foods that are processed or prepared with high levels of salt, added sugar and other ingredients beyond the basic agricultural products shown in food balance sheets.

Some aspects of global dietary transition involve shifts among products within each food group, which is shown in Fig. 10.15.

Seeing global dietary transformation by food group in Fig. 10.15 yields an unusually clear picture of changing supply-demand balances for each type of agricultural product. Starting at the top left of, a first observation is the dominance of wheat and rice in total starchy staples consumption and reaching peak levels and then stabilizing since the 1990s. All other food groups are more diverse. Three agricultural products account for more than half of animal source foods (pig meat, poultry meat, and milk), and four account for more than half of all fruits (bananas, oranges, apples and coconuts).

Among the animal source foods, it is notable that bovine meat plays a modest and almost unchanged role in total dietary energy supply since 1961. Almost all the global increase in animal source food consumption consists of pig and poultry meat, plus dairy. Those three foods come from predominantly grain-fed animals often raised in confinement, and the genetic potential for rapid growth of pigs and poultry, and large volumes of milk per day from dairy cows, has been transformed by selective breeding. A visitor from 1961 would be astonished to see how pigs, poultry and dairy are produced in 2020, whereas beef production methods has changed much less.

The expansion of bananas among fruits, tomatoes and onions among vegetables, and groundnuts among legumes, nuts and seeds each derives from different aspects of agricultural and food system transformation. Bananas are unusual due to their genetic uniformity, as about half of global consumption and almost all the expansion since 1961 consists of the Cavendish variety, widely adopted to replace the Gros Michel and other varieties that were more vulnerable to fungal disease. The evolution and spread of new diseases inevitably threaten each production system, and the Cavendish may soon need to be replaced with other banana varieties or different fruits.

Almost all the growth in global consumption comes from species that were widely used in global diets prior to 1960. The exception is for vegetable oils,

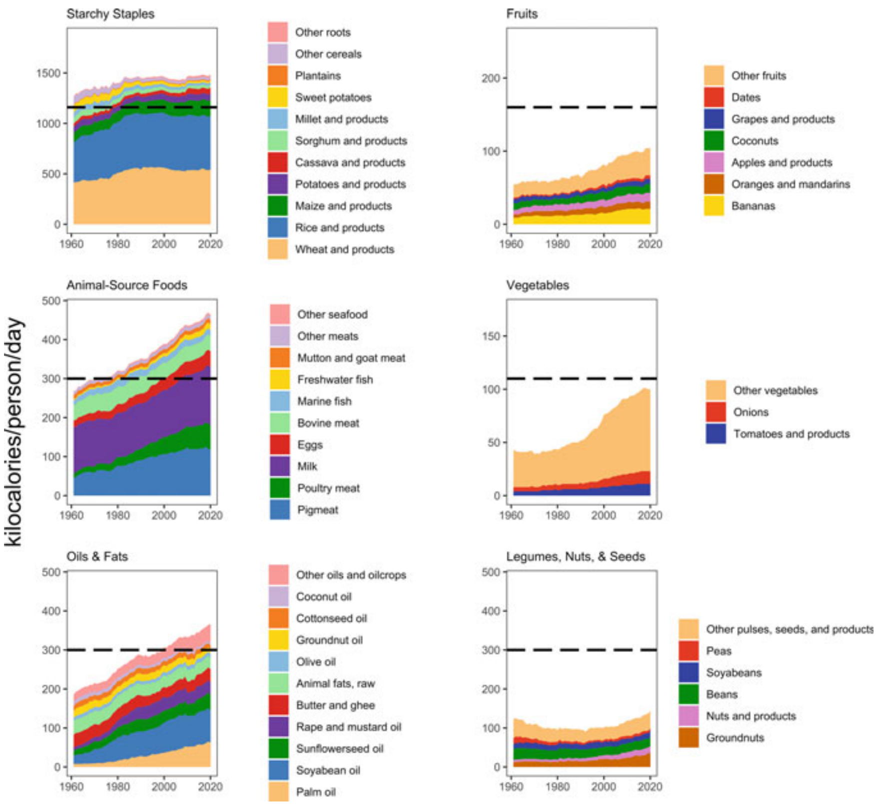

Fig. 10.15 Composition of the global food supply by food group, 1961–2020 *Source*: Data visualization by Leah Costlow, showing kilocalories per person per day available for food consumption in each region, merging historical and current estimates from FAO Food Balance Sheets at https://www.fao.org/faostat. Panels are aligned with horizontal guidelines showing energy balance from each food group in the Healthy Diet Basket reference targets used by FAO to measure the cost and affordability of healthy diets, https://www.fao.org/faostat/en/#data/CAHD

for which three large sources expanded rapidly in new ways: palm oil in tropical forest regions, soybeans initially in temperate areas and increasingly also tropical locations, and rapeseed expanded in temperate areas due to breeding of the canola varieties (so called due to being a Canadian oil with low erucic acid). Of these, soybeans and canola expanded with yield gains and cost reduction due to genetic improvement in yield potential combined with new forms of plant protection, while palm oil expanded primarily through area expansion. We will return to these questions of production-side changes in Chapters 11 and 12.

Dietary Transition Towards Packaged and Processed Foods

Changes in supply-demand balance for agricultural products by food group is just one step in dietary transition, much of which occurs through the ways that food is transformed after harvest for sale through processing or food preparation outside the home. These transformations turn the few hundred agricultural products shown in Figs. 10.14 and 10.15 into many thousands of distinct retail food items available at grocery stores anywhere in the world, many of which are newly introduced each year and may be available for only short periods of time.

Each retail product has its own distinct nutritional attributes, only some of which are disclosed publicly. Testing a food for all known aspects of nutritional composition would cost thousands of dollars per sample in a lab, so information disclosed to comply with regulatory requirements is typically based on recipes rather than testing, and composition data about those ingredients may be outdated or incorrect. Restaurant menu items have only recently been subject to any disclosure requirements at all.

Tracking dietary transition in the attributes of foods that are processed or prepared outside the home is difficult not only because those attributes are unknown, but more fundamentally because the total quantity of each item sold is usually private information, used by the suppliers themselves to guide their own marketing efforts. Some information is collected by private-sector firms that sell data and market intelligence reports to food businesses, and typically also use that data in consulting work for food businesses about market trends and opportunities.

For worldwide monitoring of the packaged food sector, one of the most useful kinds of data is collected by a marketing research firm named Euromonitor International. The origin of its name comes from the company's founding in London in 1972 when the UK joined the European Common Market, creating opportunities for statistical research to guide British firms for sales to Europe. The company's 'Passport' database later grew into a worldwide service, employing consultants who compile estimates of how much of each kind of branded product is sold every year in each of 40 countries. The company then uses food composition data to add up foods in terms of calories per person, which can be analyzed in many ways.

One particularly important dimension of dietary transition towards foods that are processed or prepared and consumed outside the home is the rise of caloric beverages, shown in Fig. 10.16.

