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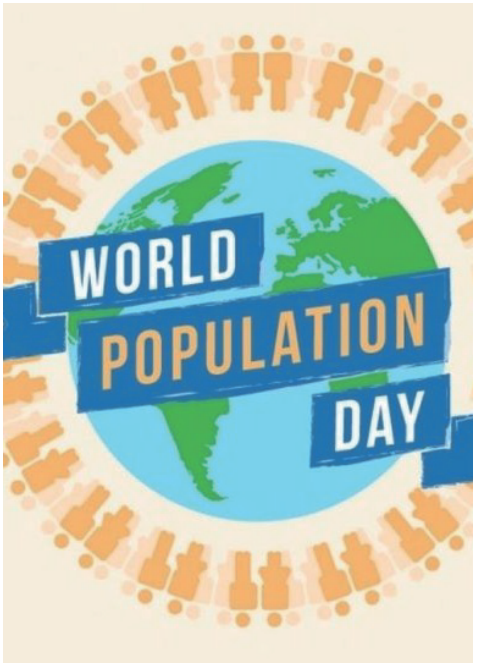

WORLD POPULATION DAY ISSUE

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China CDC Weekly

This week's issue was organized by Guest Editor Xiaoying Zheng.
Cover Image: Adapted from http://www.newdelhitimes.com/safeguarding-the-health-and-rights-of-women-and-girls-theme-of-this-Ayears-world-population-day/

Foreword

The Uncertainties of Population Research: Challenges and Opportunities

An estimated 7.7 billion people are living in the world today, and that total is expected to reach around 8.5 billion in 2030, 9.7 billion in 2050, and further increase to 11.2 billion by 2100 (*1*). In 1987, the world's population hit 5 billion. To mark the date, the Governing Council of the United Nations Development Programme (UNDP) established the annual World Population Day to be observed on July 11 every year since 1989.

The 32nd World Population Day (WPD) is coming. In this second year of the coronavirus disease 2019 (COVID-19) pandemic, the United Nations Population Fund (UNFPA) has expressed continued concern over various population issues such as changing fertility rates, healthcare systems, sexual and reproductive health, and gender equality against the backdrop of the ongoing pandemic.

For the current population development, it is not difficult to find some trend changes, such as the recognized global demographic "megatrends," i.e., population growth, population aging, international migration, and urbanization. The population size in the present and future as mentioned above, indicates that the world population will continue to grow during a certain period in the future. However, the global fertility is projected to fall from 2.5 children per woman in 2019 to 2.2 in 2050, and life expectancy at birth is expected to rise from 72.6 years in 2019 to 77.1 years in 2050 (*1*). The decreasing fertility combined with increasing longevity makes population aging inevitable. In addition, although international migration usually contributes much less to population change compared with births or deaths, its effect is undeniable, given that the world is accelerating migration and urbanization.

The results of the Seventh National Population Census of China that was recently released also shows China's similar status. First, the fertility of China is exceptionally low. The total fertility rate in 2020 was only 1.3 children per woman, which is far below the replacement level (*2*). In addition, China is experiencing rapid population aging and persons aged 60 years or over account for 18.70% of the total population, which was an increase of 5.44% compared with the Sixth National Population Census results conducted in 2010 (*3*). In addition, more and more populations are involved in migration. In 2020, there were 375.8 million individuals in the floating population in China, with an increase of 69.73% compared with that in 2010. Furthermore, nearly 902 million individuals lived in urban areas, accounting for 63.89% of the total population (*4*).

However, the outbreak and global pandemic of COVID-19 reminds us that we should not ignore the uncertainty of population development, especially short term trends compared to what seems to be regularity in the long run. The uncertainties are partly due to the huge population of the world, especially in China, and also come from the internal characteristics such as the polymorphism of population structure changes and the uncertain development of external environments to include increasing adverse climate and ecosystem changes, regional conflicts and wars, and unpredictable public health emergencies such as the pandemic.

In this special issue, we invited colleagues from the UNFPA, United Nations Population Division, Princeton University, Duke University, University of British Columbia, Peking University, and Renmin University of China to report their latest findings on challenges and opportunities under the population trends around the world. Gu et al. assessed major trends in population growth around the world and variations across regions and countries (*5*). Luo et al. estimated the trends and challenges for population and health during population aging in China (*6*). Wang et al. analyzed the factors of Chinese population fertility changes from the perspective of economics and education (*7*). Finally, Qian et al. examined the China–US difference in attitudes toward COVID-19 and evaluated the role of belief in science to explain the differences (*8*).

The findings from this special issue further confirmed the trend of growth in the world's population at a slower pace, the substantial variations in population trends across regions and countries, and important role of population momentum in determining future population growth. For China, the increases in life expectancy, declines in fertility rate and consequent population aging, and increasing life expectancy with disability are predicted. However, this special issue also indicated uncertainties in future population growth and multiple states of future trends of

population structure change — that is the complex effects of economic development and education on fertility rate, the uncertainties and inaccuracies in urbanization rate statistics, and various public trust in science and public support for population health measures will all impact the fertility, migration, and mortality of a population.

In the context of approaching the 2030 Sustainable Development Goals, the uncertainties in population research and the reasons behind them put forward challenges to social governance and provide important opportunities for us to make changes. To deal with these internal and external challenges of population research, it is urgent to review and further explore the complementarities between economic development and population development and to improve global policy, institutional support structures, and dynamic evaluation. Timely adjustment, innovations, and perfection of population health strategies are needed, especially for females, older adults, floating populations, and populations with disability.

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Preplanned Studies

Trends and Challenges for Population and Health During Population Aging — China, 2015–2050

Yanan Luo[1,2]; Binbin Su[2,4]; Xiaoying Zheng[2,3,4,#]

Summary

What is already known about this topic?

As the largest country in the world, China experienced a demographic transition at a historic scale during the past 50 years with extraordinarily associated changes in the age structure of the population, declining fertility rates, accelerating process of population aging, and growing population scale.

