6 Theme Chapter: Demographic Change, Productivity, and the Role of Technology

Introduction

The Asia and Pacific region, home to more than half of the world's population, is undergoing rapid demographic changes. Access to better medical and public health services was realized in the early stages of development, which led to a precipitous fall in mortality and fertility rates in many countries. With extended life expectancy following increased healthy years of life, countries are needing to adapt to a changing labor market shaped by a growing share of the elderly population and a fall in the percentage of younger cohorts. This means that Asia will progressively depend more on older workers.[51]

Older people are already staying active in the labor market longer for financial and nonfinancial reasons. Their prolonged stay and reentry is seen in the agriculture and services sectors, which absorb a large share of the workforce. A significant share of older workers is involved in part-time and self-employed jobs and perform nonroutine manual tasks. Even though some countries in Asia are still relatively young, similar aging trends will likely show up in their labor markets over the coming decades.

Meanwhile, developing countries in Asia are experiencing strong human capital development thanks to increases in per child investment. Today, more children are staying longer at school and then going on to attain higher education. This improvement will steadily produce more educated elderly workers. In countries where educational attainment increased rapidly in a short period, however, the gap in schooling between younger and older populations remains wide.

Population aging presents a challenge to maintaining strong and inclusive growth in the region. Historically, population growth is closely linked to the rate at which an economy grows, with benefits reaped from the so-called "demographic dividend." Fewer Asian economies are expected to gain from a demographic dividend as the share of the working age population in the region peaks in 2015–2020. In the coming decades, some countries' working age group will shrink gradually, yet significantly. Aging of working members of the population is inevitable in most countries. Mature and older workers are not necessarily unproductive, and they may perform continuously well in certain types of work, but their productivity in others may naturally decline. In addition, the scarcity of young-to-middle-aged workers could drag down the pace of innovation and technology adoption.

The rich pool of economic literature on how population aging affects economic growth presents mixed results. While many studies argue that the growing elderly populations could slow growth, some studies highlight the positive effects of aging through the formation of a mature workforce. The most recent literature emphasizes how the relative dependency on an aging workforce induces technology adoption in the workplace, and may help mitigate (or reverse) the negative effects of aging on economic growth.

[51] Asia refers to the 49 Asia and Pacific members of the Asian Development Bank (ADB), which includes Japan and Oceania (Australia and New Zealand) in addition to the 46 developing Asian economies.

This theme chapter reviews the trend of demographic transition across Asia and examines the effects of aging on productivity and economic growth. In particular, it investigates how technologies alter the aging effects on an economy and discusses policy options highlighting the role of technologies where possible. Experience from economies in advanced stages of aging suggests that population aging can induce innovation and adoption of technologies, and so promote productivity and sustained growth. But there is no guarantee that all aging societies stand to benefit from the same types of technology. For example, automation and artificial intelligence may reduce the demand for certain types of jobs. This may drive older workers out of the workforce instead of complementing them. While digitization and smart devices can improve worker productivity and workplace efficiency, older workers may be discouraged from participating in the workforce if the digital divide is not effectively addressed.

A variety of technologies that offer unique solutions to an aging workforce will be introduced and discussed. This chapter highlights five categories of technologies that (i) substitute labor and skills (such as industrial and service robots); (ii) complement labor and skills (remote office, collaboration tools); (iii) aid education, skills development, and lifelong learning (such as through online learning platforms); (iv) improve the matching of worker with job and task (through job portals and cloud sourcing platforms); and (v) extend life and healthy life expectancy (with digital therapeutics and bioinformatics).

Given that countries are at different stages of demographic transition, with varying age–education population mixes, the policy priorities and strategies for technology adoption and skills development necessarily differ across the region. For example, countries that are aging quickly but have made large improvements in education need different technology and skills development than countries with a relatively younger population and lower educational attainment. Nevertheless, a common need exists for policies that support technology adoption and lifelong learning. Countries should seek to adopt technologies befitting their demographic transition and to facilitate learning across all age groups and skills. Government policy can help create broader learning ecosystems, where learning environments (teachers, peers, pedagogy that fits well with technology) and a culture of learning are fostered internally and across countries.

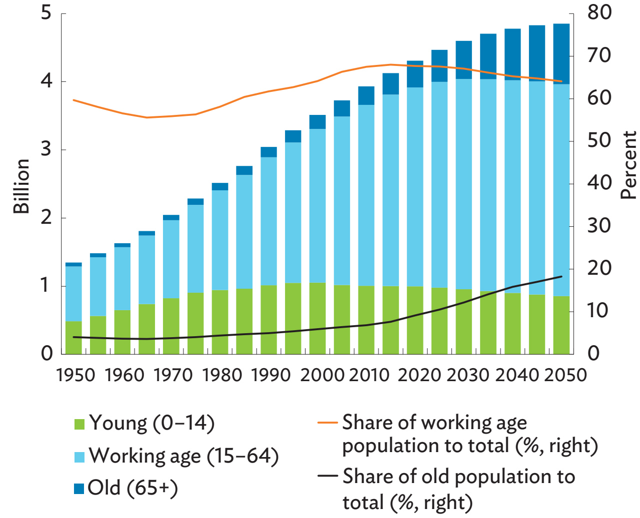
Policies that leverage technology to improve workforce efficiency and provide greater flexibility in labor market participation should be put in place across Asia. Three areas of investment can be encouraged. First are policies that provide funding for research and development and help the diffusion, adoption, and application of technological innovation. Specific government policy could focus on encouraging application of breakthrough technologies through multi-stakeholder collaboration that makes them more accessible to elderly populations. Second is promoting labor laws that adapt to employees' diverse and flexible working styles, such as those encouraging mid- and late-career employment, work-sharing, and gradual retirement. The third policy area is restructuring social security and tax systems so they do not disincentivize elderly workers from staying in or returning to work. These policies would involve revisiting the concepts of "pensionable age" rather than "retirement age," and encourage workers to invest in retaining, upgrading, and acquiring new skills.

Asian economies can also benefit from regional cooperation for more efficient use of the diverse demographic profiles and input resources. This could take the form of encouraging capital, labor, and technology to move across borders, and include support for foreign direct investment that creates jobs for middle-skilled workers. Labor migration can help alleviate bottlenecks in the supply of low-skilled workers in some countries and the shortage of high-skilled workers in others, while technology transfers between countries of different demographic and technology adoption levels can speed up technology diffusion. To encourage these movements, proper regional frameworks need to be established. These could include mutual skills recognition along with other mechanisms that promote the mobility of labor across borders.

Population Aging in Asia

Asia is undergoing rapid demographic change. The share of the region's working age population has started to decline, and several economies imminently face aging populations. This transition leaves many economies progressively depending on older workers, whose challenges may differ from their younger counterparts. On the positive side, better lifestyles, advanced healthcare and medical technologies, and improvements in educational attainment imply that tomorrow's older workers will be healthier and more educated than today's older workers. Nevertheless, without appropriate action, the aging and shrinking workforce could profoundly impact the ability to innovate and sustain high economic growth.

Figure 6.1: Population by Major Age Group—Asia



Source: ADB calculations using data from United Nations Department of Economic and Social Affairs, Population Division. Population Database. https://population.un.org/wpp/Download/Standard/Population/ (accessed June 2019).

Asia's Demographic Trajectory

Asia is home to 4.3 billion people, or 55% of the world's population in 2019.

Since the turn of the century, population growth in the region averaged 1% per year, well below the 1.7% annual growth from 1980 to 1999. The region's population is expected to peak at 4.85 billion between 2055 and 2060, with its share of world population falling to 48.7%.

The region's working age population (between ages 15 and 64) stood at 2.9 billion in 2019. It is expected to peak at 3.1 billion by 2045 and then fall 0.6% (equivalent to a 20 million workforce) by 2050 because of subdued expansion in the young population cohort. As a share to Asia's total population, the working age population peaks at 68% in 2015. The changing shares of varied age cohorts will gradually reshape the age and sex distribution of the region's population from a pyramid to a vase (Figure 6.2).

Amid slowing population growth, the share of the working age population will plateau around 70%, while the share of the older population is rising.

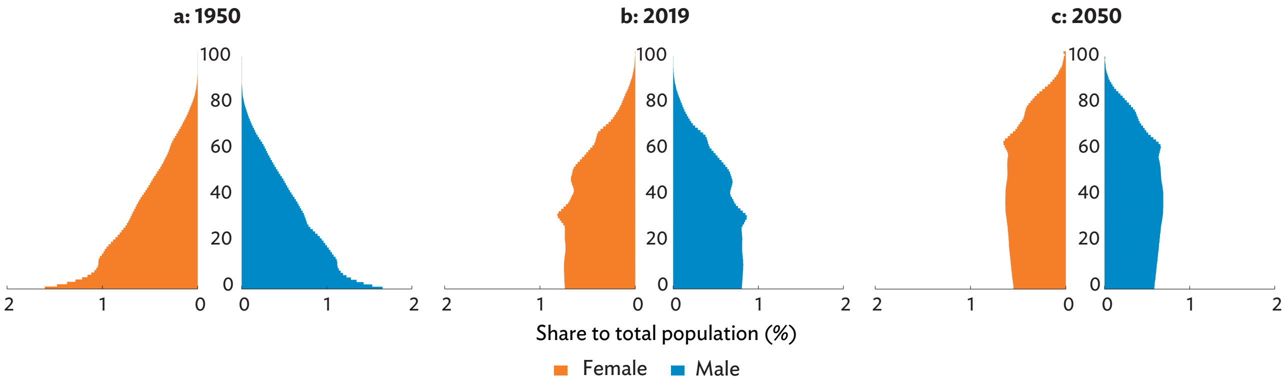
About 379 million Asians were of ages 65 and above in 2019.[52] This represents 8.9% of the region's total population, and a 3-percentage-point increase from 5.9% (208 million) in 2000. The proportion of old people in Asia is projected to rise more steeply, so that by the end of 2050, the 888 million old individuals will comprise 18.3% of the population (Figure 6.1).

On average, Asians are healthier and living longer.

Life expectancy across the region grew from 62 years in 1980 to 73 years in 2017 (Figure 6.3). In those 4 decades, increases were largest in Cambodia (41.8 years) and Timor-Leste (34.8 years). Bhutan, Maldives, Nepal, and Afghanistan all extended life expectancy by more than 20 years. It was prolonged even in economies in advanced stages of population aging: Australia extending by 8.2 years; Hong Kong, China by 10.0 years; Japan by 8.0 years; New Zealand by 8.8 years; and Singapore by

[52] In this section, old persons are defined as those of age 65 and above.

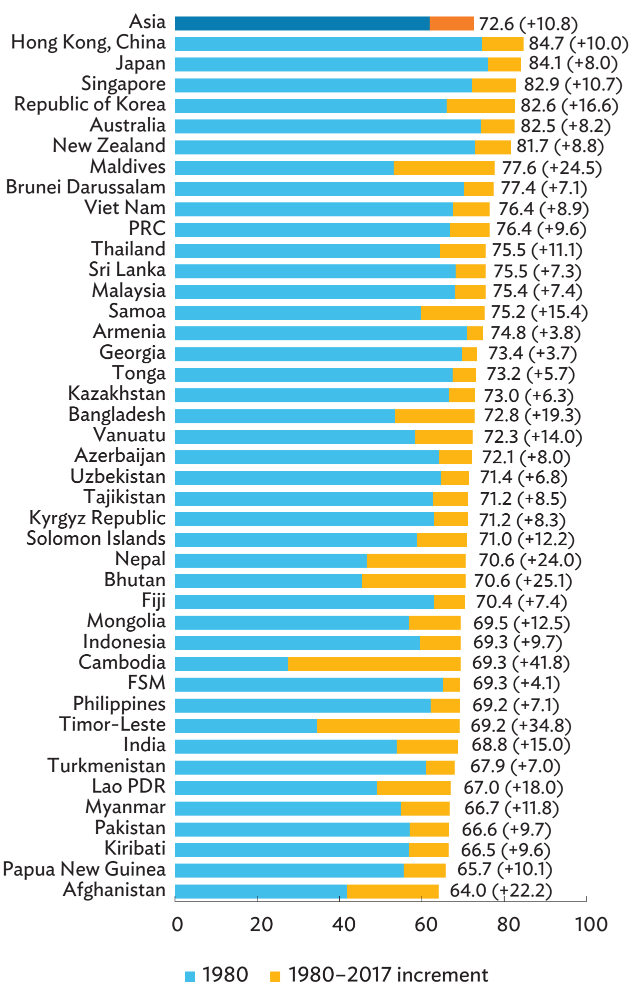
Figure 6.2: Evolution of the Population Pyramid—Asia



Note: Age of the population in y-axis follows a continuous data format.

Source: ADB calculations using data from United Nations Department of Economic and Social Affairs, Population Division. Population Database. https://population.un.org/wpp/Download/Standard/Population/ (accessed June 2019).

Figure 6.3: Life Expectancy—Asia (number of years)



FSM = Federated States of Micronesia, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Note: Data labels refer to the life expectancy at birth in 2017, and the increment from 1980 is in parentheses.

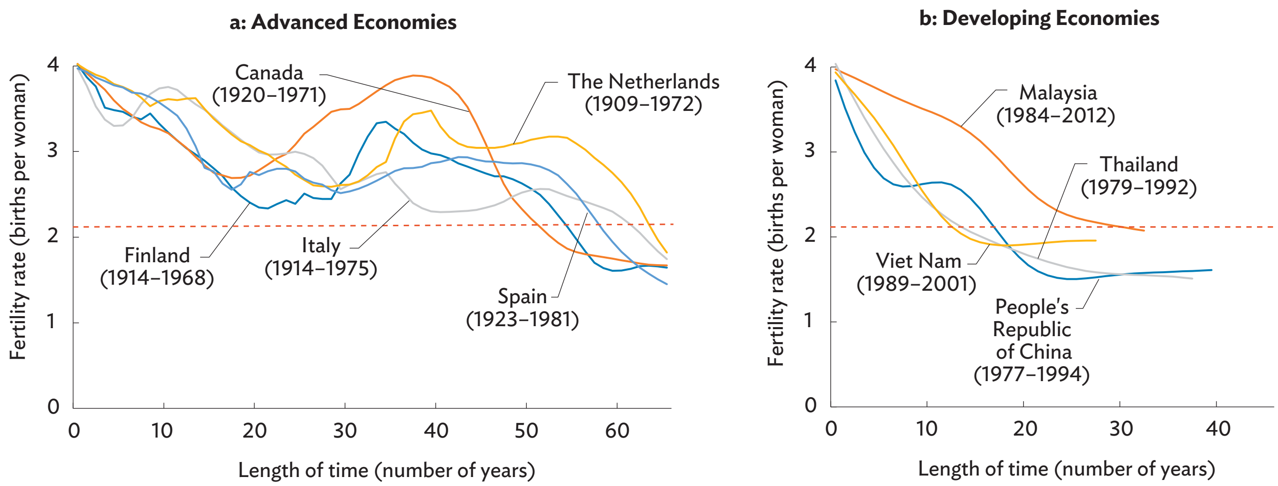
Source: ADB calculations using data from World Bank. World Development Indicators. https://databank.worldbank.org/source/world-development-indicators (accessed July 2019).

10.7 years. Consequently, the number of centenarians in the region is expected to increase from 245,000 in 2019 to 1.65 million by 2050. By that time, 5 years is expected to be added to the average life expectancy of Asians (at 78 years), with one-third of economies in the region reaching life expectancy of more than 80 years.

A precipitous fall in mortality and fertility rates explains the extension of life expectancy and a growing share of the older population.

The drastic reduction in infant mortality—from 88 per 1,000 births in 1970 to 21 in 2017—is one significant force behind the drop in the overall mortality rate in the region. Increased chances of infant survival also contributed to the decline of fertility rates (measured by births per woman), sliding to 2.5 in 2017 from 5.5 in 1970. Fertility rates have dropped remarkably fast. While it took more than 50 years for advanced economies to fall below the present replacement level fertility rate of 2.1 births per woman from 4.0 births per woman (Figure 6.4a), some developing Asian economies have made this change in less than 20 years (Figure 6.4b). Among other factors, improvements in public health and medical services, the spread of education, increased women's economic participation, and family planning programs played critical roles in reducing mortality and fertility rates.

Figure 6.4: Pattern of Fertility Rate Decline—Selected Economies



Notes: Fertility rate refers to the number of births per woman. The red-dashed line indicates the current global replacement level of 2.1 births per woman.

Sources: ADB calculations using data from Chesnais (1992); and World Bank. World Development Indicators. https://databank.worldbank.org/source/world-development-indicators (accessed July 2019).

Many economies in Asia are aging at an accelerated rate.

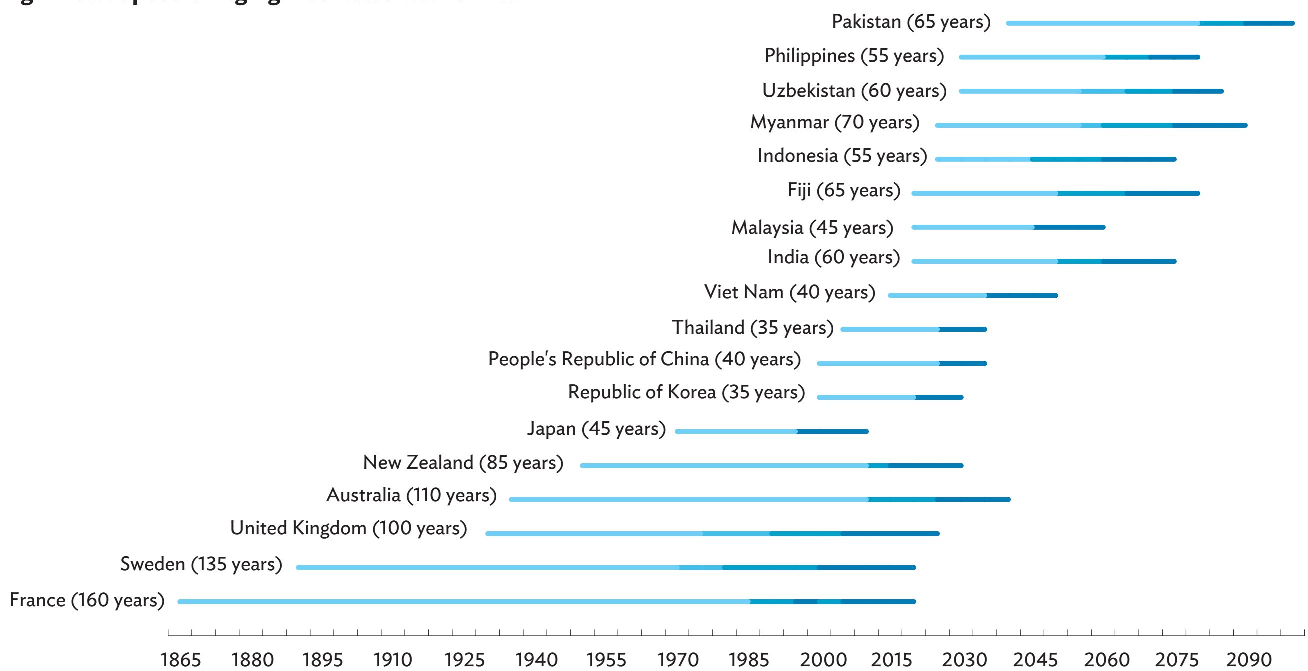
Following the United Nations definition, a country transitions to different phases of economic aging based on the share of old individuals to its total population. An economy is classified as "aging" when the share to total population of people of ages 65 and above reaches 7%, "aged" once the share reaches 14%, and ultimately "super-aged" when it exceeds 21%. It has taken several decades to more than a century for some Western nations to shift from aging to super-aged societies. That transition has taken place over 160 years in France, 135 years in Sweden, 110 years in Australia, and 100 years in the United Kingdom (Figure 6.5).

In Asia, population aging is occurring at a much faster pace. It is strikingly fast in Japan, where the old population share grew from 7% to 14% in only 25 years to 1995, and increased to 21% 20 years later. The pace of graying in Japan will be mirrored in other Asian countries, with some expected to reach "super-aged" in even shorter periods. It is anticipated to take no more than 40 years for the share of old persons in the People's Republic of China (PRC) to increase from 7% to 21%, and 35 years for the Republic of Korea. Thailand will make the same transition in less than 35 years and it will happen in Viet Nam over 40 years. Meanwhile, the shift to "super-aged" will be slower in India, at 60 years, and will take 55 years in Indonesia.

Fast-paced population graying may pose inadvertent risks particularly among the developing economies.

Figure 6.6 presents contemporaneous population aging and incremental per capita gross domestic product (GDP) (at constant 2010 prices) relative to 1960 for select Asian economies. Japan, for example, experienced a $10,000 per capita income rise when the older population comprised 7% of its population. The same is true for the Republic of Korea and Hong Kong, China that show similar trajectory while Singapore's aging was met by a much higher income rise. In contrast, the per capita income of developing countries currently exhibiting quick demographic transition—such as Armenia, the PRC, Georgia, Sri Lanka, and Thailand—has only witnessed a per capita increment below $4,000 (at constant 2010 prices) when the share of the old reached 7% of their populations. These newly aging countries have seen fiscal expenditure for healthcare and pensions increase, while still allocating resources to build basic and large-scale economic infrastructure necessary to promote and sustain growth.

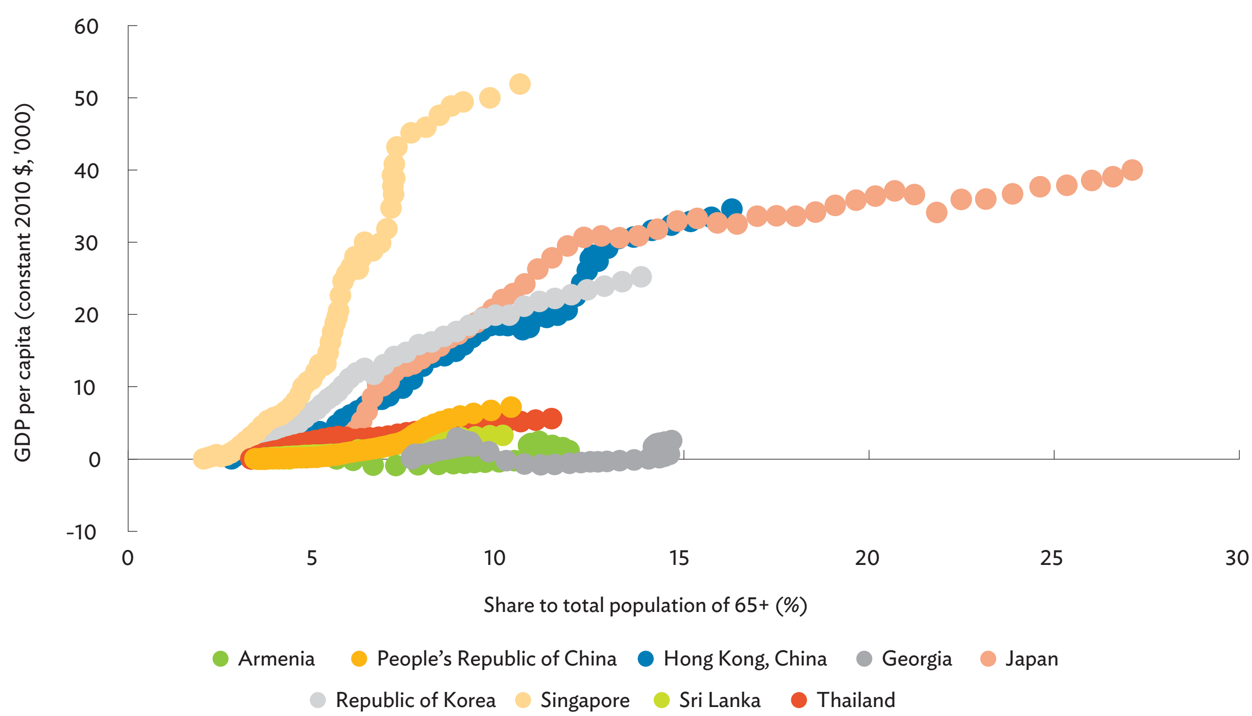
Figure 6.5: Speed of Aging—Selected Economies



Note: The lines refer to the number of years for the share of the population of age 65 and above to increase from 7% to 21%, with light blue indicating 7% to 14% movement.

Source: ADB calculations using data from United Nations Department of Economic and Social Affairs, Population Division. Population Database. https://population.un.org/wpp/Download/Standard/Population/ (accessed June 2019).

Figure 6.6: Income Levels and Share of Older Persons, 1960–2017—Selected Asian Economies



GDP = gross domestic product.

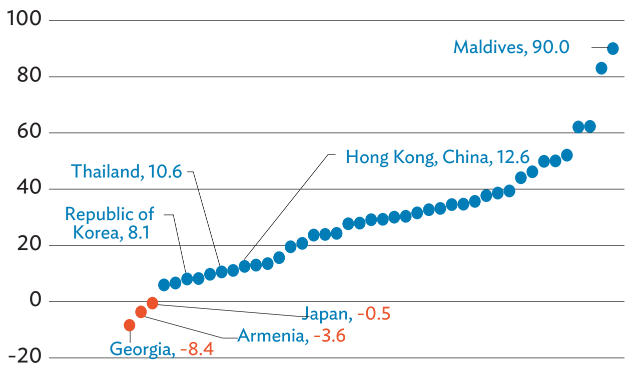
Note: GDP per capita is normalized to zero during the earliest period of availability.

Sources: ADB calculations using data from United Nations Department of Economic and Social Affairs, Population Division. Population Database. https://population.un.org/wpp/Download/Standard/Population/ and World Bank. World Development Indicators. https://databank.worldbank.org/source/world-development-indicators (both accessed June 2019).

Economies in Asia are undergoing different phases of demographic transition and are feeling the impact of aging at different points in time.

An aging population poses an immediate policy concern in the region overall, but country-specific trends leave room to tackle the diverse challenges. In 2019, the populations of Armenia, Georgia, and Japan were smaller than in 2000, while the rest of the economies in the region experienced an expansion of population (Figure 6.7). In Japan, this decline is explained by fluctuating yet sustained below-replacement births per woman. Population decline in Armenia and Georgia is due to sizable emigration of labor (Cancho, Facusse, and Berenice 2019; and Badurashvili and Nadareishvili 2012). Varying degrees of population expansion are observed in other countries.

Figure 6.7: Population Growth, 2000–2019—Asia (%)



Source: ADB calculations using data from United Nations Department of Economic and Social Affairs, Population Division. Population Database. https://population.un.org/wpp/Download/Standard/Population/ (accessed June 2019).

Population Aging and the Labor Supply

Ongoing demographic transition leads to a decline in the working age population among aging economies.

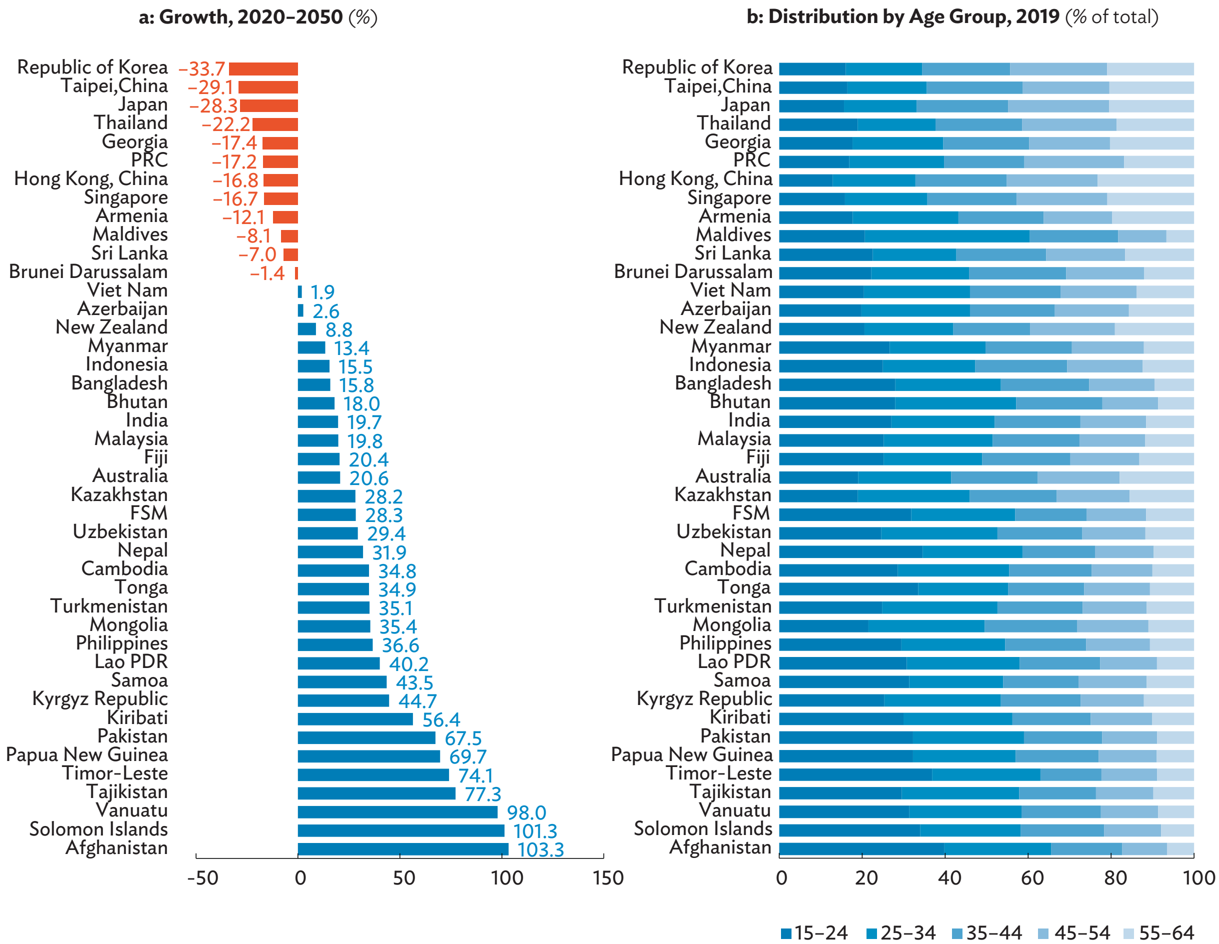
Between 2020 and 2050, economies in an advanced stage of aging such as Japan; the Republic of Korea; and Taipei,China will show the most rapid contraction in working age population (Figure 6.8a). The potential workforce is also projected to decline in Armenia; Brunei Darussalam; the PRC; Georgia; Hong Kong, China; Maldives; Singapore; Sri Lanka; and Thailand. These economies account for 41.8% of the region's working age population in 2019, but the shrinkage is expected to reduce this share to 31.9% by 2050. In contrast, further increases in the working age population will occur across many economies over the same period. The largest expansions are expected in Afghanistan, Solomon Islands, and Vanuatu, while the other 30 Asian economies will see more moderate growth. Overall, the region's working age population is expected to decline after reaching a peak of about 3.13 billion between 2045 and 2050.

More importantly, the workforce will age in most economies.

Figure 6.8b shows that the economies whose working age populations will fall by 2050 have a larger share of workers of aged 55 and above. This age group made up at least 17% of the total working age population in the PRC; Georgia; Hong Kong, China; Japan; the Republic of Korea; Singapore; Taipei,China; and Thailand. But workforce aging is common across economies, including ones with younger populations. The working age population from the rapidly aging economies of Hong Kong, China; Japan; the Republic of Korea; Singapore; Taipei,China; and Thailand will have an average age of 40 and above in 2020 (Figure 6.9). By 2050, Armenia, Azerbaijan, Bhutan, Brunei Darussalam, the PRC, Maldives, and Nepal will also have average workforce ages of at least 40. Notably, the aging trend will even be more pronounced in countries such as Bangladesh (+4.7 years) and the Lao People's Democratic Republic (Lao PDR) (+4.4 years).[53]

[53] Actual average age of the workforce is potentially underestimated by exclusion of workers of ages 65 and above who, by definition, are not included in the working age population of those between ages 15 to 64.

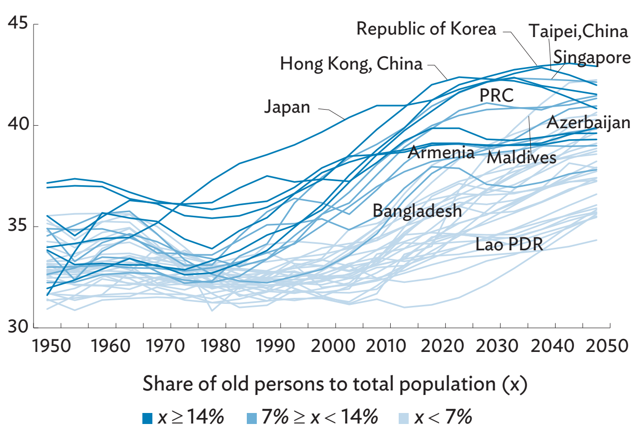
Figure 6.8: Working Age Population—Asia



FSM = Federated States of Micronesia, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: ADB calculations using data from United Nations Department of Economic and Social Affairs, Population Division. Population Database. https://population.un.org/wpp/Download/Standard/Population/ (accessed June 2019).

Figure 6.9: Average Age of the Working Age Population (number of years)



Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

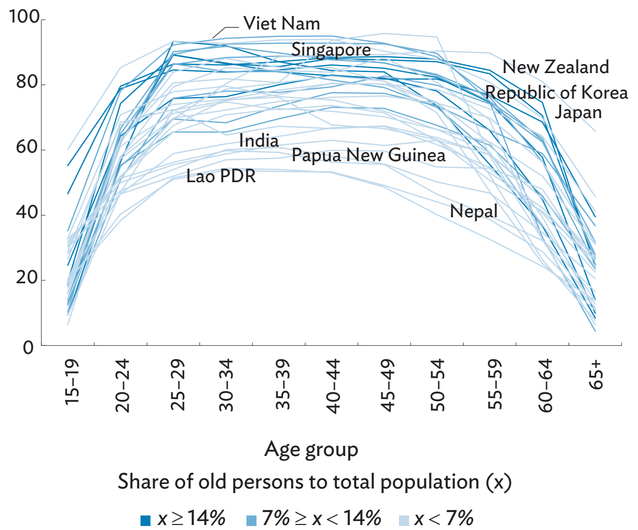
Note: The color gradient refers to the share to total population of people of ages 65 and above in 2019.

Source: ADB calculations using data from United Nations Department of Economic and Social Affairs, Population Division. Population Database. https://population.un.org/wpp/Download/Standard/Population/ (accessed June 2019).

For various reasons, age remains critical in influencing decisions to take part in the labor market.

Generally, labor force participation increases with age, especially during the early years, and peaks during a person's forties, then declines gradually, following an inverted-U pattern shown in Figure 6.10. The young cohorts have low participation, with an increasing share of youth pursuing further education and advanced degrees. Participation rates gradually decline among older cohorts for many different reasons, including health and retirement. On average, economies at a more advanced phase of population aging have higher participation rates across all ages, including the older ones. Gender differences exist in how age affects

Figure 6.10: Labor Force Participation by Age Group—Asia (%)



Lao PDR = Lao People's Democratic Republic.

Note: The color gradient refers to the share to total population of people of ages 65 and above in 2019.

Source: ADB calculations using data from the International Labour Organization. ILOSTAT. https://www.ilo.org/ilostat (accessed June 2019).

labor force participation. The likelihood of joining the workforce fluctuates more with age for women than men as they often take a greater share of responsibility in managing the household and providing care to family members. For example, women tend to retreat from the labor market more gradually starting from their early fifties, often to take a more active role in raising grandchildren (Ko and Hank 2014).

A growing share of older people stay in the labor market.

Figure 6.11 shows growing labor participation among workers of ages 60 and above within economies undergoing rapid aging. The rising share of people in the 70–74 cohort who are working way past retirement age is notable. In contrast, the rate remains much more stable in economies, such as India and Indonesia, with youth populations that are still growing. Shifts from agriculture to other sectors and shifts toward wage employment that brings more rigidity to job structures, including the enforcement of the statutory retirement age, might explain the retreat of older workers in these countries, especially in urban areas. Labor force surveys in some countries exclude older workers from the sample, which makes it difficult to assess their employment status and working conditions.

Financial and nonfinancial drivers help explain extension and reentry of older workers in the labor market.