The scatterplot in Fig. 10.16 shows total calories of all nonalcoholic beverages sold in each country from 2009 to 2020, converted to quantity per person per day for ease of comparison across countries. Along the horizontal axis is the total calories of all packaged foods or restaurant menu items tracked by Euromonitor. Based on other data, actual average intake per capita is usually 2000–3000 calories, around the healthy diet basket target of 2330. If the Passport data are accurate, the countries with less than 2000 calories in sales are consuming the rest from own production or other vendors not

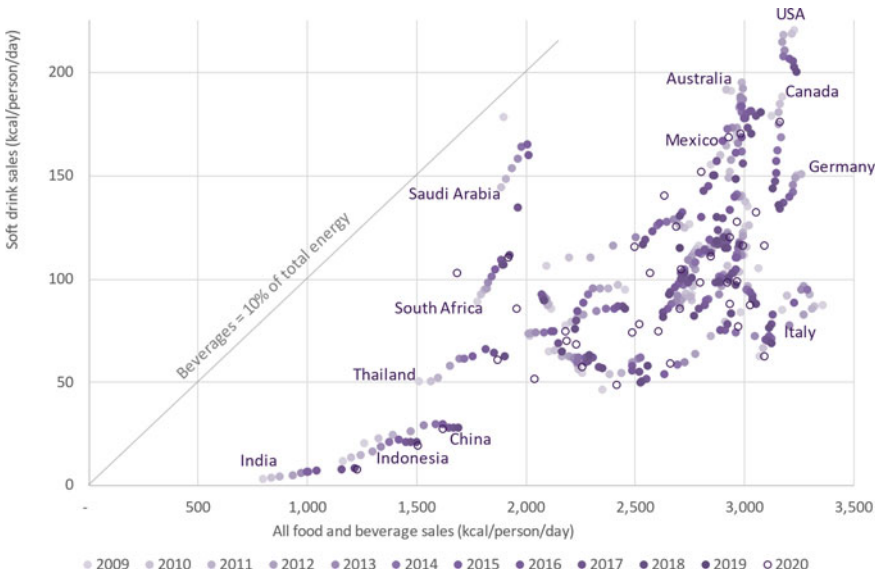

Fig. 10.16 Estimated dietary energy from non-alcoholic drinks in 40 countries, 2009–2020 *Source*: Authors' chart of data from Euromonitor International Limited ©2009–2020, all rights reserved and used here by permission. Each dot is the national average for one country, after converting annual sales data to total calories per person per day. Years are shown with darker shading to indicate the passage of time, with the pandemic year of 2020 as a circle. Details on the data source are available at https://www.euromonitor.com/our-expertise/passport

tracked by Euromonitor, while quantities above about 2500 calories involve kitchen and plate waste or nonfood uses.

The scatterplot uses darker shading for more recent years, with the pandemic year of 2020 highlighted as a circle. Most countries reveal an 11-year trajectory of dietary transformation in consumption of caloric beverages relative to all other foods recorded by Euromonitor, with 2020 as an outlier. The scatterplot shows an upward sloping pattern across all countries, with interesting variation in the speed and direction of change, including differences in how country data reflects pandemic response. Outliers above the international pattern include Saudi Arabia with high and rising sales but a sharp decline in 2020 for both soft drinks and all foods to the isolated dot just to the left of data for South Africa, whose data for 2020 continued the high and rising trajectory from 2009. From the bottom left we see countries such as India, Indonesia and Thailand experiencing what could be described as the early stages of a transition towards more foods that are packaged and processed or sold in restaurants of the type tracked by Euromonitor, with some upward slope. South Africa and Saudi Arabia are outliers above the pattern formed by other countries, while Italy is an outlier below the international pattern. Mexico is towards the far end of the global pattern, and Australia, the U.S., Canada and Germany are all countries where caloric beverage sales have declined noticeably since the start of these data in 2009.

One aspect of Fig. 10.16 is that scaling of the vertical axis is in units of 50 kcal and the horizontal axis is units of 500 kcal, so all points along the diagonal line shown on the chart would have 10% of all calories sold be from soft drinks. In fact, India and Indonesia have much less than that, but the trajectories for South Africa and Saudi Arabia are steeper than that line, so a rising fraction of all calories being sold in those countries are in beverage form.

Dietary Transition Towards Foods Away from Home

The pattern over time and across countries for restaurant and food service sales reveals a particularly notable aspect of dietary transition, as shown in Fig. 10.17.

The Euromonitor Passport data in Fig. 10.17 reveal the challenge of measuring the quantity sold of meals away from home, as several countries show linear change without the year-to-year fluctuations that would result from measurement error or variation in the actual trajectory. Each linear

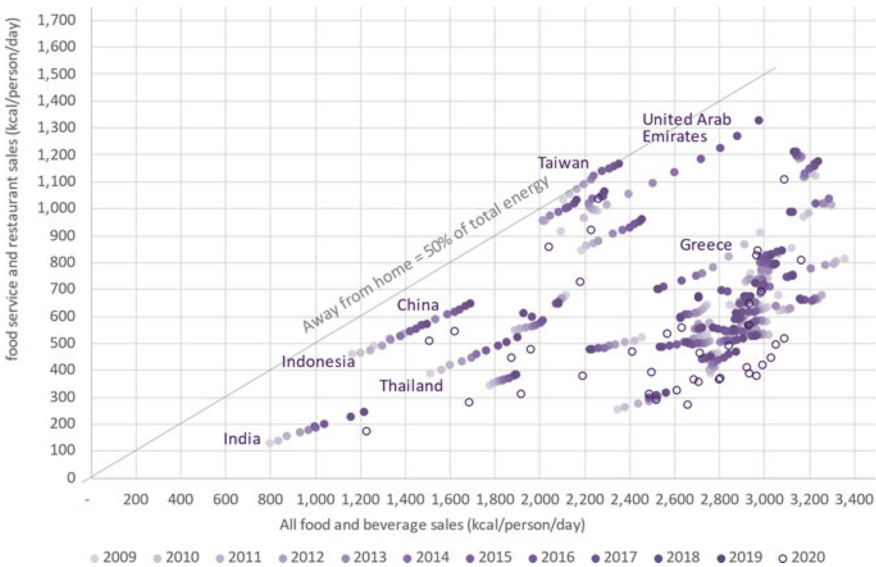

Fig. 10.17 Estimated dietary energy from food away from home in 40 countries, 2009–2020 *Source*: Authors' chart of data from Euromonitor International Limited ©2009–2020, all rights reserved and used here by permission. Each dot is the national average for one country, after converting annual sales data to total calories per person per day. Years are shown with darker shading to indicate the passage of time, with the pandemic year of 2020 as a circle. Details on the data source are available at https://www.euromonitor.com/our-expertise/passport

projection is nonetheless revealing of the information collected by Euromonitor consultants in each country, including especially the sharp declines in meals away from home during the pandemic year of 2020, and the challenge of undercounting food sold away from home.

Trends for each country can be compared to the diagonal line indicating 50% of total reported calories being sold by food service establishments and restaurants. Taiwan and some other countries are close to that line. It is possible that the share of calories obtained away from home declined over this period in countries such as India, Indonesia, Thailand and China, but it is also possible that those countries had growth in unmeasured food service activity such as street foods and prepared meals sold in open markets, as well as school meals and other institutional cafeterias.