What is added by this report?

This study presented future trends of five important population indicators in China. From 2015–2050, China experienced outstanding demographic changes — increases in life expectancy and declines in fertility rate — that have led to population aging. In addition, disability prevalence is growing, and life expectancy with disability is also increasing.

What are the implications for public health practice?

This study provided evidence of healthy life expectancy improvement and disease burden declining, healthy aging, and active aging. Due to the uncertainties of future trends of population structure changes, dynamic evaluations, timely adjustments, and innovations in population health strategy design and management should be strengthened to ensure quality of life under the background of population aging.

China experienced significant changes in the age structure of the population, declining fertility rates, and accelerating population aging (*1*) and has made considerable strides in raising its life expectancy. However, the double burden of population aging and an increasing chronic disease burden has led to the continuous growth of the disability burden in China (*2*). An increasing pace of aging and fluctuated population trends in China poses serious challenges for population health, which makes predicting future trends increasingly important. By using the Sample Census in 2015 and secondhand data in China, this study used the Population-Development-Environment (PDE) model and used the Sullivan method to present the future trends of scale, structure of population, life expectancy, disability, and disability-free life expectancy. This study presented predictions of five important indicators of population trends from 2015–2050 in China, which showed China experiencing major demographic and health changes. Elderly population health promotion and disability prevention measures should be implemented to eliminate adverse health effects influenced by population aging.

This study used data from the 2015 Sample Census and previous publications (*3*–*4*) to predict future population trends. The 2015 Sample Census was conducted by the National Bureau of Statistics, which provided detailed data on the population scale and structure of China, covering 31 provincial-level administrative divisions (PLADs) in China. Disability-related data was mainly calculated based on the First and Second National Sample Surveys on Disability, which were nationally representative population-based surveys conducted in 1987 and 2006, respectively, according to the World Health Organization (WHO) International Classification of Functioning, Disability, and Health. The PDE model, epidemiological calculations, and Sullivan method were used to predict population trends and healthy life expectancy from 2015–2050, respectively. The mathematical expressions for PDE were as follows:

$$P_{(t+1,n+1)}=P_{(t,n)}\times\left(1-D_{(t+1,n+1)}\right)+N_{(t+1,n+1)} \quad (1)$$

$$P_{(0,n+1)}=\sum_{l=15}^{49}\left[F_{(t,n+1)}\times FR_{(t,n+1)}\right]\times\left(1-D_{(0,n+1)}\right) \quad (2)$$

$$F_{(0,n+1)}=P_{(0,n+1)}\times fr_{n+1} \quad (3)$$

$$PT_{n+1}=\sum_{l=1}^{m}P_{(t,n)}+P_{(0,n+1)} \quad (4)$$

Where t, n, P, PT, D, and N represent the age, year, population, total population, mortality rate, and net migration flow, respectively. F, FR, and fr represent the number of women, the fertility rate for specific age groups, and the total proportion of women with

newborns, respectively. PT and m represent the total population and the highest age of the population, respectively. The principles underlying the PDE model can be found in Supplementary Figure S1 available in http://weekly.chinacdc.cn/.

Based on the assumptions of three scenarios, the predictive parameters of the PDE model include total fertility rate (TFR) and mortality rate (MR). The TFR parameters from 2015–2017 of Scenarios 1 and 2 were set according to the survey findings from National Fertility Intention Survey. Scenario 1 assumes that TFR declines from 2017 and reaches 1.60 in 2018–2020 and will increase to 1.70 from 2021–2050 due to the Three-Child Policy based on expert's judgement. Scenario 2 assumes that TFR will decline to 1.60 from 2026–2050 with the fading effects of the three-child policy. Scenario 3 assumed that birth patterns across the mainland of China were similar to those in Taiwan, China in 2000, because the TFR of the mainland of China in 2015 was similar to that of Taiwan, China in 2000. More details can be found in Supplementary Table S1 available in http://weekly.chinacdc.cn/. Mortality rate was calculated according to assumptions from a previous study (*5*). According to the Outline of Healthy China 2030 Plan, life expectancy in 2020 was assumed to be 77 years and 80 years in 2030. By 2050, life expectancy was projected to reach 85 years according to China's General Program for Sustainable Development. Furthermore, we assumed that the prevalence of disability to be increasing at the same rate as from 1987–2006. The scale of disability was calculated according to the prediction of population scale and the assumption of disability prevalence. Disability-free life expectancy was calculated through the Sullivan method.

Findings from the PDE model showed that the total population would reach 1.40–1.44 billion by 2030 and 1.29–1.40 billion by 2050 (Figure 1). Our findings indicated that in 2030, about 70% of the total population would live in cities, and this percentage would reach over 81% in 2050.

In the future, China is expected to face rapid population aging even after considering the effects of two-child and three-child policies on population. According to the moderate prediction, China was projected to become an aged society by 2022 and a super-aged society by 2033. This 11 year transformation sees the population aged 65 years or older (henceforth referred to as the elderly) comprise 14% of the total population to 20% by 2033 (Figure 2). From the Fifth Population Census to the Seventh Population Census, the proportion of elderly was continuously increasing from 6.96% in 2000 to 8.87% in 2010, and 13.50% in 2020. Overall, 30 of 31 provincial-level administrative divisions (PLADs) in the mainland of China in 2020 entered the "aging society phase" with the proportion of elderly making up over 7% of the population, and 12 PLADs entering the "aged society phase" with the proportion of elderly over 14%. Only Tibet Autonomous Region did not enter the "aging society" phase, which may be due to its low life expectancy (Table 1, Figure 3).