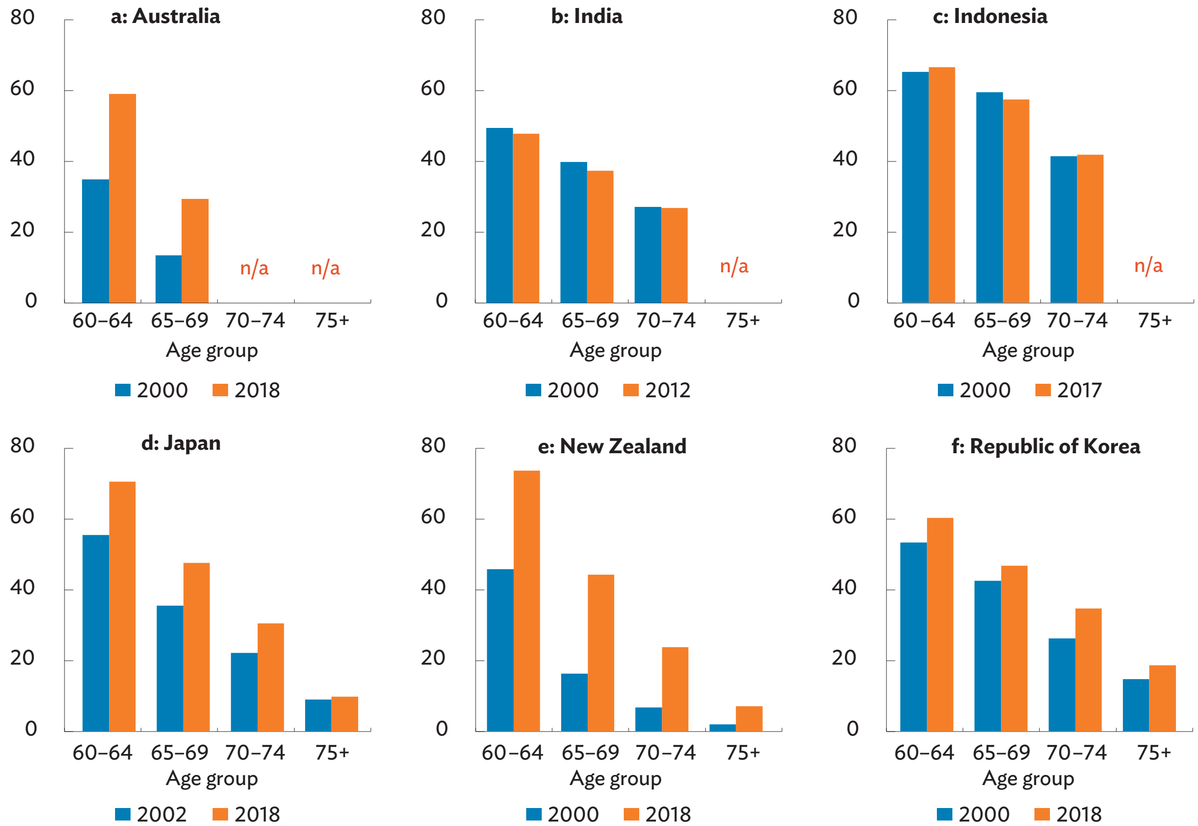
Social security reforms and the necessity to earn a living influence the labor participation of older persons. In Japan, like many other advanced economies, the labor force participation of older cohorts is highly sensitive to aging-related policies, including the statutory retirement age and the pension system. Oshio, Usui, and Shimizutani (2018) show that labor participation decisions among older workers are strongly associated with changes in social security incentives, such as the rise in pensionable age. Inadequate retirement savings programs and expected cost of living upon retirement are major factors motivating older workers to remain in—or return to—the workplace. Active labor market policy may also influence participation. Singapore introduced a reemployment program in 2017 to boost the employment rate of older residents.

Nonfinancial factors such as the desire to pursue an active professional life and self-fulfillment by connecting with other people at work remain important in motivating older people to remain in the workplace. Most importantly, the participation of older workers greatly depends on their capacity to handle workplace tasks; accordingly, improved health conditions are among the major drivers for old individuals to seek employment or remain in work beyond retirement age.

The confluence of work preferences of older people and labor market demand leads to older workers being more concentrated in certain sectors.

A large share of workers of ages 60 and above is generally observed in agriculture, and holds true in real estate, transportation, and construction. Workers age

Figure 6.11: Labor Force Participation of Older Workforce—Selected Asian Economies (%)



n/a = data not available.

Note: Latest available data for India are 2012, while those for Indonesia are 2017.

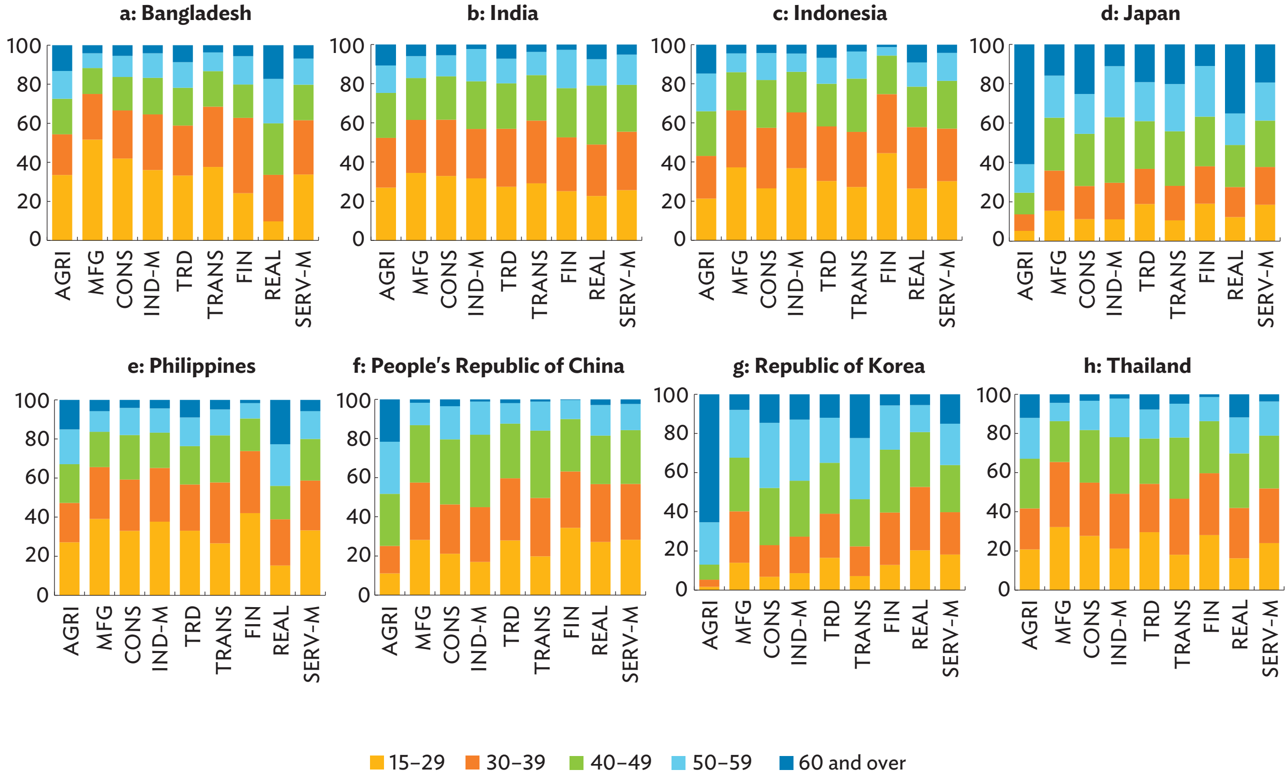
Source: ADB calculations using data from Organisation for Economic Co-operation and Development (OECD). OECD Stat Database. https://stats.oecd.org/ (accessed June 2019).

60 and above account for as high as 61% of agricultural workforce in Japan and 65% in the Republic of Korea (Figure 6.12). Agriculture offers some advantages for older workers. First, it does not usually impose strict retirement ages. Second, it provides more flexibility in working hours, especially given the prevalence of family-owned farms. Third, with increasing mechanization, farming becomes less physically demanding. Aside from agriculture, real estate also attracts older workers. In Japan, employees of ages 60 and above comprise 35% of staff in the real estate sector. Older workers also seek wage employment in real estate, for example as brokers, for flexibility in working hours.

Given abilities decline with age, along with other factors, older workers prefer occupying less physically demanding jobs; adoption of technology may enable them to handle more routine-oriented tasks.

Compared with routine tasks, occupations involving nonroutine manual tasks are less physically demanding. These include service jobs requiring human interactions, and this partly explains the large share of workers age 60 and above performing jobs with nonroutine manual tasks (Figure 6.13). This group has the highest share of workers over the age of 60—25% of the total employed

Figure 6.12: Sector Distribution of Employment by Age Group—Selected Asian Economies (%)



AGRI = agriculture, CONS = construction, FIN = finance, IND-M = other industries, MFG = manufacturing, REAL = real estate, SERV-M = other services, TRANS = transportation, TRD = wholesale and retail trade.

Note: Employment data for the People's Republic of China refer to urban employment only.

Sources: ADB calculations using data from Government of the People's Republic of China, Ministry of Human Resources and Social Security. China Labour Statistical Yearbook 2016. http://www.mohrss.gov.cn/2016/indexeh.htm (accessed June 2019); Korean Statistical Information Service. https://kosis.kr/eng/ (accessed June 2019); Statistics Bureau of Japan. Employment Status Survey 2018. https://www.stat.go.jp/english/data/index.html (accessed June 2019); and respective labor force surveys for other economies.

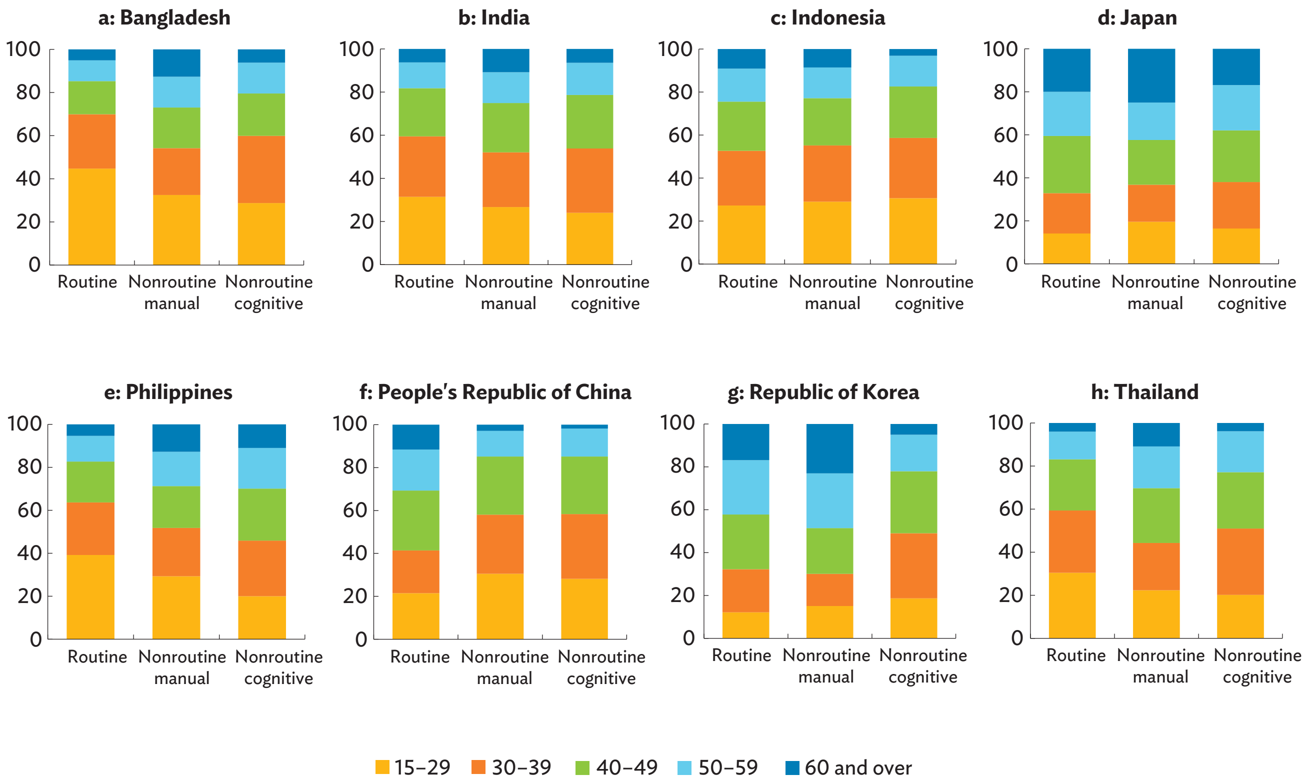
in nonroutine tasks in Japan and 23% for the Republic of Korea, and this is also the case in younger economies, including India and the Philippines.

In some countries, however, adoption of industrial robots and other automation capital makes it easier to retain and involve older workers in handling routine and manual tasks, which traditionally require physical ability and dexterity. This possibly explains the large share of older workers in routine jobs in Japan, the Republic of Korea, and the PRC. Technology use at the workplace may change the landscape of how susceptible jobs and tasks are to workforce aging, which at present varies across occupations (Box 6.1).

While unemployment is low among the elderly, selection bias potentially masks real labor market conditions.

It is not surprising that unemployment is higher among youth than for middle-aged or older workers because youth try different career paths. The median unemployment rate of workers of ages 15–19 across the 35 Asian economies with available data is 14.6%, and 11.9% for ages 20–24 (Figure 6.14). The reported unemployment declines with age, falling to as low as 1% among workforce older than 65. However, low unemployment among older workers does not necessarily indicate that their labor market situation is better. Official unemployment figures do not capture discouraged older jobseekers, leaving the job market for

Figure 6.13: Task Distribution of Employment by Age Group—Selected Asian Economies (%)



Notes: Task categories follow the International Labour Organization's classification of occupations. Routine occupations include clerical support workers, craft and related trades workers, plant and machine operators and assemblers, and elementary occupations. Nonroutine manual includes services and sales workers, and skilled agriculture workers. Nonroutine cognitive includes managers, professionals, and technicians.

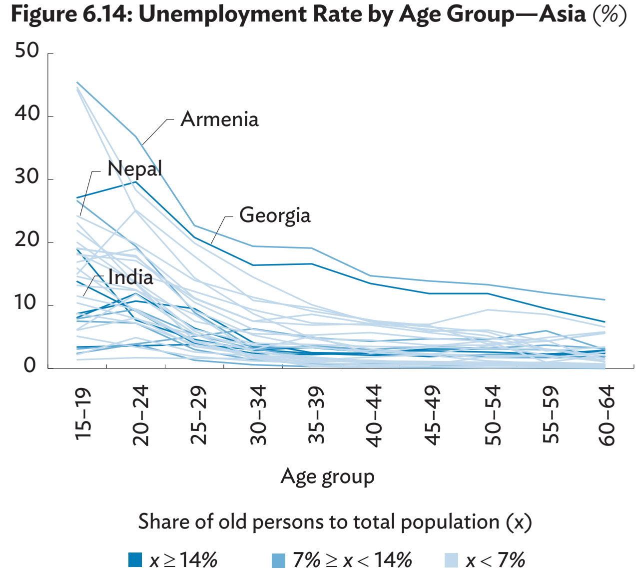
Sources: ADB calculations using data from Government of the People's Republic of China, Ministry of Human Resources and Social Security. China Labour Statistical Yearbook 2016. http://www.mohrss.gov.cn/2016/indexeh.htm (accessed June 2019); Korean Statistical Information Service. https://kosis.kr/eng/ (accessed June 2019); Statistics Bureau of Japan. Employment Status Survey 2018. https://www.stat.go.jp/english/data/index.html (accessed June 2019); and respective labor force surveys for other economies.

involuntary reasons besides declining health and their ability to collect a pension.

Older workers tend to face more difficulty than young ones in finding a new job when they become unemployed.

In Australia, workers of ages 55 and above who found new jobs did so on average 15.9 months after becoming unemployed, double the average 7 months of unemployment for workers of ages 15–24. Extended job searches partially explain the lower labor participation rates among older workers. Rones (1983) pointed out that older unemployed workers are less likely to find jobs than the younger cohorts, and that they are more likely to leave the labor market involuntarily after a prolonged spell of unemployment. Job markets tend to be less responsive to the needs and

Figure 6.14: Unemployment Rate by Age Group—Asia (%)



Note: The color gradient refers to the share to total population of people of ages 65 and above in 2019.

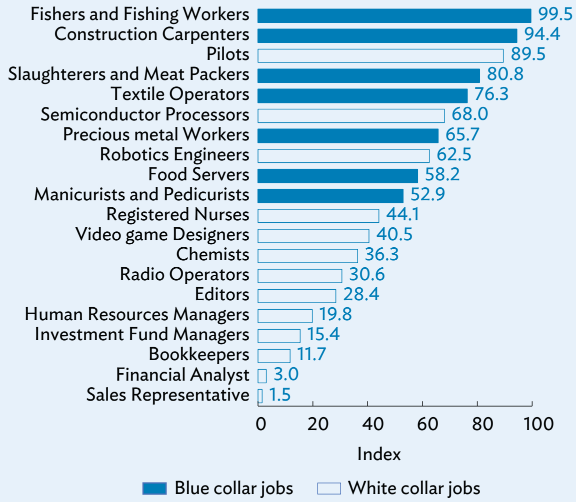
Source: ADB calculations using data from the International Labour Organization. ILOSTAT. https://www.ilo.org/ilostat (accessed June 2019).

Box 6.1: Which Jobs Are More Susceptible to Aging?

Different occupations require different skills and abilities. Since these abilities decline with age at different tempos, the direction and extent of impact of aging can vary substantially across occupations. Belbase, Sanzenbacher, and Gillis (2015) developed a Susceptibility Index that systematically assesses the physical and cognitive skills required for each occupation and the tendency of such skills to decline with age.[a] The study first identifies the cognitive and physical abilities that decline by early to mid-sixties (Box Table).

Occupations are then indexed based on the number of abilities and their importance to the job, where a higher index indicates that the job relies on many abilities that tend to decline early. The index therefore reflects how susceptible an occupation is to declines in ability, and it is found to predict early retirement. The Box Figure shows selected occupations and their susceptibility index percentiles. Interestingly, it shows that some white collar occupations are just as susceptible as blue collar occupations to early ability declines in work. However, blue collar occupations are especially susceptible to early ability declines, such that workers in these occupations are less likely to be able to work to full retirement age as it increases to 67.

Susceptibility Index Percentiles—Selected Occupations



Source: Center for Retirement Research at Boston College. Susceptibility Index. http://crr.bc.edu/wp-content/uploads/2016/04/Susceptibility-Index_April-2016.pdf (accessed July 2019).

Abilities that Show Early Decline

Cognitive	Psychomotor	Physical strength	Sensory
Fluency of ideas	Arm–hand steadiness	Explosive strength	Night vision
Inductive reasoning	Manual dexterity	Dynamic strength	Peripheral vision
Deductive reasoning	Finger dexterity	Extent flexibility	Depth perception
Memorization	Reaction time	Dynamic flexibility	Glare sensitivity
Information ordering	Wrist-finger speed	Gross body coordination	Sound localization
Speed closure	Speed of limb movement	Gross body equilibrium	
Perceptual closure			
Spatial orientation			
Visualization			
Time sharing			

Source: Belbase, Sanzenbacher, and Gillis (2015).

[a] The Occupational Information Network (O*NET), a free online database owned and maintained by the United States Department of Labor that contains occupational definitions, was used to evaluate occupations. After indexing, the Health and Retirement Study (HRS)—a model of early retirement—was used to estimate the likelihood of early retirement for individuals in certain occupations. Read the full paper for deeper explanation of the susceptibility index.

Source: Belbase, Sanzenbacher, and Gillis (2015).

preferences of the older workers who might lack necessary skills and training, among other attributes for employment. Employers are expected to have less desire to take on older workers because their hiring and training costs tend to outweigh the shorter tenure they can expect compared with younger workers (Munnell, Sass, and Soto 2006).

Aside from preference, labor market bias against the older workforce also explains the large representation of older cohorts in casual jobs and self-employment.

Based on the 2018 Labor Force Survey in Japan, 37% of nonagriculture sector employees aged more than 54 were involved in part-time and temporary employment, compared with 24% among the 15–34 cohort. Self-employment is also common among older individuals: 54% in agriculture and 13% in non-agricultural activities. In contrast, in ages 15–34, 13% in agriculture and 2% in nonagricultural activities are self-employed. Data from the 2016 China Labour Statistical Yearbook suggests a very similar pattern in the PRC, with 14.3% of workers of ages 65 and above working less than 20 hours a week, compared with 2.6% for workers aged 20–24. Self-employment is also relatively high among old people, at 8.8% of the employed of ages 65 and above, compared with 3.7% for ages 20–24.

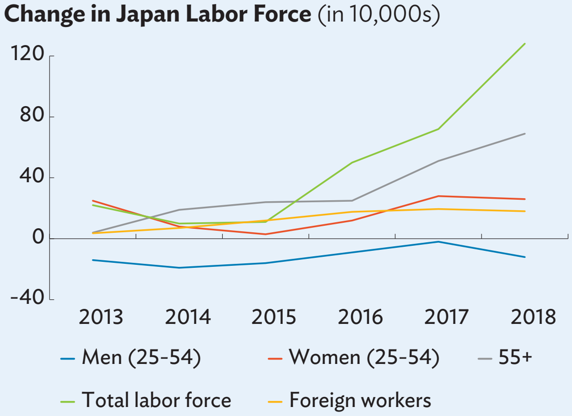
Tapping the latent workforce can offer huge benefits during demographic transition in Asia.

The region, especially among economies at advanced stages of aging, could reap benefits from breaking barriers for women and the older workforce to reenter the labor market (Box 6.2 highlights the case of Japan). Efforts focus

Box 6.2: Japan's Expanding Labor Force in a Time of Population Contraction

The share of the productive-age (15 to 64 years) population in Japan peaked in the middle of the 1990s and has been declining since. It is projected to drop by 28.3% (about 21 million) between 2020 and 2050. Contrary to the demographic scenario, Japan's labor force has grown in recent years. This growth is largely explained by the steadfast rise of older workforce (ages 55 and above) alongside increasing number of female and foreign workers (Box Figure).

Change in Japan Labor Force (in 10,000s)



Note: Labor force data is inclusive of foreign workers.

Source: ADB calculations using Japan Labour Force Surveys (2012-2018) data from e-Stat (Portal Site of Official Statistics of Japan). https://www.e-stat.go.jp/ (accessed August 2019).

The more mature workforce of ages 55 and above has increased from 1.9 million in 2013 to 2 million in 2018. Better health, longer lives, higher education levels, and working in less physically demanding jobs all contributed to their greater participation in the labor force. However, the key drivers behind such trend are major policy reforms: reduced social security benefits and an increase in the eligibility age from 60 to 65. For workers past retirement age, data show that they continue working part-time, and more women do so than men.

Increased female participation can also be explained by policies such as Prime Minister Abe's "Womanomics," aimed at encouraging women, especially mothers with young children, to continue to work. These include programs such as establishing childcare facilities, increasing childcare leave, and enforcing options for shorter working hours. The share of women who continued to work after having a child significantly increased from 15.3% in 2000 to 28.3% in 2014 (Government of Japan, Ministry of Health, Labour, and Welfare).

With labor demand exceeding supply, foreign workers have filled job vacancies largely in construction from 2015 and in nursing-care from 2017. In April 2018, Japan introduced new visa categories for manual workers and skilled blue collar workers, hoping to attract more than 300,000 foreign workers within 5 years. Data from the Ministry of Health, Labour, and Welfare show that the number of foreign workers has increased from 720,000 in 2013 to 1.46 million in 2018.

Sources: Gale (2018); Ip (2019); Nagase (2018); Oshio, Usui, and Shimizutani (2018); and Sato (2019).

at balancing work and family life and other personal needs to incentivize their labor force participation. The size of the untapped older workforce can potentially be large. Using the population-based 2016 Comprehensive Survey of the Living Conditions, Oshio (2018) estimates that about 6.7 million workers of ages 60–74 could have been added to the labor supply, equivalent to 10% of Japan's total labor force in 2016.

The unemployed younger population of some countries belies a need for action on workforce aging.

Several policy agenda items need to be tackled for young economies to better prepare for the inevitable demographic transition to a more mature population. For one, these economies have particularly high youth unemployment, which is even more prevalent among the highly educated. Prolonged unemployment early in a career may render people less employable. Bell and Blanchflower (2011) found that it imposes costs later in their careers including lower pay and higher risk of displacement.

Education Trends and Human Capital

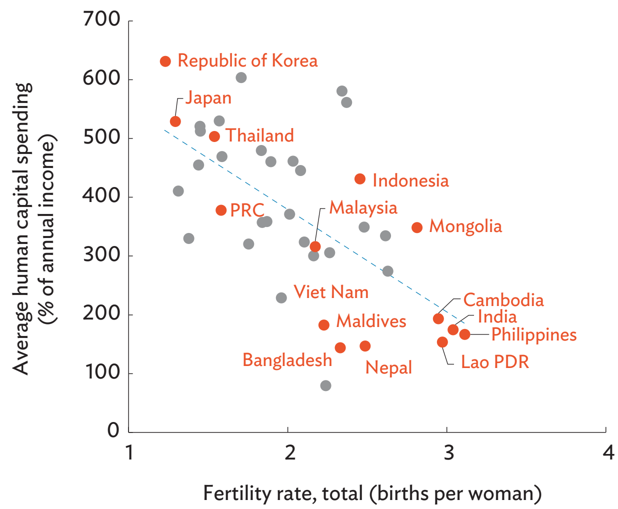
Factors shaping demographic change also influence the level and pattern of human capital development in the region.

The recorded drop in the fertility rate over 4 decades has translated to higher investment in improving children's welfare and potential. Parents decide on the number of children they want to raise in consideration of expected spending on their offspring's education and health, given the potential family income and the availability and quality of the public welfare system. Figure 6.15 gives a broad view of the quantity–quality trade-off that was put forward by Becker (1960), as economies with lower fertility rates spend more on human capital investment per child.

Children are staying in school longer and the gender gap in education has largely closed.

Increased public and private expenditure on education per child, along with other factors, has led to an expansion in schooling years. Between 1980 and 2015,

Figure 6.15: Human Capital Development and Fertility



Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Notes: Red dots refer to Asian economies with available data; gray dots to non-Asian economies. Human capital spending refers to the combined public and private spending per child given per capita health spending for children age 0–17 and per capita education spending for children age 3–26. Total fertility rate refers to births per woman in 2017.

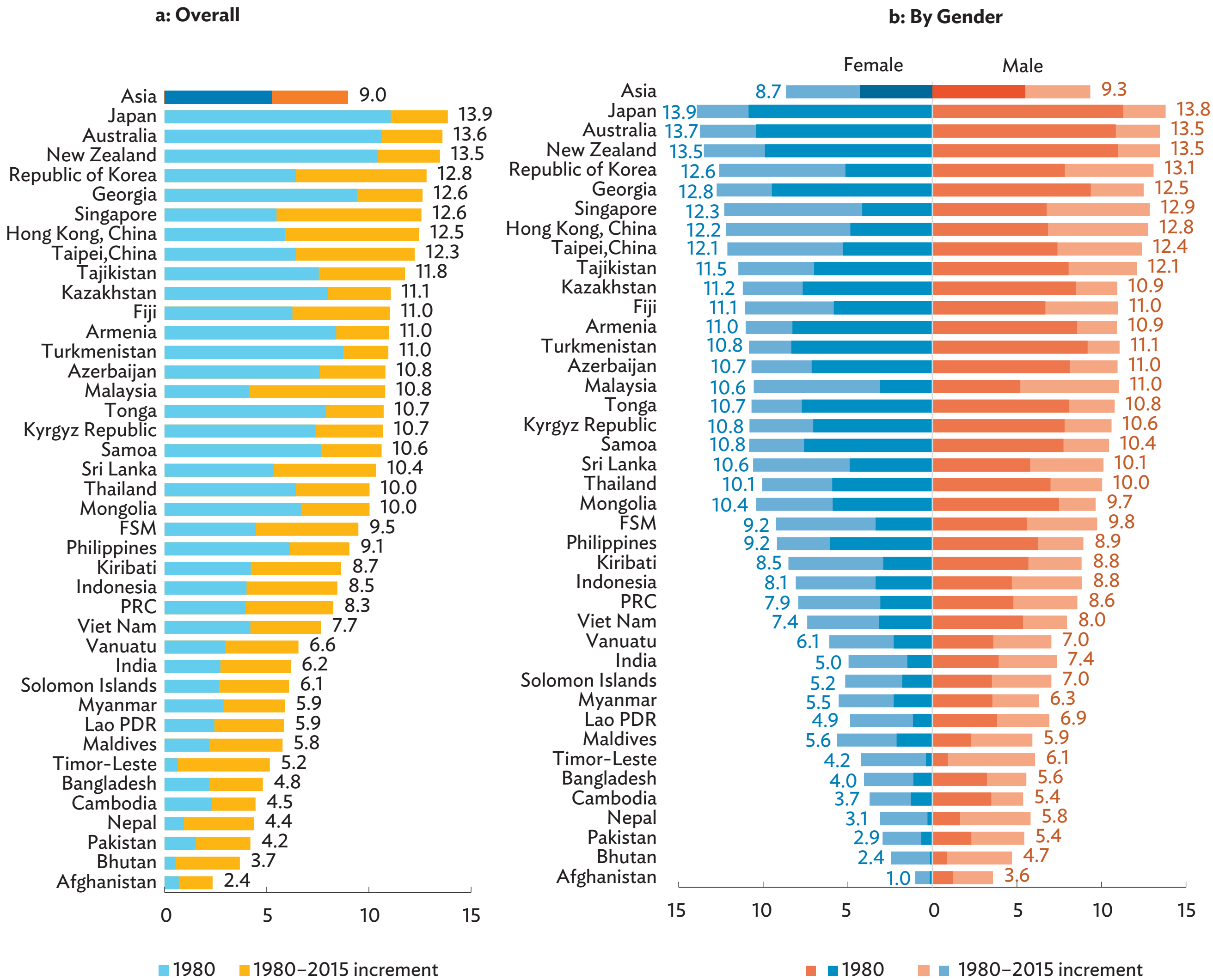
Sources: ADB calculations using data from East–West Center. National Transfer Accounts Data Sheet 2016. https://www.ntaccounts.org (accessed July 2019); and World Bank. World Development Indicators. ttps://databank.worldbank.org/source/world-development-indicators (accessed June 2019).

the average years of schooling among the economically active population (ages 25–64) across Asia increased from 5.2 to 9.0 years (Figure 6.16a). More than half the economies observed 10 or more years of increment in schooling. Another notable pattern of change is the closing of the gender gap in education. Figure 6.16b clearly illustrates how schooling years of females reached the same as males in many economies. In 1980, for ages 25–64, males had had an average of 1.3 years more schooling than females. By 2015, the gap narrowed to 0.7 years, reflecting improvements in Kiribati and Mongolia. Significant change also came about in the Republic of Korea; Singapore; and Taipei,China. This trend is expected to translate into a further reduction in fertility.

Improved schooling among younger cohorts leads to a decline in the share of a less-educated older population.

Figure 6.17 shows the mean years of schooling across all age cohorts in the region in 1980 and in 2015. During the

Figure 6.16: Mean Years of Schooling of Population Ages 25–64 (Number of years)



FSM = Federated States of Micronesia, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Note: Data labels denote the mean years of schooling in 2015.

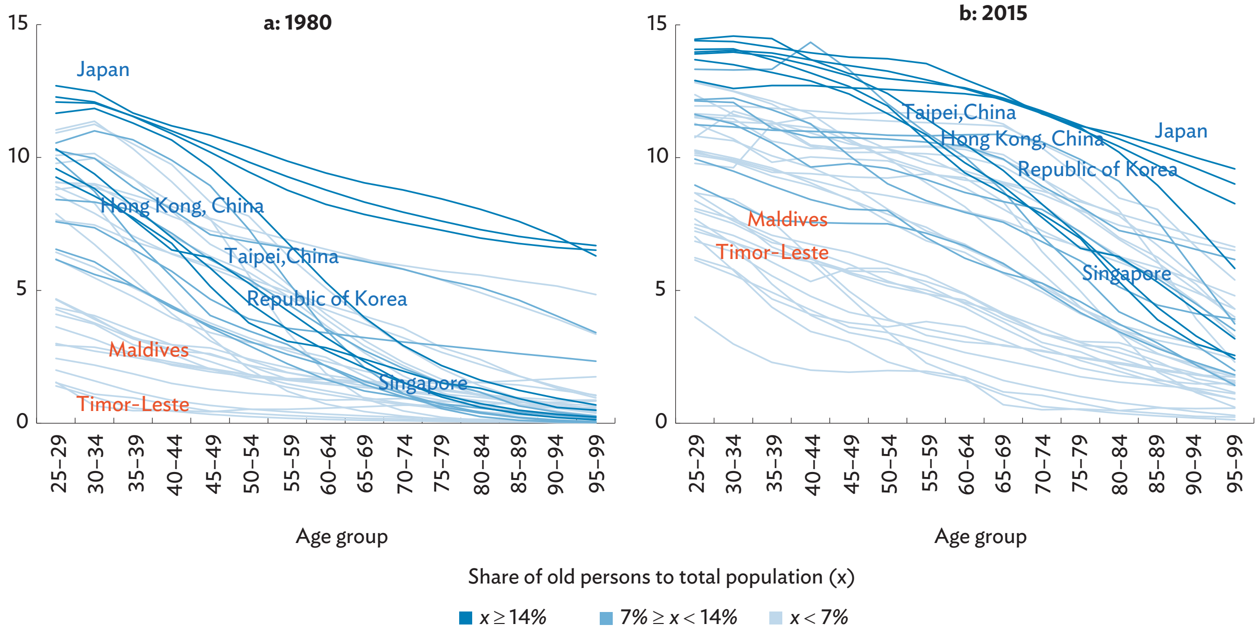
Source: ADB calculations using data from Wittgenstein Centre for Demography and Global Human Capital. Wittgenstein Centre Data Explorer Version 2.0. www.wittgensteincentre.org/dataexplorer (accessed June 2019).

period, the years of schooling of population of ages 25–34 increased from 7.1 years to 10.2 years. Greater improvement is witnessed among the old. The years of schooling among older cohorts of age 55–64 have extended from 3.4 years in 1980 and 4.6 years in 1990 to 7.8 years in 2015, reflecting expansion of basic education in their youth. Correspondingly, the share of people ages 55–64 with highest attainment of primary schooling decreased from 89.1% in 1980 to 58.1% in 2015.

Nevertheless, the schooling gap between the young and old remains wide and visible.

This is particularly true among economies that have quickly climbed the education ladder. In 2015, Singapore and Taipei,China both exhibited a 7 years gap in average years of schooling between the age groups 25–29 and people in their seventies. The education gap also remains high in countries that have increased enrollment in primary to secondary education, such as Timor-Leste

Figure 6.17: Mean Years of Schooling by Age Group—Asia (number of years)



Note: The color gradient refers to the share to total population of people of ages 65 and above in 2019.

Source: ADB calculations using data from Wittgenstein Centre for Demography and Global Human Capital. Wittgenstein Centre Data Explorer Version 2.0. www.wittgensteincentre.org/dataexplorer (accessed June 2019).

(8 years) and Maldives (6 years). In addition, a considerable gap remains in economies with highly educated adults, including the Republic of Korea showing a gap in schooling of 6 years. This trend is apparent in many of the region's economies, and differs only in the extent and speed of such progress. This implies that adult learning will be essential for the older cohorts to remain economically active, especially when the nature of work is rapidly changing with the advancement of technology.

Aging Demographics and Growth Potential

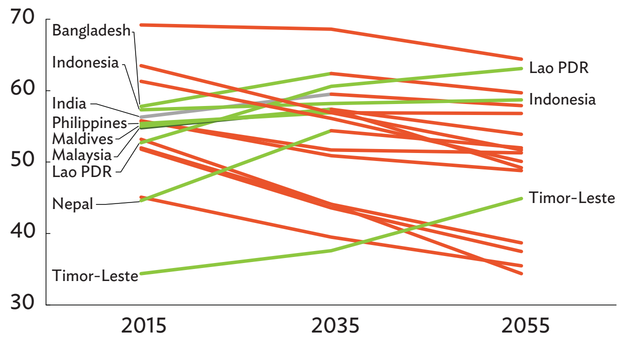
Demographic changes and population growth are historically linked to the speed at which an economy grows, reaping the so-called demographic dividend from labor abundance.

This is especially evident in Asia, where foreign investment boosted growth of strategically targeted countries with an ample supply of workforce. Bloom and Williamson (1998) estimated that workforce expansion explains around a third of the rapid economic growth experienced by the East Asian tiger economies. Bloom and Canning (2004) also validated the positive and significant relationship between rising shares in the working age population and economic growth.

The first demographic dividend is realized when the working population expands at a faster rate than the total.

A growing supply of workers boosts production and income while stimulating consumption and market expansion. Taxes on labor income support public investment and government services that build social and economic infrastructures. For many countries in Asia, a window of opportunity to gain from the first demographic dividend will remain open for several more years before eventually closing. Estimates proxying the dividend with the ratio of producers to consumers, suggest that out of 18 Asian economies, 9 will remain at the stage of reaping the first demographic dividend for 20 years from 2015 (Figure 6.18). These countries are Bangladesh, India, Indonesia, the Lao PDR, Malaysia, Maldives, Nepal, the Philippines, and Timor-Leste (East-West Center 2017). By 2055, the number will fall to three: Indonesia, the Lao PDR, and Timor-Leste.

Figure 6.18: First Demographic Dividend in Selected Asian Economies (Effective number of producers per 100 consumers)



Lao PDR = Lao People's Democratic Republic.

Note: Green line indicates increasing trend, while red line indicates a fall in income per effective consumer.

Source: ADB calculations using data from National Transfer Accounts. Data Sheet 2016. https://www.ntaccounts.org (accessed July 2019).

As countries in the region start experiencing a gradual decline in the share of working age population, their ability to sustain high growth will be challenged.

The transitory bonus from the first demographic dividend should be turned into sustainable assets and investment, realizing a "second demographic dividend." Potential growth relies heavily on labor productivity, which calls for investing in raising the quality of human and physical capital. Such investment can be sourced from accumulated savings and increased demand for wealth in preparation for longer years of retirement amid extending longevity. Lee and Mason (2011) estimate that population aging in developing Asia could lead to substantial capital deepening, where pension assets are expected to rise from 1.2 times total labor income in 2010 to 2.7 times in 2050. For Japan, the study also found that longer life expectancy was accompanied by increasing life cycle pension wealth in the postwar period.

The sequential gain from a demographic dividend does not need to end at the second harvest.