Household surveys and dietary recall data often find that food away from home provides a growing fraction of total consumption. The quantity and composition of that food is typically unknown, due to the absence of nutritional composition data, and the limited ability of survey respondents to recall how much they ate of each item. To provide a more complete measure, we can turn to data collected for national accounts from the businesses themselves, regarding their total sales. These data do not track items sold so cannot be matched to food composition and nutritional attributes, but they can be adjusted for inflation and provide a much more precisely measure of the total value of foods served in restaurants and other establishments.

The U.S. trajectory for the total value of food served away from home spans almost a century, as shown in Fig. 10.18.

The two panels in Fig. 10.18 are designed to include all kinds of food and beverages consumed away from home, excluding alcohol. That total includes commercial sales reported by food service enterprises and administrative data on meals provided in schools and other public or private institutions. The data for food and beverages intended for consumption at home includes estimated values of food grown by the household, direct sales from farms to consumers, and food donated through the charitable sector. Our visualization combines the USDA food expenditure data with total spending by households on all goods and services, to provide the most complete possible picture of dietary transition from meals at home to foods served elsewhere from 1929 to 2020.

Starting from the top left of Panel A, the two years of observation in 1929 and 1932 show the decline in the share of spending on food during the great depression, when food prices fell even more than the cost of other things. By 1935 food prices and spending were at their historically high share of total personal consumption expenditure of around 22%, which then declined to stabilize around 6% of total spending in the 2000s. Meanwhile expenditure on food away from home was around 5% of the total in 1929 and through the 1930s before rising sharply during World War II, then returning to around 6% until the 2000s.

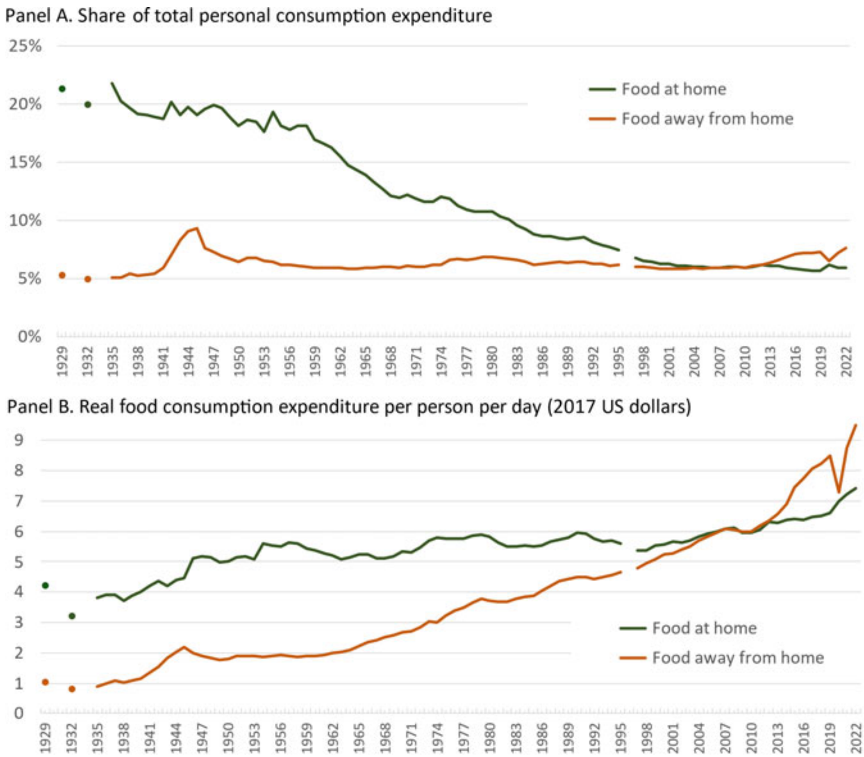

Fig. 10.18 Real spending on food at home and away from home in the U.S., 1929–2022 *Source*: Authors' chart of data on food expenditure from the USDA Economic Research Service [https://www.ers.usda.gov/data-products/food-expenditure-series], with total personal consumption expenditure from the U.S. Bureau of Economic Analysis [https://www.bea.gov/itable/national-gdp-and-personal-income]. Food expenditure data collection methods changed in 1997, so data for 1996 are omitted to show lack of comparability. Personal consumption expenditure [PCE] is personal income net of savings, interest payments and transfers paid to people abroad. Real values adjust for inflation using the Bureau of Economic Analysis PCE deflator

The roughly constant share of food away from home in total expenditure, over decades of rising incomes and increased total spending, implies a unit-elastic demand for food served away from home. Each 1% of additional total spending must have involved a roughly 1% increase in consumption of food and beverages away from home. In contrast, the top line for food at home follows Engel's Law, with increments of income spent primarily on other goods and services. The implications of that for the absolute level of spending is shown in Panel B, where expenditure is converted to daily values in 2017 dollars for convenience of comparison with other data about diet costs and food spending.

The top line in Panel B shows that the level of real spending for food at home rose significantly into the 1950s, from around $4 per person per day in the late 1930s to around $5.50 per day in the mid-1950s. That number stayed roughly constant in real terms until the early 2000s. The composition of that spending is not well documented, but one possible explanation is that upgrading of grocery spending to higher-value items was almost exactly offset by a reduction in the real cost of farm-to-market supply chains for those items, enabling real grocery spending to stay roughly constant for half a century.

The two panels of Fig. 10.18 show important changes in U.S. food spending since the 1990s. The USDA method for measuring food expenditure was revised in 1996, making the two data series not entirely comparable, but there is a sharp rise in spending for food at home from $5.36/day in 1997 to $6.60 in 2019. That rise then accelerated during the pandemic, reaching $7.41 in 2020. Meanwhile spending on food away from home rose even faster. Using the new USDA data series real spending on food at and away from home had equalized by 2006, and after the decline in real spending around the great recession of 2008–2009, food spending away from home rose sharply after 2012 to $8.48 per day in 2019 and snapped back after the COVID recession to $8.74 in 2021 and $9.51 in 2022. Those values are at 2017 prices, partly reflecting changes in the price of food and food service relative to all other goods and services, but also the sharply higher incomes and greater income equality experienced in the U.S. since 2012 as shown in Section 9.2 of the chapter on food in the macroeconomy.

The U.S. trajectory of expenditure for food and beverages at home and away from home is especially revealing when using monthly estimates of total sales before and during the COVID pandemic as shown in Fig. 10.19.

When describing events that took place during the period shown in Fig. 10.19, it can be difficult to recall the speed and magnitude of that disaster. Focusing just on the number of deaths, U.S. vital statistics maintained by the Centers for Disease Control (CDC) show that weekly mortality rates fluctuated normally and then spiked far above normal in mid-April 2020, spiked again even higher for three successive weeks in December-January 2021, and again for three successive weeks in January 2022. Between those peaks, U.S. mortality rates were well above average in most weeks, for a two-year cumulative total of more than 1.3 million excess deaths. About one fourth of those were due to other conditions whose mortality rates rose during the pandemic, with total mortality from COVID itself at more than one million deaths.