The study prediction showed that, currently,

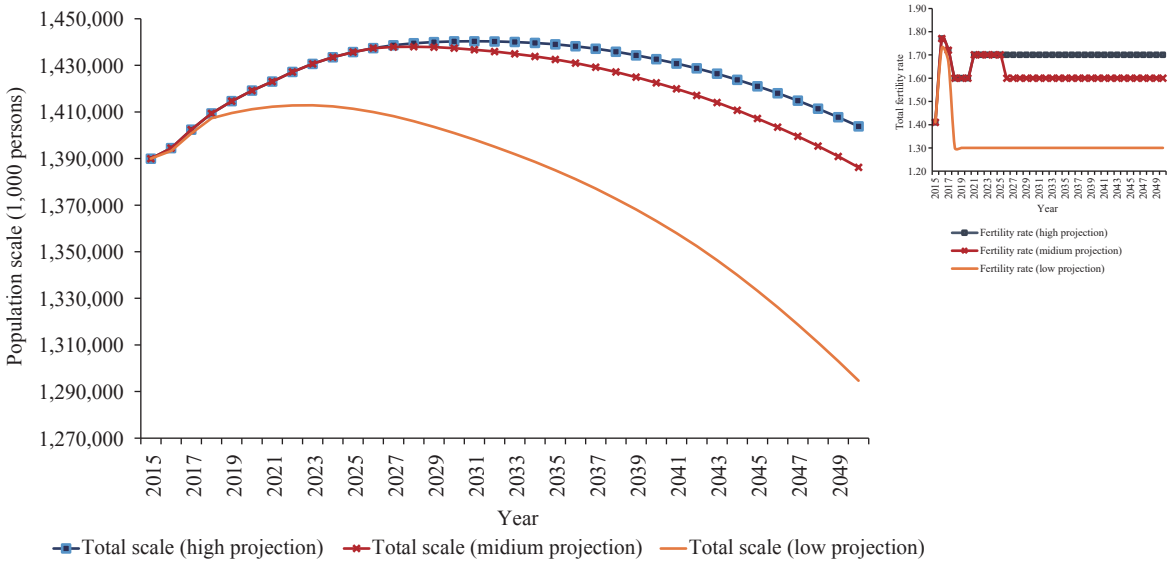
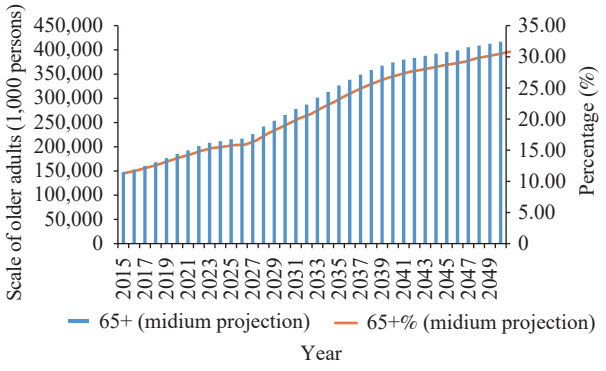


FIGURE 1. The predicted population trends and total fertility rate in China, 2015–2050.



Aging society	Aged society	Super aged society	Years of transition	
>7%	>14%	>21%	7% to 14%	14% to 21%
2000	2022	2033	22	11

FIGURE 2. The predicted proportion and prevalence of older adults in China, 2015–2050.

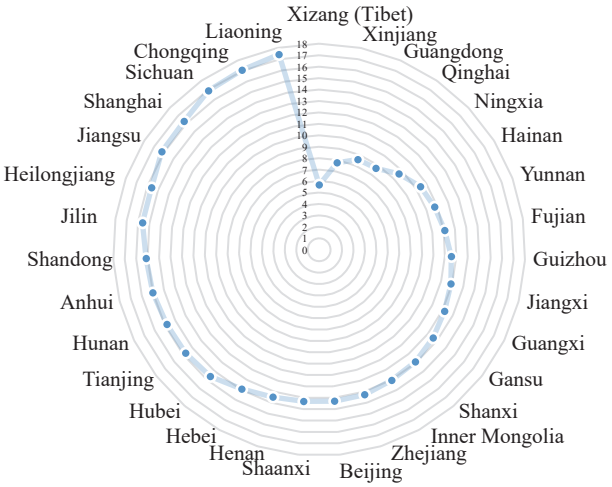


FIGURE 3. Scale of older adults (65+ years) by PLAD, Seventh Census, 2020.
Note: Aging society, 65+ years%=7%–14%; aged society, 65+ years%=14%–20%; super aged society=65+ years %>20%.
Abbreviation: PLAD=provincial-level administrative division.

108.67–108.79 million persons with disability were estimated in China in 2020. By 2030, this number was projected to increase to 136.24–136.74 million (Figure 4). Along with population aging, the challenge of disabled population aging has become an increasingly prominent issue in China. In 1987, disability in China had a balanced distribution of age, but this shifted towards people of older ages in 2006. The number of elderly people with disability reached 52.71 million in 2020, and the proportion of disabled elderly was projected to account for over 57% of total disabled persons by 2030 and would further increase to over 70% by 2050 if no prevention and control measures are implemented.

According to our prediction, life expectancy of males and females is expected to continue increasing. For males, life expectancy increased from 73.9 years in 2015 to 74.9 years in 2020, to 77.2 years in 2030 and 81.85 years in 2050. For females, life expectancy was projected to increase from 79.9 years in 2015 to 80.65 years in 2020, to 83.14 years in 2030 and 88.13 years in 2050 (Figure 5).