Potential sources of growth in an aging society (the "third" or "silver" dividend) is longevity and longer working life. Harvesting the gain requires tapping previously untapped talents, including those of old men and women, and encouraging continuous learning and upgrading or acquiring new skills. Using the Japanese Study of Aging and Retirement, a longitudinal survey of people of ages 50–70, and considering the extension in years of good health among the old, Matsukura et al. (2018) estimated that more than 11 million Japanese of ages 60–79 years are untapped for the labor force, and they could have contributed 4.5% more in Japan's real GDP in 2010. Households and individuals, facing dramatic extension in healthy life spans over the years, have incentive to invest in human capital—not only in early education, but in lifelong education. The next section takes a close look at how population and workforce aging affect productivity growth and explores ways in which technology can help to reignite growth.

Workforce Aging, Productivity, and the Role of Technology

With rapidly changing demographics, Asia faces contraction in the working age population share, and the growth potential of some economies may be at imminent risk. Aging restricts economic growth in multiple ways, but the biggest concern is slowing productivity (e.g., Maestas, Mullen, and Powell 2016; Aiyar, Ebeke, and Shao 2016). Although economic literature generally points to negative economic impacts of aging, new technologies can help maintain productivity growth and skill augmentation for aging populations.

Aging Effects on the Factors of Production Growth

An aging workforce impacts overall economic productivity.

A changing age profile of the population can affect productivity in many ways. Aging populations can impact inputs into production, which in turn affects overall productivity and future economic growth (Chomik and Piggott 2018). Productivity growth, commonly measured by the growth of output per unit of input, is driven particularly by (i) an increase in the quantity and quality of labor inputs (due to better health and education outcomes, experience, and skills); (ii) increased or technology-enhanced capital (machinery, and equipment, factories, and infrastructure); and (iii) other factors such as technological advance that affect all factors combined (Figure 6.19).

Human abilities and skills change over the life cycle, affecting the quantity and quality of labor.

Population aging is believed to have direct and indirect effects on the quantity and quality of labor, subject to the changes in the age and skill composition of the workforce. The biological effect of aging on physical strength and fitness is somewhat obvious. A range of physical ability and fitness measures such as balance, agility, and muscle strength all fall with age. Figure 6.20 shows that balance and instantaneous power are the fastest to deteriorate in both sexes, though at varying speed. For jobs and industries that require these abilities, productivity can be at risk if the dependence on older workers is growing.

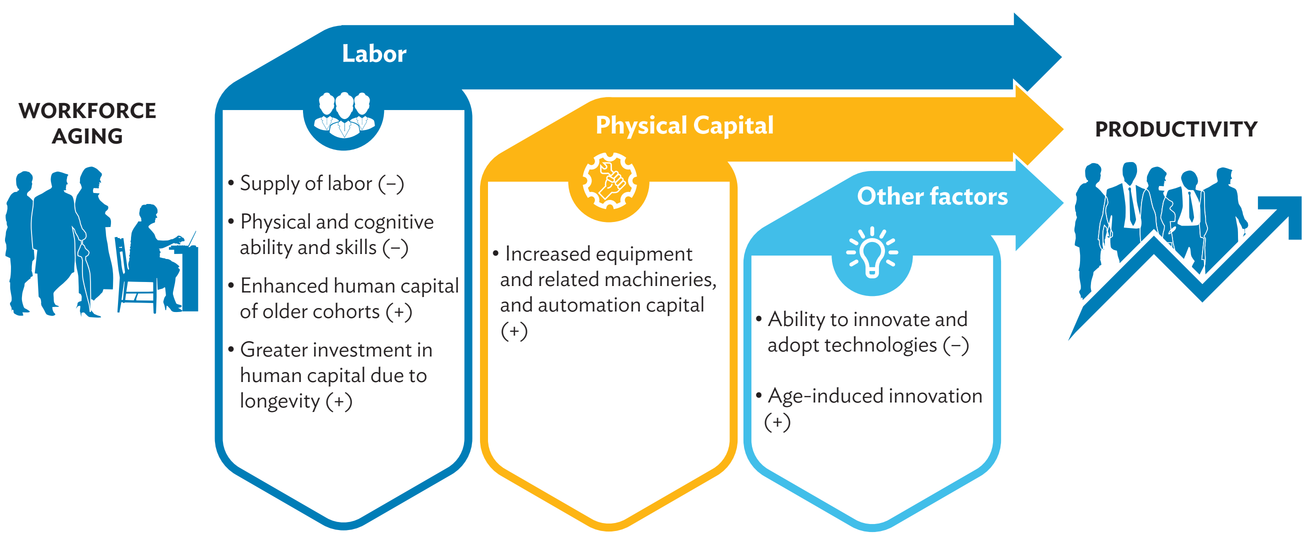
But knowledge-based intelligence is sustained until very old age.

Drawing from a population-based study of 291 individuals of ages 6 to 89, Li et al. (2004) find that fluid intelligence, like problem-solving and pattern recognition skills, goes into steep decline as early as in the twenties (Figure 6.21). Crystalized intelligence, which relates to accumulated knowledge, strategic skills, empathy, and big-picture perspective, is more resilient, and declines only marginally between ages 40 and 60 and beyond (vocabulary, for instance, is shown to continue increasing into very old age). These patterns are broadly consistent across cultures, including in Asia (Park, Nisbett, and Hedden 1999).

Essential work-related skills such as numeracy and literacy decline with age.

Adult skills in numeracy and literacy show an inverted U-shaped pattern over the life cycle, peaking at middle-

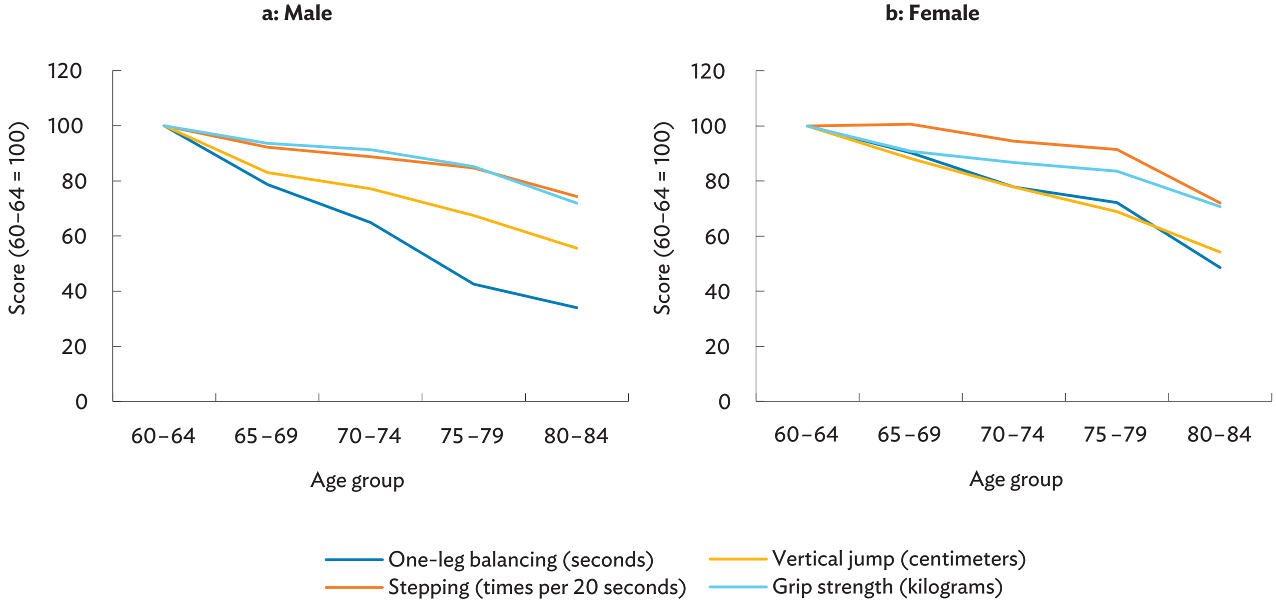
Figure 6.19: Aging Workforce and the Three Factors of Production



+ = positive contributor to productivity growth, – = negative contributor to productivity growth.

Source: Asian Development Bank.

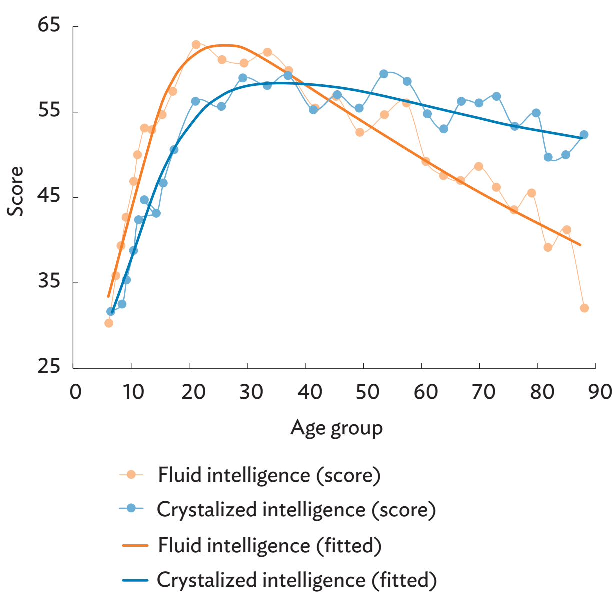
Figure 6.20: Physical Ability and Fitness Level by Age Group: A Case of Japan



Notes: Scores are obtained from a battery of fitness tests including one-leg balancing, stepping, vertical jump, and grip strength performed by 900 Japanese volunteers aged 60 and above. For illustration purposes, calculated raw scores are transformed as index with the score of age group 60–64 equals 100.

Source: Kimura et al. (1989).

Figure 6.21: Cognitive Ability by Age Group Based on Psychometric Tests



Notes: Scores are based on a battery of 15 psychometric tests from the Berlin Aging Study conducted to 356 participants aged 6–89 randomly drawn from a parent sample of 1,920 individuals provided by the Berlin City Registry. Fluid intelligence refers to the composite scores of psychometric tests involving (i) mental mapping, (ii) memory, and (iii) reasoning. Crystalized intelligence is a composite score of tests involving verbal knowledge and fluency. Higher scores indicate higher level of intellectual abilities.

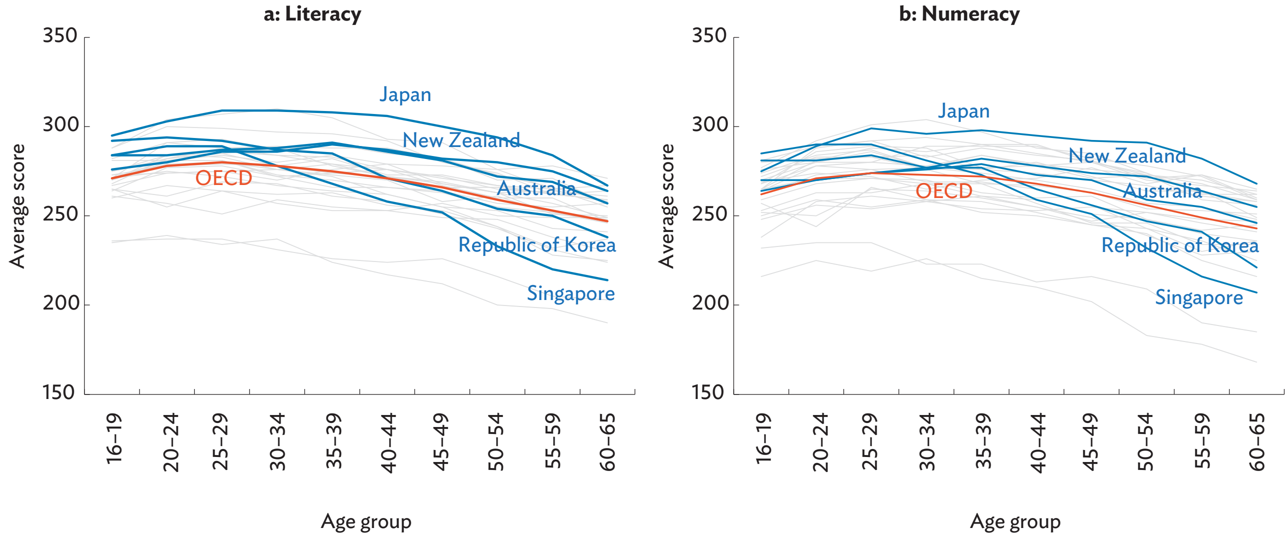
Source: Li et al. (2004).

age, suggesting that the older population are more at risk to skills-related job disruptions (Figure 6.22). Even after controlling for factors that might overestimate differences across age, such as gender, education, and socioeconomic background, the skills gap between the prime age (25–44) and older (45–65) cohorts remains persistent (Paccagnella 2016).

Aging populations may adversely affect innovation and technology adoption of an economy.

As a society ages, the speed of innovation and technology adoption may decline (Weinburg 2004). It is often argued that a healthy share of the young population is favorable to innovation considering the longer investment horizon over their lifetimes, and characteristics relating to risk behavior, creativity, and interactivity (Derrien, Kecskes, and Nguyen 2018). Meyer (2007, 2011) and Wasiluk (2014) show that firms in Germany with a higher share of younger employees are more likely to adopt new technologies, while the older the workforce, the less likely it is that new technologies are adopted. One recent research

Figure 6.22: Literacy and Numeracy Skills by Age Group

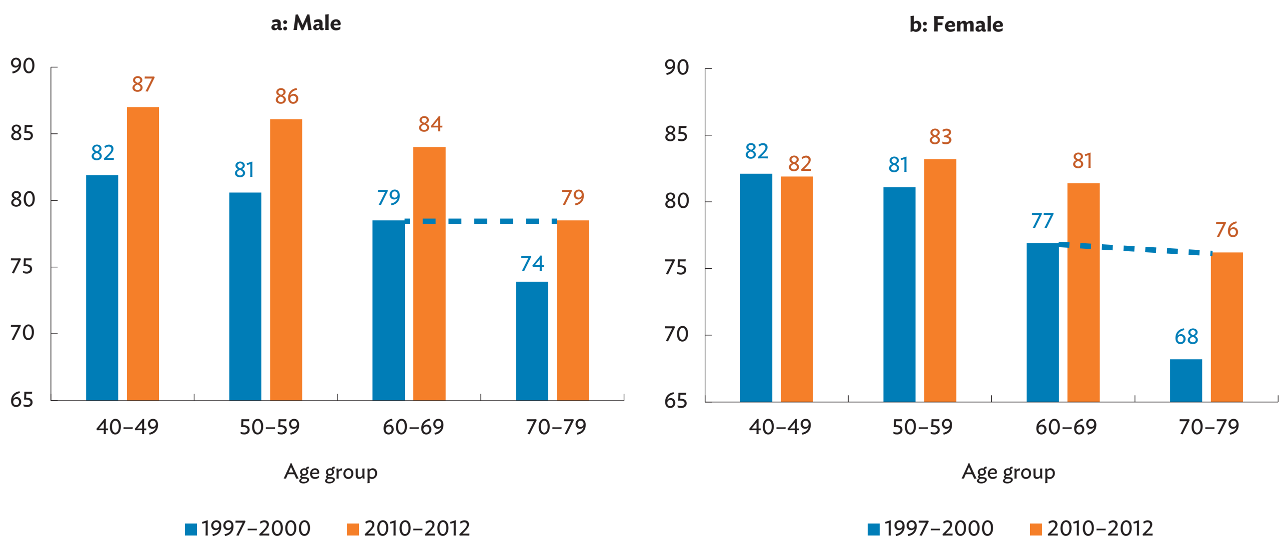


OECD = Organisation for Economic Co-operation and Development.

Notes: Both scores are derived from the direct assessment of 5,000 respondent individuals age 16–65 in each participating country. Literacy evaluates adults' ability to read digital texts (e.g., texts containing hypertext and navigation features, such as scrolling or clicking on links) as well as traditional print-based texts. Numeracy evaluates the ability to use, apply, interpret, and communicate mathematical information and ideas.

Source: ADB calculations using data from Organisation for Economic Co-operation and Development. 2014–2015 Survey of Adult Skills of the Programme for the International Assessment of Adult Competencies. http://www.oecd.org/skills/piaac/data/ (accessed May 2019).

Figure 6.23: Walking Speed of Older Persons—Japan (meters per minute)



Source: ADB calculations using data from National Center for Geriatrics and Gerontology (Japan). http://www.ncgg.go.jp/cgss/english/department/nils-lsa/index.html (accessed July 2019).

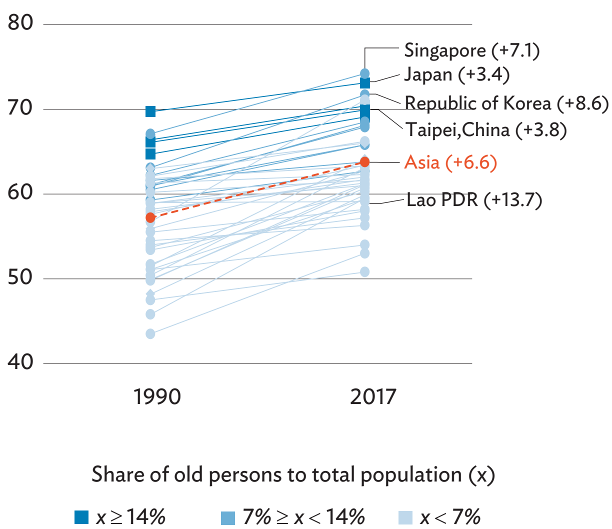
points out that, in aging economies, innovation is depressed because young people lack opportunities to boost entrepreneurship. The chances for youth to learn and acquire business and management skills become slimmer in an aging society where older people linger in senior posts (Liang, Wang, and Lazear 2018).

But today's elderly are different from seniors in the past.

Longitudinal data in Japan suggests that elderly people today may be as much as 10 years younger in biological age as far as walking speed is concerned (Figure 6.23).

Healthy life spans among Asian economies have expanded 6.6 years from 57.2 in 1990 to 63.8 in 2017 (Figure 6.24). A comparative study that translates the improved health status of elderly people into their capacity for work shows that extended years of working life, among men of ages 55–69 can be as much as 8 years and 5.5 years on average among Organisation for Economic Co-operation and Development (OECD) countries, when comparing that cohort between 1977 and 2010 (Coile, Milligan, and Wise 2017).

Figure 6.24: Extension of Healthy Life Span in Asian Economies (number of years)



Lao PDR = Lao People's Democratic Republic.

Notes: Numbers in parentheses refer to the additional years of healthy life span from 1990 to 2017. The color gradient refers to the share to total population of people of ages 65 and above in 2019.

Source: GBD 2017 DALYs and HALE Collaborators (2018).

In addition to improvements in health, the extension in schooling years observed since 1980 (see Figure 6.17) makes today's new older cohorts better educated and therefore, more likely to be equipped with the foundational skills to learn new and emerging skills. Rapid improvement in the human capital of older groups presents an opportunity for society to revisit the conventional definition of "an old person," now benchmarked at ages 65 or above. Box 6.3 discusses how to redefine and quantify the new "old" population.

Longevity and a longer working life will likely induce greater investment in education and skills acquisition among both the younger and older cohorts.

The returns from education are greater when working lives are longer (Bloom, Canning, and Sevilla 2003). Moreover, longer working lives mean skills acquired at a younger age will likely become obsolete at a later age, requiring more adult education and continuous learning. The rapid pace of technological change will also render many of current skills obsolete in the near future (ADB 2018).

Workforce aging can influence the firms' investment decision on the quantity and quality of complementary factors such as capital and resources.

Labor shortages and scarcity of prime age workers can prompt labor-saving capital investment, ultimately raising the productivity of older workers. In the PRC, firms with an aging or declining supply of workers due to the declining working age population are likely to adopt machinery and equipment that strengthen and complement human labor (Ge and Zhang 2019). In Japan's agriculture sector, manual and physical intensive tasks such as plowing, planting, harvesting, processing, and transferring are being automated, allowing old workers to remain in the fields. The average age of farmers in the country was 66.8 years in 2018.[54] Merging of information technology and artificial intelligence has led to further automation (smart agriculture) in the last few decades.

More generally, for countries in the advanced stage of aging, labor-saving (complementing) robots and artificial intelligence are increasingly being adopted. However, such phenomena may be more pronounced in specific

[54] Data from the Government of Japan, Ministry of Agriculture, Forestry, and Fisheries. Agriculture and Forestry Census. http://www.maff.go.jp/j/tokei/sihyo/data/08.html (accessed July 2019).

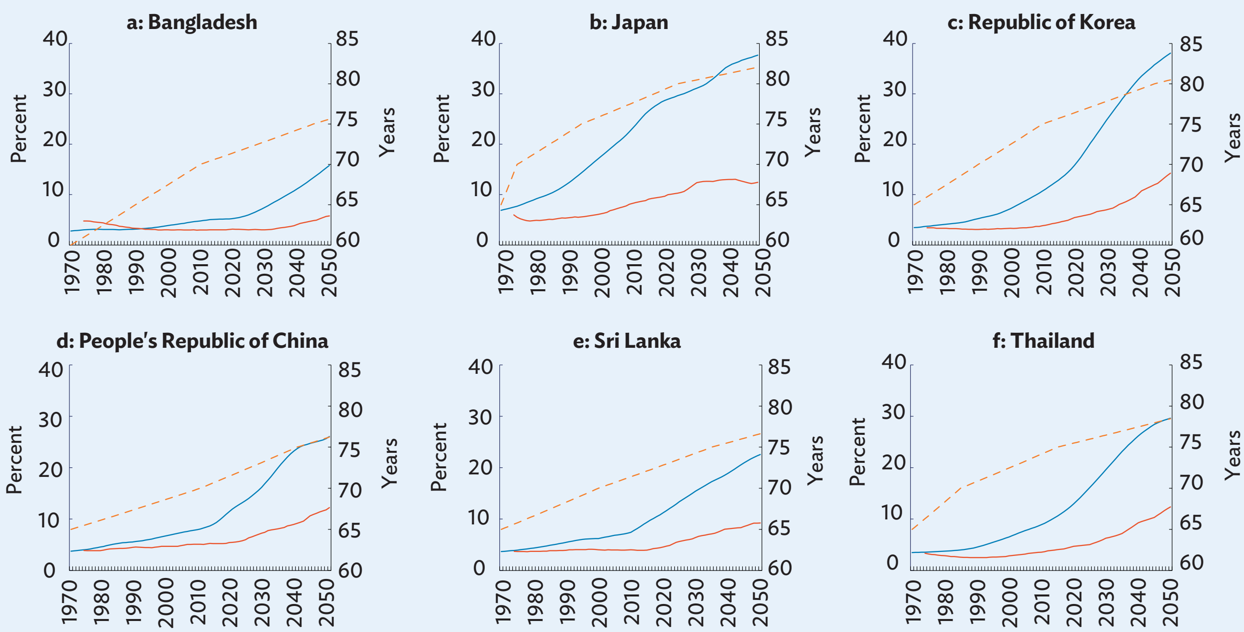
Box 6.3: How Do We Define the "Old Age" Group?

There is a growing debate about how we define "old age" group. An individual is often classified "old" when he/she turns the age of 65, just above the working age of 15 to 64. But when the new cohort of older adults are getting healthier, more educated, and less prone to severe age-related disabilities than the same cohort in the earlier periods, the use of a fixed benchmark to identify the old age group can be questioned.

Sanderson and Scherbov (2007) and Balachandran et al. (2017) bring light to this issue by defining "old" based on "prospective age" in lieu of the chronological age. Individuals should not be considered old just because he or she reached a certain number. Instead, the concept of old should evolve and shift as life expectancy extends and the physical and cognitive functions of older persons improve over time. Sanderson, Scherbov, and Gerland (2017) redefine the "old" applying the "prospective" concept, that is, based on the expected remaining years of life. Accordingly, old persons are those with the remaining life expectancy (RLE) of 15 years or less, which was derived from the observed life expectancy at age 65 from low mortality countries in 1970. With sustained extension of life expectancy, the threshold age at which to consider individuals old will eventually move up over the years.

The Box Figure presents the population shares of "old" persons based on chronological and prospective age along with the threshold old-age in selected Asian economies. In 1970, old persons in the PRC, Sri Lanka, and Thailand are those at around aged 65 and above. In 2019, the threshold old-age increased to as high as 75 in Thailand, 73 in Sri Lanka, and 71 in the PRC. With relatively low life expectancy, 60-year-olds are considered old in Bangladesh in 1970, but improved to 71 in 2019. The share of the "old" to the total population based on prospective age are significantly smaller than what is expected using a fixed chronological age of 65. The charts suggest that countries that will successfully capitalize on longevity through encouraging older persons to remain active and stay employed may undergo a more gradual and possibly smoother transition towards aging society.

Redefining the Old



Share of old population based on "chronological" age (i.e., 65-year-olds and above)
Share of old population based on "prospective" age (i.e., above the threshold old-age)
Threshold old-age, accounting for those with RLE of 15 years or less (rhs)

RLE = remaining life expectancy

Note: Five-year data series on average remaining life expectancy by age group are used in the calculation, and the resulting share of redefined old is smoothed using 5-year moving averages.

Source: ADB calculations using data from United Nations Department of Economic and Social Affairs, Population Division. https://population.un.org/wpp/Download/Standard/Population/ (accessed October 2019).

Sources: Balachandran, et al. (2017); Sanderson and Scherbov (2007); and Sanderson, Scherbov, and Gerland (2017).

industries (such as labor-intensive sectors) or in firms that increasingly rely on older workers, as the decline in saving rates and returns to capital associated with aging generally dampen economy-wide effects.

Population aging may incentivize firms to invest in technology adoption.

More innovation will arise to meet the needs of growing elderly consumers. Workforce aging (or contraction) may encourage firms to invest in innovative technologies that can boost the productivity of the scarce young workforce while accommodating a growing number of elderly workers (Hayami and Ruttan 1984).

Aging Effects on Economic Growth in Aggregate

If age and aging have both positive and negative effects on productivity by impacting the supply of labor, capital, and technology in production, what are the economy-wide net effects on productivity and growth in aggregate? The rich pool of macroeconomic literature presents mixed evidence.

A strand of existing macroeconomic literature finds that a growing elderly population slows down growth.

For example, Lindh and Malmberg (1999) use OECD country data from 1950 to 1990 and find that the increasing share of people of ages 65 and above reduces real per worker GDP growth. Similarly, Aiyar, Ebeke, and Shao (2016) find that growth in the share of workers of ages 55–64 reduces labor productivity growth in Europe. Using US data, Maestas, Mullen, and Powell (2016) find the same negative relationship between aging and state per capita output—a 10% increase in the population of ages 60 and above is associated with a 5.5% decline in the GDP per capita growth rate. Further decomposition analysis shows that only a third of this decline is attributable to a shrinking labor force, while the remaining two-thirds is explained by slower growth of labor productivity. Table 6.1 summarizes related literature.

But another strand of literature notes the positive effect arising from a maturing workforce.

Feyrer (2007) found that a 5% increase in the age 40–49 cohort over 10 years is associated with a 1% to 2% increase in annual productivity over that period. In contrast, an increase in the younger age 15–39 cohort was associated with lower productivity. Results are mostly insignificant and mixed for the older age groups of 50 and above. Liu and Westlius (2017) also find, using prefectural data from Japan, that an increase in the age 40-49 cohort affects total factor productivity (TFP) positively. Where aging is still in progress and workforce growth is not occurring at the extreme end of the age distribution, having a greater share of the workforce in the resourceful, mid-career cohort boosts growth.

This mixed evidence may be partly explained by the fact that despite population aging, the projected demographic change will likely be accompanied by a stable share of workforce in some economies.

The growing share of older population will coincide with a period of continued expansion in the share of working age population if fertility falls rapidly in a short time span (Lee and Shin 2019). For example, the share of working age population in the Republic of Korea has expanded, though at a much slower rate, at the same time as the share of elderly to total population increases toward a more advanced stage of aging (Figure 6.25). This pattern can also be observed in other aging economies of Asia, such as the PRC, Bangladesh, Sri Lanka, Thailand, and Viet Nam. Under this scenario, countries will have at least some time (longer for some than others) to benefit from a healthy supply of economically active workers, even as the elderly population grows. These countries still have an opportunity for increased shares of these productive cohorts to propel economic growth and to make necessary adjustments before they decline.

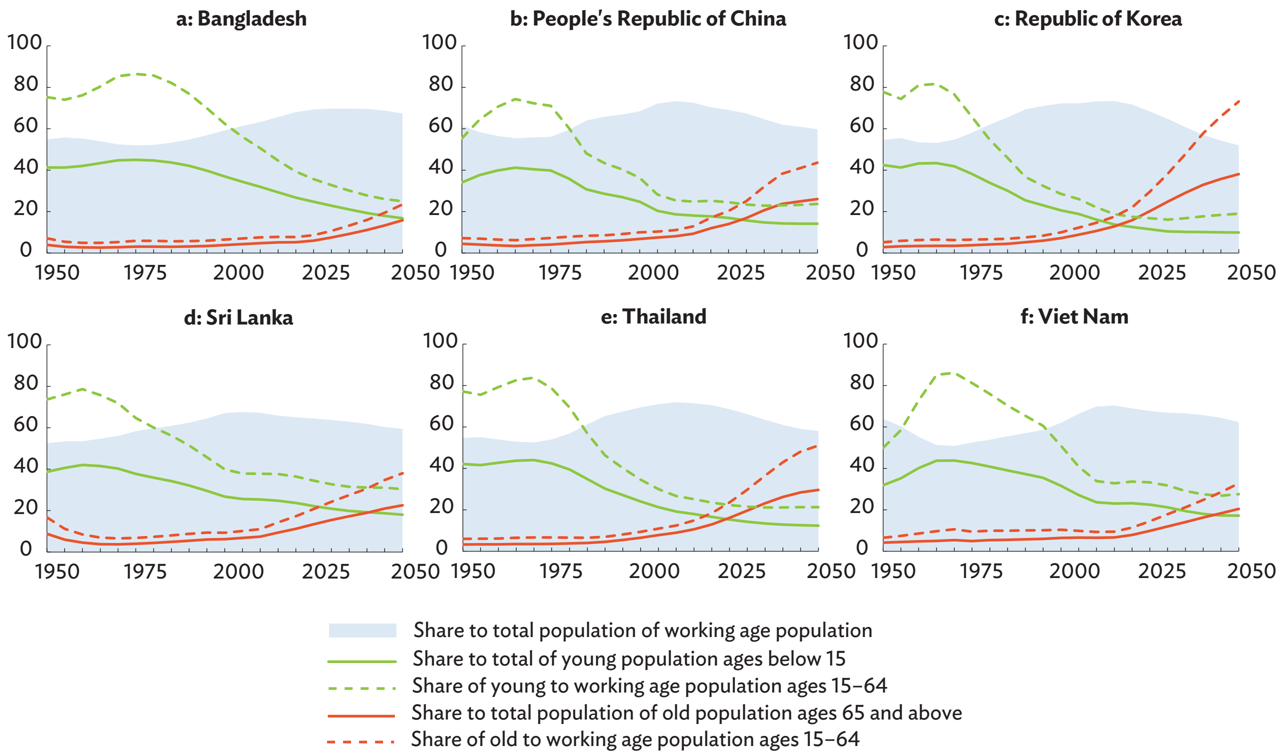
Table 6.1: Aging and Productivity: A Literature Review

Study	Economy and Data Coverage	Productivity Indicator	Demographic or Aging Indicator	Main Results
Lindh and Malmberg (1999)	OECD economies 1950–1990	Real GDP per worker	Change in share to total population of the four age groups: 15–29, 30–49, 50–64, and 65 and above.	• Labor productivity growth declines as share to total population of people ages 65 and above rises. • A 1-percentage point increase in share to total population of ages 50–64 is associated with a 25 to 50 basis-point increase in labor productivity growth. • Labor productivity effects of rise in share of ages 15–29 and 30–49 are ambiguous.
Feyrer (2007)	87 economies 1960–1990	Real GDP per worker	Change in age composition of the labor force at 10-year age intervals: 10–19, 20–29, 30–39, 40–49 (*benchmark group*), 50–59, and 60-above.	• A 5% shift of 30–39 age group to 40–49 group is associated with 15% increase in labor productivity. • Labor productivity lowers as share of workforce ages 15–39 rises. • Insignificant and mixed results for the older age groups of 50–59 and 60–above.
Liu and Westlius (2017)	Japanese prefectures 1990–2007	Prefectural total factor productivity	Share to total working age population (ages 20–69) of 10-year age intervals: 20–29, 30–39, 40–49 (*benchmark group*), 50–59, and 60–69.	• The association of productivity and age follows an inverted U-shaped pattern, peaking at ages 40–49. • A 1-percentage point shift of people in their 30s to 40s increases total factor productivity by 4.4%. • Total factor productivity drops by 1.3% if people in their 40s get older to their 50s.
Maestas, Mullen, and Powell (2016)	US states 1980–2010	State level GDP per capita	Change in share of individuals ages 60 and above to the total population (*considers only individuals aged 20 and above*)	• A 10% increase in the share to state population of individuals aged 60 and above is associated with 5.5% (*IV estimates*) to 8.3% (*OLS estimates*) decline in state per capita GDP growth.
Aiyar, Ebeke, and Shao (2016)	EU28 economies 1950–2014	Real output per worker	Share to the total workforce of ages 55–64	• Labor productivity decreases as share of workers age 55–64 rises. • Main channel identified through which aging workforce dampens growth is lower total factor productivity growth.
Acemoglu and Restrepo (2018)	27 EU economies (19 industries) 1995–2007	Real value added per worker at the industry level	Change in the ratio of workers age above 56 to workers of ages between 21 and 55 from 1990 to 2025.	• A 10-percentage point increase in aging is associated with a 14.5%–17.3% decline in value added per worker. • Adoption of automation technologies helps industries gain higher productivity in the face of aging workforce.
Liang, Wang, and Lazear (2018)	57 economies (31 non-OECD) 2001–2010	Entrepreneurship rate	(i) Cohort shrink rate (derived by relating the size of ages 45 to another cohort), and (ii) Median age (20–64)	• Aging slows entrepreneurship when older workers limit skills acquisition among younger workers. • One standard deviation decrease in median age increases new business formation by 2.5 percentage points.

EU = European Union, GDP = gross domestic product, IV = instrumental variable, OECD = Organisation for Economic Co-operation and Development, OLS = ordinary least squares, US = United States.

Source: ADB compilation.

Figure 6.25: Population and Dependency Ratios—Selected Asian Economies (%)



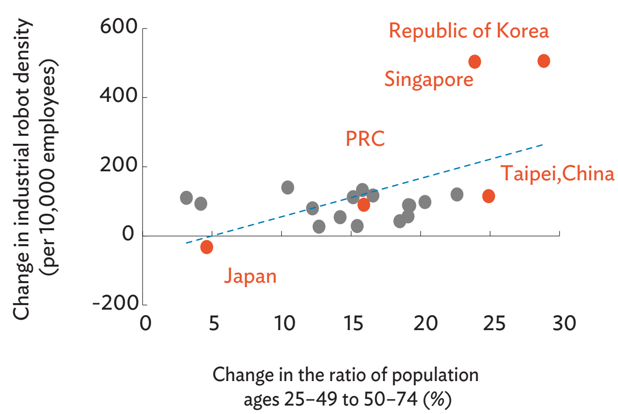
Source: ADB calculations using data from United Nations Department of Economic and Social Affairs, Population Division. Population Database. https://population.un.org/wpp/Download/Standard/Population/ (accessed June 2019).

In addition, recent literature offers new insight into how technology can alter the ways population aging affects productivity.

Recent literature argues that the relative scarcity of a productive age workforce can prompt technological innovation and adoption that sustains productivity growth. Figure 6.26 suggests that the growing share of more mature workers (ages 50–74) relative to younger workers (ages 25–49) during the past decade is accompanied by increasing use of industrial robots in manufacturing.

Acemoglu and Restrepo (2018) claim that population aging can promote productivity growth by encouraging more active adoption of robot technology. Theoretical and empirical evidence shows that aging leads to more intensive use and development of robots. Using US data, they find that robots substitute for middle-aged workers

Figure 6.26: Workforce Aging and Industrial Robot Adoption, 2007–2017



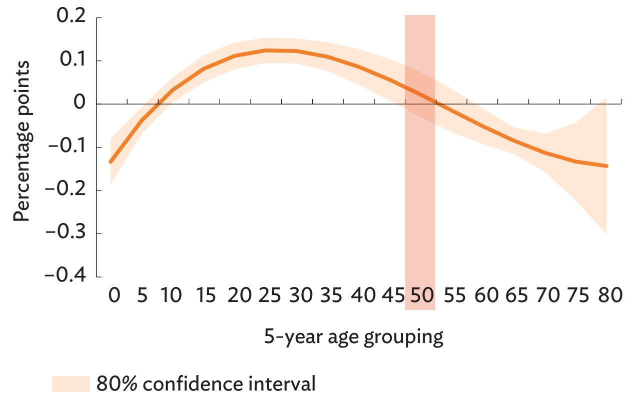
PRC = People's Republic of China

Note: Red dots refer to Asian economies with available data; gray dots to non-Asian economies.

Sources: International Federation of Robotics. Statistics. https://ifr.org (accessed July 2019); and United Nations Department of Economic and Social Affairs, Population Division. https://population.un.org/wpp/Download/Standard/Population/ (both accessed June 2019).

while industries amenable to automation witness rising productivity. Abeliansky and Prettner (2017) provide a theoretical model that predicts countries with low population growth will introduce automation technologies earlier than those with high population growth, with supporting empirical evidence from 60 countries over 1993–2013. They find that a percentage-point increase in population growth is associated with a 2% reduction in the growth of robot density. In a study of robot adoption in 17 countries from 1993 to 2007, Graetz and Michaels (2018) find that increased robot use contributes to labor productivity and TFP and lowers output prices. Aiyar, Ebeke, and Shao (2016) find that government investment in research and development offsets the negative effect of a percentage-point increase in workforce aging by about 0.35 percentage points (i.e., from a roughly 0.7 decrease in TFP growth).