The data shown in Fig. 10.19 track how the U.S. food system responded to the pandemic with monthly sales reported by grocery outlets in the top line, and bars and restaurants in the lower line. These data differ from the USDA food expenditure series primarily in that they include alcohol in total spending on food away from home, but exclude food provided by institutions such as school meals. This shows how commercial spending on food away from home had surpassed commercial purchases at grocery stores starting in September 2019, and kept rising until the start of pandemic response in February 2020.

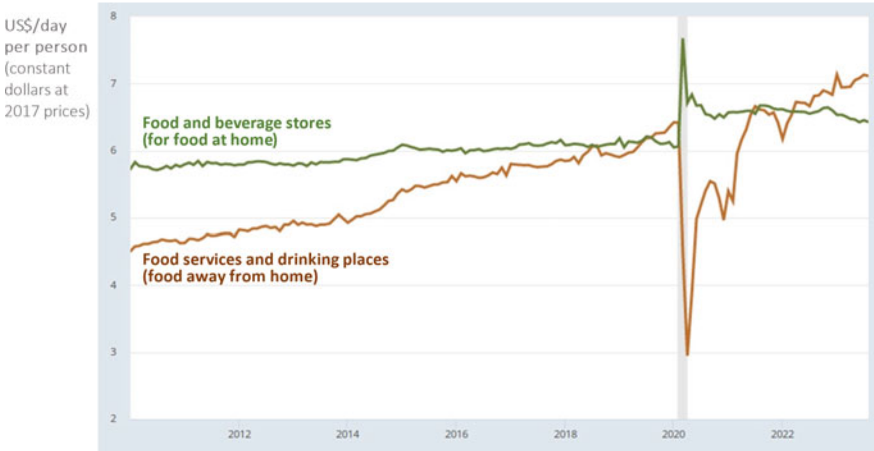

Fig. 10.19 Retail sales of food in the U.S. before and during the pandemic, January 2010–August 2023 *Source*: Reproduced from Federal Reserve Economic Data [FRED] showing data from the U.S. Census Bureau Monthly Retail Trade Survey, with preliminary advance estimates for August 2023. Values are deflated by the U.S. consumer price index. Data on food service and drinking places includes sales of alcohol, which are omitted from USDA food expenditure data. Updated versions of this chart are at https://fred.stlouisfed.org/graph/?g=1amTK

From February to April 2020, total sales of food away from home dropped from $6.42 to $2.95 per day. Food at home rose from $6.06 in February to $7.68 in March before falling back to $6.71 in April and stabilizing around $6.60 during 2021 and 2022.

Different communities experienced the COVID pandemic differently around the world, with varied levels of illness and mortality from the disease itself, and varied degrees and duration of isolation at home in response to news about the risk of infection. Some of stay-at-home behavior was a direct response to government policies, but U.S. cities and states did not begin to mandate lockdowns until mid-March, several weeks after restaurant traffic had already declined sharply. Communities also differed greatly in their ability and interest in returning to pre-pandemic trends. The national average experience of people in the United States, who quickly returned to high and rising levels of food spending away from home, indicates only what can happen when people return to high levels of employment and income growth as they have in the U.S., as shown at the end of Chapter 9.

Nutrition Transition in Physiology and Health: The ABCDs of Measuring Nutritional Status

Changes in food consumption affect nutritional status, altering lifelong health and disease risk in various ways summarized in Table 10.1 at the outset of this chapter as the *nutrition transition*. That table summarized a few changes in nutritional status potentially caused by many different food attributes that affect metabolism and health. Modern knowledge of food composition began in the eighteenth and nineteenth centuries with measurement of energy in food, now described as coming from each of three macronutrients (protein, fats or carbohydrates). In the twentieth century biochemists then isolated and measured food composition in terms of over two dozen essential micronutrients that are needed for human metabolism, classified as either minerals (inorganic compounds, bringing elements known from chemistry in the periodic table) or vitamins (organic compounds produced by plants or animals). In the modern era of nutrition research, the nineteenth and twentieth century focus on essential nutrients has been complemented by measurement of many other bioactive compounds in food that also affect health.

All three kinds of nutritional attributes in food can have upper and lower bounds for health. Fluctuations within those bounds typically have no known consequences, in some cases due to known regulatory mechanisms that maintain homeostasis when dietary intake fluctuates within the normal range. Some example consequences of exceeding those bounds are listed in Table 10.5.

Specific compounds and attributes of food are sometimes associated with specific outcomes as shown in Table 10.5, but more often the attributes interact with each other to jointly determine nutritional status and health outcomes. This is particularly important for populations that have brought their intake of micro- and macronutrients to within the bounds beyond which they cause nutrient-specific diseases, so that remaining health risks are due

Table 10.5 Essential nutrients and other bioactive compounds needed for health

Type of compound	*Example effects of diet quality on human health*	
	Examples from excess intake	*Examples from insufficient intake*
Macronutrients (protein, fats and carbohydrates)	Diabetes from unbalanced diets; cardiovascular disease from excess of saturated fats	Low birthweight and stunted linear growth; underweight and wasting; insufficient weight gain in pregnancy and poor gestational health
Micronutrients (vitamins and minerals)	Hypertension from excess sodium; toxicity from excess of some vitamins in high doses	Blindness and poor immune function from Vitamin A deficiency; goiter and neurological impairment from iodine deficiency
Other compounds in food	Cancers caused by contaminants; malabsorption caused by anti-nutrients	Severity of illness worsened by low intake of phytochemicals from plants, whole grains and fermented foods that promote gut health

to interactions and other less easily detected aspects of food composition. Since the 1990s, nutrition guidance has increasing focused on overall dietary patterns, meaning the relative proportions of different food groups, first because that brings essential nutrients to within upper and lower bounds for most people, but also to ensure adequacy of other food attributes associated with health.

The measurement of nutritional status can be summarized using a convenient memory aid known as the ABCD approach, mentioned in the context of Table 10.1 at the start of this chapter. For convenience, the four categories are spelled out in somewhat more detail here before we turn to some of the observed data.

Anthropometry is the oldest category of data about nutritional status, measuring heights and weights or other dimensions of the body. The earliest datasets refer to heights of adult men in military service or other institutional settings. Later discoveries showed that almost all human populations converge to a similar distribution of adult heights when all nutritional and health needs are met, as each person reaches their genetic potential which has a similar distribution among people in all regions of the world. Other research showed that trajectories of attained heights were largely determined in early childhood, roughly the thousand days from gestation to the child's second birthday. That discovery was associated with the creation of standardized growth charts based on monthly measurement of a healthy reference population, ethnically diverse but given the highest standard of health care starting with prenatal nutrition, so that growth faltering or excess weight gain can be measured in terms of standard deviations around the median of that reference group. Weight gain or loss later in life is most commonly measured by adjusting for height using the body mass index (BMI), defined as weight divided by height squared. Conventional thresholds suggest that the lowest health risks are experienced by people with BMI between 18.5 and 25.0 kg/m^2, with higher risks associated with obesity which is defined as a BMI of 30 or above. Over time, improvements in anthropometry are refining these measures and diagnostic criteria for specific purposes, including the use of electronic imaging techniques and wearable sensors to measure physical and metabolic activity in more useful ways.