Figure 6 showed that disability-free life expectancy at birth (both sexes combined) was forecasted to increase from 69.53 years in 2015 to 72.87 years in 2030 and over 78.26 in 2050. However, the percentage of life expectancy with disability will keep growing: from 9.60% in 2015 to 11.22% in 2030 and

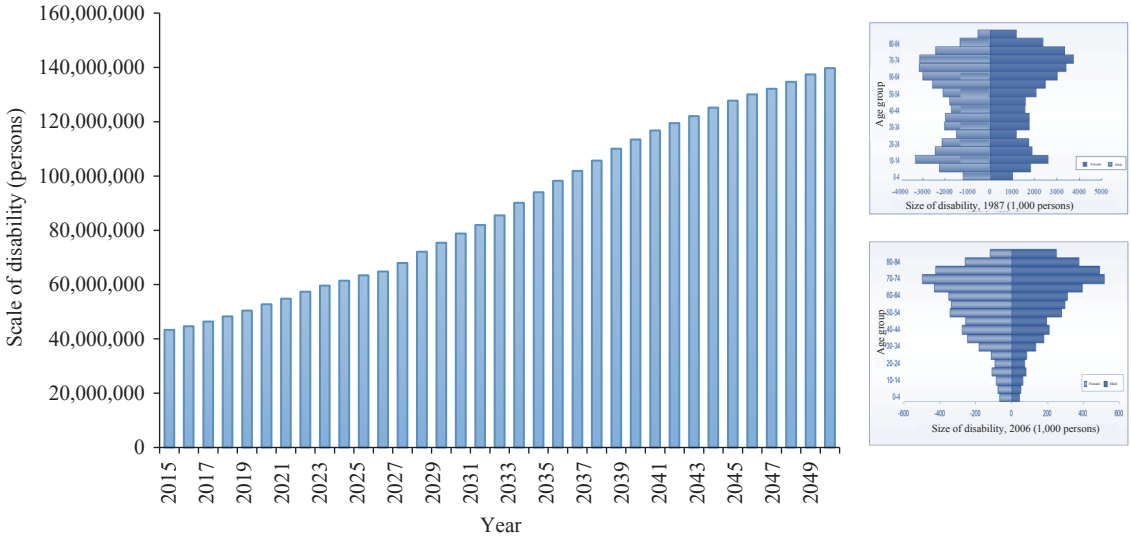


FIGURE 4. The estimated total population living with disability in China, 2015–2050.

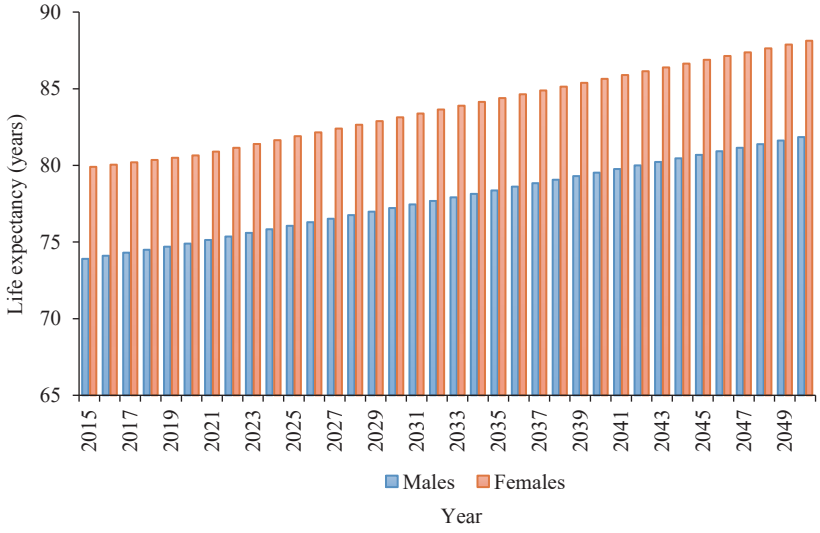


FIGURE 5. The predicted life expectancy in China, 2015–2050.

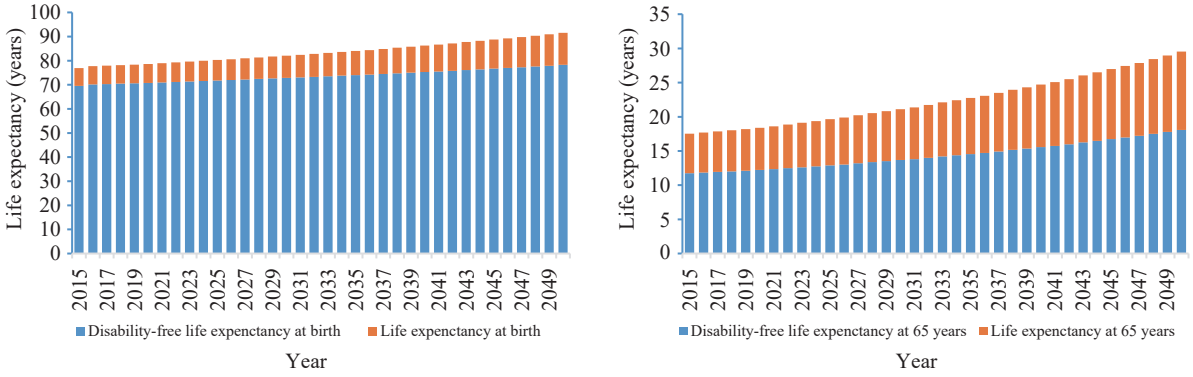


FIGURE 6. The predicted life expectancy and disability-free life expectancy in China, 2015–2050.

14.54% in 2050. Older adults were estimated to experience 5.78 years lived with disability in 2015, and this number is expected to increase to 7.44 years in 2030 and to 11.45 in 2050.

DISCUSSION

This study estimated future trends of 5 important population indicators from 2015–2050 in China. Since the 21st century, China experienced significant demographic changes — increases in life expectancy and declines in fertility rate — that have led to population aging. Along with population aging, the age structure of the population living with disability shifted towards people of older ages living with disability, and the life expectancy with disability also continuously increased.

Although the general trend of fertility rate was projected to decline, China still has a large population. As the most populous nation in the world, China also has the largest older population. With the fading of the effects of the two-child policy and the influence of coronavirus disease 2019 (COVID-19), China entered a phase with the lowest low-fertility rates in history according to the results of the Seventh Census. The two-child policy had delayed the arrival of an aging society brought forth by the one-child policy, but its effect are slowing down. The sheer size of the elderly population and rapidity of aging drives the implementation of the policy of actively dealing with the challenge of aging. Providing support policies for women of childbearing age to achieve their fertility goals and postponing the retirement age may have immediate effects on population aging. Moreover, regional differences were found in the progress of population aging. Furthermore, unbalanced socioeconomic and technological developments may one of the important contributions to this difference

TABLE 1. Age structure of population in China by PLAD, Seventh Census, 2020.