Figure 6.27: Relative Contribution to Per Capita GDP Growth by Age Cohorts



GDP = gross domestic product.

Notes: Derived from the fixed effects estimates (see Annex 6a for details on the methodology). In the horizontal axis, 0 represents the age group (0,4), 5 represents the age group (5,9) and so on. Shaded area in red represents the threshold old-age cohort that positively contributes to growth.

Source: Park, Shin, and Kikkawa (2019b).

The Age Cohort Effects on Growth

Population aging can trigger a mixture of positive and negative impacts on growth depending on the stage of aging and the age distribution of the population.

Following the estimating equation from Fair and Dominguez (1991) using the whole age-distribution of the population of a country as a regressor, relative age group contribution to per capita GDP growth is derived from a panel of 170 countries in years 1965–2015 (Annex 6a details the methodology based on Park, Shin, and Kikkawa 2019b).

Figure 6.27 illustrates the estimated relative contribution of different age groups to per capita GDP growth. The results suggest that the increase in the share of the age cohorts of 10 to 54 push up a country's economic growth, with incremental contribution plateauing at 25–34 age brackets. The contribution to growth then slows down and becomes negative for cohorts of ages 55 and above. Overall, a change in age distribution that increases the elderly population and decreases the working age population is expected to dampen economic growth. In this estimation, expansion of age cohorts below age 10 will also have negative impact on growth. This implies that with a sharp fall in fertility, the effects aging will have on growth can be positive at the early stage. The inverted U-shape relationship between age cohorts and growth mirrors that of worker's age and productivity presented in earlier section.

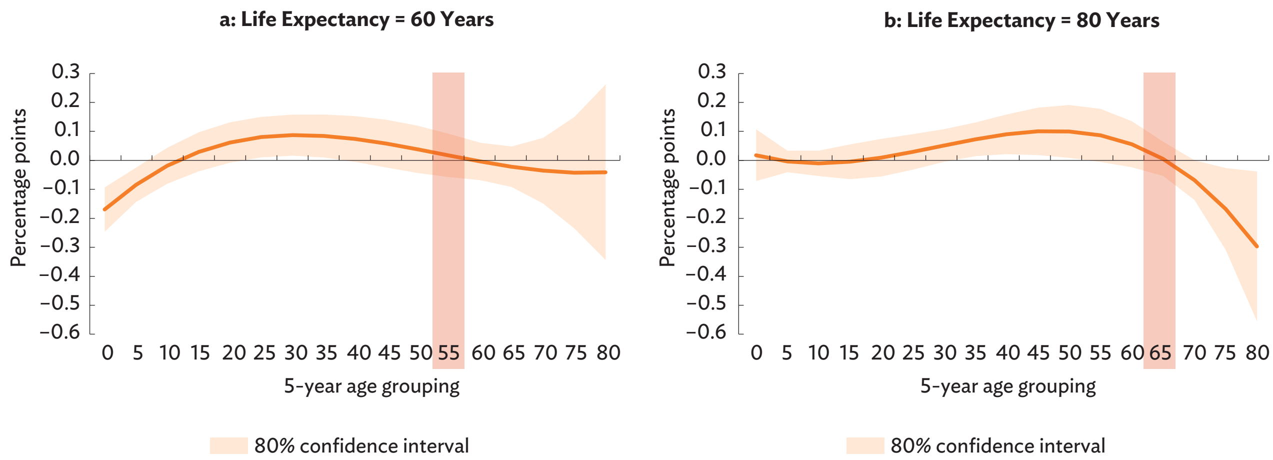
Can Technology Mitigate the Effect of Aging on Growth?

Simulation analysis shows that technology helps extend productive contributions of older workers.

An extended version of the above analysis is used to examine whether the degree of technological adoption in a country alters the way population aging affects economic growth. Two proxies for technological progress are used: life expectancy, which extends with the advances in medical sciences and biotechnology, and the level of TFP, reflecting the degree of technological adoption. Each of these variables are interacted with aging indicators to evaluate if they can help mitigate the negative effects of population aging.

Figure 6.28 shows the relative contribution of different age cohorts to growth under two scenarios: low life

Figure 6.28: Relative Contribution to Per Capita GDP Growth by Age Cohorts with Interactions: Life Expectancy



GDP = gross domestic product.

Notes: Derived from the fixed effects estimates (see Annex 6a for details on the methodology). In the horizontal axis, 0 represents the age group (0,4), 5 represents the age group (5,9) and so on. Shaded area in red represents the threshold old-age cohort that positively contributes to growth.

Source: Park, Shin, and Kikkawa (2019b).

expectancy of 60 years and high life expectancy of 80 years. The contributions to growth across the range of age cohorts in both cases show an inverted U-shape. But under the low life expectancy scenario, the productive cohorts are between ages 15 and the late 50s while an extension of life expectancy to 80 years shifts the curve further to the right, generating a positive contribution of workers as old as those in the 65–69 age group. In addition, growth contribution stays positive for old workers until their early 60s under the extended life expectancy compared with a negative contribution to growth by workers of age 55 and above in the shorter life expectancy scenario. In other words, the extension of healthy life span and longer working life will allow countries with growing shares of relatively older cohorts in their 60s to maintain growth.

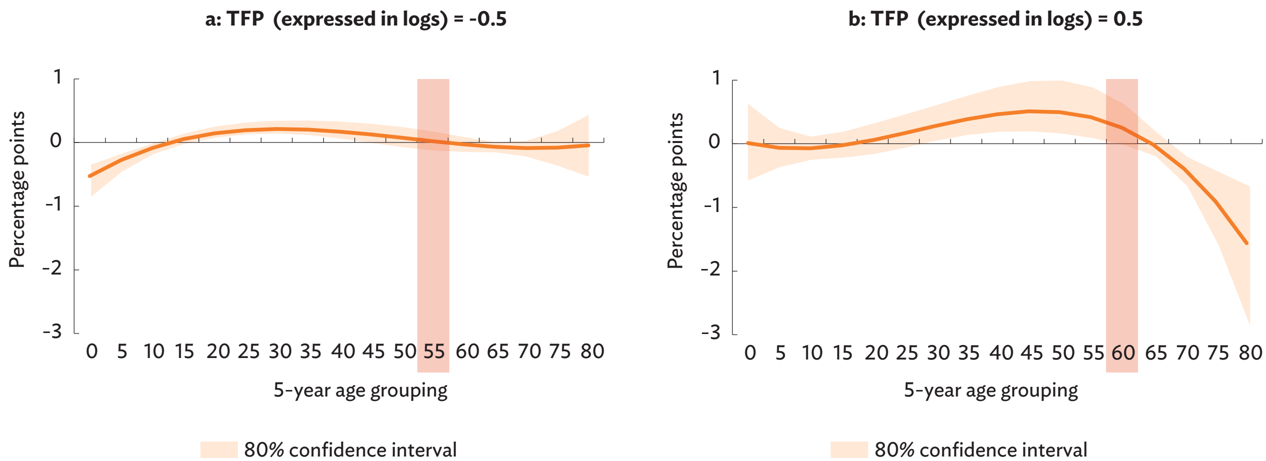
The degree of technological adoption of a country proxied by TFP also seems to affect the relative contributions to growth by different age cohorts (Figure 6.29). Comparing the scenarios between low TFP (in log) at −0.5 and high TFP at 0.5, the difference is visible in the growth contribution of the age group between the 30s to the 60s. A percentage increase in the share of these age cohorts can boost their contributions to growth up to 20 times larger in high technology adoption scenario than in low adoption case. Like the case of life expectancy, the high TFP scenario extends the productive years by 5 years. Interestingly, in the high TFP scenario, the age threshold for one to make positive contribution to growth will also be raised. This implies that more years of education would be needed for the youth to be productive in such scenario.

Country Case Studies and Policy Implications

Whether technology adoption mitigates the negative consequences of population aging depends on factors such as labor intensity of industry, types of technologies, private sector responses, and policy environment.

Country-specific cases from the Republic of Korea, Japan, and the PRC suggest more granular interplays between aging, technology adoption, and productivity (Ge and Zhang 2019; Kawaguchi and Muroga 2019; and Park, Shin, and Kikkawa 2019b). Whether and how technology adoption helps sustain growth amid an aging population depend, among other factors, on (i) specific characteristics of the industry such as the labor intensity of the sector, (ii) the types of technologies to be

Figure 6.29: Relative Contribution to Per Capita GDP Growth by Age Cohorts with Interactions: TFP



GDP = gross domestic product, TFP = total factor productivity.

Notes: Derived from the fixed effects estimates (see Annex 6b for details on the methodology). In the horizontal axis, 0 represents the age group (0,4), 5 represents the age group (5,9) and so on. Shaded area in red represents the threshold old-age cohort that positively contributes to growth.

Source: Park, Shin, and Kikkawa (2019b).

adopted, (iii) responses from the private sector, and (iv) the policy environment. Box 6.4 summarizes the main findings of the three case studies.

In the Republic of Korea, the relatively high labor intensity in textiles and construction enables these sectors to benefit from robot adoption by boosting the productivity of older workers. In the PRC, aging-induced technology adoption is evident only in labor-intensive sectors, not in capital-intensive ones.

Adoption of industrial robots helps improve the productivity of older workers in selected industries in the Republic of Korea, but that effect is not significant in Japan and the PRC. Interestingly, the mitigating role of technology on aging-induced productivity slowdown holds true in the PRC among relatively low-tech capital, such as machinery and equipment and also in research and development (R&D) expenditures. In Japan, the adoption of information and communication technology equipment showed a very small but significant association with the degree of workforce aging.

Varying firm responses also influence the mitigating role of technology adoption. Industries dependent on older workers react differently: they may either install industrial and service robots or move operation to countries with relatively young population. In Japan, the latter case possibly explains why the intensive technology adoption is not met with an equivalent increase in domestic productivity. Data show that Japan's robot exports are growing and are reportedly shipped to overseas manufacturing plants of Japanese companies in developing countries.

The policy environment shaping labor market conditions and technology adoption also matter if countries want to capitalize on technology's potential to mitigate the aging effect. The case of the Republic of Korea suggests how labor market rigidities partly explain the rapid adoption of automation and robots in some industries. These rigidities also seem to explain why some industries are unable to capitalize on certain technologies.

Box 6.4: Technology Adoption and Its Implications on Economic Growth in Aging Asia: Case Studies for Japan, the People's Republic of China, and the Republic of Korea

Using firm or industry-level data of Japan, the Republic of Korea, and the People's Republic of China (PRC), country-specific case studies attempted to answer the following questions (see Annex 6b summarizing the data and methodology):

- What is the effect of aging on productivity growth?
- What is the effect of aging on technology adoption?
- What is the effect of aging and technology adoption on productivity growth?

Republic of Korea

Using industry-level information on productivity (from the Bank of Korea and Korea Productivity Center) and robot adoption (from the International Federation of Robotics dataset), Park, Shin, and Kikkawa (2019a) find that aging is negatively associated with labor productivity or TFP growth. Evidence also points that the mitigating role of robot technology adoption applies strongly on labor-intensive or non-automobile industries. Further, results show how labor market rigidity can limit the interplay anticipated between technology adoption, the age distribution of the workforce, and productivity.

The study finds no evidence that robots are more heavily adopted in industries with an older workforce. While robot technology does not directly contribute to higher productivity growth, findings suggest that robot adoption can alleviate the negative impact of aging by reducing the adverse impacts on productivity growth from workers in their fifties and sixties, possibly by complementing their abilities.

Japan

Using the Japan Industrial Productivity database to capture labor productivity and the Cabinet Office's Survey of Orders Received for Machinery to capture technology adoption, Kawaguchi and Muroga (2019) find that an aging workforce is negatively associated with labor productivity growth—a 10% increase in the older workforce is associated with a 3% reduction in labor productivity growth. The study also finds no association between an aging workforce and industrial robot purchases, indicating that an aging workforce does not promote industry-wide technology adoption. Although the purchase of electronic machines is positively associated in a statistically significant way, the magnitude is limited.

Interestingly, the study finds no evidence of the mitigating role of technology adoption (proxied by shipments of industrial robots or computers) in Japan despite the country being at the forefront of robot technology and population aging. One possible explanation, which deserves more empirical inquiry, is the influence of Japanese companies' active foreign direct investment, especially the relocation of production sites in neighboring Asian countries with ample young and cost-efficient labor and growing market. Growth of robot exports are anecdotally destined to Japanese-owned plants located in Asian countries.

People's Republic of China

Using the Annual Survey of Industrial Firms and population censuses, Ge and Zhang (2019) find positive effect of population aging on GDP per capita, possibly capturing the benefit of the increased share of mature and experienced workers. Considering the extremely low density of robot use in many industries and minute cross-industry variation in aging, the study could not identify any relationship between adoption of robotics and population aging in the PRC.

Using firm-level capital–labor ratio and research and development (R&D) spending to capture technology adoption, the study finds systematic evidence that population aging has significant and sizable positive effects on firm-level economic outcomes. Evidence also indicates that technology adoption in the form of increases in capital–labor ratio and R&D investment offset the potential negative effects of population aging on productivity.

Sources: Ge and Zhang (2019); Kawaguchi and Muroga (2019); and Park, Shin, and Kikkawa (2019a).

Technology Options for Graying Asia

Technology could play a key role in sustaining productivity growth amid population aging by enabling countries and firms to mitigate the challenges posed by a shrinking and aging workforce. Technologies historically have been labor-saving and making production more efficient, but recent studies also point to population aging as a factor inducing the adoption of new and advanced technologies. These "age-conducive" technologies can be broadly classified into five categories—technologies that (i) substitute labor and skills; (ii) complement labor and skills; (iii) aid education, skills development, and lifelong learning; (iv) improve matching workers with jobs and tasks; and (v) extend life and healthy life expectancy. This section provides in-depth, real-world examples of technologies under each category and examines their contribution to productivity and growth.

Interactions of Technology with Aging

Aging population induces technology adoption, which enhances capital accumulation and productivity.

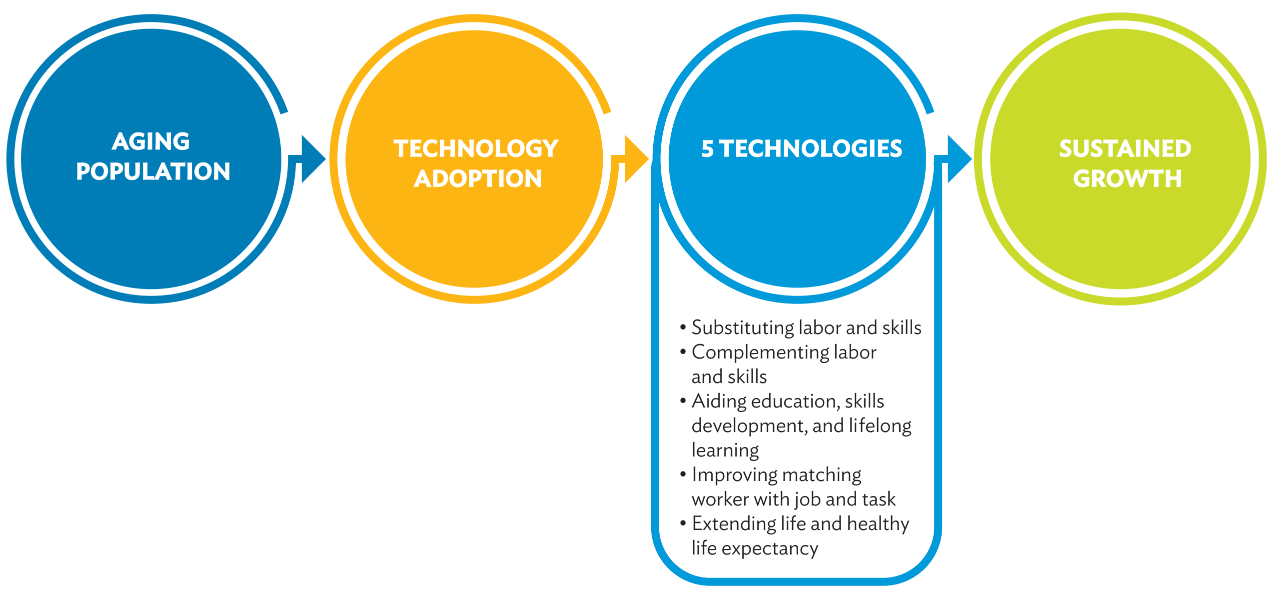
Growing literature since the seminal work of Abeliansky and Prettner (2017) and Acemoglu and Restrepo (2017, 2018) incorporate workforce aging as an endogenous factor in directing technological changes (Figure 6.30). An aging population induces technology adoption, which in turn improves human and physical capital efficiency and productivity—and therefore future economic growth.[55]

Five Ways Technology Enhances Productivity

There are a wide range of technologies that can enhance productivity of labor and capital amid population and workforce aging. These can be classified into five groups based on its purposes.

Tech Group 1 addresses a shrinking workforce by substituting labor and skills with automation capital to save on labor inputs and reduce human error (Figure 6.31). These are supported by key innovations such as artificial intelligence (AI) or internet connectivity that boosts productivity of existing capital in many businesses. *Tech Group 2* can complement labor and skills by providing tools and platforms to perform tasks more efficiently, as exemplified by physical augmentation, remote office, and online collaboration tools. *Tech Group 3* includes online learning platforms and communities, which improve human capital by

Figure 6.30: Framework on Aging and Growth



Source: Asian Development Bank, expanding the framework of Acemoglu and Restrepo (2018).

---

55 More precisely, Acemoglu and Restrepo (2018) states that productivity growth is expected in industries where the involved tasks and the age profile of the workforce is amenable to automation.

Figure 6.31: Ways Technology Enhances Factors of Productivity

Source: Asian Development Bank.

facilitating education and skills development and promoting lifelong learning. *Tech Group 4* uses Big Data algorithms to improve the match between workers and jobs or tasks. *Tech Group 5* are devices and advances in health and medical science that contribute to extending longevity and healthy life spans.

The first group of technologies, exemplified by AI-powered industrial and service robots, can minimize the input requirement for scarce labor and skills and help sustain productivity.

Technologies that save on scarce labor bring substantial benefits where the workforce is contracting and aging. Emerging automation technologies such as industrial robots help substitute labor not only for physical and routine tasks but also for the types of works that involve cognitive tasks thanks to the advancement in AI and the applications tools (Box 6.5).

Industrial and Service Robots

Robot adoption is high among aging economies in the region, contributing to increased productivity by automating tasks and allowing workers to concentrate on tasks that require human presence and intelligence.

Automation of production and service provision is an essential solution for countries and firms facing a contracting and aging workforce, and an industrial robot[56] is one of the most sophisticated forms of automation capital. Aging Asia, as the supply chain hub of the world, has the largest number of industrial robots at 262,000 units as of 2017 (equivalent to 70% of world's total), and

[56] The definition of industrial robots as per International Federation of Robotics (IFR), based on the International Organization for Standardization (ISO), is an "automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes."

Box 6.5: Artificial Intelligence and Its Application in the Workplace

Artificial intelligence (AI) is the ability of computers or computer-controlled robots to simulate intelligent human behavior, which includes the ability to adapt to changing circumstances (Marr 2018). AI is a versatile technology that is adopted in all five types of "age-conducive" technologies to automate business processes and boosts workforce productivity. Generally, the use of AI in routine tasks allows a company to focus on other success drivers, such as creativity and collaboration.

Office tasks, such as information gathering, analysis, and reporting processing are increasingly being automated through robotics process automation (RPA), which uses software with AI and machine learning capabilities. RPA automates repetitive human tasks, thereby reducing human error, increasing efficiency, and freeing employee time for higher-value work (IBM). Deloitte's global survey of organizations that use RPA showed improved compliance (92%), improved quality or accuracy (90%), improved productivity (86%), and reduced costs (59%) (Wright, Witherick, and Gordeeva 2018). The data also showed that returns on RPA investment can be seen in less than a year and average to an additional 20% full-time equivalent capacity. Other major applications of AI at the workplace include image recognition and language translation or processing (e.g., chatbots).

For agriculture and aquaculture, AI use has had a significant impact on productivity. AI is used to make predictions about the environment, determining the best times to harvest, fertilize, and irrigate using sensors that gather vital farming information such as soil moisture, leaf wetness, light, wind, and rain (Ho 2018). In Asia, these technologies are timely, considering the rising average age of farmers.

Autonomous vehicles, another key application of AI, provide the mobility that most seniors need by enabling them to visit family, meet friends, or continue working (see Box 6.8). Lastly, in industries such as manufacturing, where older workers accumulate skills and precision, AI can facilitate the transfer of advanced skills from experienced older workers to younger ones by offering mentorship and apprenticeship programs (Schwartz et al. 2018).

Sources: Ho (2018); IBM. What is Big Data Analytics? https://www.ibm.com/analytics/hadoop/big-data-analytics (accessed July 2019); Marr (2018); Schwartz et al. (2018); and Wright, Witherick, and Gordeeva (2018).

is expected to grow further to 463,000 units by 2021.[57] The PRC tops with 137,900 units in 2017, followed by Japan (45,600 units), and the Republic of Korea (39,700 units)(Figure 6.32). In robot density (i.e., for every 10,000 employees), the Republic of Korea leads the region with 710 units, while Singapore has 658 units.

The economic benefit of robot adoption is large. Arbulu et al. (2018) estimate productivity gains of 10% to 50% amid adoption of robots in six countries of the Association of Southeast Asian Nations: Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam.[58] Overall equipment effectiveness, the standard in measuring manufacturing productivity which accounts for quality (i.e., good parts), performance (i.e., as fast as possible), and availability (i.e., no stop time), increased by 10% to 20%. Huge gains can be expected in electronics, chemicals (including oil and gas, and mining), consumer goods, food, and pharmaceuticals through reduction in equipment downtime, improvement in equipment lifetime, and reduced maintenance costs leading to quality products.

Service robots[59] are revolutionizing business processing, construction, and care facilities.

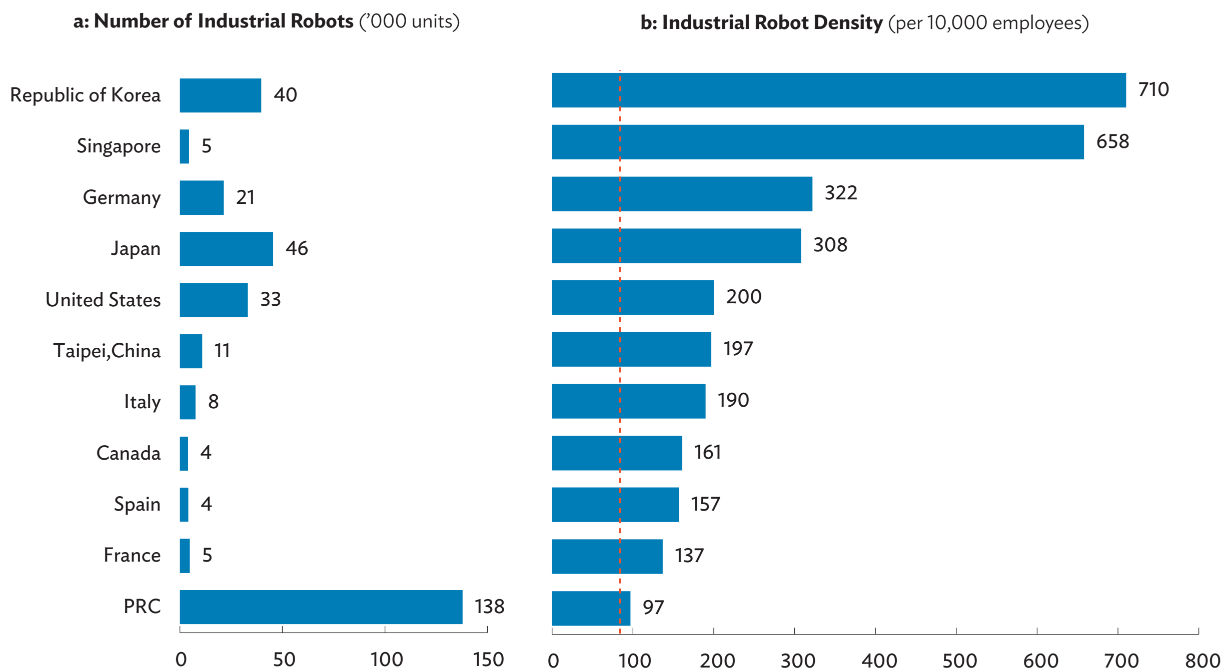
Equipped with AI and other innovations such as mobile technologies, Global Positioning System (GPS), and improved computer processing power, service robots

57 As shown in Figure 6.26, the intensity of robot installation is high in the economies with a rapidly aging workforce.

58 These gains were across five of the largest manufacturing industries: (i) electronics; (ii) chemicals, oil and gas, and mining; (iii) consumer goods; (iv) food; and (v) pharmaceuticals.

59 A service robot defined based on ISO is a robot "that performs useful tasks for humans or equipment excluding industrial automation applications."

Figure 6.32: Robot Adoption in Selected Economies, 2017



PRC = People's Republic of China.

Note: Red dashed line refers to the world average of 85 installed industrial robots per 10,000 employees.

Source: International Federation of Robotics (2018).

perform highly sophisticated tasks. Japan's construction industry is one industry whose workforce is rapidly aging, and it is shifting gear toward increased adoption of robots not only to save on labor and reduce the physical intensity of task, but also to improve precision (Box 6.6). Robots are meeting some of the increasing demand for professional caregiving. Nursing homes in Japan are experimenting with different types of robots—from voice recognition systems to wearables and devices that reduce physically demanding tasks such as transferring and bathing. Socially assistive robots are found to improve elderly well-being such as positive emotions and an increase in social interactions (Matuszek 2017, and Kachouie et al. 2014).

The second group of technologies complements the application of labor and skills to improve productivity.

While the first technology group substitutes human labor, the second group are technologies that work side-by-side with workers, allowing them to stay in jobs and perform better, while at the same time assisting them in maintaining life-work balance.

Physical Augmentation

An aging workforce can remain productive with physical augmentation technologies aiding mobility and endurance.

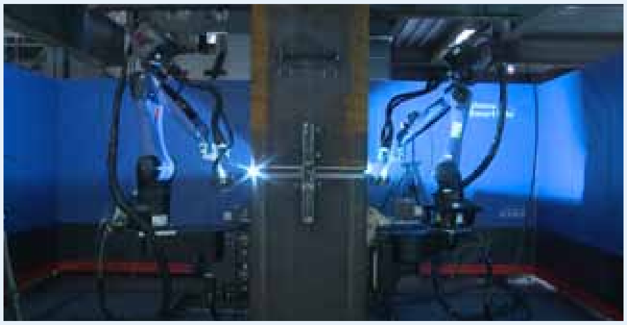
Physical ability declines with age but technology can help older workers maintain their performance. Robotic exoskeletons are wearable electromechanical devices designed to enhance the physical ability of the user or provide locomotive support (Sirlantzis et al. 2019). One of the latest developments is an exoskeleton-type wearable robot designed to help with bending and stretching movements and give elderly people a natural walking experience by incorporating wire-type walking assistance technology. For example, HIMICO produced by ATOUN Inc. can provide as much as 30.7% assistance in rough terrain walking, 19% in hill walking, and 17.8% in stairs climbing (Panasonic 2018).

Box 6.6: Case Study of Japan's Shimizu Corporation's Adoption of Industrial Robots

One-third of Japan's construction workers are over the age of 54, and only around 10% are below 30. This construction labor pool is expected to decrease, especially with the 20% reduction of Japan's workforce from 2017 to 2040 projected by the Ministry of Health, Labour, and Welfare (Fleming 2019).

This is one of the major reasons why Shimizu, one of Japan's biggest construction companies, is increasing the number of robots on site. Shimizu has invested $179 million in construction robots from 2015, and it has reduced staffing needs for specific tasks by between 70% and 80%.

Shimizu Corporation (2018) tested three autonomous construction robots in the Shimizu Smart Site. These robots, specially designed for welding, ceiling installation, and transport, are equipped with artificial intelligence and building information modeling, allowing them to operate and decide on their own. They were designed to work with humans at a job site, reducing strenuous and repetitive tasks while increasing productivity. Trials show labor-savings equivalent to 2,700 staff days on lifting and carrying, 2,100 days on ceiling and floor installation, and 1,150 days on column welding.



Coworking with autonomous robots. The robo-welder is among the three autonomous robots, equipped to operate on their own and work alongside people in Shimizu's Smart Sites (photo provided by Shimizu Corporation).

Sources: Fleming (2019) and Shimizu Corporation (2018).

Industrial exoskeletons and wearable robots also help workers meet agility and ergonomic requirements for specialized production tasks while minimizing physical injury. This feature is especially helpful for older workers more at risk of injuries during physical work. Box 6.7 summarizes the adoption of exoskeletons, especially in vehicles production, that reduces strain on overhead assembly tasks. Commonly known physical augmentation techniques such as prosthetics and bionics are introducing new features. For example, robotic gloves by Nuada help users who have lost control of hand movements to regain a strong grip, allowing them to pickup, carry, or maneuver heavy objects (Kolodny and Petrova 2017).

Remote Work Platforms

Technologies allowing workers to perform tasks remotely help retain older and younger talent.

Remote work platforms and cyber office space are gaining ground in the workplace by allowing tasks to be performed from a remote location, for example, from home or other sites away from an office. Telecommuting is a widely known working arrangement, replacing a traditional office commute with "commuting" by phone or computer (Reynolds 2018). It is often tagged as a business strategy to retain talented staff who may prefer flexibility. By cutting commuting time, remote work raises productivity as it creates more time to spend on productive tasks and encourages elderly people experiencing difficulty in commuting to continue using their skills.[60]

Remote work platforms include collaboration software, new teleconferencing technologies, and 5G-powered offices that make working in teams seamless. Telework/information and communication technology (ICT)-mobile work is largely being adopted in Europe and is used by 32% of employees in Sweden and 28% in Finland (Figure 6.33). In Asia, quite substantive shares are observed in India (19%) and Japan (16%).

[60] For old workers facing challenges in commuting to work, the autonomous vehicle is a promising alternative to remote work (Box 6.8).

Box 6.7: Exoskeleton Use in Vehicle Manufacturing

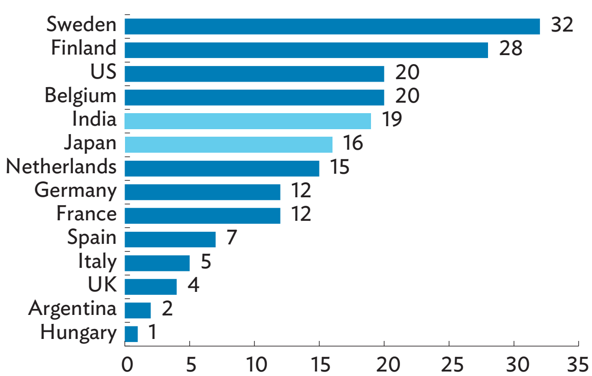
Wearable robotics have been widely used by automotive companies and others—including BMW, Ford, and Hyundai— are using or testing exoskeletons. The main reasons automotive companies report for using exoskeletons are to improve efficiency and reduce or prevent work-related injuries.

Hyundai, the multinational auto manufacturing company from the Republic of Korea, developed two wearable industrial robots to be used in production. First, the Hyundai Chairless Exoskeleton (H-CEX) is a knee-joint protective device to help workers who sit for long periods and can withstand weight of up to 150 kilograms. The other is Hyundai Vest Exoskeleton (H-VEX), which adds 60 kilograms to the weight workers can lift, and so relieves pressure on their necks and backs.

Exoskeletons at work. Hyundai's Chairless Exoskeleton (H-CEX) is among the first to be used in car manufacturing, reducing strain on the workers (photo provided by Hyundai Motor Company).

Sources: Hyundai (2018) and Marinov (2019).

Figure 6.33: Rates of Telework or ICT-Mobile Work in Selected Countries (% of all workers)



ICT = information and communication technology, UK = United Kingdom, US = United States.

Notes: Telework or ICT-mobile work refers to work done outside the employer's premises in a variety of locations. Latest available data vary across countries: 2011 for Argentina, Belgium, and Spain; 2012 for France, Sweden, and the US; 2013 for Finland and Italy; 2014 for Germany, Hungary, Japan, and the Netherlands; and 2015 for India and the UK. Lighter blue bars refer to Asian economies.

Source: Eurofund and the International Labour Office (2017).

In the PRC, Ctrip, a 16,000-employee online travel agency saw productivity increase by as much as 30% when over half of its staff worked from home (Bloom et al. 2015). In an initial experiment where employees were randomly assigned to either work from home or continue in the office for 9 months, the former group performed 13% better, with more minutes per shift and more calls per minute. The group also exhibited a 50% lower attrition rate, suggestive of higher work satisfaction.

Collaboration Tools

A new generation of virtual offices is arriving with 5G technologies and facilitating better work collaboration.

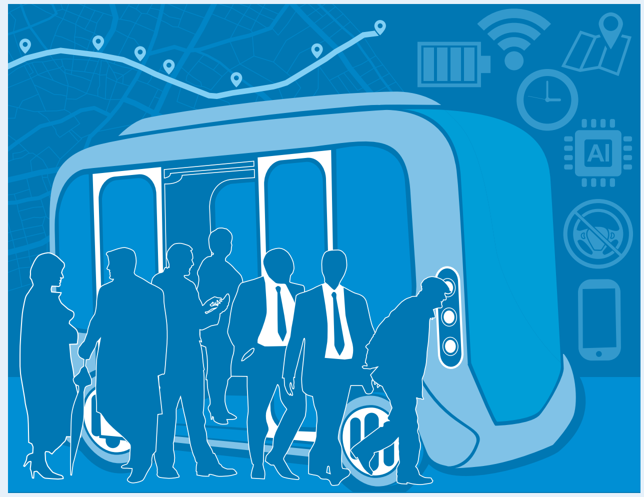
The increasing preference for remote work requires interconnected devices ranging from e-mails and digital documents to more advanced technologies such as the internet of things and virtual and augmented reality to maintain collaborative efforts. The smooth transition to 5G, or fifth-generation, cellular wireless that has greater speed, lower latency, and allows more devices to be connected simultaneously, has a key role in achieving better synergies and synchronization (Segan 2019). In the Republic of Korea, SK Telecom, Samsung, and Cisco have collaborated to build 5G smart offices, that allows

Box 6.8: Autonomous Vehicles: Steering Technology in Favor of Seniors

The advancement of technology drove self-driven vehicles out of science fiction and into the streets in a matter of a decade. The development of autonomous vehicles is at the stage where the vehicle can manage all safety-critical functions under certain conditions, with driver taking over when alerted. Full automation, where the vehicle is completely capable of self-driving in every situation, is not expected until 2025.

The many benefits from using autonomous vehicles include improved traffic safety, convenience, and cheaper operation costs. For the elderly, autonomous vehicles provide a viable mobility option that may keep them economically active.

Japan, with its aging population, is experimenting with the idea in its rural communities, like Nishikata (Chakraborty 2017). In this community, a third of the population is age 65 and over, total population has contracted, and transport services are insufficient as the workforce has also shrunk. The experiment will use a driverless shuttle bus to take elderly passengers to hubs where medical, retail, and banking services are available. Should the trials succeed, self-driving services will be made available in 2020. It should be noted that other countries fully supporting this technology are those that are less populated and have orderly traffic, e.g., Australia, France, New Zealand, and Singapore.



Autonomous driving technology, however, is not for everyone. Aside from the prohibitive cost, densely populated countries with chaotic traffic situations will not find autonomous driving a viable transportation alternative. The adoption of autonomous vehicles will depend a lot on societies' need for such a solution, road readiness, and government backing through laws and infrastructure support.

Sources: Chakraborty (2017).

workers from different locations to hold meetings and watch visual materials altogether (Jun 2019).

Existing online collaboration tools range from e-mails and instant messaging, to working on documents simultaneously. Slack, with millions of users globally, is a well-integrated platform that allows users to collaborate between different departments of their company, to work with other companies, and to use other applications such as Asana for task assignments, or Dropbox for seamless file sharing. Slack lets users organize conversations, share files and documents, find archived information, integrate tools, and even talk face-to-face (Slack).

The third group of technologies builds professional and foundational skills by aiding education, skills development, and lifelong learning.

Exponential growth has occurred in technologies that build occupational and foundational skills through the use of devices (i.e., personal computers, smartphones, tablets, and Virtual Reality [VR] headsets) and online platforms, such as Coursera offering customized and interactive learning opportunities. Some of these technologies cater specifically for lifelong learning and for mature workers to update their skills (Kapoor 2019).

Online Professional Skills Learning

The rise of massive open online courses enable learners, including older workers, to access customizable and often free education from leading educational providers and institutions.

The United States (US)-based Coursera offers more than 2,700 courses from over 150 university partners, allowing over 35 million learners from 200 countries to create a curriculum tailored to their schedules and career needs.[61] Coursera's Skills Graph links learners to contents they plan to learn using skill nodes from a library of skills. Based on Coursera's 2017 Learner Outcomes Survey, users of the platform, from students seeking to advance their education to professionals upskilling for their current or future jobs, reported benefits such as being able to start new careers, getting a pay raise, or completing credits toward a degree (Levin 2017). Other major international and English-based massive open online courses (MOOCs) include edX, Udemy, Khan Academy, and Udacity. In many Asian countries, MOOCs in the local language help connect learners to domestic and international online learning resources.

Access to skills development technologies in local communities is growing in developing Asia.

One of the most interesting large-scale educational technology efforts in the world is led by EkStep, a philanthropic effort in India that builds open source platforms for government use. These technologies enable developing content and tools locally (Box 6.9). This is particularly important as one of the main challenges in the use of ICT in remote, low-income communities is that most products, services, usage models, expertise, and research come from high-income contexts and environments, with languages that are not used by local learners, and not fit in the context of developing countries.