Biomarkers derived from physical samples have long been used to help diagnose nutritional status. The oldest measure is detection of sugar in urine to diagnose diabetes, dating from the seventeenth century. Since then, a wide range of innovations include faster and lower cost measurements at home or in field settings, such as photoelectric measurement of blood oxygen levels and pinprick samples to measure blood hemoglobin and diagnose anemia. The most used biomarkers for nutrition care in high-income countries are cholesterol and triglycerides to indicate cardiovascular health, fasting blood glucose to indicate problems with glucose metabolism, and blood urea nitrogen and creatinine to indicate kidney function. Frontier techniques include analysis of genetic material in stool samples to measure composition of the gut microbiome. All of these can potentially be used to diagnose imbalances and prescribe supplements or dietary changes for prevention as well as treatment after disease symptoms appear.

Clinical signs and symptoms of disease conditions sometimes relate to specific micronutrient deficiencies, such as discolored nails relating to zinc deficiency, neuropathy and fatigue associated with vitamin B12 deficiency, or impaired night vision linked to vitamin A deficiency. Like anthropometry and biochemical measures, these measures can be used in health services for early detection before nutrient-related diseases progress into severe illness and disability. More than one measure is typically needed, for example combining bone densitometry plus blood and urine tests to assess the role of calcium deficiency in osteoporosis. For research purposes, clinical techniques include isolating research subjects in metabolic chambers that account for all inflow and outflow of energy and nutrients. Metabolic chambers allow researchers to conduct trials that vary aspects of dietary intake or other factors and trace their consequences, with less of the background variation and measurement errors that limit research on diets in the population at large.

Dietary assessment is the toolkit used to overcome the difficulty of remembering and reporting what was eaten with sufficient accuracy to estimate nutrient intake. Early efforts include food diaries but those are invasive, difficult to sustain and likely to alter intake. Most often dietitians and survey staff use dietary recall after the fact, asking qualitative (yes/no) and sometimes quantitative (weight or volume) questions about broad food groups or specific items eaten over the previous day and night. Standard practices call for two 24-hr recalls on different days, followed by a set of data transformations to convert responses into estimated usual intakes, adjusting for infrequently consumed foods. Even with the most careful 24HR recall surveys, respondents typically report implausibly low total intake, so analysis of data is done on an energy-adjusted basis per thousand calories, or per 2000 calorie diet or some other benchmark such as 2330 kcal/day.

The ABCD classification used in nutrition textbooks can be extended to a longer memory aid, for example to add *E*nvironmental and social factors that interact with dietary intake such as bacteria, viruses and parasites linked to sanitation, airborne toxins and particulates from kitchen smoke or industrial pollution. In the health sciences, these are often described as social-ecological factors or social determinants of health. The ABCDE can be stretched further to add *F*ood system metrics, including farming methods, food safety and food processing, food waste and other variables that might affect diet quality, as well as *G*overnance factors that include labeling and disclosure of food composition, mandates for fortification like iodine in salt, bans on harmful ingredients like trans fats, or enforcement of food safety standards like hazard analysis and critical control point (HACCP) systems. Having this ABCDEFG classification in mind helps us remember the wide range of variables that could potentially be measured and used to characterize nutrition transition.

Nutrition Transition in Physiology and Health

Variation in attained height was reported by early travelers who noticed big differences in average stature of groups around the world. One of the first systemic records for large samples is the height of military recruits, especially in countries where conscription is broadly representative of the general population. Other samples include volunteer armies or prisoners who may be less representative of the population at large, but nonetheless reveal large differences and important similarities as illustrated in Fig. 10.20.

The countries shown in Fig. 10.20 are all success stories, in the sense of having significant increases in attained height over the twentieth century. The sample of successive cohorts is not globally representative of all countries, and by measuring only males enrolled in specific institutions they are not representative of all people within the countries shown, but they do show remarkable commonalities.

A first observation about these samples is that only Denmark and the Netherlands show sustained height increases in successive cohorts through the nineteenth century. The U.S. initially had very tall recruits in the early nineteenth century, with successively shorter cohorts until the twentieth century,

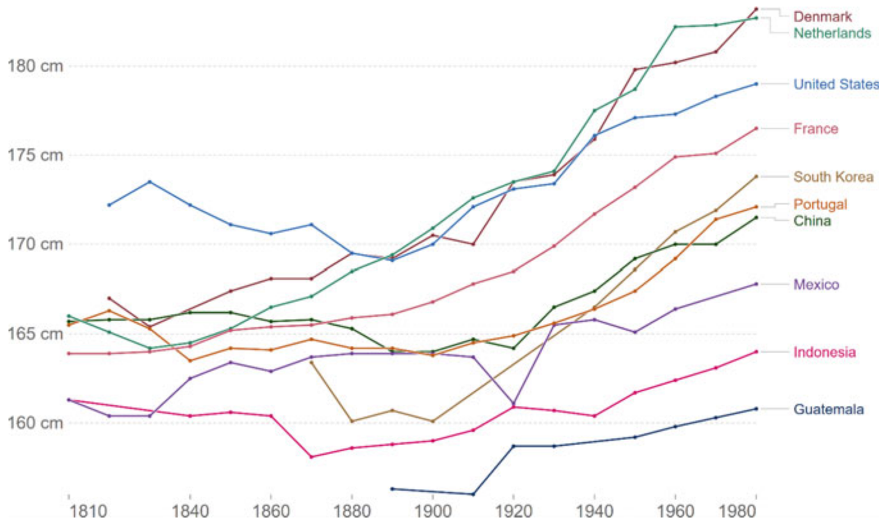

Fig. 10.20 Average heights of men by year of birth in selected countries, 1810 to 1980 *Source*: Reproduced from Max Roser, Esteban Ortiz-Ospina and Hannah Ritchie [2019], Our World in Data: Human Height [https://ourworldindata.org/human-height], based on Jorg Baten and Mattias Blum, 'Why are you tall while others are short? Agricultural production and other proximate determinants of global heights', *European Review of Economic History* 18 [2014], 144–165. Other countries can be selected at https://ourworldindata.org/grapher/average-height-of-men-for-selected-countries

most likely due to selection effects and enrollment of immigrants and others with more disadvantaged backgrounds.

A second observation is all successive cohorts grew taller over the twentieth century, even in the countries with least initial height. Early observers often believed that short stature of certain groups was an inherited trait associated with ethnicity, but it turns out that the mechanism of inheritance at a population level is environmental rather than genetic. Almost all populations now appear to have approximately the same distribution of genetic potential for attained height. Individuals differ in their genetic potential for height, for any sufficiently large population is likely to have sufficient variation within the group that their average potential height converges to the global average observed in well-nourished populations.