PLAD	0–14 years (%)	15–59 years (%)	60+ years (%)
Beijing	11.84	68.53	19.63
Tianjin	13.47	64.87	21.66
Hebei	20.22	59.92	19.85
Shanxi	16.35	64.72	18.92
Inner Mongolia	14.04	66.17	19.78
Liaoning	11.12	63.16	25.72
Jilin	11.71	65.23	23.06
Heilongjiang	10.32	66.46	23.22
Shanghai	9.80	66.82	23.38
Jiangsu	15.21	62.95	21.84
Zhejiang	13.45	67.86	18.70
Anhui	19.24	61.96	18.79
Fujian	19.32	64.70	15.98
Jiangxi	21.96	61.17	16.87
Shandong	18.78	60.32	20.90
Henan	23.14	58.79	18.08
Hubei	16.31	63.26	20.42
Hunan	19.52	60.60	19.88
Guangdong	18.85	68.80	12.35
Guangxi	23.63	59.69	16.69
Hainan	19.97	65.38	14.65
Chongqing	15.91	62.22	21.87
Sichuan	16.10	62.19	21.71
Guizhou	23.97	60.65	15.38
Yunnan	19.57	65.52	14.91
Xizang (Tibet)	24.53	66.95	8.52
Shaanxi	17.33	63.46	19.20
Gansu	19.40	63.57	17.03
Qinghai	20.81	67.04	12.14
Ningxia	20.38	66.09	13.52
Xinjiang	22.46	66.26	11.28

Abbreviation: PLAD=provincial-level administrative division.

(*6*–*7*). Due to the uncertainties of future trends in population structural changes, dynamic evaluation, timely adjustment, and innovations in population health strategy design and management should be strengthened to ensure the quality of life for the population in the future.

The results showed that the life expectancy of the Chinese people would continuously increase, but life expectancy with disability would also keep increasing. Older adults with disabilities are among the most severely affected, as their age coupled with disabilities would impede their full and equal participation in all aspects of life. Therefore, understanding trends and estimations in the prevalence of disabilities is key to assessing the implications of aging for population health (*8*). The findings from the disability forecast were important scientific and political references to healthy life expectancy improvement and disease burden declining, healthy aging, and active aging.

This study was subject to some limitations. Because of restrictions associated with the Seventh Census and other demographic materials, the findings should be interpreted with caution. Although three hypothetical scenarios were set up, an inevitable bias between the predicted results and the real results existed. For example, fertility policy may change in the future, and the TFR might be not in the range of our assumptions. More studies should be taken to fix these issues in the future.

In conclusion, this study predicts population trends and associated health indicators influenced by population aging in China. The uncertainties in population structure and health will lead to challenges in political strategies and management of population. Future health action plans should consider the uncertainties of multiple scenarios in the future and promptly adjust health strategies to reflect innovations and real health impacts caused by aging and disability.

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Conflicts of interest: No competing interests declared.

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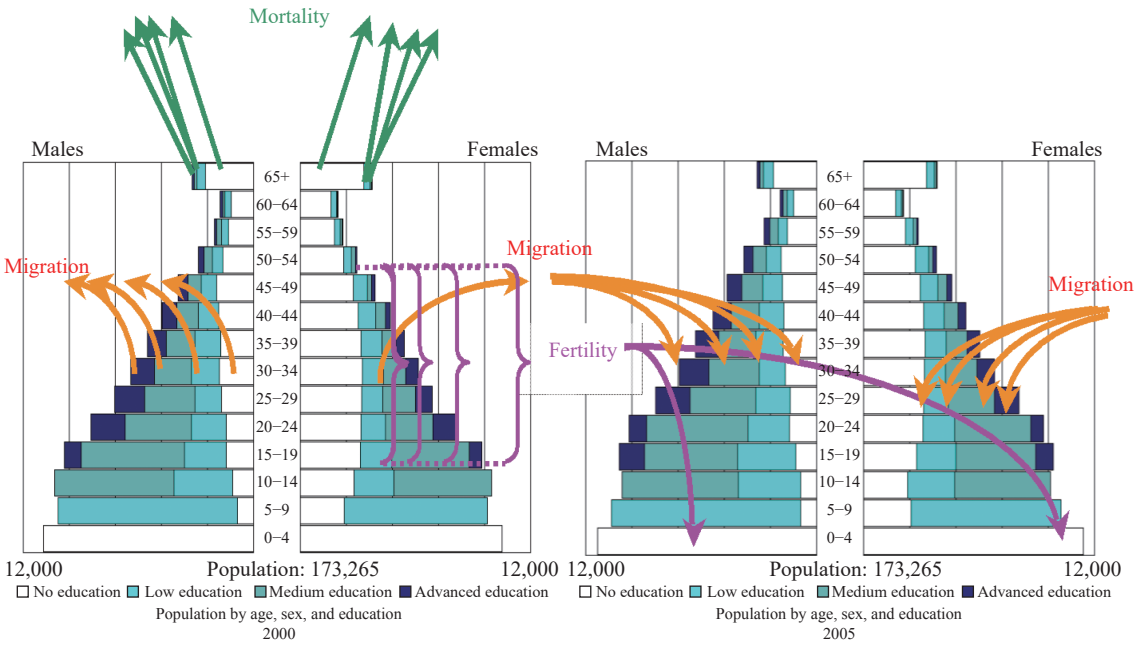

SUPPLEMENTARY FIGURE 1. The principle of Population-Development-Environment model (PDE) models.

SUPPLEMENTARY TABLE S1. Assumptions of Total Fertility Rate in China, 2015–2050.