In the Philippines, the Technical Education and Skills Development Authority (TESDA) Online Program

Box 6.9: Skills Development Technologies in Developing Asia

Technologies have been increasing access to education in different ways—creating content available in local or native languages and creating learning experiences that can be accessed virtually.

EkStep is an open learning platform in India with over 34,000 resources about literacy and numeracy and can be accessed on smartphones or other mobile devices. Since it allows for crowd-sourced collaboration and the creation of learning content in multiple languages, EkStep significantly increases the reach of students across the country.

Virtual Reality and Augmented Reality (VR/AR) have been used in higher education for learning the human anatomy or medical training for surgery across most developed nations. In developing Asia, VR/AR for education is still in its infancy. In the Philippines, as of 2017, only 13% of schools have science laboratories. Haraya Labs, a science and technology education platform, fills this gap by making experiential learning affordable and more accessible. It offers laboratories in subjects such as biology, physics, robotics, chemistry, and even aerospace engineering (Haraya Learning Innovations).

VR/AR for education. Haraya Labs enables Philippine schools without physical laboratories to access science and technology education through VR/AR laboratories (photo provided by Paolo Espiritu).

Sources: EkStep. https://ekstep.in/ (accessed July 2019); and Haraya Learning Innovations. https://haraya.xyz/ (accessed July 2019).

[61] See Coursera. https://blog.coursera.org/about/ (accessed July 2019).

(TOP) is providing free online technical education to advance skills and increase the income potential of workers. Over a million Filipinos, in the Philippines and abroad, have accessed the 59 available online courses teaching business, ICT, and electronics-related skills. Among users, only 4.4% are ages 45 and over (Dumaua-Cabauatan et al. 2018). People in this age group, representing 12.6% of the total unemployed in January 2019, can be encouraged to use TOP to improve their employability.

Organizations are exploring Virtual Reality technologies to educate and train the workforce.

Krokos, Plaisant, and Varshney (2018) found improvement in memory recall upon using Virtual Reality (VR) instead of traditional computers. In the field of medicine, VR has been increasingly used for surgical training and assessment. Osso VR provides the platform, content, and tools to address the training gap for surgeons by providing objective assessments. A pilot study showed that surgeons trained using Osso VR performed twice as well as those who used traditional means.

Benefits are enhanced when online learning is combined with face-to-face learning.

Blended learning is an approach where students learn using electronic or online media and traditional face-to-face teaching. This is considered more effective than just face-to-face learning for problem-solving skills and for recalling facts. Blended and e-learning broadens teaching and learning by providing a venue to explain complex issues and retain student attention. Replacing some traditional classroom time with online interactive content helps reduce instruction costs, especially when curriculums are more standardized. It has grown in developed countries and is now gaining traction in developing countries. Box 6.10 goes over examples of blended and e-learning in India and Thailand.

Box 6.10: Education and Information and Communication Technology in India and Thailand

In India, the Tata Institute of Social Sciences and the Massachusetts Institute of Technology (MIT) together launched the Connected Learning Initiative (CLIx), a program which integrates technology to create new learning experiences, such as active learning for secondary school students. The international collaboration included working on pedagogy, teacher development, school systems, and course technology (MIT Open Learning 2018). CLIx provides access to interactive, hands-on learning experiences from English, science, and mathematics, to instilling professionalism and related values among young people, mostly from lower- to middle-income rural areas (MIT Open Learning 2016). From its launch in 2016, CLIx now offers 15 science, technology, engineering, math, and English courses, which are also available in Hindi and Telugu, to 460 schools, 2,000 teachers, and 35,000 students in 2017. It has also received a United Nations Educational, Scientific and Cultural Organization award for its use of information and communication technology in education.

With India short of over a million trained and qualified teachers in primary and secondary schools, Teacher Education through School-based Support (TESS)–India offers a solution through freely available and easily adaptable Open Educational Resources. These resources, aimed at pre- and in-service teachers, focus on a more learner-centered, inclusive, participatory, and engaging classroom pedagogy. TESS-India was initiated in 2012 across seven key states and has already reached over a million teachers and teacher educators (The Open University).

Social entrepreneurs are also active in distributing the promise of technology to all. Learn Education from Thailand is a social enterprise that uses innovative learning platforms to help teachers provide better quality education with technology. They similarly use blended learning, which involves integrated content, real-time assessments, and school implementation. As of 2016, they have reached 100 schools and 25,000 students, and achieved better performance in science and mathematics compared with the national average.

Sources: Learn Education. https://www.learneducation.co.th/ (accessed July 2019); MIT Open Learning (2016, 2018); TESS-India. http://www.tess-india.edu.in/ (accessed July 2019); and The Open University. Projects and Programmes: TESS-India. http://www.open.ac.uk/about/international-development/projects-and-programmes/tess-india. (accessed July 2019).

Education Management System

The delivery of education can be improved using technologies that monitor teaching and learning outcomes.

Formal education that builds foundational skills like literacy, numeracy, communication, and digital literacy is ever more important in preparing the youth and adult workforce for future jobs. Digital learning materials and devices, teacher training programs, communication tools between teacher or among classmates, and data-driven evaluation of education outcomes are all part of education management systems, rapidly introduced in schools, contributing to raising the quantity and quality of education.

The Republic of Korea has laid out an extensive program for building an information technology (IT)-based school management and learning system to foster digital skills from primary to higher education across 891 pilot schools throughout the country (Korean Education and Research Information Service). E-textbook access is being launched, together with the installment of a wide range of hard and soft infrastructure in those schools. Infrastructure includes internet connectivity, IT devices, learning materials and trainings for teachers, and students, and cyberspace that facilitates communication among students, teachers, and parents.

Integrating ICT in education management improves the accessibility of quality education in developing economies.

Using and integrating ICT in the teaching and learning process are becoming increasingly important to improve education quality. For example, Bridge International Academies has introduced a comprehensive technology-based education management system and succeeded in upgrading the quality of education, as suggested by improved scores from children in underserved and low-income communities. Bridge uses technology to upskill teachers with extensive and continuous training, and provides tools (for example, "teacher guides" with detailed and step-by-step instructions to deliver lesson content for each subject) through teacher tablets, which can be also used to monitor both the teaching pace and students' progress.

Lifelong Learning

Education technology helps overcome constraints on pursuing lifelong learning.

Financial constraints – A segment of the elderly population is unable to afford training. Online learning courses and webinars such as MOOCs often offer free or cost-effective learning opportunities, eliminating both tuition and transportation costs. Many of these modules are easily accessible through mobile phones, tablets, television, or computers. Singapore allows its citizens to access over 1,000 courses at Udemy for free through its lifelong learning support program, SkillsFuture.

Time constraints – Finding time is a major constraint for adult learners faced with work and family obligations. MOOCs have become increasingly accessible and provide a wide array of self-learning courses that can be followed at a person's own pace. Still, some may be longer than necessary to meet the needs of adult and senior learners (Lee, Czaja, and Sharit 2009). This preference, along with cognitive decline over time, suggests a demand for succinct and specific courses using creative technologies. One example is Singapore's National Silver Academy (NSA), which developed short duration active e-learning courses and "bite-sized" 3-hour courses on employable fields such as finance, business, IT, and science, which seniors could complete quickly.

Motivation – Several technology-based strategies can be implemented with lifelong learning initiatives to retain seniors' motivation to learn. Learn@50+, a platform of the American Association of Retired Persons provides interactive workshops to improve elderly technology use, especially in searching for jobs. The United Kingdom's University of the Third Age utilizes social media to encourage seniors to pursue skills or courses they are interested in, and to engage other people with similar interests. Singapore's NSA has an Intergenerational Learning Programme (ILP), which matches the youth and seniors to facilitate knowledge sharing, such as learning how to use social media (NSA). Another strategy to motivate learning is to track and reward learnings. The Republic of Korea's National Institute of Lifelong Learning runs K-MOOC, which links the institute's online Academic Credit Bank Systems. The system tracks formal and nonformal learning experiences of citizens and converts these to certificates and equivalent degrees.

The fourth kind of technologies underpins a supportive labor market infrastructure by improving the matching of workers to jobs and tasks.

A range of emerging technologies are contributing to better functioning of labor markets by closing information asymmetry among workers, employers, and providers of skills training and education services. This includes online job portals and cloud-sourcing platforms, and they use big data and machine learning to better match workers to jobs and tasks to workers, including the older ones. Alongside these matching tools are technologies providing career counseling and guiding skills development.

Job Portals and Job Matching

Cyber job portals and social network sites match jobs with potential candidates.

For most jobseekers, acquiring the skillsets needed for specific types of jobs is not enough. They need information source and a strong social network that connects them to jobs. Online job portals and cloud-sourcing platforms are now using big data and machine learning to better match workers to jobs and tasks to workers. These services make finding jobs easier for older workers who possess special skills and experiences and prefer to work at specific times or hours.

The portal Indeed is one of the leading job sites in the world. It has over 250 million unique monthly visitors, over 120 million resumes, 500 million salary data points, and 9.8 jobs added per second. The website offers features such as company reviews from previous employees and salary trends for different positions and locations. All types of companies post jobs on *Indeed*, from tech giants such as Amazon and Facebook to government agencies, including the US Army. SkyHive, a skills-based work matching and training platform, automates job searching for candidates by extrapolating skills based on their background, work experience, and other preferences, and matches them with opportunities that fit their skills (SkyHive 2018).

Job-matching technologies allow for efficiently screening thousands of applicants and help employers to directly reach the talent they need. AI and machine learning can aid gathering, extracting, and processing information from jobseekers such as skills and experience and help translate these into compatible opportunities, interviews, and hires (Strauss 2018). Such technologies allow firms to identify top candidates for a position then prompt companies to reach out to them (Box 6.11).

Given the infancy of the industry, independent evaluations of impacts on job-matching remain scant. Online job portals have been widely studied and have shown positive results. In Germany, results of a large-scale field experiment showed that individuals who had access to information, which included job search strategies, had increased employment and increased earnings by around 4% (Altmann et al. 2018).

Social Networking Career Sites

Digital technology makes networking easier, allowing jobseekers to expand their networks virtually.

Estimates show that in the US, 70% to 85% of jobs are found through networking (Harden 2016 and Adler 2016). LinkedIn, a social network for businesses and professionals, has over 630 million members across 200 countries, 30 million companies represented, 20 million job openings, 90,000 schools, and 35,000 skills listed (LinkedIn Newsroom). It allows employers to quickly identify potential candidates based on the skills they need, and for jobseekers to find jobs. Although these platforms are effective, it may be that more effort is needed to reach out to the older workforce. Pew Research Center found in a survey

Box 6.11: Digital Interviews and Artificial Intelligence-Powered Human Resources

In addition to simple video platforms such as Skype or Google Hangouts, artificial intelligence (AI) technologies have made possible interviewing hundreds of potential hires in a short time. These new hiring technologies eliminate transportation costs for both recruiter and potential employee, and reduce the time required to hire. These tools are particularly helpful for senior workers doing remote work and for those in charge of human resources, as they improve worker productivity and efficiency.

Several platforms offer advanced software that uses AI and machine learning for talent acquisition, which includes audio, text, on-demand, and live video interviewing. On-demand video interviews allow firms to choose or create questions, the format they prefer the answers to be in (i.e., audio, text, or video), set time limits for answering, and allow managers to skip to specific portions of the interview in evaluating candidates. Some platforms allow for video and feedback sharing, for panel evaluations. For candidates, especially those working fulltime, on-demand interviews allow them to select their interview schedule and not have to spend time traveling. Such platforms include Montage, HireVue, Interview Stream, and GreenJob Interview. Montage says that its platform to date has resulted in a 30% increase in recruiter efficiency, a 70% reduction in the interview-to-hire ratio for their clients, and 97% of candidates having felt better represented. HireVue assessments involve using AI to assess facial expressions and body language, and it has been used to filter up to 80% of candidates for Unilever, while being able to feedback in multiple languages, saving time for candidates and recruiters.

Sources: HireVue. Unilever + HireVue: Unilever Finds Top Talend Faster with HireVue Assessments. https://www.hirevue.com/customers/global-talent-acquisition-unilever-case-study (accessed July 2019); and Montage. https://www.montagetalent.com/ (accessed July 2019).

of online users in the US that among the one in four who used LinkedIn, 29% were ages 18 to 29, 33% were 30 to 49, 24% were 50 to 64, and just 9% were ages 65 and over (Smith and Anderson 2018). LinkedIn's personalized job recommendation system uses a machine learning framework in its candidate selection model, incorporating user data, and returns the top-ranked job recommendation results. This feature, in preliminary testing experiments, increased the engagement of LinkedIn users for underserved jobs by 6.5% (Kenthapadi, Le, and Venkataraman 2017).

Crowdsourcing Platforms

Online platforms in the sharing economy let individuals offer their skills, create businesses, and access clients and finance.

Elderly workers can take advantage of crowdsourcing platforms to market their skills as experts, take on flexible jobs, or create businesses. Different types of platforms cater to specific needs of a firm or an individual, and account for, among other attributes, the quality and number of responses needed and the preferred level of expertise (Deloitte LLP 2016). Freelance work, for example, is growing in different areas across Asia. In India, one of the fast-growing platforms involves the provision of home services. India-based UrbanClap links over 100,000 skilled workers in home maintenance and repair, beauty and wellness services, and even fitness and yoga instruction, to over 32 million customers (Sharma 2019). To ensure a smooth customer experience, UrbanClap uses AI and machine learning to gather historical data from professionals, assess their performance, and provide training needed. The module determines when a worker lags in skills, then sends alerts to make sure the training is completed before taking up a job (Team YourStory 2019). This feature is especially relevant for the older workers who need to update their skills given advances in their specializations. To make these task sourcing services available to the older workforce, it is important that the platform, including job search functions and training modules, are accessible to older workers and serve their needs. Box 6.12 examines job-matching systems for older workers in Japan.

Career Counseling and Guidance

Technology can also be leveraged to understand what skills employers need, tackling gaps and mismatches.

Box 6.12: A Cloud Job-Matching System for Elderly Workers in Japan

Negative perceptions of elderly workers make it harder for them to access employment. This tendency for unemployment perpetuates social isolation and financial problems. However, aging societies are increasingly recognizing the potential of healthy senior workers and are tapping them for simpler tasks through crowdsourcing.

Gathering Brisk Elderly in the Region (GBER), is a web application, accessible through personal computers, tablets, and smartphones, that matches tasks and jobs with active seniors in Japan. In addition to skills-based matching, GBER features calendar-based and location-based matching capabilities (Arita, Hiyama, and Hirose 2017). The platform, supported by a groupware function, allows retired people to maintain good health and socialize by working on community-based projects with other seniors. In the area of Kashiwa, it has resulted in 2,300 job placements (University of Tokyo 2018).

A pilot study in Kashiwa of 92 users with an average age of 67, showed that GBER was easy to use even for seniors with limited information and communication technology experience and that it promoted their engagement in local activities (Arita, Hiyama, and Hirose 2017). Given its success, GBER will expand to other cities. Its developers also plan to implement a recommendation system that will evaluate the platform's skills-matching functions.

Sources: Arita, Hiyama, and Hirose (2017); GBER. http://gber.jp/ (accessed July 2019); and University of Tokyo (2018).

Workforce and prospective labor market entrants will benefit from having access to information on the types of skills potential employers need or the skills that fit their employment or earning prospects. However, it is more often the case that students and jobseekers depend on advice from parents and peers who may not have up-to-date information about particular careers (ADB 2019). Emerging technologies help solve that information asymmetry.

Big data analytics and AI help identify skills in demand using data from professional job portals, company, and government databases. Such information, along with analysis of emerging and dying occupations, helps to establish dynamic labor market intelligence systems that provide real-time labor market information, including for elderly jobseekers and the providers of education and training. AI-powered career guidance is becoming essential to extending working life, which requires workers to continually upskill and reskill to stay employed.

A career development platform in Singapore, JobKred, uses AI in providing digital career guidance, skills gap analysis, and training recommendations. Real-time labor market information from multiple sources, such as job boards, resume sites, and government sites helps their AI to understand current demand for skills and jobs. Based on platforms such as this, students can be guided effectively to the careers of the future, while employees are given ideas about the skills they should develop to fit their companies' direction. The technology possesses promising benefits if applied more systematically to guide the career and skills development of older workers.

The fifth type of technologies boosts health and healthy life expectancy by improving mental and physical health.

Emerging technologies that help maintain mental and physical wellness and other digital health services bode well for an aging population and workforce. These technologies include biotechnology, new drugs and treatments developed through medical science, and other innovative forms of health service delivery that integrate ICT, such as automated diagnosis and wearable devices.

Wearables, nonwearable smart devices, and mobile applications can help monitor and improve personal health.

New smart devices and mobile applications can obtain and track vital signs and monitor physiological responses to activities. The wearables deliver patients' diagnostic information to health providers to monitor symptoms, and help them refine and optimize treatment. There are also digital products that help manage chronic and noncommunicable diseases.

Digital therapeutics are evidence-based medical interventions that make use of high-quality software to help prevent, manage, or treat a medical disorder or disease (Digital Therapeutics Alliance 2018). These typically involve the online transmission of data to alert healthcare professionals to potential problems and emergencies, enabling a quicker medical response. Feedback on physical conditions is sent through smartphones, encouraging patients to be more engaged in their health status. Some clinical trials even found wearables efficient in treating people with metabolic syndrome. A pilot study in the Republic of Korea used wearable devices to patients with metabolic syndrome. Throughout 12 weeks, patients received feedback from a trained nurse on their physical activity, to provide encouragement and improve self-monitoring. Researchers found that feedback via wearable device was able to increase physical activity and resolve the metabolic syndrome for 45% of the participants who completed the trial (Huh et al. 2019).

Mental health is just as important as physical health, with older people facing higher risks of conditions such as dementia, Alzheimer's disease, depression, and anxiety attacks. The World Health Organization (WHO) (2017) estimates over 20% of people of ages 60 or over suffer from mental or neurological disorders, while 6.6% of older people's disability is mental or neurological. A number of digital therapeutic products are designed to address mental health, replacing conventional medications or used in conjunction with them to produce direct clinical benefit.[62]

VR has also been increasingly used as a tool to improve care of seniors who are especially at risk of dementia, depression, and isolation.

With VR headsets, custom software, and a tablet, seniors could travel the world virtually, attend sports games or even family gatherings. Other relevant features include cognitive therapy and early diagnosis of dementia. Residents of a senior community in Massachusetts with access to the VR-based services are reported happier by 40% (Matheson 2017). Similarly, robotic pets have been found to reduce loneliness among the elderly by providing canine or feline companionship (Dawson 2019). A study of patients suffering from dementia showed that the group that interacted with Paro, a robotic furry seal that responds to touch and provides companionship, had decreased stress and anxiety and needed less psychoactive and pain medications (Petersen et al. 2017). Pepper, a humanoid robot, leads group exercises for senior citizens, among its other features (Foster 2018).

Technology for Easier Access to Healthcare

Remote patient monitoring, or telemedicine, uses technology to deliver certain healthcare services remotely.

This entails using remote monitoring devices in nonclinical environments, such as in the home, to enable patients to consult their doctors, or for medical professionals to communicate and arrive at decisions on how to treat patients without needing to be physically present. Remote patient monitoring (RPM) increases access to healthcare and potentially decreases delivery costs, which can significantly improve the quality of life for patients, especially those with chronic diseases, who are often seniors. Globally, Dexcom, Honeywell Life Sciences, *and* Philips Healthcare are among the top RPM solution providers.

[62] For example, in the US, FDA approved the prescription of a number of digital therapeutics targeting at treating opioid use disorder, mental illness, and major depressive disorder.

Box 6.13: Digital Interventions in Healthcare

Early diagnosis with technology

Early diagnosis can be achieved through two mechanisms. The first mechanism is through improvements in technologies for early disease detection. Identifying and detection of biomarkers, which refers to a broad subcategory of medical signs that can be measured accurately and reproducibly (Strimbu and Tavel 2010), for life-threatening diseases like cancer offer a wider range of treatment options, vastly improving diagnosis, prognosis, and survival rates. Developments in nanotechnology-enhanced biochips and computer-aided software based on artificial intelligence (AI) which utilizes big data in healthcare, enable automated diagnosis of conditions leading to early detection of malaria, tuberculosis, various types of cancer, Parkinson's disease, Alzheimer's, schizophrenia, and blindness.

The second mechanism is through genomic profiling—which involves the study of all of a person's genes (i.e., the genome), including interactions of those genes with each other and with a person's environment. This genetic information is examined to determine the likelihood of certain types of diseases, which allow for both preventative medicine and precision or customized treatment. Foundation Medicine, a molecular information company founded in 2010, is at the forefront of genomics. In 2012, it launched the first commercially available comprehensive genomic profiling test for cancer diagnosis. In 2018, its genomic profiling procedures for all solid tumors were approved for Medicare and Medicaid services coverage in the United States (US). Japan's Ministry of Health, Labour and Welfare has also approved the test for individuals living with advanced cancer (Foundation Medicine 2018). In Asia, a joint venture between Japan's Canon Medical Systems Corporation and Taipei,China's ACT Genomics formed ACTmed to offer precision cancer medicine, treatment for cancer relapse, drug resistance monitoring, cancer risk assessment, and immunotherapy evaluation using AI-powered bioinformatics database integrated with Asia-specific genome profiling.

Electronic management of health data

Electronic management of health data, which includes patients' electronic health records, staff information, stock levels of medicine or other commodities, has several benefits. Digitized records allow health workers to track and follow-up on patients' health status, enables telemedicine and targeted client communication, augments health workers' decisions through digitized job aids, and allows for better management of stocks and commodities (World Health Organization 2019). Adoption of electronic medical records in the US achieved an estimated net cumulative saving of $371 billion from 2004 to 2018 because of improved efficiency and increased safety (Hillestad et al. 2005). Kaiser Permanente, a US-based health plan provider, saved about $1 billion in reduced visits and lab tests and improved health outcomes. The implemented computer system encouraged use of electronic health records and ensured data exchange across medical facilities (Groves et al. 2013).

Big data analysis for healthcare

Big data analytics can transform the healthcare landscape. Some of its uses range from prevention to cure and cover everything else in between such as better-informed strategic planning and integrating medical imaging for broader diagnosis. Applications of big data analytics to health data, or bioinformatics could have a large benefit on patients and the general population by enhancing quality care, offering more precise treatment, and reducing healthcare costs. For healthcare providers, it could mean identifying people and populations at high risk for particular diseases, or improving accuracy in diagnosis based on evidence-based medicine. Around 40% of direct health interventions have been geared toward predictive capabilities (Groves et al. 2013). For example, advanced analytics used by Dignity Health, the largest hospital provider in California, have predicted sepsis, a fatal inflammatory response to infection, and so reduced the mortality rate by 5% (Beall 2019). For healthcare insurers, it could mean more efficiency and cost saving. For example, insurers can reduce costs by being able to streamline processes, preventing fraud and theft, and creating more appropriate coverage for their plan holders.

Sources: Beall (2019); Foundation Medicine (2018); Groves et al. (2013); Hillestad et al (2005); Strimbu and Tavel (2010); and WHO (2019).

In Asia, the lifting of regulatory restrictions on the use of devices on medical consultations has paved the way for telemedicine/telehealth companies to expand their services. In Japan, around 560 medical institutions have made use of remote medical consultations since 2014. *Ping An Good Doctor*, a one-stop healthcare ecosystem in the PRC, provides its 265 million users 24/7 online consultation services using AI technology—an AI-assisted chatbot routes a patient to a doctor. In early 2019, it rolled out its One-Minute Clinics across eight provinces and cities and signed service contracts for nearly 1,000 units, providing healthcare services to more than 3 million users (Koh 2019). In the Philippines, medical practitioners can diagnose patients from underserved and geographically isolated provinces through the Philippine Research, Education and Government Information

Network (PREGINET), a multiplatform delivery that provides accessible, affordable, and quality healthcare services. In Singapore, a fee of S$20 (about $14) entitles a registered user to a video consultation with one of Doctor Anywhere's pool of doctors.

Telehealth and telemedicine companies aiming for maximum reach have to contend with both regulations and their absence. In Southeast Asia, the lack of clear laws and regulations surrounding RPM-type medical services is an issue to growth-oriented companies that could be confronted by future laws and regulations. Another issue is that in many of the geographically inaccessible areas that stand to benefit most from remote healthcare delivery, people are not so trusting of technology and still prefer face-to-face consultation with doctors.

Aside from the telemedicine, a wide range of digital health systems make medical services more accessible, timely, and accurate, especially for the elderly.

Longer life expectancy means higher incidences of chronic conditions, and digitalization helps make health systems more responsive and sustainable (WHO 2019). Box 6.13 highlights other important applications of digital health interventions.

Assessing the Technology Needs of Countries Based on Age-Education Profiles

Population aging may be largely irreversible, but the economic consequences depend, in part, on how well countries adapt to the changes.

Looming scarcity of a productive workforce and a corresponding increase in the share of older workers can add downward pressure to aggregate productivity. With rapid technological advances, there is a need to take full advantage of new technologies, such as increasingly sophisticated automation, and much-improved robots and versatile uses of digital technologies, to halt an age-related slowdown in productivity.

Economies in Asia are undergoing varying stages of demographic transition. The identification of technological solutions to labor market challenges in the economies of Asia demands a tailored approach. This section lays the ground for policy recommendations by assessing (i) the course of progression of the age and education profile of the region's economically active population, and (ii) the pattern of labor demand highlighting the evolution of tasks.

The section begins by mapping the transformation of age and educational attainment distribution in the region that can be classified into four broad types. The pattern of employment and labor market demand within each group is then assessed using information from labor force surveys.

Aging and Educational Attainment in Asia

Distribution of the economically active population is projected using trends in aging and the level of educational attainment since 1950.

Country-specific past (1980), current (2015), and projected (2050) population distribution by age and the level of educational attainment are gathered from the Wittgenstein Centre for Demography and Global Human Capital (Box 6.14 provides a brief note on the dataset). With formal qualifications easily and readily observable, these are often used as a satisfactory if not perfect proxy for actual skills (Massing and Schneider 2017).

Using a radar chart, the economically active population disaggregated by age and education level are fitted on six axes with the upper portion referring to the older (50–74) age group while the younger (25–49) age group occupies the bottom part.[63] The education level of the two broad age groups is mapped with the share of economically active population completing at most primary education

[63] In this exercise, economically active population of ages 25 to 74 is used, which is different from the standard working age population of 15 to 64. For one, youth may still be in school up to early twenties so their educational attainment level may deviate substantially from the final attainment. Upper bound of working age is also extended to 75, given the rapid expansion of healthy life expectancy in the region (Figure 6.24).

Box 6.14: Future Aging and Educational Attainment Profile

Historic and projected level of human capital by age and level of educational attainment is gathered from the Human Capital Data Explorer (version 2.0) made available by the Wittgenstein Centre for Demography and Global Human Capital, a collaboration among the World Population Program of the International Institute for Applied Systems Analysis (IIASA), the Vienna Institute of Demography of the Austrian Academy of Sciences (VID/ÖAW), and the Demography Group of the Vienna University of Economics and Business.

The database includes historical and projected population by age, sex, and educational attainment for the period 1950–2100 for 201 economies, of which 42 are from Asia.[a]

It uses register and census data from national statistical institutes as the main data source to build historical data and others such as the Demographic and Health Surveys or Multiple Indicator Cluster Surveys where needed (Speringer et al. 2019).

The construction of database benefited from the large global expert inquiries which set assumptions on future fertility, mortality, migration, and education for all parts of the world (KC et al. 2018). One important feature of the Wittgenstein Centre's population projections is its alignment to the narratives in the context of Shared Socioeconomic Pathways, a forecasting model offering trajectories of society and economy for coming decades, and broadly used in development-related issues such as climate change mitigation and adaptation (KC and Lutz 2017).

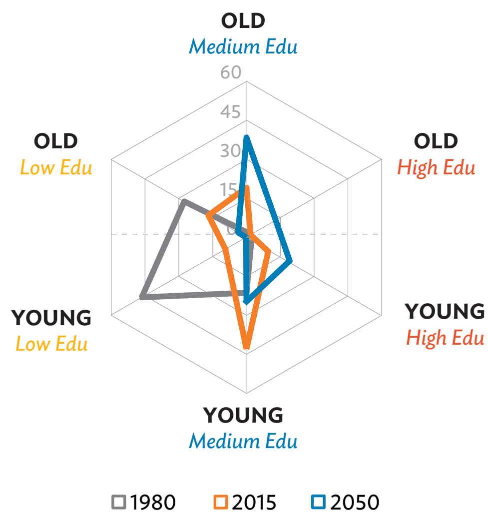
[a] The 42 Asian economies are Afghanistan; Armenia; Australia; Azerbaijan; Bangladesh; Bhutan; Brunei Darussalam; Cambodia; the Federated States of Micronesia; Fiji; Georgia; Hong Kong, China; India; Indonesia; Japan; Kazakhstan; Kiribati; the Kyrgyz Republic; the Lao People's Democratic Republic; Malaysia; Maldives; Mongolia; Myanmar; Nepal; New Zealand; Pakistan; Papua New Guinea; the People's Republic of China; the Philippines; the Republic of Korea; Samoa; Singapore; Solomon Islands; Sri Lanka; Taipei,China; Tajikistan; Thailand; Timor-Leste; Tonga; Uzbekistan; Vanuatu; and Viet Nam.

Sources: KC et al. (2018); KC and Lutz (2017); and Speringer et al. (2019).

occupying the left-most part (*Low Edu*), those attaining at most secondary education in the middle part (*Medium Edu*), and those with post-secondary education, including ones attending short-cycle and post-secondary non-tertiary programs in the right-most portion (*High Edu*).

Using the People's Republic of China (PRC) as an example in Figure 6.34, in 1980, the younger age group attaining at most primary education comprises about 47% of the total economically active population in the PRC, while the older age group with similar level of educational attainment was about 30%. The distribution is shaped almost like a "compass," where it points to the age-education demography accounting for the largest proportion. As citizens age and receive more education, the age-education compass changes shape over time. The same figure swung to the right in 2015, suggesting that much of the population had improved educational attainment, and by 2050, the projection shows that a large portion of the population will be considered high-educated after receiving at least a post-secondary education. It is also interesting to note how the shape gravitates toward the upper portion of the chart. Broadly speaking, the potential labor force in the PRC is shifting gradually from largely a young low-educated labor force to one that will be older but more educated.

Figure 6.34: Population Distribution by Age and Education—People's Republic of China (%)



Notes: Young refers to the economically active population ages 25–49, while old are ages 50–74. Horizontal dashed line delineates the young (lower half) and old (upper half) population. *Low Edu* denotes completion of at most primary education, *Medium Edu* attains secondary education, and *High Edu* has post-secondary education including attendance to short-cycle non-tertiary programs.

Source: ADB calculations using data from Wittgenstein Centre for Demography and Global Human Capital. Wittgenstein Centre Data Explorer Version 2.0. www.wittgensteincentre.org/dataexplorer (accessed June 2019).

Four Types of Aging and Education Attainment Trajectories in Asian Economies

Using the available age and educational attainment information from 42 Asian economies, varying demographic trajectories are classified into four broad types.

Applying the calculated median from the 42 Asian country-observations as thresholds defining aging and improvements in human capital (in terms of education) outlined in Table 6.2, four representative age-education demographic patterns are derived.

First, the aging of economies is described as "Fast" if the share of economically active population ages 50–74 by 2050 exceeds the calculated median share of 44% (Box 6.15 contains a discussion on the choice between level and rate of aging). Economies below the median are otherwise classified as "Slow-Aging." Second, there is favorable human capital development if the proportion of the economically active population that completed post-secondary education (tertiary and non-tertiary training/short courses) exceeds the median of 27.1% by 2050. Using the two distinctions, demographic patterns follow four broad types: (i) Fast-Aging, Above Median Education; (ii) Fast-Aging, Below Median Education; (iii) Slow-Aging, Below Median Education; and (iv) Slow-Aging, Above Median Education. The population characteristics of each types are described in the table below.

Type-1 (Fast-Aging, Above Median Education) represents a group of countries seeing a radical shift from young low-educated workers to older and more educated workers.

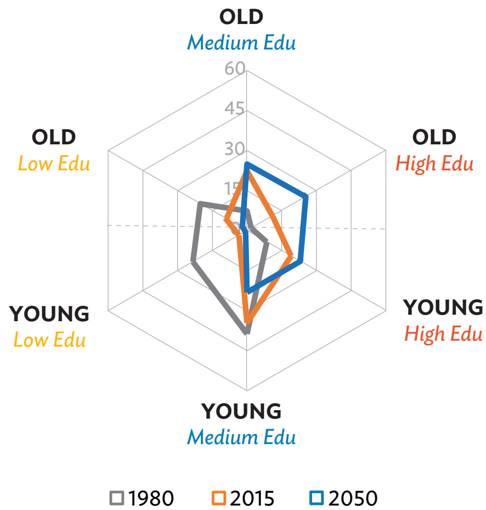
Rapid aging is visible with the share of older economically active population increasing from 29.4% in 1980 to 42.9% in 2015. This pattern is also apparent with its compass demographic chart (Figure 6.35) steadily moving upward over time. On average, a typical Type-1 economy, such as Japan and the Republic of Korea, would have the largest share of older economically active population by 2050, at around 53.3%, although the growth rate is slower at 0.6%.

Table 6.2: Description of Criteria Used to Classify Selected Economies in Asia

Criteria	Type-1 Fast-Aging, Above Median Education	Type-2 Fast-Aging, Below Median Education	Type-3 Slow-Aging, Below Median Education	Type-4 Slow-Aging, Above Median Education
a. The share of older economically active population or those ages 50–74 by 2050.	Above the median share of 44% by 2050.	Above the median share of 44% by 2050.	Below the median share of 44% by 2050.	Below the median share of 44% by 2050.
Average share of older population	**53.3%**	**50.5%**	**39.4%**	**39.0%**
b The share of post-secondary (high) educated economically active population by 2050.	Above the median share of 27.1% by 2050.	Below the median share of 27.1% by 2050.	Below the median share of 27.1% by 2050.	Above the median share of 27.1% by 2050.
Average share of population by educational attainment:				
• Post-secondary education (*High Edu*)	**48.4%**	**18.5%**	**15.6%**	**31.6%**
• Secondary education (*Medium Edu*)	**48.0%**	**58.1%**	**65.1%**	**61.6%**
• Primary education (*Low Edu*)	**3.6%**	**23.3%**	**19.3%**	**6.9%**

Source: ADB calculations using data from Wittgenstein Centre for Demography and Global Human Capital. Wittgenstein Centre Data Explorer Version 2.0. www.wittgensteincentre.org/dataexplorer (accessed June 2019).

Figure 6.35: Type-1 Population Distribution by Age and Education—Selected Asian Economies (%)



Notes: Young refers to the economically active population ages 25–49, while old are ages 50–74. Horizontal dashed line delineates the young (lower half) and old (upper half) population. *Low Edu* denotes completion of at most primary education, *Medium Edu* attains secondary education, and *High Edu* has post-secondary education including attendance to short-cycle non-tertiary programs.

Source: ADB calculations using data from Wittgenstein Centre for Demography and Global Human Capital. Wittgenstein Centre Data Explorer Version 2.0. www.wittgensteincentre.org/dataexplorer (accessed June 2019).

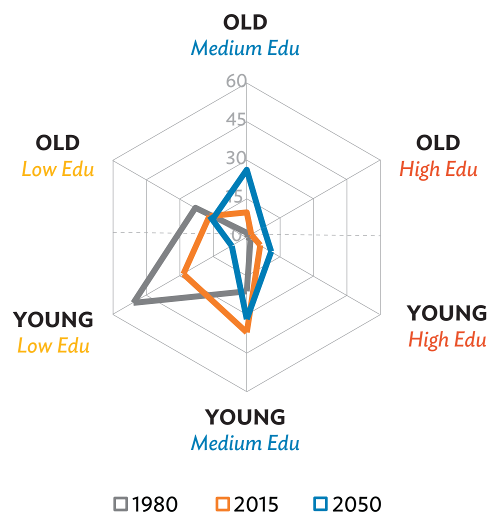
In the 1980s, the younger age group with at most secondary education qualification represented most of the population. There was also a large representation of the less educated population from both old (20.2%) and young (23.4%) age groups who achieved only up to primary education. By 2015, the educational attainment of the overall population improved markedly, with an outward distribution of young and old age groups achieving post-secondary education.

Many of the older cohort in 2015 completed post-secondary education and the younger ones achieved post-secondary education; therefore, the population distribution in the lower portion of the compass moves further to the right. By 2050, as the high-educated cohort gets older, further educational attainment backed by higher budget allocation per child leads to a majority of the population having had a post-secondary education. A typical country under Type-1 is expected to have a large pool of high-skilled workers as far as educational attainment is concerned by 2050, benefiting from their aggressive education and human capital interventions during their early development and demographic transitions.

Type-2 (Fast-Aging, Below Median Education) has had historically low levels of education, especially among the younger economically active population.

While aging demography is showing a similar pattern with Type-1, the improvement in educational attainment in Type-2 in 2015 is not as quick, thus the younger population remains largely with a primary education. However, the proportion of those primary school educated has decreased significantly from 1980 resulting in a large movement toward the middle spectrum of education level (Figure 6.36).

Figure 6.36: Type-2 Population Distribution by Age and Education—Selected Asian Economies (%)



Notes: Young refers to the economically active population ages 25–49, while old are ages 50–74. Horizontal dashed line delineates the young (lower half) and old (upper half) population. *Low Edu* denotes completion of at most primary education, *Medium Edu* attains secondary education, and *High Edu* has post-secondary education including attendance to short-cycle non-tertiary programs.