A third observation is that heights grew slowly and in parallel towards humanity's genetic potential height, without clear evidence of convergence to a frontier, at least in this set of example countries. Such a frontier must exist, but the data in this chart show that we still see the effects of gradually removing environmental and epigenetic constraints on each population's attainment. When large numbers of people are uprooted and move from low- to high-height locations, such as migrants from Asia to Europe or the U.S., they gain height from generation to generation much faster than successive cohorts within countries who experience less rapid change in environmental conditions.

Over time, nutrition researchers have identified just a few of the many mechanisms likely to be involved in determining whether a cohort achieves their genetic potential for height. Some of the most important findings involve timing, especially the fact that at least some height regulation occurs in utero and early infancy, influencing the child's trajectory long before the actual growth itself occurs throughout childhood and adolescence. Some of these effects work through the tempo of growth, delaying the onset and shortening the duration of growth spurts.

Concern about population growth in the late 1960s and 1970s led to surveys of women regarding fertility and family planning, and concerns about maternal and child health led to many surveys around the world focusing on women and children. For low- and middle-income countries, data from the Demographic and Health Surveys (DHS) funded by the U.S. government and run by local statistical agencies have now measured over 1.5 million mothers and their children under five around the world. Other data collection efforts such as the Multiple Indicator Cluster Surveys (MICS) led by UNICEF are also important for low-income settings, as well as national surveys run independently in each high-income country.

In the 1990s and 2000s, research efforts shifted towards understanding maternal and child health, but the frequency of surveys is still too low to permit annual monitoring in every country. Instead of that, the World Bank together with UNICEF and the World Health Organization (WHO) produce joint monitoring estimates by combining all available surveys for updates, resulting in the data shown in Fig. 10.21.

The top panel of Fig. 10.21 shows the prevalence of stunting in every region of the world for 2000, 2005, and then from 2010 to 2022. Stunting rates are a helpful indicator of a population's overall nutritional and health status affecting child development, capturing the sum total of all influences on whether the population is achieving their genetic potential for height. The metric is defined relative to the WHO's reference population of healthy children, a multiethnic cohort recruited in the late 1990s from households able to provide the highest standard of care throughout pregnancy and childhood in Brazil, Ghana, India, Norway, Oman and the United States. Stunting is defined as having a height-for-age under −2 standard deviations below the median of that healthy population. The same population also provides a distribution of child weights, and the same metric is used for child overweight as more than +2 standard deviations above the median. By definition, in a healthy population approximately 2.5% of children would meet these criteria,

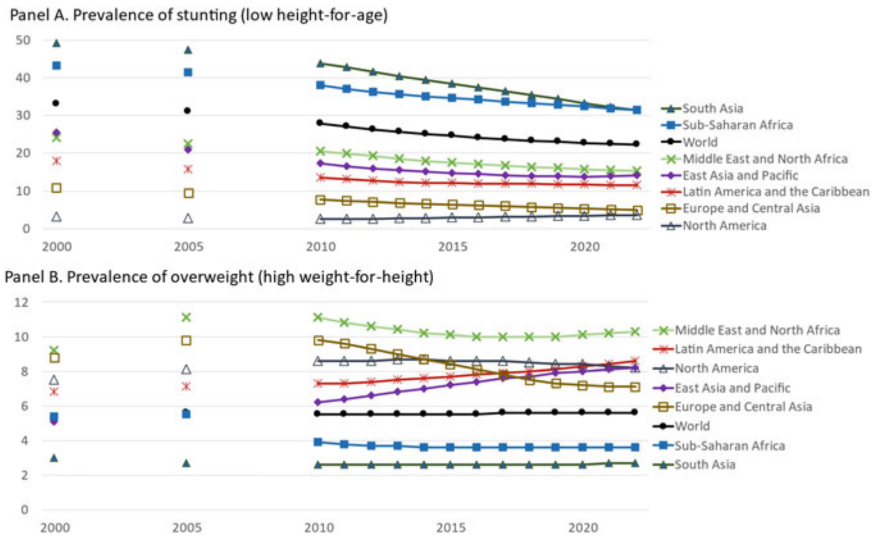

Fig. 10.21 Prevalence of stunting and overweight in children under five, 2000–2022 *Source*: Authors' chart of data from UNICEF, World Bank and World Health Organization Joint Child Malnutrition Estimates, published May 2023. Prevalence of stunting is the percentage of children aged 0–59 months who are below minus two standard deviations from median height-for-age of the WHO Child Growth Standards, and overweight is the percentage who are more than two standard deviations above the median weight-for-height of that healthy population. Methods are detailed at https://data.unicef.org/resources/jme-report-2023, with underlying survey data and results for individual countries at https://data.unicef.org/topic/nutrition/malnutrition

so the degree of stunting or overweight in a population is the extent to which their prevalence exceeds 2.5%.

The global estimates provided by merging all available surveys show that over 30% of all the world's children were stunted in 2000 and 2005, principally in South Asia and Sub-Saharan Africa where stunting rates were between 40 and 50%. Since then, child stunting in South Asia has dropped sharply, faster than the decline in Africa, leading to convergence at just above 30% in 2022. Stunting rates in all other regions have also fallen towards the benchmark level of 2.5% which is approximately characteristic of North America.

The bottom panel of Fig. 10.21 shows the prevalence of overweight, for which the world average was just above 5% in 2000 and remains near that level. Child overweight prevalence rose sharply from 2000 to 2005 in the Middle East and North Africa, Europe and Central Asia then declined in both those regions, and rose in North America. In Latin America and the Caribbean as well as East Asia and the Pacific, child overweight prevalence has continued to rise through 2022, and in North America it has declined since the late 2010s.

These data are far from definitive, due to limited survey frequency and sample sizes. Their focus on early childhood is also a limiting factor, and many efforts in recent years have expanded the window of measurement through adolescence. In higher income countries, monitoring also extends to adult men. What all these results show is continued variation in the experience of different populations living under different conditions, even at similar levels of real income and facing similar food costs. Nutrition transition clearly involves a variety of determinants beyond income and prices, some of which can be addressed by policy intervention.

Nutritional status in multi-dimensional, with multiple forms of malnutrition coinciding in each person and community, interacting to influence their susceptibility to disease over the life course. Children may have their linear growth be stunted in utero and infancy, and then experience a food environment that leads to rapid weight gain and a high level of weight-for-height, as well as deficiencies in a variety of micronutrient deficiencies. Those three dimensions of harm can be seen as a 'triple burden' of malnutrition affecting many communities around the world, contributing to disease risks that cumulate over the life course and drive large changes in longevity around the world.

Epidemiological Transition in Disease Risks

The attribution of mortality to specific causes and underlying risk factors is a challenging statistical exercise. All aspects of health interact with each other and contribute the progression of any given disease that might ultimately be listed as the cause of death. In recent years, the world's leading effort to correlate causes of death with potentially modifiable risk factors is known as the Global Burden of Disease (GBD) study, whose most recent complete accounting was published in late 2020 and is known as GBD 2019.

The complete set of risk factors used for GBD 2019 is based on variables for which data are available on both the risk factor itself, for example whether a child is breastfed, and its relative risk for a health outcome, such as diarrheal disease, which itself has a known relationship to disability and eventual mortality. A selection of risk factors related to nutrition, together with others for context, is shown in Fig. 10.22.