Year	Total fertility rate
Scenario 1	
2015	1.41
2016	1.77
2017	1.72
2018–2020	1.60
2021–2050	1.70
Scenario 2	
2015	1.41
2016	1.77
2017	1.72
2018–2020	1.60
2021–2025	1.70
2026–2050	1.60
Scenario 3	
2015	1.41
2016	1.73
2017	1.67
2018	1.30
2019	1.30
2020–2050	1.30

Preplanned Studies

Trend and Factors of Population Fertility Changes From the Perspective of Economics and Education — China, 1949–2020

Yiran Wang[1,2]; Huiyun Fan[1,2]; Chao Guo[1,2,#]

Summary

What is already known on this topic?

Diverse social factors such as economic development, policy, culture, and special historical events could affect population fertility directly. At present, the influence of social factors on fertility is still controversial. With the diversification of population characteristics, the cross-group robustness of the classical theories and research conclusions are broken.

What is added by this report?

This research explores the population fertility trajectory of China and its association with economy and education. Although the social fertility shows an opposite trend with the Gross Domestic Product, the economy plays a role in improving the fertility rate. The schooling years per capita inhibits the increase of fertility rate, whereas the proportion of higher education population helps to increase the fertility rate.

What are the implications for public health practice?

Facing the continuous low fertility rate in the post-demographic transition period in China, promoting economic development and advancing the popularization of higher education would be important paths to create supportive and friendly social and family environments for female fertility, so as to enhance female fertility willingness and level.

As a direct result of several influencing factors, including those that are economic, political, scientific, technological, cultural, and historical, the fertility of China's population presented a trend of fluctuating decreases. This study explored the impact of economy and education on population fertility using existing literature and analysis of longitudinal data at the provincial level. This study found that the economy does play a role in improving the fertility rate although inverse development trends of gross domestic product (GDP) and crude birth rate (CBR) were found. Furthermore, schooling years per capita (PEDU) also had an inverse relationship with fertility, but the proportion of higher education population (HEDU) was positively associated with fertility. Due to urgency concerning the continuously low fertility rate in the post-demographic transition period in China, this study provides some evidence for the formulation of fertility policy in China. The results also suggest that promoting economic development and advancing the popularization of higher education are important paths to enhance female fertility willingness and fertility rates.

Data used in this study were obtained from the China Statistical Yearbooks from National Bureau of Statistics of China and from provincial-level bureaus of statistics. Based on the CBR (from 1949 to 2020) and GDP (from 1952 to 2020) of China, this study analyzed the correlation between fertility and economic activity nationwide. The GDP and CBR trends at the regional level (the eastern, central, western, and northeastern region, divided by the overall national levels provided by the National Bureau of Statistics of China*) were further described. Then, a panel database of 31 provincial-level administrative divisions (PLADs) of China from 2002 to 2019 was constructed with indicators of CBR (%), GDP (100 billion CNY), PEDU (year), and HEDU (%), sex ratio (female=100), urban population density (100 persons/km^2), urbanization rate (%), urban registered unemployment rate (%), old-age dependency ratio (%), labor proportion (total population=1), and average family household size (persons).

Based on the panel data, a fixed-effects model was used for regression analysis with CBR as the predicted

* The National Bureau of Statistics of China divides 31 PLADs in mainland China into 4 major regions: the eastern, central, western, and northeastern regions. The eastern region includes Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; the central region includes Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan; the western region includes Neimenggu, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Xizang, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang; the northeastern region includes Liaoning, Jilin, and Heilongjiang.

variable, GDP, and PEDU and HEDU as explanatory variables, and other indicators mentioned above as control variables. Stata 13.0 (developed by StataCorp LLC, Texas, USA) was used for all the data analysis.

Figure 1 presents long-term changes in the economy and fertility. At the national level, Chinese CBR decreased overall from 1949 to 2020, which is inverse to the overall increase in GDP. From a regional perspective (Figure 2), the CBR of the four regions also presented an inverse-economic distribution pattern since 1949. However, the northeastern region displayed a both decreased economic activity and decreased fertility over this time period since 2014.

Table 1 shows the results of the association of fertility with economic activity and education from the regression analysis. Based on the fixed-effects model, it was found that after controlling for multiple covariates, a significant positive impact of GDP on CBR was found (coefficient=0.045, P<0.001). In addition, we found a negative impact of PEDU on CBR (coefficient=–0.945, P<0.001), but a significant positive impact of HEDU on CBR (coefficient=0.085, P=0.004). The Hausman test was conducted and the results suggested using the fixed-effects model. The multi-collinearity of the 10 variables in the regression was also tested and found that the variance inflation factors of them were all less than 10 (Supplementary Table S1, available in http://weekly.chinacdc.cn/), meaning that there was no multi-collinearity among the variables in the model.

DISCUSSION

This study provided evidence of declining fertility rates to be correlated to increased economic activity in China, which was consistent with common trends between a country's economy and population fertility over a long period of time. However, the northeastern region had both low fertility and low economic activity since 2014, which may be due to comprehensive and systemic issues such as regional economic systems, industrial structures, and social policies that led to population loss and decreased fertility willingness, etc. (*1*). Western demographic transition theory often described a close connection between population size and means of subsistence (*2*), and there were no limitations on population fertility in an era of extremely low productivity. However, with continuous development of productivity, the economy begins to affect fertility by acting on intermediary variables such