Source: ADB calculations using data from Wittgenstein Centre for Demography and Global Human Capital. Wittgenstein Centre Data Explorer Version 2.0. www.wittgensteincentre.org/dataexplorer (accessed June 2019).

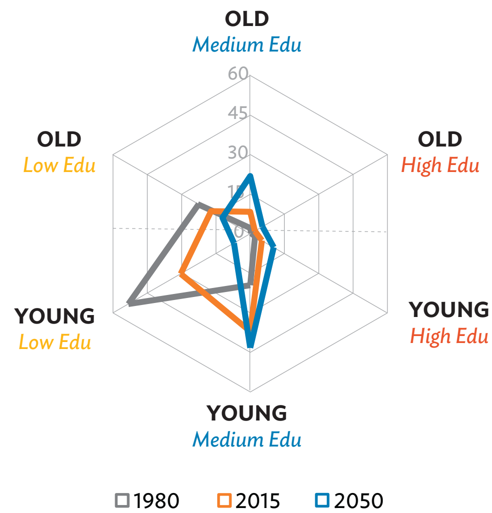
Unlike Type-1's rightward movement, in a typical Type-2 country, such as Bangladesh and Maldives, only a slight improvement in education can be expected in the younger age group if the current slow momentum persists, so that by 2050 there will be a large representation of the older population with at most a secondary education qualification. Correspondingly, there is a stable large share of young workers with secondary education. These patterns create an upward stretched population distribution compass toward the center. On average, the share of the older economically active population is expected to reach 50.5% by 2050, accompanied by a less favorable education demography, in which the share of the high-educated economically active population by 2050 is projected only at 18.5%.

Type-3 (Slow-Aging, Below Median Education) shares a similar historic demographic shift with Type-2, with a slower pace of societal aging and progression of education attainment, leading to a predominance of younger and middle-educated group in the workforce.

In the 1980s, almost 90% of the older population and over two-thirds of the younger population had achieved just the minimum education level (Figure 6.37). By 2015, the younger cohort dramatically shifts toward more completing secondary education. The share of the older population with primary education decreases slightly during the period, accompanied by a growing number in the older age group having secondary education. Improved educational attainment among the new, younger cohort shifts the distribution toward the middle, and is accompanied by very little increases in post-secondary education.

By 2050, the trajectory in a typical Type-3 country is leading toward a modest increase in the proportion of population with at least post-secondary education, which is more apparent among the younger age group. Government expenditure on tertiary education (as a proportion to total government expenditure on education) in economies following this type of age-education demographic pattern, such as Cambodia and Nepal, is generally lower than their other Asian counterparts. Relative to economies following the Type-2 pattern, both private and public spending on basic education and health per children is higher, which allows a stronger rightward pivot toward higher educational attainment, especially among the younger

Figure 6.37: Type-3 Population Distribution by Age and Education—Selected Asian Economies (%)



Notes: Young refers to the economically active population ages 25–49, while old are ages 50–74. Horizontal dashed line delineates the young (lower half) and old (upper half) population. *Low Edu* denotes completion of at most primary education, *Medium Edu* attains secondary education, and *High Edu* has post-secondary education including attendance to short-cycle non-tertiary programs.

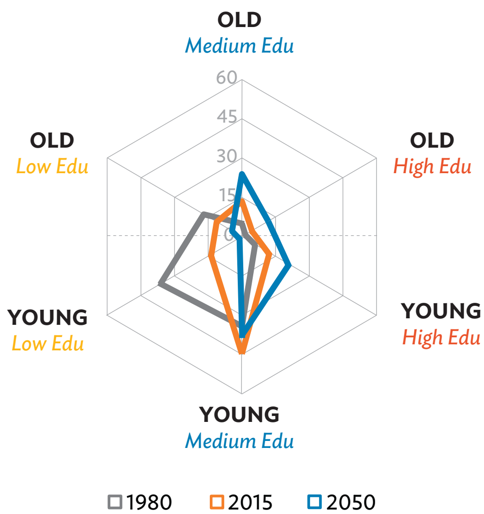
Source: ADB calculations using data from Wittgenstein Centre for Demography and Global Human Capital. Wittgenstein Centre Data Explorer Version 2.0. www.wittgensteincentre.org/dataexplorer (accessed June 2019).

economically active population. On average, the share of older population in Type-3 economies will reach 39.4% by 2050, while the share of high-educated economically active population is projected to approach 15.6%, two-thirds of which is accounted for by the younger age group.

Type-4 (Slow-Aging, Above Median Education) experiences a strong rightward movement by 2050, as more and more of their younger population completes tertiary education.

Economies following this age-education demographic pattern expect the share of the older economically active population by 2050 to reach 39.0%. They are also expected to exhibit favorable human capital as the share of high educated population by 2050 is projected around 31.6%, almost two-thirds of which are ages 25–49 (Figure 6.38). It is interesting, however, that the government expenditure on both the secondary and post-secondary education (a percentage of total government expenditure in education) in these countries was relatively smaller than those following a Type-3 demographic pattern, although, private investment in human capital per children is particularly high in some countries typically classified as Type-4, such as Mongolia and the Philippines. Other factors seem to be playing a critical role for these countries to experience improved human capital despite education having low priority in state budgets.

Figure 6.38: Type-4 Population Distribution by Age and Education—Selected Asian Economies (%)



Notes: Young refers to the economically active population ages 25–49, while old are ages 50–74. Horizontal dashed line delineates the young (lower half) and old (upper half) population. *Low Edu* denotes completion of at most primary education, *Medium Edu* attains secondary education, and *High Edu* has post-secondary education including attendance to short-cycle non-tertiary programs.

Source: ADB calculations using data from Wittgenstein Centre for Demography and Global Human Capital. Wittgenstein Centre Data Explorer Version 2.0. www.wittgensteincentre.org/dataexplorer (accessed June 2019).

One important factor that could perhaps explain the rightward shift, but deserves further investigation for empirical evidence, would be cultural differences and how conducive the economic and policy environment are for women. Compared with the young economies in Type-3, Type-4 economies such as Kazakhstan and Mongolia are among the economies lauded for facilitating women's empowerment through improved access to education and participation in the labor market. If this is validated, then gender-sensitive or at least gender-neutral and more inclusive initiatives would indeed complement human capital development efforts.

Labor Market Momentum by Age and Tasks Across Different Types of Demographic Pattern

Understanding the patterns of evolving labor demand by age and tasks helps match appropriate groups of technologies to the demographic trajectory.

Adding insights on labor demand dynamics to the age/education analysis above will provide a more holistic view on the technologies appropriate for addressing potential challenges and take advantage of opportunities arising from societal aging.

Changing patterns of labor demand within the types are assessed based on information gathered for employment across three types of tasks—routine, nonroutine manual, and nonroutine cognitive—by younger and older age groups.

Disaggregated employment information sourced from labor force survey data in multiple economies are gathered within the types that stretch over several years to decades.[64] Age-occupation groups were created using that information. The age category follows the demographic compasses, with the younger group referring to ages 25–49 and the older group ages 50–74.

For occupation category, following the guidelines of the International Labour Organization (2015), the nine major groups of International Standard Classification of Occupations 2008, excluding armed forces occupations under code [0], are categorized into three different

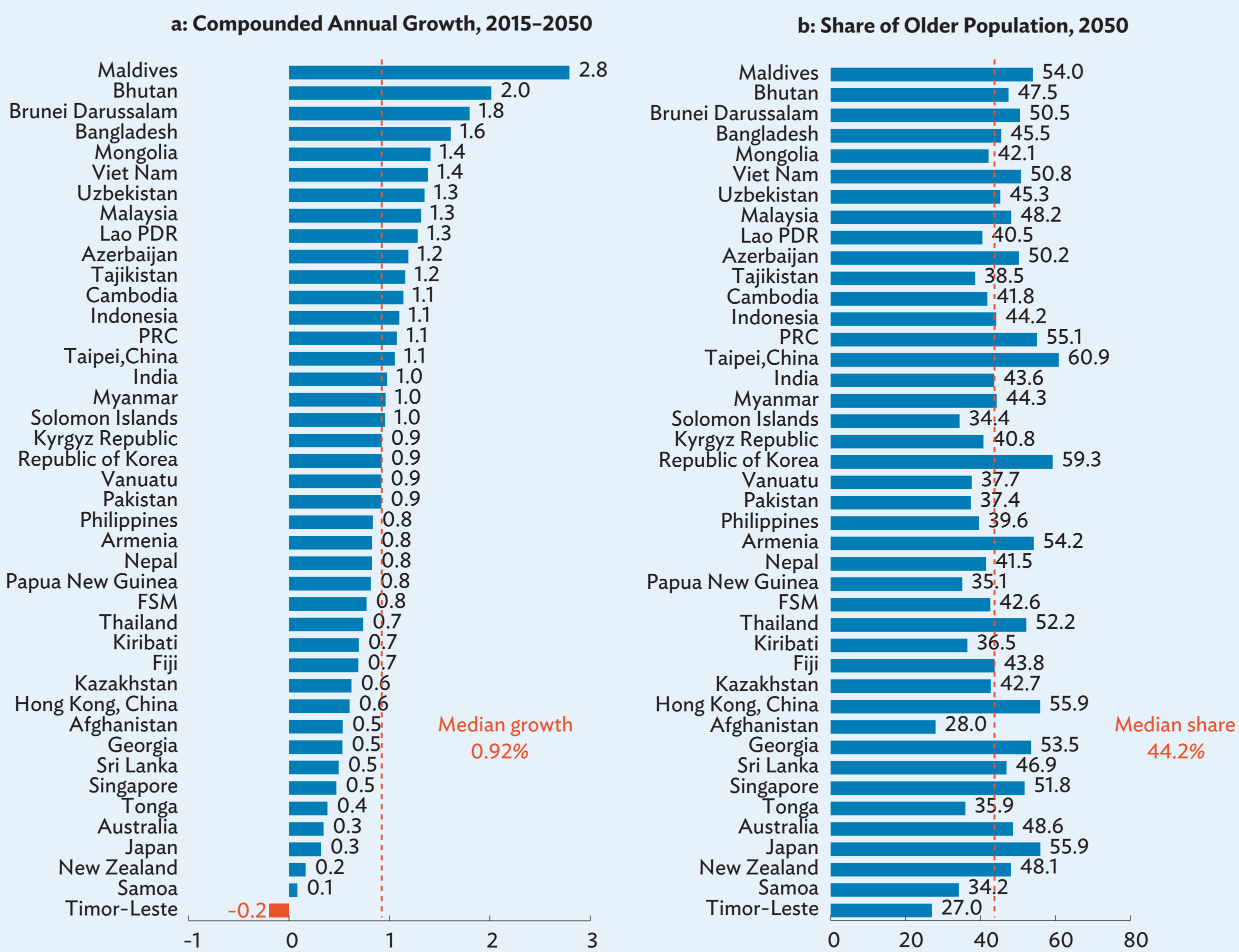
[64] This analysis uses labor force survey data for Japan (2007, 2017), the Republic of Korea (2010, 2017), and Australia (2000, 2018) which are readily downloadable from their respective statistical agencies. For other economies, labor force survey microdata from Bangladesh (2006, 2013); the People's Republic of China (2000, 2015); India (2000, 2012); Indonesia (2000, 2014); Mongolia (2002, 2016); Nepal (1999, 2008); Pakistan (2002, 2013); the Philippines (2001, 2016); Sri Lanka (2004, 2014); Taipei,China (2000, 2013); Thailand (2000, 2010); and Viet Nam (2007, 2013) are used. The sample economies represent more than 90% of the total employment of workers of ages 25 and above in Asia.

Box 6.15: Level of Aging versus Rate of Aging

The representative demographic types are determined by looking at the share of older economically active population (ages 50–74) by 2050. If the economies are above the median in share, they are listed as "Fast-Aging" and below the median as "Slow-Aging." An alternative distinction would be to generate types by how quickly the population was aging between now and 2050, or the annual growth rate of the elderly population from 2015 to 2050. In this case, if the economy's growth rate were above the median, it would be considered "Fast-Aging." The Box Figure shows the different composition of economies amid the aging definition.

On the right side are economies listed by the level of their population that will be older by 2050. The median share is 44.2%, and economies above this level are considered "Fast-Aging." On the left side are economies ordered by growth rate. If classified by growth rate, a typical profile of Types 1 and 2 would have been quite different, as several economies with rapidly aging populations, such as Mongolia and the Lao People's Democratic Republic, still would not have large elderly populations by 2050. Similarly, many economies have slower rates of aging, but will have a significant elderly population by 2050. Among them are Japan and Singapore. Given that the primary objective of this chapter is to discuss economies with large elderly population, the share of older population is used as the metric.

Defining Aging—Speed and Level (%)



FSM = Federated States of Micronesia, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Note: Both figures refer to the old population ages 50–74.

Source: ADB calculations using data from Wittgenstein Centre for Demography and Global Human Capital. Wittgenstein Centre Data Explorer Version 2.0. www.wittgensteincentre.org/dataexplorer (accessed June 2019).

Source: Asian Development Bank.

tasks: (i) *routine* involve occupations such as clerical support workers [4], craft and related trades workers [7], plant and machine operators and assemblers [8], and elementary occupations [9]; (ii) *nonroutine manual* involve occupations such as services and sales workers [5], skilled agricultural, forestry, and fishery workers [6]; and (iii) *nonroutine cognitive* include those of managers [1], professionals [2], and technicians and associate professionals [3].

The concordance of occupations into tasks is straightforward, simple and intuitive, though not perfect. People employed in elementary occupations perform mainly routine tasks, although some tasks of helpers or cleaners can be considered nonroutine manual jobs. After deriving employment distribution by age and task component, the country-specific average annual change of each age-task is calculated and then averaged, depending on where economies fall in the type of demographic pattern.[65] Figure 6.39 presents the type-specific changes in employment distribution by age and tasks, which proxy for labor market employment trends.

Asian economies' rapid structural transformation shifts employment patterns from routine to nonroutine tasks in all groups.

Much of the contraction in routine employment can be attributed to the gradual reallocation of jobs from low-skill agriculture toward modern industries and services-oriented sectors that require different skills. Figure 6.39 shows that the contraction in employment share involving routine activities is more pronounced among younger workers. Economies following the Type-2 (Fast-Aging, Below Median Education) pattern exhibit large declines with the share to total employment lower, on an annual average, by 1.53 percentage points.

With population aging, the share of employment of older workers increases across varied task types, especially among fast-aging groups.

Demographic patterns of Type-1 and Type-2 countries show a rise in the (net) share of employment by older workers across most tasks. The slow-aging demographic types also see moderate increase in the share of elderly employment in some tasks, while the share of younger workers is increasing, especially in jobs that requires nonroutine cognitive skills. However, the substantial decline in routine jobs among younger workers (or nonroutine manual jobs in Type-4) stymie the overall growth of the group's employment.

The increasing share of employment for nonroutine cognitive tasks bodes well for the expansion in schooling years and technological advancement occurring in many Asian economies.

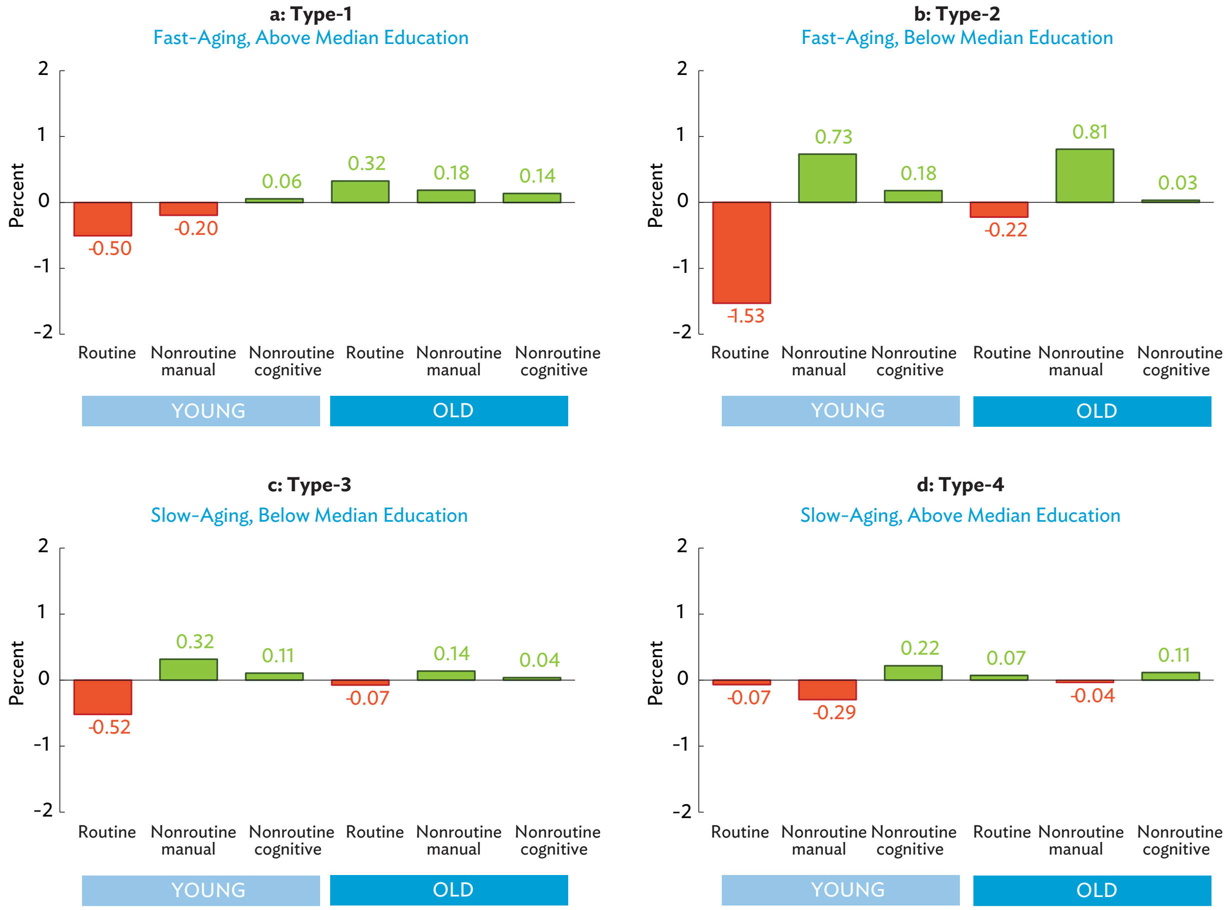
Figure 6.39 also shows, across all types of demographic pattern, that the share of employment handling nonroutine cognitive-oriented tasks increases for both younger and older workers. Economies following a Type-4 demographic pattern have seen the largest expansion in nonroutine cognitive employment.

Changing patterns of jobs and tasks amid rapid advancement and permeation of technologies also explain some contraction and expansion in employment.

Most obviously, mechanization and automation contribute to the reduction of routine jobs, shifting the workforce to perform more sophisticated tasks. According to an ADB report, 43%–57% of new job titles in selected countries of the region in the past 10 years are related to ICT, including specialized technicians needed to work with computer-controlled machines (ADB 2018). In this category, employment for young workers is growing at a faster pace than for older workers. Demand for workers to handle nonroutine cognitive tasks is growing among the above median education Type-1 and Type-4 at a similar rate to the below median education Type-2 and Type-3.

65 Country-specific average annual change in employment distribution by age and task can be denoted as $\Delta\varepsilon_{cyt} = \frac{(\varepsilon_{cyt,m=latest} - \varepsilon_{cyt,m=earliest})}{m_{latest} - m_{earliest}}$ where *c* refers to country, *y* denotes age group (i.e., young and old), *t* refers to the task category, and *m* is the labor force survey year.

Figure 6.39: Average Annual Change in Employment Share by Age and Task—Selected Asian Economies
(percentage points)



Note: Young refers to economically active population ages 25–49, while old are ages 50–74.

Sources: ADB calculations using data from respective country labor force surveys: Japan (2007, 2017); the Republic of Korea (2010, 2017); Australia (2000, 2018); Bangladesh (2006, 2013); the People's Republic of China (2000, 2015); India (2000, 2012); Indonesia (2000, 2014); Mongolia (2002, 2016); Nepal (1999, 2008); Pakistan (2002, 2013); the Philippines (2001, 2016); Sri Lanka (2004, 2014); Taipei,China (2000, 2013); Thailand (2000, 2010]; and Viet Nam (2007, 2013).

Increasing demand for handling nonroutine manual tasks will require medium- to high-skilled workers.

Over time, there has been a reallocation of employment toward nonroutine manual employment, for both younger and older workers. But nonroutine manual tasks, especially in service-oriented industries, are also at high risk of automation given advances in artificial intelligence, robotics, and the internet of things. The timing of this technology adoption, however, will vary across the four types, depending on the economic viability and technical feasibility of particular technologies in different countries (ADB 2018).

A changing labor market landscape can be expected amid further aging in Asia, altering the nature of work in the region.

Growing dependence on an older workforce will greatly influence the region's search for viable technology solutions to sustain productivity, and therefore growth. It is likely that job disruption caused by automation will hit the older workers more (Box 6.16). As discussed in the next section, both older and younger workers will need to gain foundational skills that help them pursue lifelong learning to adapt to the rapidly changing environment, especially given the expected longer working life.

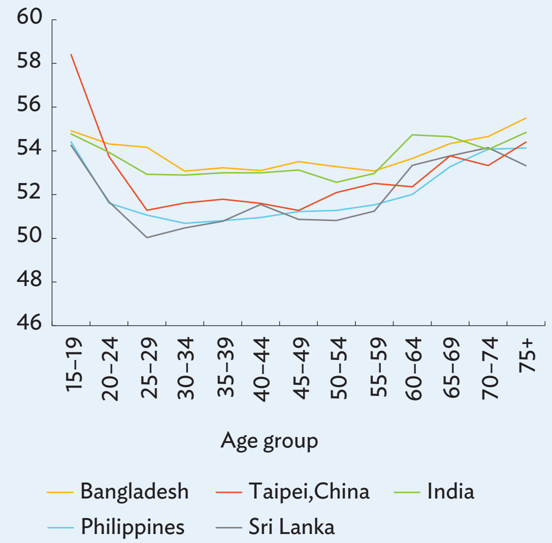
Box 6.16: Technology and Older Workers

With the rapid adoption of technology at the workplace, a larger share of older workers who now handle routine tasks will need to learn nonroutine manual tasks, such as in manufacturing and retail trade industries. These conditions make older workers vulnerable as shown by estimates for higher potential job displacement rates (Box Figure 1).

Estimates show that older workers are more likely performing activities in industries that are at higher risk of automation. In the Philippines, for example, 53% of workers of ages 55 and above face automation-related risk, 1.5 percentage points higher than the median of all age groups, and 2 percentage points higher than workers of ages 30–54. Such a trend is shared across Asia.

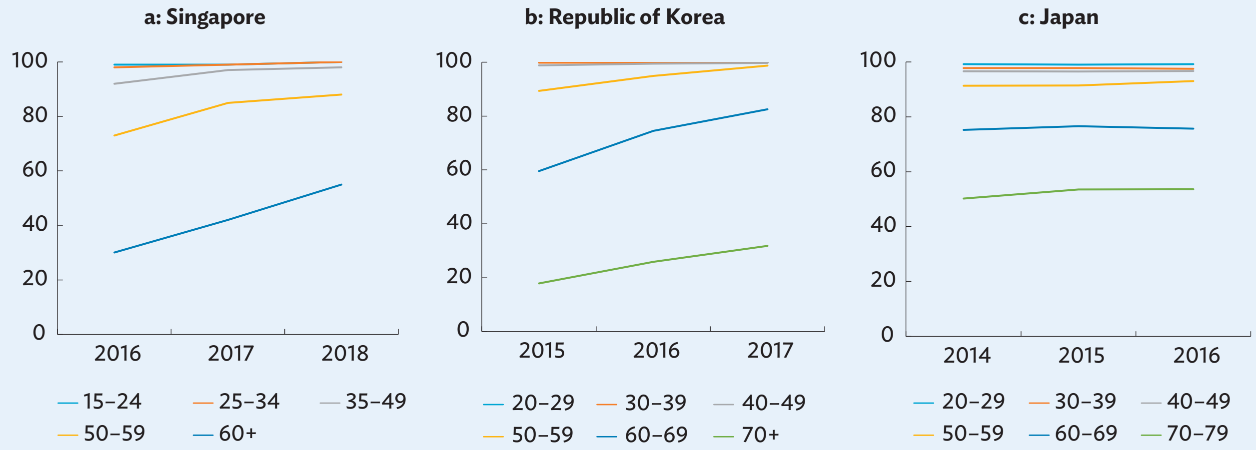
Complicating the situation is the existing "gray divide" (Box Figure 2), where older cohorts remain less familiar with technologies that are often created with youth as primary users. The coverage and depth of use of these technologies remains significantly lower among the elderly than other age groups. In Singapore, the rate of internet access among people ages 60 and above was 68 percentage points lower than for ages 25–34 in 2016. Growing familiarity lowered the gap to 45 percentage points by 2018. Similar trends are evident in the Republic of Korea and Japan. The gray divide has narrowed over time but remains apparent. Governments and the private sector can do more to narrow the gap.

1 : Potential Automation-Related Job Displacement by Age Group—Selected Asian Economies (% of total)



Sources: ADB calculations using data from labor force surveys of Bangladesh (2013); India (2012); the Philippines (2016); Sri Lanka (2014); and Taipei,China (2013); and McKinsey Global Institute (2017)'s technical automation potential by sector.

2: Internet Usage Among Older Cohorts (% of age-specific population)



Sources: Infocomm Media Development Authority (Singapore). Annual Survey on Infocomm Usage in Households and by Individuals. www.imda.gov.sg; Ministry of Internal Affairs and Communications (Japan). Information & Communications Statistics Database. http://www.soumu.go.jp/johotsusintokei/whitepaper/h30.html; and Ministry of Science and ICT (Republic of Korea). http://english.msip.go.kr/english/main/main.do (all accessed May 2019).

Source: Asian Development Bank.

Turning the Demographic Headwind to a Tailwind–Policy Considerations

The role of technology for economies with aging populations and workforces has been discussed, and different technologies are systemically presented to show how they can help achieve sustained growth. This last section turns to the question of how government policies can encourage and catalyze technology adoption, in particular grouping these policies for each of the type of economies described in the previous section.

Based on each demographic pattern and corresponding labor market conditions described in the previous section, the first part of this section describes potential challenges and technology opportunities, focusing on where government intervention would be beneficial. Identification of specific technologies to tackle looming labor market challenges for different labor demographic types may help better provide a customized policy approach. In the second part, technology and related labor and social policies are identified that would need to be implemented across the region, along with the adoption of specific technologies. The section concludes with a discussion about how policies that help across the labor demographic types can be introduced.

Analysis of varying patterns of the demographic transition and employment evolution can help identify labor market opportunities and challenges for each type.

An opportunity may arise if demographic patterns are moving in concert with employment patterns. For example, an increase in the workforce as a share of total population by 2050 is accompanied by an increase in employment, balancing labor supply and demand. On the other hand, if these two forces to balance labor markets move in opposite directions or in a noncomplementary manner, then policy makers may have to step in to deal with the imbalances or challenges.

The benefit of using this approach might be that the patterns of mismatch between labor supply and demand for each type can suggest strategic directions about how technologies should be guided (focusing either on supporting the workforce or on modifying and adjusting work and the workplace) given the changing demographic pattern and employment conditions for that type. The caveat is that employment patterns are based on historic trends, which may not be the benchmark for future change. The exercise is to help countries understand how the changing age and education profile of their workforces may be aided by different types of technology.

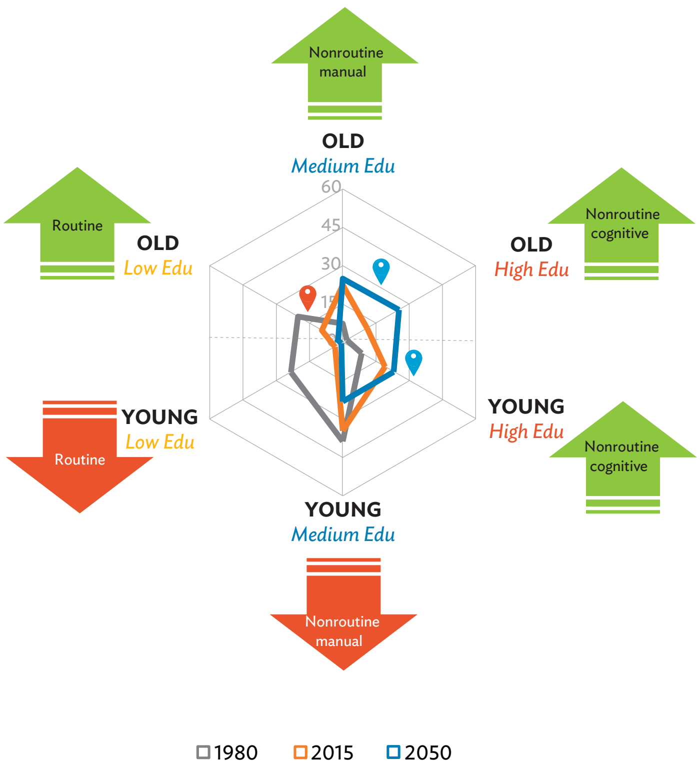
Type-1: Fast-Aging, Above Median Education

Improved human capital and fast aging suggest Type-1 economies can benefit from all five technology groups.

The dynamics of labor demographics from 1980 to 2050 overlaid with task-disaggregated employment trends in Figure 6.40 reveal two potential opportunities. The first is the relatively large supply of older medium- and high-educated workers by 2050 coinciding with expanding employment opportunities for these segments. Governments in Type-1 countries should place high policy priority on promoting the adoption and application of technologies that complement labor and skills, aid education and skills development throughout one's working life; facilitate job search and match workers to jobs and tasks; and, last, help extend the healthy life expectancy of the aging population. Such types of technologies are particularly suited to support older workers with skills in the middle to high spectrum.

The second opportunity is on expanding supply of younger high-educated workers, given the historic expansion in employment of younger workers performing nonroutine cognitive tasks. A priority should be to take advantage of this opportunity by adopting technologies that complement labor and skills; aid education, skills development, and lifelong learning; and match educated younger jobseekers in work performing relevant nonroutine cognitive tasks.

Figure 6.40: Opportunities and Challenges in Type-1 (Fast-Aging, Above Median Education) Pattern



Opportunities for Type-1

Large supply of older medium- and high-educated workers
- Tech complementing labor and skills (2)
- Tech aiding education, skills development, and lifelong learning (3)
- Tech improving matching worker with job and task (4)
- Tech extending life and healthy life expectancy (5)

Expanding supply of younger high-educated workers
- Tech complementing labor and skills (2)
- Tech aiding education, skills development, and lifelong learning (3)
- Tech improving matching worker with job and task (4)

Challenges for Type-1

Low supply of older routine workers
- Tech substituting labor and skills (1)

Notes: Young refers to the economically active population ages 25–49, while old are ages 50–74. Horizontal dashed line delineates the young (lower half) and old (upper half) population. *Low Edu* denotes completion of at most primary education, *Medium Edu* attains secondary education, and *High Edu* has post-secondary education including attendance to short-cycle non-tertiary programs. Numbers in parentheses refer to the technology groups as classified.

Source: Asian Development Bank.

One potential challenge can be gleaned from Type-1 labor demographic and employment patterns. By 2050, the supply of older, low-educated workers will contract even as employment for routine tasks performed by older workers may expand. This mismatch would necessitate implementing technologies that substitute labors and skills, where possible. This could involve automating tasks previously undertaken by manual labor, and use of industrial or service robots. Because of fast aging, a Type-1 country likely faces a contraction of working age population, which calls for the adoption of labor-saving technologies in a wide range of industries. Table 6.3 summarizes the policies that are outlined in this section for all four types of labor demographic pattern.

An appropriate mix of technology and policy support should be designed to aid elderly employees performing routine and/or manual tasks, who are vulnerable to disruptive technologies.

The less educated older cohort may face more challenges given their limited ability to switch careers once their routine manual tasks become obsolete or redundant. However, it is encouraging that the relative increase in employment in other age-task components indicates that skills enhancement could benefit these workers.

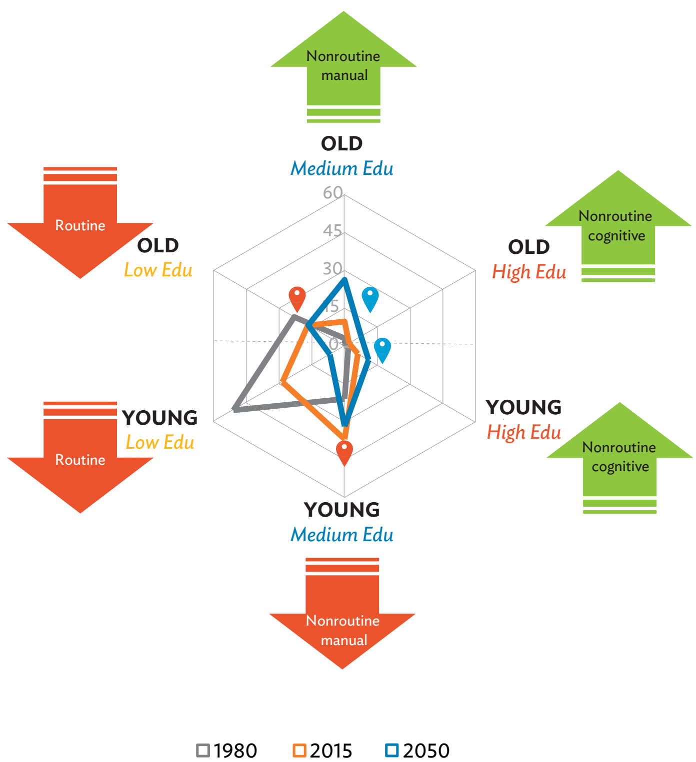
Type-2: Fast-Aging, Below Median Education

With delayed improvement in education, the Type-2 pattern suggests that policy be directed to promote technologies toward building skills and job matching.

The primary opportunity for the Type-2 labor demographic pattern will come from an expanding supply of the older medium- and high-educated workforce, provided the relative expansion in employment of nonroutine tasks conducted by older workers continues (Figure 6.41). To harness this opportunity, countries can prioritize technologies that complement workers and their skills, aid skills development and lifelong learning, match workers to appropriate tasks and jobs, and extend healthy life expectancy. A similar set of technologies can benefit the moderately increasing supply of high-educated younger workers as well. A challenge facing a Type-2 country is the persistently high share of low-educated older workers. Routine tasks conducted by low-educated older workers are contracting. Therefore, the challenge is how to train this segment of the labor force to acquire appropriate skills. Adoption of education-related technologies targeting this group is recommended. Another challenge is the undersupply of young middle-educated workers. This can be partly offset by the growing older middle-educated workforce, but technologies that substitute labor or complement existing labor and skills would be also helpful.

With the early stage of technological adoption, Type-2 may be at risk of deindustrialization unless its challenges are properly addressed.

Figure 6.41: Opportunities and Challenges in Type-2 (Fast-Aging, Below Median Education) Pattern



Opportunities for Type-2

Expanding supply of older medium- and high-educated workers
- Tech complementing labor and skills (2)
- Tech aiding education, skills development, and lifelong learning (3)
- Tech improving matching worker with job and task (4)
- Tech extending life and healthy life expectancy (5)

Expanding supply of younger high-educated workers
- Tech complementing labor and skills (2)
- Tech aiding education, skills development, and lifelong learning (3)
- Tech improving matching worker with job and task (4)

Challenges for Type-2

Oversupply of older and low-educated workers
- Tech aiding education, skills development, and lifelong learning (3)

Undersupply of younger middle-educated workers
- Tech substituting labor and skills (1)
- Tech complementing labor and skills (2)

Notes: Young refers to the economically active population ages 25–49, while old are ages 50–74. Horizontal dashed line delineates the young (lower half) and old (upper half) population. *Low Edu* denotes completion of at most primary education, *Medium Edu* attains secondary education, and *High Edu* has post-secondary education including attendance to short-cycle non-tertiary programs. Numbers in parentheses refer to the technology groups as classified.

Source: Asian Development Bank.

With gradual progress in educational achievement, the development of the manufacturing sector, which largely employs workers performing routine tasks, remains a potential vulnerability. As the labor demographic structure shifts toward more medium-educated workers, expansion in employment performing nonroutine tasks will be helpful. Type-2 countries risk premature deindustrialization if less-educated older workers do not get opportunities to improve their skills and health to continue their contribution to the workforce.