The selection of thirteen risk factors in Fig. 10.22 is a subset of all potentially modifiable behaviors and health conditions that are linked to premature death. The vertical axis shows the number of deaths per 100,000 people that are associated with variance in that risk factor, relative to the base rate of deaths without it.

In 1990, child and maternal malnutrition was the most important of these thirteen risks for early death, defined here as sum of risks from child growth failure and stunting, plus also suboptimal breastfeeding, low birthweight and short gestation, and three specific micronutrient deficiencies for iron, zinc and vitamin A. These are commonly found together and are jointly targeted by nutrition and health interventions, using a combination of prenatal and obstetrical care plus support for exclusive breastfeeding to six months of age followed by nutrition assistance, all designed to reduce eventual mortality and intermediate indicators such as stunting.

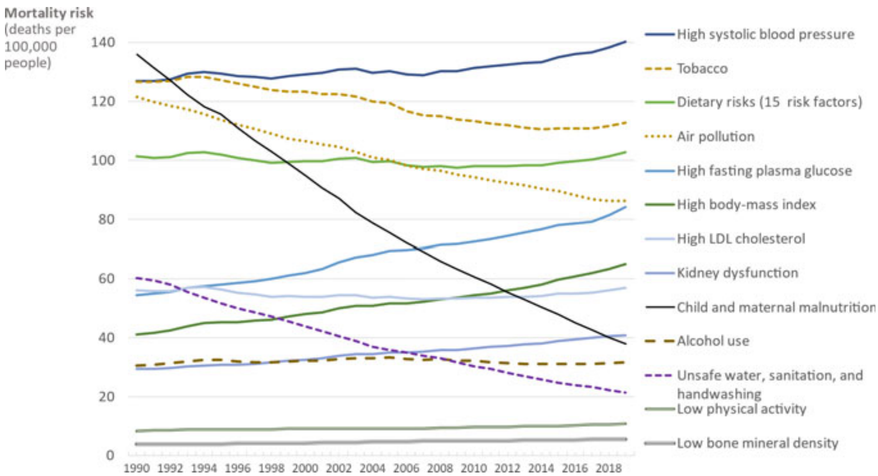

Fig. 10.22 Nutrition-related and selected other risk factors for mortality, 1990–2019 *Source*: Authors' chart of data from Institute for Health Metrics and Evaluation [IHME], Global Burden of Disease study [GBD 2019], ©2020 and used with permission. Data shown are estimated global number of deaths per 100,000 people associated with each risk factor or group of risk factors. Details on methods and the database query to reproduce a version of this chart with other related variables is: https://vizhub.healthdata.org/gbd-results?params=gbd-api-2019-permalink/9fd8c1a283a9a13959f2ee5dc69fe04c

The GBD 2019 data in this chart reveal how mortality associated child and maternal malnutrition has plummeted from 136 to 38 deaths per 100,000 people over the past three decades. That is a cumulative reduction of almost one death for every thousand people. The reduced burden of disease caused by child and maternal malnutrition is partly due to lower fertility and a smaller fraction of all people who are children, but also to improvement in conditions surrounding each birth as shown for example by lower stunting rates. A smaller but also dramatic decline has occurred in the number of deaths associated with unsafe water, sanitation and handwashing, and its associated transmission of water-borne diseases. Tobacco use and air pollution have also declined in importance but remain among the top four of these thirteen risks.

Those four risk factors shown in Fig. 10.22 to have declined in importance were the main targets of many public health interventions in the 1990s and 2000s. Those interventions generally have high levels of cost-effectiveness per life saved, and contributed to the higher level of life expectancy at each income level as shown in Preston curves of Fig. 10.1. Other factors such as tobacco and air pollution remain very important risk factors for early death, and there have been large increases in the burden of diet-related metabolic conditions.

In 1990, the next highest risk factor after child and maternal malnutrition was high systolic blood pressure, which can have various causes and for some people is worsened by high sodium intake. The importance of high blood pressure rose after the mid-2000s, and as of 2019 was associated with 140 deaths per 100,000 people, more than the 113 deaths now associated with tobacco use. After those two, the third most important risk factor is a combined set of 15 dietary risks including a diet low in five food groups (vegetables, legumes, whole grains, milk, or nuts and seeds) or high in three other food groups (red meat, processed meat, and sugar-sweetened beverages), or else low in four nutrients (fiber, calcium, omega-3 fatty acids, and polyunsaturated fatty acids) or high in two other nutrients (trans fatty acids or sodium). As of 2019, that overall metric of poor diet quality is associated with 103 deaths per 100,000 people.

The fastest-increasing risk factor is high fasting plasma glucose as an indicator for diabetes, rising from 54 to 84 deaths per 100,000 people between 1990 and 2019. High BMI also grew quickly in importance, rising from 41 to 65 deaths, and kidney dysfunction rose from 29 to 41 deaths per 100,000. These three are interconnected with each other and with high blood pressure as conditions that are closely tied to dietary patterns. An additional risk is posed by the 15 dietary factors that add almost as much additional mortality as tobacco.

The epidemiological transition towards increased importance of diet-related noncommunicable disease can be measured in many ways. The GBD 2019 results are the result of statistical modeling, not direct observation, but they clearly reveal how the interaction of economic growth, demographic transition and food system change have made diet quality a central concern for public health worldwide.

Causes of Difference Between Benchmark Healthy Diets and Actual Food Choice

As we saw in Fig. 7.17 at the end of our chapter on poverty and risk, many of the world's lowest-income people spend less on food than even a least-cost diet that meets minimal criteria for health, as specified in the healthy diet basket targets used at the start of this section to describe the dietary transition. As shown in Fig. 10.14, at higher incomes people typically meet their daily energy needs with larger quantities of animal source foods, oils and fats, and sugars than would be needed for a healthy diet, which displaces items from the other food groups that would be needed to deliver sufficient nutrients and other bioactive compounds for lifelong health.

The lack of convergence towards a balanced diet when incomes rise can most simply be attributed to the fact that the health attributes of food cannot generally be detected by the consumer and may often be misunderstood. Each person's beliefs about how eating a food would impact their future health reflects their own self-experimentation, remembering how their health changed after eating different things, and the centuries of trial and error behind humanity's varied culinary practices and food cultures passed down within families and communities. People also may have ideas about how their bodies have reacted to foods when previously tried, and they may be wary of trying again. People are also influenced by the news they read. That news influences food choice and is subject to strong selection effects, emphasizing certain things and not others based on the incentives that guide what is written, read and shared.

Amelia hears a lot of beliefs about food in her work as a clinical dietitian, with each person's different beliefs all deeply rooted in that person's background and experiences. Cultural and other differences drive wide variation in the composition of diets between individuals, communities and regions of the world. One of the very few constants is the need for sufficient total energy intake to maintain bodyweight, triggered by hormonal and other signals. The sources of that energy then vary in ways that are often culturally determined, like the clothes or shoes people wear. All humans need to maintain body temperature and protect our feet, but what people wear depends on social, historical and technological circumstances. The furniture in our houses has a similar mix of functional and cultural roles. Food differs from clothing, shoes or furniture in part due to its outsized impact on future health, influencing nutritional status and susceptibility to disease.