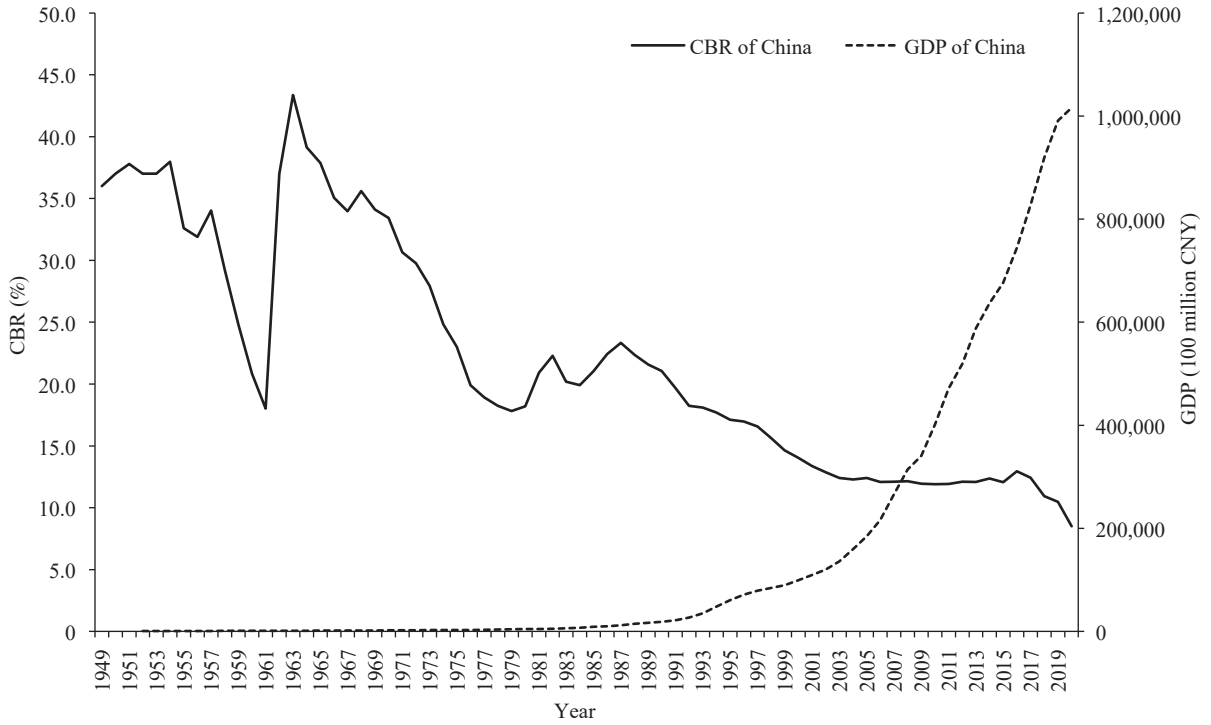

FIGURE 1. Changes of CBR of China (1949–2020) and GDP of China (1952–2020).
Source: the National Bureau of Statistics of China.
Abbreviations: CBR=crude birth rate, GDP=gross domestic product.

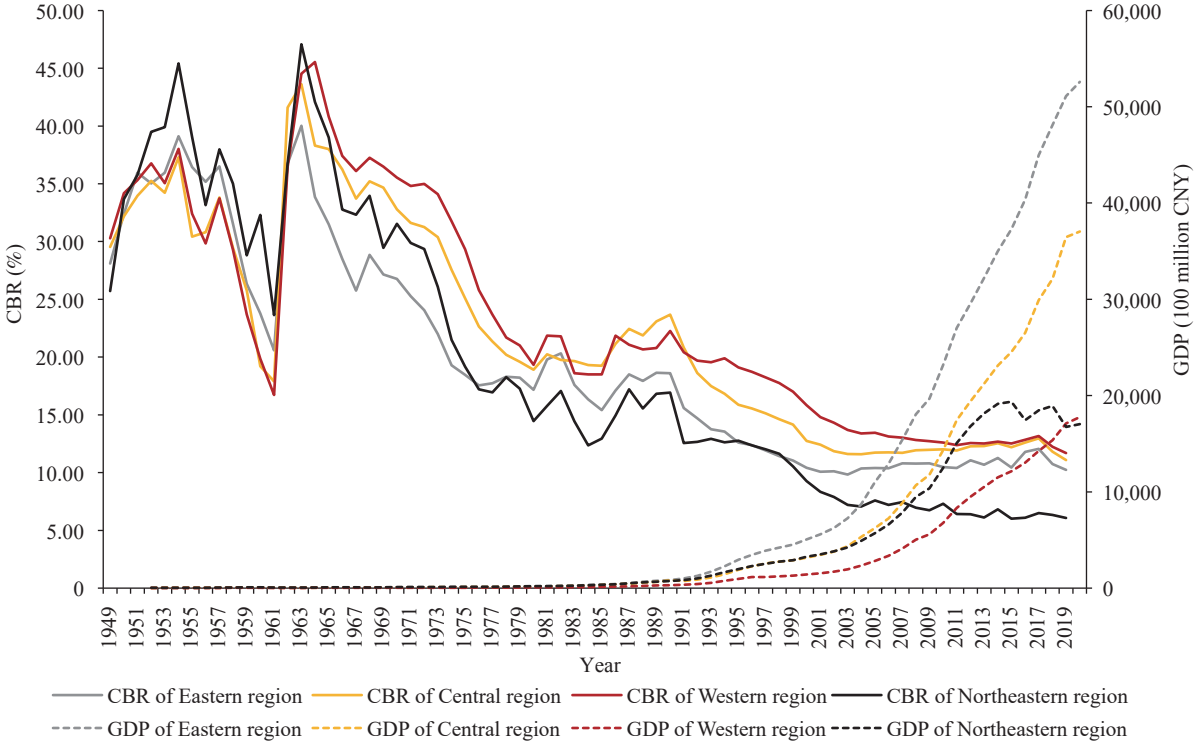

FIGURE 2. Changes of CBR of 4 regions in China (1949–2019) and GDP of 4 regions in China (1952–2020).
Source: the National Bureau of Statistics of China.
Abbreviations: CBR=crude birth rate, GDP=gross domestic product.

TABLE 1. The association between economy and education with CBR: results of fixed-effects model (n=533) in China, 2002–2019.