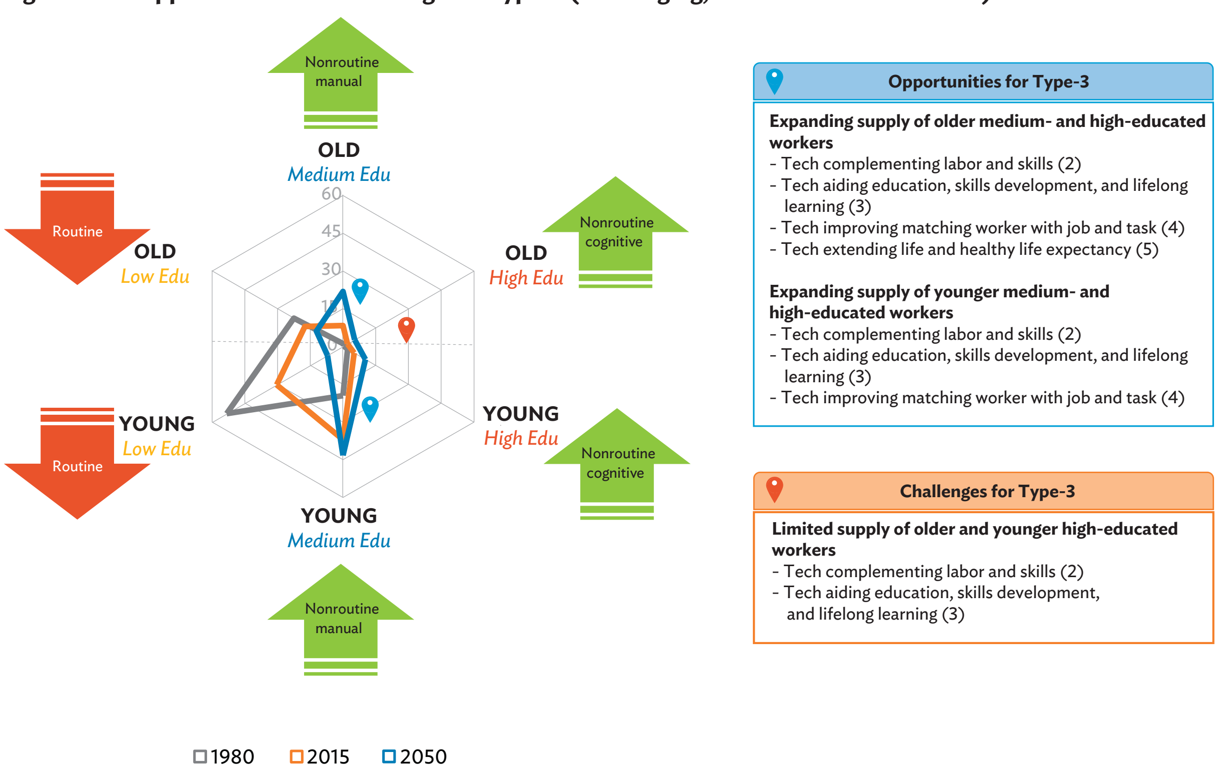
Type-3: Slow-Aging, Below Median Education

The Type-3 pattern of age and education demography should prioritize policies to promote technologies that enhance education and skills for both young and old.

There are two opportunities for the Type-3 economies. The first is an expanding supply of older medium-educated workers and a moderate increase of high-educated older workers to match the relative expansion in nonroutine task employment (Figure 6.42). The second opportunity is when the expanding supply of younger medium-educated workers and young high-educated workers are met with increase in employment. Policy makers should pay attention to the types of technology that can complement and develop skills and enhance lifelong learning, and boost job-matching, along with the efforts to adopt technologies that extend healthy working lives. One challenge facing the Type-3 economy is the limited growth in the supply of high-educated workers, be it younger or older, which calls for particular attention to education and skills development technologies as well as those that complement the skilled workforce.

Past structural transformation in Type-3 economies, often characterized by shrinking agriculture sectors,

Figure 6.42: Opportunities and Challenges in Type-3 (Slow-Aging, Below Median Education) Pattern



Notes: Young refers to the economically active population ages 25–49, while old are ages 50–74. Horizontal dashed line delineates the young (lower half) and old (upper half) population. *Low Edu* denotes completion of at most primary education, *Medium Edu* attains secondary education, and *High Edu* has post-secondary education including attendance to short-cycle non-tertiary programs. Numbers in parentheses refer to the technology groups as classified.

Source: Asian Development Bank.

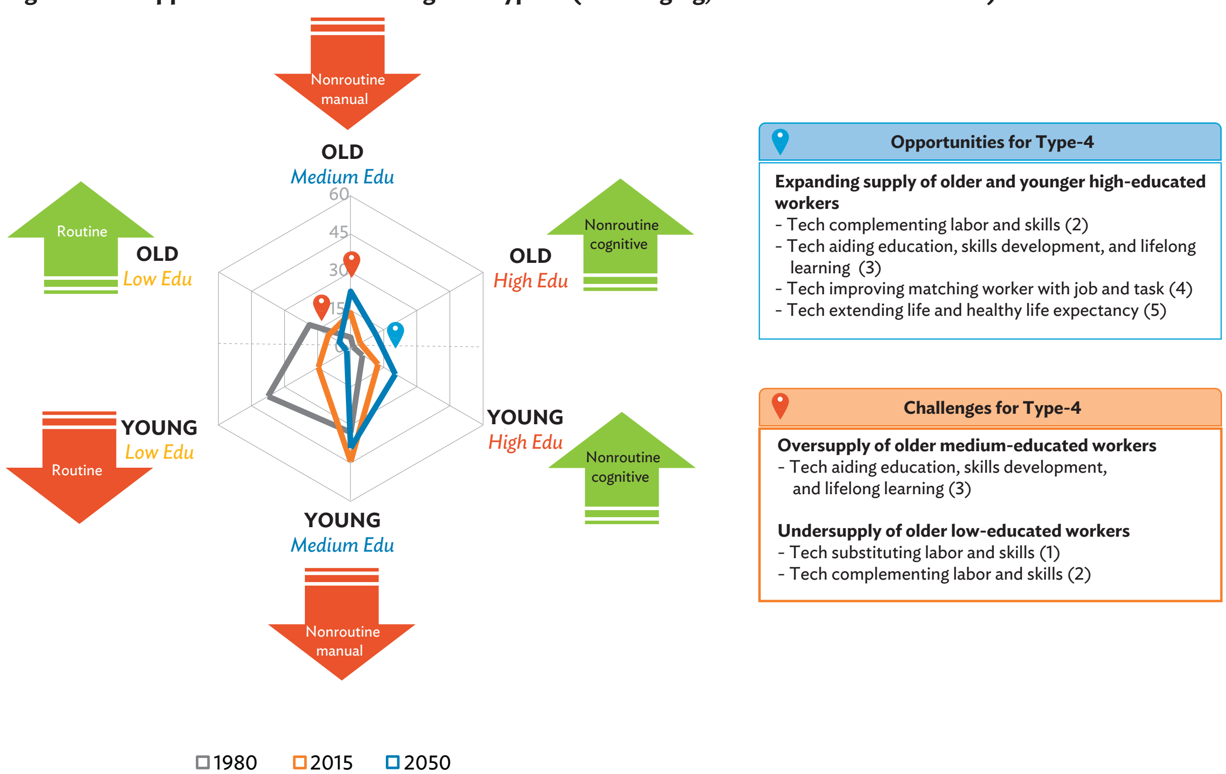
explains much of the decline of largely routine employment. In addition, although not apparent in the analysis, both Type-3 and Type-4 economies show low labor force participation by young, educated women. Technology that helps with career counseling and job-matching could help bring these untapped talents to the labor market. Absent proper technologies and policies to build skills, these economies will end up having a large share of the workforce that are willing to work but do not have skills that match the tasks in demand.

Type-4: Slow-Aging, Above Median Education

Type-4 with rapid improvement in educational attainment may face a crunch in middle educated positions.

The opportunity here is that, given the strong human capital development, the supply of both older and younger high-educated workers is expanding (Figure 6.43). Simultaneously, employment for nonroutine cognitive tasks has increased over time. Policy support to adopt technologies that augment skills, improve job market efficiency, and enhance career counseling will be especially important to make the most of this opportunity. Increasing healthy working lives also hold a promise for the technology policy area. The challenge for Type-4 involves an oversupply of older medium-educated workers along with a severe contraction in employment of nonroutine manual tasks. Policy that prioritizes technology adoption for building skills and guiding lifelong learning will be useful to deal with such population and employment trends. Type-4 economies may also experience an undersupply of older low-educated workers to supplement younger workers who often perform routine manual tasks in early stages of their

Figure 6.43: Opportunities and Challenges in Type-4 (Slow-Aging, Above Median Education) Pattern



Notes: Young refers to the economically active population ages 25–49, while old are ages 50–74. Horizontal dashed line delineates the young (lower half) and old (upper half) population. *Low Edu* denotes completion of at most primary education, *Medium Edu* attains secondary education, and *High Edu* has post-secondary education including attendance to short-cycle non-tertiary programs. Numbers in parentheses refer to the technology groups as classified.

Source: Asian Development Bank.

careers. The adoption of automation capital or technologies that substitute scarce labor to deal with the shortage may be needed.

While Type-4's high education seems advantageous for rapid technological advances, increased labor market pressure for medium-educated workers remains a concern. Without policies to build skills, unemployment tensions will arise among medium-educated workers. Shifting resources from low productivity traditional sectors toward productive, modern ones is already happening in Type-4 countries. Without this, underemployment could persist. Type-4 economies should leverage technologies that reskill and boost employment and labor productivity. Without such efforts, middle-skilled workers can be squeezed between job replacement by adoption of automated industrial processes, and demand for a highly educated or well-trained workforce along with advanced technologies.

In sum, Table 6.3 summarizes the different technology needs identified for each labor demographic type that help to harness the unique opportunities and challenges of the varied age/education patterns. Across all four types, fostering professional and foundational skills is important. Last, and importantly, individual countries need to examine their own economic and technological circumstances as well as their unique labor market opportunities and challenges to establish where they should place their priority among varied types of technologies.

Table 6.3: Summary Policy Matrix—Technology Needs by Type of Demographic Pattern and Priority

Type of Age-Education Demographic Pattern	Opportunities and Challenges	Tech Group 1 Substitutes labor and skills	Tech Group 2 Complements labor and skills	Tech Group 3 Aids education, skills development, and lifelong learning	Tech Group 4 Improves matching worker with job and task	Tech Group 5 Extends life and healthy life expectancy
Type-1 Fast-Aging, Above Median Education	Large supply of older medium- and high-educated workers					
	Expanding supply of younger high-educated workers					
	Low supply of older routine workers					
Type-2 Fast-Aging, Below Median Education	Expanding supply of older medium- and high-educated workers					
	Expanding supply of younger high-educated workers					
	Oversupply of older and low-educated workers					
	Undersupply of younger middle-educated workers					
Type-3 Slow-Aging, Below Median Education	Expanding supply of older medium- and high-educated workers					
	Expanding supply of younger medium- and high-educated workers					
	Limited supply of older and younger high-educated workers					
Type-4 Slow-Aging, Above Median Education	Expanding supply of older and younger high-educated workers					
	Oversupply of older medium-educated workers					
	Undersupply of older low-educated workers					

Note: Shaded cells indicate priority consideration.

Source: Asian Development Bank.

Technology Policy Considerations Across Demographic Types

Changing demographics and employment patterns require a major rethinking of education and skills training policies, with an acknowledgment of the necessity of lifelong or adult learning for all.

Technology may make skills of older workers depreciate rapidly, but it can also support workers by providing access to lifelong learning.

In the fast-transforming world of work, it is imperative for workers to acquire the proper skills needed for their jobs and to maintain them. Appropriate technology policy can help countries foster proper skill mixes for future jobs, like strong cognitive skills, including literacy and numeracy, basic ICT skills, analytical skills, and a range of noncognitive skills like creativity, problem-solving, and critical thinking. Interpersonal and communication skills, as well as emotional skills like self-awareness and the ability to manage stress and change, are also increasingly important.

A recent report of the Organisation for Economic Co-operation and Development (OECD) identifies technology, globalization, and aging as leading to widening disparities among workers in OECD countries (OECD 2019). It finds that younger workers without post-secondary education especially have experienced deteriorating labor market conditions (similar to the findings in this report). The report argues that all workers should have access to adequate employment protections, among which collective bargaining continues to be a flexible tool. In addition, advocating for policies that strengthen adult learning is crucial to help workers navigate a changing labor market. The concept of adult learning should be extended here by looking at technologies that support learning to adults, and technologies that support lifelong learning across populations.

Enhancing productivity with a longer working life necessitates regular upgrading of skills in various careers. For effective lifelong learning, governments will need to encourage behavioral change among workers and employers. On the workers' side, older workers face time constraints and a need for repetition and practice (Knowland and Thomas 2014). They also need to recognize the commitment required to acquire the desired skills and make the time to practice (or play out or repeat) what is learned. To maximize the gain from adult learning, it is important to build fundamental skills for learning, unlearning, and relearning of skills, i.e., developing a "learner's mindset." Government policy can help create broader learning ecosystems, where learning environments (teachers, peers, pedagogy along with technology) and a culture of learning (community, gender, age stereotypes) are fostered both internally and across countries in the region.

On the employers' side, firms will need to be incentivized to invest more in employee skills development that is age-neutral. This would imply instituting pedagogy that suits adults and seniors. Neuroscience finds that adults can learn just as well as children when the entire spectrum of learning elements are compared—adults can make better use of reason and learn based on their experiences (Knowland and Thomas 2014). Countries can help bridge the "gray divide" (see Box 6.16) by incentivizing firms to account for elderly workers' specific needs and concerns on technology usage.

Although the previous section highlighted specific policy areas for technology, significant work is still needed to identify all the ways that technology can help encourage lifelong learning in the workplace. Box 6.17 outlines potential directions for policy, given the economic literature. Technology policy that supports lifelong learning will be a common need in all Asian countries, and finding methods to apply the learning across all age groups and skill types will be critical.

Supportive Policies for Technology Adoption in Asia

To gain from increasingly available new technologies, countries will need to put in place policies that are wider in scope and can connect the technology to the workforce.

These include policies that (i) enhance diffusion, adoption, and application of technologies; (ii) adjust

Box 6.17: Setting New Directions Toward Lifelong Learning

In the paper, New Directions in Policies for Lifelong Learning, Kim and Park (2019) address issues to effectively capitalize on digital and new technologies especially in the era of lifelong learning.

Following is a set of new directions for policies drawn based on the review of existing literature:

- **Early childhood learning.** Although advocates on lifelong learning usually emphasize learning in old age, efficient lifelong learning should start from the early years. The effectiveness of human capital investment in later years of a worker's life depends critically on whether the worker was equipped with cognitive skills in early childhood. It is possible to compensate for exposure to adverse environments in early childhood if policy interventions are made sufficiently early in children's lives. Policies directed toward families and their children at early ages may improve the children's later school performance more effectively than expenditure on teacher salaries or new computers. A childcare facility well-staffed with qualified teachers can be a good alternative investment for lifelong learning.
- **Quality of formal education.** A new direction to take in formal education can focus on quality rather than quantities like schooling years. Educational expenditure should be spent wisely because supply-side policies like spending on educational equipment are not typically effective. Instead, teacher quality should be an area for active policies. Hiring and monitoring high-quality teachers will be essential. This can be accomplished by maintaining high standards of curriculum design and teacher performance and recognizing the significance of retraining and regular assessments of educators.
- **Job training.** Job training before and after market participation has been an important policy arena for lifelong learning. However, these programs do not seem to be effective for improving the socioeconomic performances of trainees. New evidence suggests that job training in the private sector, with government subsidies to firms for worker training, can be more effective.
- **Enhance the role of local governments.** Lifelong learning policies can better achieve goals when tailored to the specific needs of people across age groups and regions. Emphasis should be placed on community-based learning because local facilities in easy reach of the public can play a vital role in creating learning environments as people are more motivated to visit these centers in their spare time.

Source: Kim and Park (2019).

labor markets to allow more flexible work styles; and (iii) reform social security/pension programs to incentivize longer working life.

Firstly, countries can support technological diffusion, adoption, and application across industries and for the aging workforce.

This can be promoted through sufficient funding for research and development and subsidies and tax incentives targeting firms, along with the development of human capital and resources in targeted sectors and industries. Government spending on research and development is a good indicator of technology adoption and has been shown to affect the productivity of aging populations (Aiyar, Ebeke, and Shao 2016). Strong intellectual property protection also promotes technological application and should be put in place and strengthened, especially in countries with quickly aging populations.

The diffusion and adoption of technological innovation is an important avenue for countries to help technology connect to the workforce. Great inventions such as the internet, Global Positioning System (GPS), and artificial intelligence (AI) provide companies and individuals platforms to use these inventions for different purposes. For technologies to benefit users, such as firms and the elderly workforce, it is very important to create mechanisms that make them accessible. Typically, private companies or institutions have done this connecting, but governments can also take a role.

For example, the Massachusetts Institute of Technology in the US has created an ecosystem for academics, businesses, and workers to test recently created products (e.g., AgeLab, http://agelab.mit.edu/). Business incubation models that address the needs of an aging workforce in Europe (e.g., Active Assisted Living (AAL) Programme, http://www.aal-europe.eu/), and platforms that connect innovators to capital and networks of older workers (e.g., Aging2.0, https://www.aging2.com/) are good examples of projects that can be implemented (Box 6.18 highlights these initiatives).

A second area for wider policies is to create more flexible labor market conditions.

Labor laws should adapt to diverse and flexible working styles that go beyond the present dichotomy of full-time or part-time, employed or self-employed. So-called "gig" economies and workers that earn from it must be also covered by standard labor protection and benefits. Many times, the digital workforce is imaged and framed as "young" creators, but elderly workforce participants that prefer part-time and task-specific employment with accumulated experience and specific skill sets can equally benefit from flexible work arrangements.

Governments can institute policies that incentivize firms, and promote flexible hiring, retention, and retirement practice by encouraging and subsidizing such reform in mid- and late-career employment, work sharing, and gradual retirement options. By encouraging the matching of older workers to jobs, these policies can create better employment outcomes, as elderly workers can retain familiarity with the workplace, tasks to perform, people and networks, or the community they are in, even if they are not in full-time positions.

The third area for broader policy support is for countries to restructure their social security pension system, and tax systems so as not to penalize or disincentive the elderly to take part in the workforce.

Statutory retirement age can be made more flexible so that individuals can decide when and how to retire. The concept of "pensionable age" as opposed to "retirement

Box 6.18: Initiatives That Promote Business and Academic Collaboration and Business Incubators on Aging Technologies

Developments in aging technologies are amplified when academia partners with businesses and the government. One example is the Active Assisted Living (AAL) Programme, where the European Commission and 17 countries fund projects by small and medium-sized enterprises that create information and communication technology (ICT)-based products and services for the elderly in home, community, and workplace. These projects aim to enhance the mobility and autonomy of elderly people, either through improving health or promoting more active lifestyles.

Aging2.0 is another large-scale initiative. It works with over 40,000 innovators across over 20 countries to address "grand challenges" facing older populations, such as engagement and purpose, financial wellness, mobility and movement, daily living and lifestyle, caregiving, care coordination, brain health, and end of life. Members conduct forums to build awareness and hold global startup competitions to encourage innovation in solving issues about aging.

Since 1999, the Massachusetts Institute of Technology (MIT) AgeLab has been researching and working on projects about caregiving and well-being, retirement and longevity planning, home services and logistics, and transportation and livable communities. MIT works with businesses, governments, and nongovernment organizations to develop ideas and technologies for people to optimize their longer life spans. One of their research tools includes Age Gain Now Empathy System (AGNES), a suit that simulates the physical limitations of the elderly body, such as more fatigue, less flexibility, and sight problems. With the help of its partners and other tools, such as data studio and innovation studios, the lab has released over 280 publications.

Sources: Active Assisted Living (AAL) Programme. http://www.aal-europe.eu/ (accessed July 2019); Aging2.0. https://www.aging2.com/ (accessed July 2019); and Massachusetts Institute of Technology. Agelab. About Agelab. http://agelab.mit.edu/about-agelab (accessed July 2019).

Table 6.4: Early and Normal Retirement Ages by Type of Pension Scheme, 2016

Economy		Scheme	Early	Normal
East Asia/Southeast Asia				
People's Republic of China	*men*	DB/DC	–	60
	women	DB/DC	–	50/55
Malaysia		DC	50	55
Singapore		DC	–	65
Viet Nam	*men*	DB	55	60
	women	DB	50	55
South Asia				
India		DB	50	58
		DC		55
Sri Lanka	*men*	DC	–	55
	women	DC	–	50
OECD				
Australia		DC	60	
Japan		Basic/DB	60	65
Republic of Korea		DB	60	65
United States		DB	62	67
France		DB	62	63

– = early retirement or deferral of pension is not available; DB = defined benefit; DC = defined contribution, OECD = Organisation for Economic Co-operation and Development.

Notes: The normal retirement age is calculated assuming labor market entry at age 20. Where pension ages for men and women differ, they are shown as *men/women*.

Source: OECD (2017).

age" can be further promoted. For some countries undergoing rapid expansion of healthy life spans, revising the statutory retirement age may be needed (Table 6.4). Tax systems that give undue preferential treatment to people of working age who are not in full-time employment should be revisited.

Studies have shown that training offered for at least 1 year and on a flexible schedule has the most impact on earnings. The social security system can also be revisited to promote lifelong learning; for example, by allowing individuals to take breaks from work to upgrade and learn new skills, rather than doing so only when they lose jobs. This "gap year" approach can be encouraged where feasible and more clearly distinguished from frictional unemployment or conditions of mismatch or exit from labor markets.

Efforts can be strengthened to counter ageism in hiring, remuneration, retention, and dismissal procedures, as well as in accessing benefits and skills training.

So far, countries such as the US, Canada, Australia, and in Europe have banned discrimination based on age. There is significant variation in the provision, however. For example, the Age Discrimination in Employment Act of 1967 of the US is applicable to workers of ages 40 and above, whereas the European Commission directive is a comprehensive law prohibiting age and other discrimination across all working ages.[66] In many parts of Asia, where firms make recruitment, promotion, and retirement decisions based on seniority, comprehensive bans on workplace age discrimination

66 Council Directive 2000/78/EC of 27 November 2000 establishing a general framework for equal treatment in employment and occupation bans workplace discrimination based on age, belief, disability, and sexual orientation.

have been considered potentially disruptive to business. Experience from countries with anti-age discrimination law, especially in Europe, shows legal provisions can curtail age-based discrimination while accommodating customary employment practices if the rationale behind differential treatment is legitimate and justifiable.

Regional Cooperation in the Era of Workforce Aging

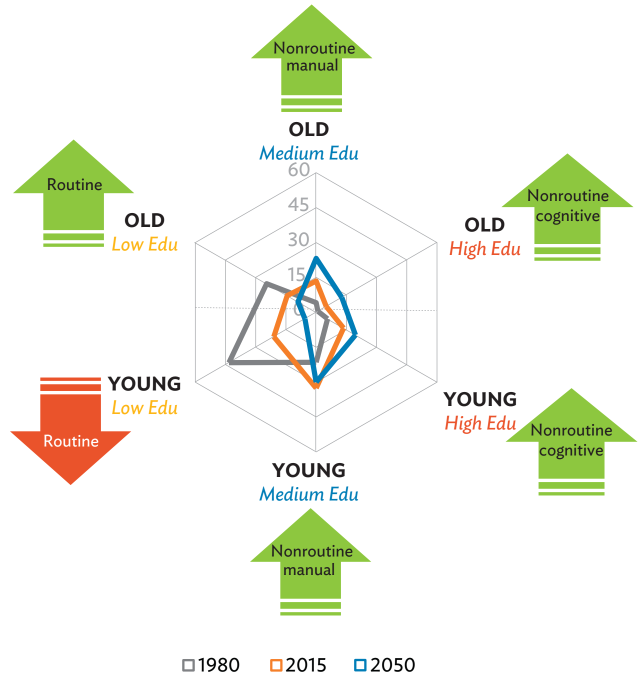
Turning to Asia, policies to promote regional cooperation and tackle issues related to aging can help leverage diverse regional demographic trends.

To determine regional policies, two broad areas can be examined: demographic change and employment patterns, and technology adoption. Examining the demographic and employment momentum for the region overall, Figure 6.44 shows balanced growth in the population in 2050, and that relatively equal employment of tasks will be available across the six categories. There is a shift in demographics toward more high-educated workers, but there will still be workers with at most a primary education available. Also, employment shows a slight overall contraction in routine tasks, but expansion in other areas. This balanced growth of population and equal employment of tasks would imply that regional cooperation in Asia can help meet future needs from aging.

The level of technology adoption is an important indicator of how willing countries will be to adopt technology to aid the elderly population in future. Using an innovation capability score as a proxy for technology adoption, it is clear that adoption varies significantly across Asia. Categorizing the region's countries into the four types, the economies undergoing a Type-1 pattern are in a more advanced stage, with the rest at early stages of technological adaption and capacity (Figure 6.45).

The regional picture on demographics, employment, and technology adoption would imply that labor, capital, and technology movement across Asia could help alleviate particular challenges facing certain types and expand on

Figure 6.44: Regional Demographics and Task Employment—Asia



Notes: Young refers to the economically active population ages 25–49, while old are ages 50–74. Horizontal dashed line delineates the young (lower half) and old (upper half) population. *Low Edu* denotes completion of at most primary education, *Medium Edu* attains secondary education, and *High Edu* has post-secondary education including attendance to short-cycle non-tertiary programs.

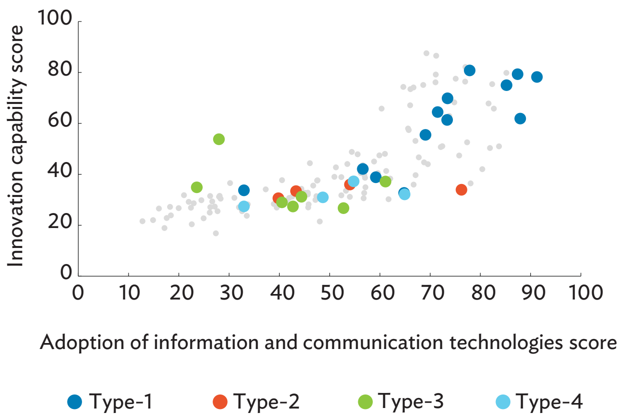
Source: Asian Development Bank.

particular opportunities (Figure 6.46). Specifically, three movements can be encouraged.

First, promoting foreign direct investment from Type-1 to three other types of labor demographic patterns can help tap a large supply of middle-skilled workers in the region.

An ADB study finds that greenfield foreign direct investment (FDI) alone generated almost a million jobs in 2018 (See Chapter 2: Cross-Border Investment). Around half these jobs were created through intraregional FDI. The potential of job generation through FDI from Type-1 fast aging countries remain large. The surge in FDI to Asia has been largely linked to the expansion of global value chains in manufacturing as multinationals relocated parts of the production process in search of lower labor costs.

Figure 6.45: Technology Adoption by Archetype—Asia



Notes: Score on adoption of information and communication technologies (ICTs) refers to the Pillar 3 of Global Competitiveness Index (GCI) 4.0 and captures the degree of diffusion of specific ICTs. Score on innovation capability is the Pillar 12 of the GCI 4.0 and captures quantity and quality of formal research and development; the extent to which a country's environment encourages collaboration, connectivity, creativity, diversity and confrontation across different visions and angles; and the capacity to turn ideas into new goods and services. Asian economies are the colored dots, and are differentiated by archetypes. Type-1 includes the fast aging and high education economies. Type-2 includes the fast aging and low education economies. Type-3 includes the slow aging and low education economies. Type-4 includes the slow aging and high education economies. In gray dots are non-Asian economies.

Source: ADB calculations using data from World Economic Forum (2018).

Type-2 and Type-3 countries can continue to leverage their comparative advantage of abundant low- and middle-educated workers to create manufacturing jobs in labor-intensive industries. More recently, however, services FDI accounted for almost 40% of the total in 2017, most notably in ICT-enabled services. Almost 30% of greenfield jobs in the region were also created in services that employ the more educated workforce.

FDI promotion depends on several factors, including comparative advantage, economic integration, the quality of institutions, and policy factors.

Business environment and the quality of governance are important policy determinants of FDI, particularly from Asian source economies. Improving the business environment—through better ease of doing business such as ease of registering property or obtaining credit—can complement governance quality, which is often more time consuming to reform. Industrial policy such as the creation of economic zones and investment liberalization that gives investors protection through dispute settlement mechanisms are all important tools for Type-2, Type-3, and Type-4 countries to create an investor-friendly environment.

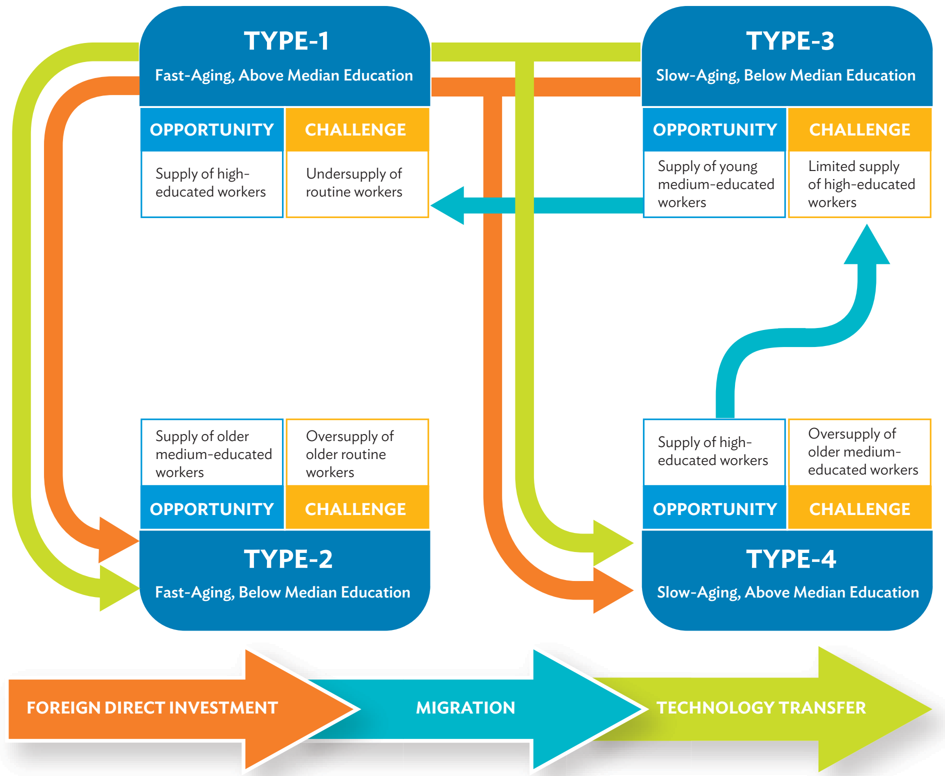
Second, facilitating the international migration of workers from Type-3 to Type-1 economies, and from Type-4 to Type-3, can alleviate challenges associated with a lack of low-educated routine workers in Type-1 economies, and the limited supply of high-educated workers in Type-3.

Of the three recommendations for capital, technology, and labor movement across the types, capital and technology are already flowing between countries. The more challenging problem is to improve cross-country labor mobility. Two general solutions are promoting portability of skills and strengthening mechanism to bring transparency in the process of hiring and employing overseas workers. Both are increasingly important and regarded as promising forms of regional public goods in aging Asia.

Mutual skills recognition such as one adopted in a few Association of Southeast Asian Nations economies has the potential to catalyze increased mobility of labor across borders.

Facilitation of labor mobility requires a framework that recognizes skills and qualification, as well as a program that links those skills to jobs. Association of Southeast Asian Nations (ASEAN), for example, have mutual recognition agreements (MRAs) for several occupations such as architecture, engineering, medicine, nursing, and tourism, and some occupations have started issuing ASEAN licenses. These initiatives can lay a groundwork for creating mechanism to recognize qualifications covering a larger number of countries in the region. In addition, a lesson from the implementation of MRAs in ASEAN is that the establishment of qualification recognition system alone may not promote the skill mobility (Kikkawa and Suan 2019). It is therefore important that acquired recognition is linked to existing

Figure 6.46: Entry Points for Regional Cooperation Strategies



Source: Asian Development Bank.

or new channels of a skill migration program to encourage and promote the use, for example, by providing priority in various immigration-related verification and visa processing. In addition to MRA, a bilateral social security agreement that provides for mutual recognition of pensions and other contributions can reduce the barriers and cost to cross-border labor mobility, especially among the mature and older workforce.

Another solution, which is particularly important in the context of facilitating the mobility of workers with vocational skills is to strengthen mechanisms to bring transparency in the labor market of overseas workers and build an effective monitoring system to ensure that recruitment, placement, and employment of workers follow the stipulated rules and regulations. Collaboration among source and destination countries are needed to guide placement agencies and employers and help promote orderly and safe cross-border movement of migrant workers.

Benefits gained from labor mobility liberalization far exceed anticipated gains from removing barriers to trade or capital flow.

Estimated global gains from 1984 (Hamilton and Whalley 1984) were as large as $3.4 trillion, and even without full migration, they were estimated in 2004 at worth up to $1.97 trillion a year (Clemens 2011, Moses and Letnes 2004). Eliminating global restrictions resulted in efficiency gains of 15%–67% of world GDP, according to Iregui (2003). Moses and Letnes (2004) also show that a 10% increase in international migration corresponded to an efficiency gain of about $774 billion. Whether Asia as a region can seize this opportunity depends partly on whether its countries can create an enabling regional mechanism to encourage cross-border labor mobility.

Third, encouraging cross-border technology transfer can facilitate greater adoption and diffusion of technology to the elderly and poorer populations.

As seen from Figure 6.45, countries in the Type-1 demographic pattern typically have higher rates of technology adoption and diffusion. For countries of other types, where such technologies are not as widespread, companies or governments may be able to create forums for technology transfer. For example, Wi-Fi provision in rural and poorer populations is usually difficult because, given the expected return, private providers do not want to make the necessary infrastructure investments. To increase public Wi-Fi coverage, countries may make Wi-Fi provision a public good—which would enhance the use of other technologies to help the elderly and low-skill populations.

Background Papers

Chomik, R., and J. Piggott. 2018. Population Ageing and Technology: Two Megatrends Shaping the Labour Market in Asia. *ARC Centre of Excellence in Population Ageing Research Working Paper*. No. 2018/10.

Ge, S., and J. Zhang. 2019. Population Aging, Technological Change, and Productivity: Case Study of People's Republic of China. Background paper for the *Asian Economic Integration Report 2019/2020* Theme Chapter on "Demographic Change, Productivity, and the Role of Technology in Asia." Manuscript.

Kapoor, R. 2019. Tapping Technology to Harness the Demographic Dividend in Asia. Background paper for the *Asian Economic Integration Report 2019/2020* Theme Chapter on "Demographic Change, Productivity, and the Role of Technology in Asia." Manuscript.

Kawaguchi, D. and K. Muroga. 2019. Population Aging, Productivity, and Technology in Japan. Background paper for the *Asian Economic Integration Report 2019/2020* Theme Chapter on "Demographic Change, Productivity, and the Role of Technology in Asia." Manuscript.

Kim, J., and C.Y. Park. 2019. New Directions of Economic Policies in the Era of Lifelong Learning. Background paper for the *Asian Economic Integration Report 2019/2020* Theme Chapter on "Demographic Change, Productivity, and the Role of Technology in Asia." Manuscript.

Park, C. Y., K. Shin, and A. Kikkawa. 2019a. Aging, Automation and Productivity: A Case of Korea. Background paper for the *Asian Economic Integration Report 2019/2020* Theme Chapter on "Demographic Change, Productivity, and the Role of Technology in Asia." Manuscript.

———. 2019b. Demographical Change, Technological Advance, and Growth: A Cross-Country Analysis. Background paper for the *Asian Economic Integration Report 2019/2020* Theme Chapter on "Demographic Change, Productivity, and the Role of Technology in Asia." Manuscript.

References

Abeliansky, A., and K. Prettner. 2017. Automation and Demographic Change. *Center for European, Governance and Economic Development Research Discussion Papers.* No. 310. University of Goettingen.

Active Assisted Living (AAL) Programme. http://www.aal-europe.eu/ (accessed July 2019).

Acemoglu, D., and P. Restrepo. 2017. Secular Stagnation? The Effect of Aging on Economic Growth in the Age of Automation. *American Economic Review*. 107 (5). pp. 174–179.

———. 2018. Demographics and Automation. *NBER Working Paper.* No. 24421. Cambridge, MA: National Bureau of Economic Research.

Adler, L. 2016. New Survey Reveals 85% of All Jobs are Filled Via Networking. 29 February. *Linkedin.com*. https://www.linkedin.com/pulse/new-survey-reveals-85-all-jobs-filled-via-networking-lou-adler/.

Aging2.0. https://www.aging2.com/ (accessed July 2019).

Aiyar, S., C. Ebeke, and X. Shao. 2016. The Impact of Workforce Aging on European Productivity. *IMF Working Paper*. No. 16/238. Washington, DC: International Monetary Fund.

Altmann, S., A. Falk, S. Jäger, and F. Zimmermann. 2018. Learning about Job Search: A Field Experiment with Job Seekers in Germany. *Journal of Public Economics*. 164 (C). pp. 33–49.

Asian Development Bank (ADB). 2018. *Asian Development Outlook 2018: How Technology Affects Jobs*. Manila.

———. 2019. *Youth Education Investment and Labor Market Outcomes in the Philippines*. Manila.

Arbulu, I., V. Lath, M. Mancini, A. Patel, and O. Tonby. 2018. *Industry 4.0: Reinvigorating ASEAN Manufacturing for the Future*. Singapore: McKinsey & Company.

Arita, S., A. Hiyama, and M. Hirose. 2017. GBER: A Social Matching App which Utilizes Time, Place, and Skills of Workers and Jobs. In Proceedings of CSCW '17 Companion of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing. 25 February–1 March. Portland, Oregon. pp. 127–130.

Badurashvili, I., and M. Nadareishvili. 2012. *Social Impact of Emigration and Rural-Urban Migration in Central and Eastern Europe: Final Country Report–Georgia*. Brussels: European Commission.

Balachandran, A., J. de Beer, K.S. James, L. van Wissen, and F. Janssen. 2017. Comparison of Ageing in Europe and Asia: Refining the Prospective Age Approach with a Cross-Country Perspective. *NIDI Working Paper.* 2017/01. The Hague: Netherlands Interdisciplinary Demographic Institute.

Beall, A. 2019. Big Data in Health Care: How Three Organizations Are Using Big Data to Improve Patient Care and More. SAS. https://www.sas.com/en_us/insights/articles/big-data/big-data-in-healthcare.html.