The dietary and nutrition transitions described in this chapter include the effects on food choice of popular or social media as well as professional guidance about food's effects on health. Past investments in nutrition research have generated rapid progress towards scientific consensus on some aspects of how food affects health, and information about that consensus is widely available through national dietary guidelines such as MyPlate in the U.S. or the Eatwell Guide in the UK. Those dietary guidelines are tailored to local circumstances but have many similarities because they draw on the same evidence about how food composition affects future health. They have some influence on food choice, but other information also matters including news about nutrition research.

The scientific consensus behind national dietary guidelines evolves with new evidence but is updated in ways that differ greatly from how news about nutrition research is shared in popular media. As with economics or other fields, consensus among full-time specialist researchers is formed by testing structural models and theories about causal mechanisms against multiple kinds of evidence. In nutrition, much of that knowledge comes from biochemistry and bench science, combined with experimentation on animals and clinical or epidemiological observation of people. There are few randomized trials in humans, for the same reason that there are few randomized trials of surgical techniques or the health impacts of smoking. Conducting double-blind, placebo-controlled trials would be impractical or unethical for many important research questions. Even when they are feasible, randomized trials in nutrition would need prohibitively large sample sizes and long duration of follow-up to avoid the false findings that often arise from small, short-duration trials.

Media reporting about nutrition research often focuses on individual studies that stand out and provide a compelling story. Simply repeating the scientific consensus as specified in dietary guidelines would not be interesting. Compelling stories aim to say something new, typically by identifying one specific food or nutrient that is unexpectedly helpful or harmful. Quite understandably, the positive stories about a helpful thing often refer to studies that turn out have been funded by food companies or industry groups producing that thing, and even when studies are conducted independently researchers themselves may be subject to confirmation bias and motivated reasoning. Researchers looking for evidence to prove a point or confirm their beliefs can readily find data to strengthen their arguments. Randomized trials with small sample sizes and short duration generate a wide range of results to choose from, as will the diverse methods and data sources used in observational studies. The most appealing results are then amplified in professional and social media, propelled by strong incentives that include the self-interest of industry groups and the prior beliefs and concerns of consumers.

Consumer beliefs about how food affects health are influenced to some degree by news about nutrition research and are also influenced by food marketing and package labels. Companies routinely use health benefits as a selling point, often for product differentiation in search of market share and price premiums that some consumers might be willing to pay for otherwise hidden attributes. Items with essentially the same nutritional composition are often sold under different brand identities at different prices to different groups of consumers. For example, a high-fiber whole grain breakfast cereal fortified with micronutrients with some sugar added might be marketed as a premium product emphasizing the whole grains and fiber to some buyers, a premium fun food when the added sugar is visibly sprinkled on top and showcased on the package, and as a low-cost food whose packaging emphasizes only the micronutrients. The same market segmentation applies to farm produce, for example the same vegetables could be sold as a premium product or as a low-cost generics, in fresh or frozen form.

The many drivers of dietary change and nutrition transition can be understood much more clearly in the light of two basic insights from health sciences addressed in this and previous chapters. A first insight is that a person's total food intake in terms of dietary energy per day is largely predetermined by their height, weight and physical activity level. Trajectories for attained height are heavily influenced by conditions in utero and infancy, long before the actual growth occurs. Weight gain can occur at any life stage and is rarely reversed, so higher weights observed in adulthood often reflect a physiological change that occurred in the past, perhaps many years earlier. A second insight is that diet-related conditions, including undesired weight gain, are driven by attributes of food that cannot readily be observed and may often be misunderstood. The food attributes that would support the future health of a given individual are a knowable fact available from scientific consensus, but there is no mechanism by which effective demand would align with health, and many reasons for people to consume foods other than those that would best support their future health. Those two insights create many opportunities for food economists to participate in the design and implementation of interventions to help people meet their health objectives, while also pursuing their many other goals in life.

Strengths and Limitations of Any 'Transitions' Framework

This chapter began with Table 10.1, listing four major transitions typically associated with economic growth: a demographic transition with rise and then fall in population growth rates, a structural transformation of the economy with urbanization and a rise then fall in the number of farmers, a food system transformation with diversification of diets made possible by specialization and intensification of production, and the resulting nutrition transition from deficiencies to excesses and perhaps ultimately balanced intake for longevity and health.

The economics of food aims to help explain transitions over time and differences among countries in terms of underlying mechanisms, each built up using the analytical diagrams in Chapters 2–6. Each analytical diagram is a structural model that aims to explain observations as the result of interactions which could potentially be improved through intervention. The diagrams sometimes include flow charts, such as the circular flow of economic activity in a population used to show the macroeconomy, using those as an accounting framework to ensure that all aspects of the system are considered.

Beginning in Chapter 7 we extend the toolkit to data visualization, observing trends or patterns over the longest time periods and the largest number of countries for which we can provide authoritative data. Many aspects of the observed data remain unexplained, perhaps due to measurement error, but seeing as much data as possible in scatterplots, line graphs, bar charts and numerical tables is helpful to ensure that we have not mistakenly focused on just a few examples or case studies that are not representative of the actual range of human experience.

Summarizing outcomes as stages in a transition can be helpful but is potentially misleading. For example, one might imagine the food system transformation as having a first stage when isolated family farmers produce food for themselves and their local neighbors, with little processing done outside the home. An archetype like that is easy to picture in one's imagination, and yet not widely observed in practice. Instead of stages, our description of transitions focuses on underlying mechanisms that cause systematic patterns of change over time, such as the rise and then fall in the number of farmers. These patterns do have turning points, such as the years when a country has its peak number of farmers, but as shown in our data visualizations the speed and timing of change depends on each country's policy choices and societal circumstances, and some countries experience periods of stagnation or even reversal when growth does not occur.

10.2.3 Conclusion

This chapter describes how the process of economic growth, meaning sustained increases in the value of goods and services provided by a country's people to each other, drives change over time and differences across countries in their agriculture and food systems, dietary patterns and nutritional status. The engine of growth is accumulation of capital, meaning valuable things made by people, including the health and education of people themselves. Capital accumulation allows people to rely less on just their land and natural resources, transitioning from having most people work as farmers to a manufacturing sector and ultimately the service economy in which most employment involves few physical inputs at all.

The food and health aspects of transition addressed in this section begin with dietary transition, as populations with higher incomes shift from diets based only on the least expensive foods, primarily starchy staples, to much higher quantities of animal source foods plus vegetable oil and sugar than would be needed for a balanced diet, leaving little room for the vegetables, fruits, and legumes, nuts and seeds that would be more health-promoting. The agricultural products in those food groups are also increasingly transformed into packaged and processed items and used in food service for meals away from home. That postharvest transformation may remove important aspects of important foods, such as removing the bran and germ from whole grains to produce refined flour with longer shelf life and may add ingredients such as sodium or added sugar which are often consumed in excess of individual needs. As societies discover how those foods affect health, and face changing environmental constraints on production, each country will have the opportunity and need for new kinds of policy intervention and private-sector food businesses.