Becker, G. 1960. An Economic Analysis of Fertility. In G. S. Becker, ed. *Demographic and Economic Change in Developed Countries*. Princeton: Princeton University Press.

Belbase, A., G. Sanzenbacher, and C. Gillis. 2015. Does Age-Related Decline in Ability Correspond with Retirement Age? *CRR Working Paper*. 2015-24. Chestnut Hill, MA: Center for Retirement Research at Boston College.

Bell, D. and D. Blanchflower. 2011. Young People and the Great Recession. *Oxford Review of Economic Policy*. 27 (2), Summer. pp. 241–267.

Bloom, D., and D. Canning. 2004. Global Demographic Change: Dimensions and Economic Significance. *NBER Working Paper*. No. 10817. Cambridge, MA: National Bureau of Economic Research.

Bloom, D., and J. Williamson. 1998. Demographic Transitions and Economic Miracles in Emerging Asia. *The World Bank Economic Review*. 12. pp. 419–455.

Bloom, D., D. Canning, and J. Sevilla. 2003. *The Demographic Dividend: A New Perspective on the Economic Consequences of Population Change*. Santa Monica: RAND.

Bloom, N., J. Liang, J. Roberts, and Z. Ying. 2015. Does Working from Home Work? Evidence from a Chinese Experiment. *The Quarterly Journal of Economics*. 130 (1). pp. 165–218.

Cancho, C., S. Facusse, and T. Berenice. 2019. *Armenia International Outmigration: An Exploration on the Effects on Armenian Households' Welfare.* Washington, DC: World Bank Group.

Center for Retirement Research at Boston College. Susceptibility Index. http://crr.bc.edu/wp-content/uploads/2016/04/Susceptibility-Index_April-2016.pdf (accessed July 2019).

Chakraborty, A. 2017. Japan's Elderly Are Banking Heavily on Driverless Cars. *NewsBytes*. 14 September. https://www.newsbytesapp.com/timeline/Science/11009/59150/japan-embracing-self-driving-technology-wholeheartedly.

Chesnais, J. C. 1992. *The Demographic Transition: Stages, Patterns, and Economic Implications*. Oxford University Press.

Clemens, M. 2011. Economics and Emigration: Trillion-Dollar Bills on the Sidewalk? *Journal of Economic Perspectives*. 25 (3). pp. 83–106.

Coile, C., K. Milligan, and D. Wise. 2017. Health Capacity to Work at Older Ages: Evidence from the United States. In *Social Security Programs and Retirement around the World*, edited by D. Wise. Chicago: University of Chicago Press.

Coursera. https://blog.coursera.org/about/ (accessed June 2019).

Dawson, H. 2019. How Robotic Pets Can Help the Elderly in Care Homes Be Happy and Mingle More (Without Needing to Feed and Walk Them). *Daily Mail*. 9 May. https://www.dailymail.co.uk/news/article-7008589/How-robotic-pets-help-elderly-care-homes-happy-mingle-more.html

Deloitte LLP. 2016. *The Three Billion: Enterprise Crowdsourcing and the Growing Fragmentation of Work*. Deloitte: London.

Derrien, F., A. Kecskes, and P. A. Nguyen. 2018. Labor Force Demographics and Corporate Innovation. *HEC Research Paper Series.* No. 1243. HEC Paris.

Digital Therapeutics Alliance. 2018. *Digital Therapeutics: Combining Technology and Evidence-Based Medicine to Transform Personalized Patient Care*. https://www.dtxalliance.org/wp-content/uploads/2018/09/DTA-Report_DTx-Industry-Foundations.pdf.

Dumaua-Cabauatan, M., S. Calizo, F. Quimba, and L. Pacio. 2018. E-Education in the Philippines: The Case of Technical Education and Skills Development Authority Online Program. *PIDS Discussion Paper Series*. 2018–08. Manila: Philippine Institute for Development Studies.

East-West Center. 2017. Sharing the Demographic Dividend: Findings from Low and Middle Income Countries in Asia. *National Transfer Accounts Bulletin*. 12 (December). pp. 1–4. Honolulu.

EkStep. https://ekstep.in/ (accessed July 2019).

e-Stat (Portal Site of Official Statistics of Japan). https://www.e-stat.go.jp/ (accessed August 2019).

Eurofund and the International Labour Office. 2017. *Working Anytime, Anywhere: The Effects on the World of Work*. Luxembourg: Publications Office of the European Union, and Geneva: International Labour Office.

Fair, R., and K. Dominguez. 1991. Effects of the Changing U.S. Age Distribution on Macroeconomic Equations. *American Economic Review*. 81 (5). pp. 1276–1294.

Feyrer, J. 2007. Demographics and Productivity. *The Review of Economics and Statistics*. 89 (1). pp. 100–109.

Fleming, S. 2019. Japan's Workforce Will be 20% Smaller by 2040. *World Economic Forum: Regional Agenda*. 12 February. https://www.weforum.org/agenda/2019/02/japan-s-workforce-will-shrink-20-by-2040/.

Foster, M. 2018. Aging Japan: Robots May Have Role in Future of Elder Care. *Reuters*. 27 March. https://www.reuters.com/article/us-japan-ageing-robots-widerimage/aging-japan-robots-may-have-role-in-future-of-elder-care-idUSKBN1H33AB.

Foundation Medicine. 2018. Foundation Medicine Announces Regulatory Approval of FoundationOne CDx in Japan. News Release. 27 December. http://investors.foundationmedicine.com/news-releases/news-release-details/foundation-medicine-announces-regulatory-approval.

Gale, A. 2018. Japan to Accept More Foreign Workers in a Break from Its Historical Stance. *The Wall Street Journal*. 7 December. https://www.wsj.com/articles/japan-to-accept-more-foreign-workers-in-a-break-from-its-historical-stance-1544215014?mod=searchresults&page=1&pos=1&ns=prod/accounts-wsj.

GBD 2017 DALYs and HALE Collaborators. 2018. Global, Regional, and National Disability-Adjusted Life-Years (DALYs) for 359 Diseases and Injuries and Healthy Life Expectancy (HALE) for 195 Countries and Territories, 1990–2017: A Systematic Analysis for the Global Burden of Disease Study 2017. *Global Health Metrics*. 392 (10159). pp. 1859–1922.

GBER: Gathering Brisk Elderly in the Region. http://gber.jp/ (accessed July 2019).

Government of the People's Republic of China, Ministry of Human Resources and Social Security. 2016. China Labour Statistical Yearbook 2016. http://www.mohrss.gov.cn/2016/indexeh.htm (accessed June 2019).

Graetz, G., and G. Michaels. 2018. Robots at Work. *The Review of Economics and Statistics*. 100 (5). pp. 753–768.

Groves, P., B. Kayyali, D. Knott, and S. Van Kuiken. 2013. *The 'Big Data' Revolution in Healthcare: Accelerating Value and Innovation*. https://www.mckinsey.com/insights/health_systems/~/media/7764A72F70184C8EA88D805092D72D58.ashx.

Hamilton, B. and J. Whalley. 1984. Efficiency and Distributional Implications of Global Restrictions on Labour Mobility: Calculations and Policy Implications. *Journal of Development Economics*. 14 (1). pp. 61–75.

Haraya Learning Innovations. https://haraya.xyz/ (accessed July 2019).

Harden, P. 2016. How to Land a Job by Networking. 23 May. *The Washington Post*. 23 May. https://jobs.washingtonpost.com/article/how-to-land-a-job-by-networking/.

Hayami, Y., and V. Ruttan. 1984. Toward a Theory of Induced Institutional Innovation. *The Journal of Development Studies*. 20 (4). pp. 203–223.

Hillestad, R., J. Bigelow, A. Bower, F. Girosi, R. Meili, R. Scoville, and R. Taylor. 2005. Can Electronic Medical Record Systems Transform Health Care? Potential Benefits, Savings, And Costs. *Health Affairs*. 24 (5). pp. 1103–1117.

HireVue. Unilever + HireVue: Unilever Finds Top Talend Faster with HireVue Assessments. https://www.hirevue.com/customers/global-talent-acquisition-unilever-case-study (accessed July 2019).

Ho, V. 2018. The Yield: How to Feed the World Without "Wrecking the Planet." Microsoft: Transform. 23 August. https://news.microsoft.com/transform/videos/yield-feed-world-without-wrecking-planet/.

Huh, U., Y.J. Tak, S. Song, S.W. Chung, S.M. Sung, C.W. Lee, M. Bae, and H.Y. Ahn. 2019. Feedback on Physical Activity Through a Wearable Device Connected to a Mobile Phone App in Patients with Metabolic Syndrome: Pilot Study. *JMIR Mhealth Uhealth*. 7 (6). e13381.

Hyundai. 2018. Hyundai Motor Group Ventures Further into New Robotics Industry of the Future. News Release. 22 October. https://www.hyundainews.com/en-us/releases/2631.

IBM. What is Big Data Analytics? https://www.ibm.com/analytics/hadoop/big-data-analytics (accessed July 2019).

Infocomm Media Development Authority (Singapore). Annual Survey on Infocomm Usage in Households and by Individuals. www.imda.gov.sg (accessed May 2019).

International Federation of Robotics (IFR). 2018. Presentation at the IFR Press Conference. Tokyo. 18 October. https://ifr.org/downloads/press2018/WR_Presentation_Industry_and_Service_Robots_rev_5_12_18.pdf.

———. Statistics. https://ifr.org (accessed June 2019).

International Labour Organization. 2015. *World Employment Social Outlook Trends 2015*. Geneva.

———. ILOSTAT. https://www.ilo.org/ilostat (accessed June 2019).

Indeed. About Indeed. https://www.indeed.com/about (accessed July 2019).

Ip, G. 2019. How Aging Japan Defied Demographics and Revived Its Economy. *The Wall Street Journal*. 11 January. https://www.wsj.com/articles/how-aging-japan-defied-demographics-and-turned-around-its-economy-11547222490.

Iregui, A. 2003. Efficiency Gains from the Elimination of Global Restrictions on Labour Mobility: An Analysis Using a Multiregional CGE Model. *WIDER Working Paper Series*. No. 027. Helsinki: World Institute for Development Economic Research (UNU-WIDER).

Jun, J. 2019. SK Telecom Creates 5G-based Smart Office. *TheKoreaTimes*. 13 February. https://www.koreatimes.co.kr/www/tech/2019/02/133_263616.html.

Kachouie, R., S. Sedighadeli, R. Khosla, and M. T. Chiu. 2014. Socially Assistive Robots in Elderly Care: A Mixed-Method Systematic Literature Review. *International Journal of Human-Computer Interaction*. 30 (5). pp. 369–393.

KC, S., and W. Lutz. 2017. The Human Core of the Shared Socioeconomic Pathways: Population Scenarios by Age, Sex and Level of Education for All Countries to 2100. *Global Environmental Change*. 42. pp. 181–192.

KC, S., W. Lutz, M. Potančoková, G. Abel, B. Barakat, J. Eder, A. Goujon, S. Jurasszovich, T. Sobotka, M. Speringer, E. Striessnig, M. Wurzer, D. Yildiz, S. H. Yoo, and K. Zeman. 2018. Chapter 2: Approach, Methods, and Assumptions. In W. Lutz, A. Goujon, S. KC, M. Stonawski, and N. Stilianakis, eds. *Demographic and Human Capital Scenarios for the 21st Century: 2018 Assessment for 201 Countries*. Luxembourg: Publications Office of the European Union.

Kenthapadi, K., B. Le, and G. Venkataraman. 2017. Personalized Job Recommendation System at LinkedIn: Practical Challenges and Lessons Learned. In *Proceedings of RecSys '17*. 27–31 August. Como, Italy. pp. 346–347.

Kikkawa, A. and E. B. Suan. 2019. Trends and Patterns in Intra-ASEAN Migration. In E. Gentile, ed. *Skilled Labor Mobility and Migration: Challenges and Opportunities for the ASEAN Economic Community*. Manila: Asian Development Bank and UK: Edward Elgar.

Kimura, M., K. Hirakawa, T. Okuno, Y. Oda, T. Morimoto, T. Kitani, D. Fujita, and H. Nagata. 1989. An Analysis of Physical Fitness in the Aged People with Fitness Battery Test. *Jpn J Phys Fitness Sports*. 38. pp. 175–185.

Knowland, V. C. P., and M. S. C. Thomas. 2014. Educating the Adult Brain: How the Neuroscience of Learning Can Inform Educational Policy. *International Review of Education*. 60. pp. 99–122.

Ko, P. C., and K. Hank. 2014. Grandparents Caring for Grandchildren in China and Korea: Findings from CHARLS and KLoSA. *Journals of Gerontology*. Series B: Psychological Sciences and Social Sciences. 69 (4). pp. 646–651.

Koh, D. 2019. Ping An Good Doctor Launches Commercial Operation of One-Minute Clinics in China. *MobiHealthNews*. 7 January. https://www.mobihealthnews.com/news/asia-pacific/ping-good-doctor-launches-commercial-operation-one-minute-clinics-china.

Kolodny, L., and M. Petrova. 2017. This Robotic Glove Will Give You Bionic Hands. *CNBC*. 23 September. https://www.cnbc.com/2017/09/23/nuada-robot-glove-will-give-you-bionic-hands.html.

Korea Education and Research Information Service (KERIS). http://www.keris.or.kr/english/index.jsp (accessed June 2019).

Korean Statistical Information Service. https://kosis.kr/eng/ (accessed June 2019).

Krokos, E., C. Plaisant, and A. Varshney. 2018. Virtual Memory Palaces: Immersion Aids Recall. *Virtual Reality*. 23 (1). pp. 1–15.

Learn Education. https://www.learneducation.co.th/ (accessed July 2019).

Lee, C., S. Czaja, and J. Sharit. 2009. Training Older Workers for Technology-based Employment. *Educational Gerontology*. 35 (1). pp. 15–31.

Lee, H. H., and K. Shin 2019. Nonlinear Effects of Population Aging on Economic Growth. *Japan and the World Economy*. 51 (100963).

Levin, R. 2017. 2017 Learners Outcomes Survey: Online Learners Report Benefits from Advancing their Careers to Discovering a Field of Study to Gaining Confidence. *Coursera Blog*. 26 April. https://blog.coursera.org/online-learners-around-world-report-benefits-ranging-advancing-careers-discovering-field-study-gaining-confidence/.

Li, S. C., U. Lindenberger, B. Hommel, G. Aschersleben, W. Prinz, and P. B. Baltes. 2004. Transformations in the Couplings Among Intellectual Abilities and Constituent Cognitive Processes Across the Life Span. *Psychological Science*. 15 (3). pp. 155–163.

Liang, J., H. Wang, and E. Lazear. 2018. Demographics and Entrepreneurship. *Journal of Political Economy.* 126 (1). pp. 140–196.

Lindh, T. and B. Malmberg. 1999. Age Distributions and the Current Account–A Changing Relation? *Uppsala Working Paper Series*. 21. Uppsala University, Department of Economics.

LinkedIn. Newsroom: Statistics. https://news.linkedin.com/about-us#statistics (accessed June 2019).

Liu, Y., and N. Westlius. 2017. The Impact of Demographics on Productivity and Inflation in Japan. *Journal of International Commerce, Economics and Policy*. 8 (2). pp. 1–16.

Maestas, N., K. Mullen, and D. Powell. 2016. The Effect of Population Aging on Economic Growth, the Labor Force and Productivity. *NBER Working Paper*. No. 22452. Cambridge, MA: National Bureau of Economic Research.

Marinov, B. 2019. Passive Exoskeletons Establish A Foothold in Automotive Manufacturing. *Forbes.com*. 15 May. https://www.forbes.com/sites/borislavmarinov/2019/05/15/passive-exoskeletons-establish-a-foothold-in-automotive-manufacturing/#3a65392434ce.

Marr, B. 2018. The Key Definitions of Artificial Intelligence (AI) That Explain Its Importance. *Forbes.com*. 14 February. https://www.forbes.com/sites/bernardmarr/2018/02/14/the-key-definitions-of-artificial-intelligence-ai-that-explain-its-importance/#44ebd01c4f5d.

Mason, A., and R. Lee. 2011. Population Aging and the Generational Economy: Key findings. In R. Lee and A. Mason, eds. Population Aging and the Generational Economy. London: Edward Elgar Publishing.

Massachusetts Institute of Technology. Agelab. About Agelab. http://agelab.mit.edu/about-agelab (accessed July 2019).

Massing, N., and S. L. Schneider. 2017. Degrees of Competency: The Relationship between Educational Qualifications and Adult Skills across Countries. *Large-scale Assessment in Educ*ation. 5 (6).

Matheson, R. 2017. Virtual-Reality System for the Elderly Wins Health Care Prize. *MIT News Office*. 24 February. http://news.mit.edu/2017/virtual-reality-elderly-sloan-health-care-innovations-prize-0224.

Matsukura, R., S. Shimizutani, N. Mitsuyama, S-H Lee, and N. Ogawa. 2018. Untapped Work Capacity among Old Persons and their Potential Contributions to the "Silver Dividend" in Japan. *The Journal of the Economics of Ageing*. 12 (November). pp. 236–249.

Matuszek, C. 2017. How Robots Could Help the Elderly Age in Their Homes. *Smithsonian.com*. 29 August. https://www.smithsonianmag.com/innovation/how-robots-could-help-elderly-age-in-their-homes-180964650/.

McKinsey Global Institute. 2017. *A Future that Works: Automation, Employment, and Productivity*. McKinsey&Company. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/Digital%20Disruption/Harnessing%20automation%20for%20a%20future%20that%20works/MGI-A-future-that-works-Full-report.ashx.

Meyer, J. 2011. Workforce Age and Technology Adoption in Small and Medium-Sized Service Firms. *Small Business Economics.* 37 (3). pp. 305–324.

———. J. 2007. Older Workers and the Adoption of New Technologies. *ZEW Discussion Paper*. No. 07-050. Mannheim: Center for European Economic Research (ZEW).

Ministry of Internal Affairs and Communications (Japan). Information & Communications Statistics Database. http://www.soumu.go.jp/johotsusintokei/whitepaper/h30.html (accessed May 2019).

Ministry of Science and ICT (Republic of Korea). http://english.msip.go.kr/english/main/main.do (accessed May 2019).

MIT Open Learning. 2016. MIT Joins Collaboration to Bring Connected Learning Experiences to Indian Students and Teachers. *MIT News*. 27 January. http://news.mit.edu/2016/collaboration-connected-learning-experiences-indian-students-teachers-0127.

———. 2018. CLIx Project Receives UNESCO Award. *MIT News*. 13 March. http://news.mit.edu/2018/mit-clix-project-receives-unesco-award-0313.

Montage. https://www.montagetalent.com/ (accessed June 2019).

Moses, J., and B. Letnes. 2004. The Economic Costs to International Labor Restrictions: Revisiting the Empirical Discussion. *World Development*. 32 (10). pp. 1609–1626.

Munnell, A., S. Sass, and M. Soto. 2006. Employer Attitudes Towards Older Workers: Survey Results. *Work Opportunities for Older Americans Series*. 3 (June). Chestnut Hill, MA: Center for Retirement Research at Boston College.

Nagase, N. 2018. Has Abe's Womanomics Worked? *Asian Economic Policy Review*. 13 (1). pp. 68–101.

National Center for Geriatrics and Gerontology (Japan). http://www.ncgg.go.jp/cgss/english/department/nils-lsa/index.html (accessed July 2019).

National Silver Academy. https://www.nsa.org.sg/ (accessed September 2019).

National Transfer Accounts. www.ntaccounts.org (accessed June 2019).

———. Data Sheet 2016. https://www.ntaccounts.org (accessed July 2019).

Organisation for Economic Co-operation and Development (OECD). 2017. *Pensions at a Glance 2017*. Paris: OECD Publishing.

———. 2019. *OECD Employment Outlook 2019: The Future of Work*. Paris: OECD Publishing.

———. OECD.Stat Database. https://stats.oecd.org/ (accessed June 2019).

———. 2014–2015 Survey of Adult Skills of the Programme for the International Assessment of Adult Competencies. http://www.oecd.org/skills/piaac/data/ (accessed May 2019).

Oshio, T. 2018. Health Capacity to Work and Its Long-term Trend among the Japanese Elderly. *RIETI Discussion Paper Series*. 18-E-079. Tokyo: Research Institute of Economy, Trade and Industry.

Oshio, T., E. Usui, and S. Shimizutani. 2018. Labor Force Participation of the Elderly in Japan. *NBER Working Papers*. 24614. Cambridge, MA: National Bureau of Economic Research.

Osso VR. The Osso Story. https://ossovr.com/the-osso-story/ (accessed July 2019).

Paccagnella, M. 2016. Age, Ageing and Skills: Results from the Survey of Adult Skills. *OECD Education Working Papers.* No. 132. Paris: OECD Publishing.

Panasonic. 2018. ATOUN to Make CES Debut with 'MODEL Y' Exoskeleton. News Release. 28 December. https://news.panasonic.com/global/topics/2018/64460.html.

Park, R. Nisbett, and T. Hedden. 1999. Aging, Culture, and Cognition. *Journals of Gerontology*: Series B Psychological Sciences and Social Sciences. 54. pp. 75–84.

Petersen, S., S. Houston, H. Qin, C. Tague, and J. Studley. 2017. The Utilization of Robotic Pets in Dementia Care. *Journal of Alzheimer's Disease*. 55 (2). pp. 569–574.

Reynolds, B. 2018. What is a Remote Job? *FlexJobs*. 9 January. https://www.flexjobs.com/blog/post/what-is-a-remote-job/.

Rones, P. 1983. The Labor Market Problems of Older Workers. *Monthly Labor Review*. May. pp. 3–12.

Sanderson W.C., and S. Scherbov. 2007. A New Perspective on Population Aging. *Demographic Research*. 16(2). pp. 27–58.

Sanderson, W.C., S. Scherbov, and P. Gerland. 2017. Probabilistic Population Aging. *PLoS ONE*. 12 (6).

Sato, H. 2019. Foreign Workers in Japan Double in 5 Years, Hitting Record. *Nikkei Asian Review*. 25 January. https://asia.nikkei.com/Spotlight/Japan-immigration/Foreign-workers-in-Japan-double-in-5-years-hitting-record.

Schwartz, J., K. Monahan, S. Hatfield, and S. Anderson. 2018. No Time to Retire: Redesigning Work for Our Aging Workforce. *Deloitte Insights*. https://www2.deloitte.com/content/dam/Deloitte/at/Documents/human-capital/at-workforce-longevity.pdf.

Segan, S. 2019. What is 5G? *PC Mag*. 16 April. https://www.pcmag.com/article/345387/what-is-5g.

Sharma, B. 2019. UrbanClap Launches Operations in Abu Dhabi. *The Urban Guide*. 24 June. https://www.urbanclap.com/blog/company-updates/urbanclap-launches-operations-in-abu-dhabi/.

Shimizu Corporation. 2018. The Shimizu Smart Site Autonomous Robots Can Transform a Job Site! 26 April. https://www.shimz.co.jp/en/topics/construction/item12/index.html.

Sirlantzis, K., L. Larsen, L. Kanumuru, and P. Opera. 2019. 11-Robotics. In D. Cowan and L. Najafi, eds. *Handbook of Electronic Assistive Technology*. London: Academic Press.

SkyHive. 2018. SkyHive Launches the World's First Skills Matching Recruitment Training Platform. *Medium.com*. 31 May. https://medium.com/@iskyhive/skyhive-was-established-in-2016-with-a-simple-mission-help-people-get-work-they-love-fast-a21650988162.

Slack. https://slack.com/ (accessed June 2019).

Smith, A., and M. Anderson. 2018. *Social Media Use in 2018*. Washington, DC: Pew Research Center.

Speringer, M., A. Goujon, S. KC, M. Potančoková, C. Reiter, S. Jurasszovich, and J. Eder. 2019. Global Reconstruction of Educational Attainment, 1950 to 2015: Methodology and Assessment. *Vienna Institute of Demography Working Papers*. 02/2019. Wien: Austrian Academy of Sciences.

Statistics Bureau of Japan. Employment Status Survey 2018. https://www.stat.go.jp/english/data/index.html (accessed June 2019).

Strauss, K. 2018. The Role of Artificial Intelligence in The Future of Job Search. *Forbes*. 2 February. https://www.forbes.com/sites/karstenstrauss/2018/02/02/the-role-of-artificial-intelligence-in-the-future-of-job-search/#1709ff2a4cb0.

Strimbu, K., and J. Tavel. 2010. What are Biomarkers? *Current Opinion in HIV and AIDS*. 5(6). pp. 463–466

Team YS. 2019. FromBbeauty to Home Repairs, How UrbanClap Leverages AI to Serve Over 2 million Workers. *YourStory.com*. 4 January. http://yourstory.com/2019/01/urbanclap-leverages-ai-serve-2-million-customers.

TESS-India (Teacher Education through School-based Support). http://www.tess-india.edu.in/ (accessed July 2019).

The Open University. Projects and Programmes: TESS-India. http://www.open.ac.uk/about/international-development/projects-and-programmes/tess-india. (accessed July 2019).

United Nations Department of Economic and Social Affairs, Population Division. https://population.un.org/wpp/Download/Standard/Population/ (both accessed June 2019).

University of the Third Age (U3A). https://u3a.org.uk/ (accessed September 2019).

University of Tokyo. 2018. Turning Aging Society on Its Head: Web App Helps Seniors Find Jobs, Stay Connected. Features. 14 September. https://www.u-tokyo.ac.jp/focus/en/features/z0508_00007.html.

Wasiluk, K. 2014. Technology Adoption and Demographic Change. *Working Paper Series*. 2014-05. Konstanz: University of Konstanz Department of Economics.

Weinburg, B. 2004. Experience and Technology Adoption. *IZA Discussion Paper Series*. 1051. Bonn: Institute of Labor Economics (IZA).

Wittgenstein Centre for Demography and Global Human Capital. Wittgenstein Centre Data Explorer Version 2.0. www.wittgensteincentre.org/dataexplorer (accessed June 2019).

World Bank. World Development Indicators. https://databank.worldbank.org/source/world-development-indicators (accessed July 2019).

World Economic Forum. 2018. *The Global Competitiveness Report 2018*. Geneva.

World Health Organization (WHO). 2017. Mental Health of Older Adults. 12 December. https://www.who.int/news-room/fact-sheets/detail/mental-health-of-older-adults.

———. 2019. What You Need to Know about Digital Health Systems. 5 February. http://www.euro.who.int/en/health-topics/Health-systems/pages/news/news/2019/2/what-you-need-to-know-about-digital-health-systems.

Wright, D., D. Witherick, and M. Gordeeva. 2018. *The Robots Are Ready. Are You?* London: Deloitte Development LLC. London.

ANNEX 6a: Demographical Change, Technological Advance, and Growth: A Cross-Country Analysis

A Methodological Note

I. Revisiting the Impact of Aging Population on Macroeconomic Growth

The empirical specification below follows the methodology of Fair and Dominguez (1991) allowing to investigate the economic growth effect of aging considering country *i* at time *t's* entire population age distribution represented by $\mathrm{p1}_{it}, \mathrm{p2}_{it}, \dots, \mathrm{pJ}_{it}$ over *J*-age groups:

$$y_{it} = \lambda + X_{it}\beta + \alpha_1 \mathrm{p1}_{it} + \alpha_2 \mathrm{p2}_{it} + \cdots + \alpha_J \mathrm{pJ}_{it} + u_{it} \quad (1)$$

where y_{it} refers to the 5-year average growth of real gross domestic product (GDP) per capita, λ is a constant term, X_{it} denotes *k*-column vector of control variables, α_j is age-group *j's* coefficient, and u_{it} is the error term. To minimize cyclical fluctuations, *t* refers to the 5-year subperiods between 1965 and 2015. With a constant term included, the sum of age-group coefficients is restricted to equal to zero such that $\sum_{j=1}^{J} \alpha_j = 0$. Further, to reduce the number of coefficients to be estimated, age-group coefficients are restricted to lie on a third-order polynomial, i.e., $\alpha_j = \gamma_0 + \gamma_1 j + \gamma_2 j^2 + \gamma_3 j^3$, thereby transforming the specification in equation (1) as follows (see Higgins [1998] for the derivation):

$$y_{it} = \lambda + X_{it}\beta + \gamma_1 D1_{it} + \gamma_2 D2_{it} + \gamma_3 D3_{it} + u_{it}$$

where $D1_{it} = \sum_{j=1}^{J} j \cdot pj_{it} - \frac{1}{J}\sum_{j=1}^{J} j$, $D2_{it} = \sum_{j=1}^{J} j^2 \cdot pj_{it} - \frac{1}{J}\sum_{j=1}^{J} j^2$,

and $D3_{it} = \sum_{j=1}^{J} j^3 \cdot pj_{it} - \frac{1}{J}\sum_{j=1}^{J} j^3$. (2)

Before estimation, outliers are removed by excluding extreme growth observations, i.e., 5-year annual average growth less than –5% or over 15%, and extremely young countries with old dependency rate less than 4%. Real GDP information refers to the GDP at constant prices in local currency unit from the version 9.0 of the Penn World Table. Dividing it by the total population gives the per capita terms. The age distribution of population (on a 5-year age groupings, i.e., 0–4, 5–9,..., 80+) is derived from the World Population Prospects 2017 published by the Population Division of the United Nations.

Annex Table 6a.1 presents the results of several estimates of equation (2). Columns 1-3 report the pooled OLS regression estimates. Column 1 is estimated without control variables, while Columns 2 and 3 control for the initial per capita GDP, with the latter adding region dummies. Columns 4 and 5 are panel FE estimates, with the latter involving only OECD samples. Age group-specific coefficients α_j ($j = 1, \dots 17$) are retrieved from the transformation: $\alpha_j = \gamma_0 + \gamma_1 j + \gamma_2 j^2 + \gamma_3 j^3$ and mapped in Figure 6.27. While there are some differences across different specifications, one common feature is that age groups between 15 and 40 (or 45) have positive and age groups below 10 and above 60 have negative contributions to the future growth.

II. Investigating the Effect of Technological Advancement on the Relation between Demographic Change and Growth

The exercise requires adding an interaction term between measures of technological advancement T_{it} and age-group distribution to the regressors while maintaining the restriction that age-group coefficients lie on a third-order polynomial, such that:

$$y_{it} = \lambda + X_{it}\beta + \gamma_1 D1_{it} + \gamma_2 D2_{it} + \gamma_3 D3_{it} +$$

$$[T_{it} \times (\sigma_0 + \sigma_1 D1_{it} + \sigma_2 D2_{it} + \sigma_3 D3_{it})] + u_{it} \quad (3)$$

Four proxies attempt to capture technological advancement: (i) life expectancy reflecting technological improvement in providing healthcare, (ii) labor productivity, (iii) robot density measuring technological progress narrowly by degree of automation, and (iv) total factor productivity. Life expectancy at birth information is gathered from the United Nations' World Population Prospects: The 2017 Revision. Labor productivity is calculated from the GDP and employment data from the Penn World Table 9.0. Robot density is derived from information on the country-specific operational stock of industrial robots available from 1993–2015 reported by the International Federation of Robotics. Total factor productivity (TFP), known for capturing development of production and process technologies, is based from the calculated series of the Penn World Table version 9.1 expressed as levels relative to the United States.

Annex Table 6a.2 presents estimation results of equation (3). Transformation to age-specific coefficients finds that expansion in life expectancy widens the range of age groups that have positive impact on future growth including the older ones (see Figure 6.28). Similar case is found when technological advancement leads to higher labor productivity. Meanwhile, higher automation adoption does not move the range of age groups that have positive impacts on economic growth. Higher robot density nevertheless enables the old population to remain growth contributors. Last, technological adoption enhances the growth contribution of productive age groups from 30s to 60s when one compares low (–0.5) to high (0.5) TFP (in log) scenarios (see Figure 6.29).

Annex Table 6a.1: Impact of Age Distribution on GDP Per Capita Growth

Variables	(1)	(2)	(3)	(4)	(5)
Log initial GDP per capita		-0.006*** (0.001)	-0.006*** (0.001)	-0.019*** (0.004)	-0.032*** (0.006)
D1	0.110*** (0.029)	0.170*** (0.032)	0.147*** (0.031)	0.139*** (0.045)	0.099 (0.068)
D2	-0.011** (0.005)	-0.019*** (0.005)	-0.017*** (0.005)	-0.015** (0.007)	-0.005 (0.009)
D3	0.000 (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.000 (0.000)	-0.000 (0.000)
Pooled OLS estimates	Yes	Yes	Yes		
Panel FE estimates				Yes	Yes
Region dummies			Yes		
OECD sample					Yes
No. of observations	1,454	1,454	1,445	1,454	321
R-squared	0.065	0.089	0.127	0.100	0.347
p-value of joint test	0.000	0.000	0.000	0.000	0.004
No. of countries	167	167	167	167	35

*** = significant at 1%, ** = significant at 5%, * = significant at 10%. Robust standard errors in parentheses. The p-value is for the joint hypothesis that the coefficients of D1, D2, and D3 are all zero.

FE = fixed effects, GDP = gross domestic product, OECD = Organisation for Economic Co-operation and Development, OLS = ordinary least squares.

Note: The tenth sub-period refers only to the four years from 2010 to 2014 due to the data availability in the Penn World Table 9.0.

Source: Park, Shin, and Kikkawa (2019b).

Annex Table 6a.2: Technological Advancements and Impact of Age Distribution on GDP Per Capita Growth

	Life Expectancy		Labor Productivity		Robot Density (in logs)		Total Factor Productivity (in logs)	
Variables	Pooled OLS	Panel FE	Pooled OLS	Panel FE	Pooled OLS	Panel FE	Pooled OLS	Panel FE
Log initial GDP per capita	-0.008*** (0.001)	-0.021*** (0.004)	-0.005 (0.004)	-0.053*** (0.012)	-0.011*** (0.003)	-0.038*** (0.012)	-0.011*** (0.003)	-0.030** (0.014)
D1	0.567*** (0.200)	0.612** (0.307)	1.672*** (0.269)	2.355*** (0.404)	0.197 (0.224)	0.572 (0.351)	0.171 (0.164)	0.072 (0.236)
D2	-0.081*** (0.031)	-0.078* (0.047)	-0.230*** (0.042)	-0.324*** (0.066)	-0.017 (0.032)	-0.067 (0.054)	-0.014 (0.023)	0.007 (0.032)
D3	0.003*** (0.001)	0.003 (0.002)	0.009*** (0.002)	0.012*** (0.003)	0.000 (0.001)	0.002 (0.002)	0.000 (0.001)	-0.001 (0.001)
Technological advancement (T)	-0.003*** (0.001)	-0.001 (0.001)	-0.021*** (0.007)	0.016 (0.018)	0.002 (0.003)	0.000 (0.012)	-0.046* (0.026)	-0.141*** (0.047)
D1 x T	-0.007** (0.003)	-0.008* (0.005)	-0.158*** (0.028)	-0.226*** (0.040)	-0.002 (0.037)	-0.053 (0.059)	-0.023 (0.349)	-0.559* (0.296)
D2 x T	0.001** (0.000)	0.001 (0.001)	0.022*** (0.004)	0.032*** (0.007)	0.000 (0.005)	0.006 (0.008)	0.009 (0.051)	0.086* (0.043)
D3 x T	-0.000*** (0.000)	0.000 (0.000)	-0.001*** (0.000)	-0.001*** (0.000)	0.000 (0.000)	0.000 (0.000)	-0.001 (0.002)	-0.004** (0.002)
No. of observations	1,439	1,439	1,324	1,324	183	183	252	252
R-squared	0.129	0.115	0.158	0.161	0.442	0.402	0.286	0.343
p-value of joint test: level terms	0.000	0.074	0.000	0.000	0.060	0.094	0.000	0.102
p-value of joint test: interaction terms	0.000	0.131	0.000	0.000	0.846	0.600	0.187	0.027
No. of countries	165	165	167	167	65	65	63	63

*** = significant at 1%, ** = significant at 5%, * = significant at 10%. Robust standard errors in parentheses. The p-value is for the joint hypothesis that the coefficients of D1, D2, and D3 are all zero.

FE = fixed effects, GDP = gross domestic product, OLS = ordinary least squares, T = Technological advancement.

Note: The tenth sub-period refers only to the 4 years from 2010 to 2014 due to the data availability in the Penn World Table 9.0.

Source: Park, Shin, and Kikkawa (2019b).

ANNEX 6b: Data and Methodology Used in Country Case Studies

Country	Japan	People's Republic of China	Republic of Korea
Growth indicator	Value added per hours worked	(i) Gross domestic product per capita, and (ii) Value added per worker at the firm level	(i) Value added per hours worked, and (ii) Total factor productivity growth
Aging indicator	(i) Share of workers over age 65 to ages 15–64, and (ii) Alternatively, share of age 55 and above	Share of population above the age of 55 to ages 21–55	(i) Share of workers in their sixties and seventies, and (ii) Median working age
Technology indicator	(i) Industrial robots, and (ii) Electrical computation machines	(i) Industrial robots, and (ii) Capital–labor ratio, (iii) Research and development expenditure	(i) Industrial robots, and (ii) Capital–labor ratio
Period of analysis	1990 to 2010 5-year growth	1998 to 2007 (and to 2016 for industrial robots)	2006 to 2015 5-year growth
Unit of analysis	Industry level	Prefecture and firm level	Industry level
Empirical method	Pooled ordinary least squares	Pooled ordinary least squares	Pooled ordinary least squares
Other controls	Industry fixed effects Capital–labor ratio, labor capital ratio, time fixed effects	Firm-level characteristics, wage level, prefecture and time fixed effects	Capital–labor ratio, time fixed effects
Instrumental variables	No	Yes, fine for unauthorized birth	Yes, 3-year growth rate

Sources: Ge and Zhang (2019); Kawaguchi and Muroga (2019); and Park, Shin, and Kikkawa (2019a).