Variables	Coef	Std. Err	t	*P*	95% CI
GDP	0.045	0.006	6.94	<0.001	0.032 to 0.057
PEDU	−0.945	0.253	−3.74	<0.001	−1.442 to −0.449
HEDU	0.085	0.029	2.91	0.004	0.027 to 0.142
Sex ratio	−0.037	0.015	−2.49	0.013	−0.066 to −0.008
Old-age dependency ratio	−0.083	0.030	−2.81	0.005	−0.141 to −0.025
Labor proportion	0.387	3.411	0.11	0.910	−6.315 to 7.089
Average household size	0.795	0.310	2.56	0.011	0.185 to 1.405
Urban population density	−0.013	0.006	−2.32	0.021	−0.024 to −0.002
Urbanization rate	0.016	0.013	1.26	0.207	−0.009 to 0.042
Urban registeredUnemployment rate	0.175	0.124	1.41	0.160	−0.069 to 0.419

Abbreviations: PLADs=provincial-level administrative divisions, CBR=crude birth rate, GDP=gross domestic product, PEDU=schooling years per capita, HEDU=proportion of higher education population, Coef=regression coefficient, Std. Err=standard error, CI=confidence interval.

as through marriage rates, education, medical and health services, etc. (*2*).

Notably, it is found that the economy does play a role in improving the fertility rate after multiple covariates was adjusted. GDP is a macroeconomic indicator, and there are multiple ways in which it may affect the population fertility. Possible reasons for the positive association between the two could include the following: 1) economic development improves the ability of couples of childbearing age to raise children and provides more security for more children; 2) economic development generally improves education, which may strengthen gender equality and better distribute the child-raising responsibility across husbands and wives to enhance incentives for women to have children; and 3) there is "CBR offset" among

regions, which means the compensations and balances between different fertility rates of different regions. For example, the urban-rural divide in China affects fertility as urban economic development stimulates the increase of fertility rate, but rural economic development reduces it (*3*).

In terms of the impact of education on fertility, we found that the PEDU inhibited the increase of CBR but that HEDU helped to improve the CBR. It is generally believed that the increase in education level for women has largely contributed to the decline in fertility (*4*–*5*). Education has tended to be correlated with reduced fertility since early in the 20th century when this phenomenon was first observed (*6*). Theories about fertility costs and benefits help explain this suppression mechanism, that is, as the education level of couples of childbearing age increases, the number of children tends to be reduced as the resources available to each child increases (*1*). However, after subdividing according to the population characteristics, the conclusions show differences. Couples with the highest and the lowest education levels tended to be more willing to have children (*7*).

Compared with the aforementioned individual research perspective, this study found the negative effects of the schooling years per capita on the fertility rate and a positive effect of the popularization rate of higher education on the fertility rate for the overall population. This suggested that overall education level of the population had a segmented effect on the fertility rate. Theoretical explanations and research conclusions from the individual perspective above provide inspiration for this study to explore the impact mechanisms of education on fertility from a macro perspective. Generally speaking, an increase in the education level of the group is correlated by an improvement of the economy, accompanied by increased market competition and crowded development channels. Compared with social development stages when a population is at lower education levels, this kind of competitive development environment has increased the opportunity cost of childbirth as well as childbirth pressure, leading to declines in women's fertility willingness. However, this phenomenon of "educational fertility suppression" began to disappear with further increases of the education level of the population. This may be attributed to popularization of higher education which represents further development of the economy and society as well as increasingly abundant resources. Under these conditions of societal development, higher education groups take the lead in breaking through restraints of limited resources. They are more likely to have equitable husband and wife relationships (*8*), abundant income, and diversified social security resources. These guarantee mechanisms provide women of childbearing age with more reproductive security as the costs and risks of childbirth are diminished. Further promoting the popularization of higher education and raising the overall education level of the population is a policy direction for improving the population fertility level.

At present, China is facing sustained decreases in fertility. The fertility regulation policy has evolved from "double-single two-child policy" (where couples may have a second child if both parents were the only children to their parents) to the universal "three-child" in just 10 years. This shows the government's determination in increasing the population fertility level. Handling the relationship between population fertility and social factors is essential for scientifically formulating fertility strategies and optimizing the population structure in China. Low fertility is an important cause of population aging in China, which may incur a heavy disease burden of large-scale non-communicable diseases, injuries, and disabilities that may cause tremendous pressure on population health protection systems. Therefore, grasping the relationship between multiple social factors and population fertility and implementing long-term strategies of optimizing population age distributions are important tasks for the construction of population health protection systems in China.

The study was subject to some limitations. First, the influencing factors of fertility rate are complex and uncertain, so confounding factors in this exploratory study need to be examined further. Second, the sample size of this study is relatively small due to the use of provincial-level data even after the time scale of the study was expanded to the limits of the data. We suggest that future studies expand to using county-level data to verify the results of this study.

Nevertheless, based on the current research results, in the face of continued low fertility in the post-demographic transition period in China, promoting economic development and advancing the popularization of higher education are important paths to create supportive and friendly social and family environments to improve willingness and overall

fertility.

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SUPPLEMENTARY TABLE S1. Test results of multi-collinearity of 10 variables.

Variables	VIF	1/VIF
GDP	1.60	0.626
PEDU	6.14	0.163
HEDU	4.96	0.201
Sex ratio	1.26	0.794
Old-age dependency ratio	3.06	0.327
Labor proportion	3.82	0.262
Average household size	4.08	0.245
Urban population density	1.14	0.876
Urbanization rate	6.51	0.154
Urban registered unemployment rate	1.62	0.616

Abbreviations: GDP=gross domestic product, PEDU=schooling years per capita, HEDU=proportion of higher education population, VIF=variance inflation factor.

Commentary

Major Trends in Population Growth Around the World

Danan Gu[1,#]; Kirill Andreev[1]; Matthew E. Dupre[2]

Summary

The world's population continues to grow, albeit at a slower pace. The decelerating growth is mainly attributable to fertility declines in a growing number of countries. However, there are substantial variations in the future trends of populations across regions and countries, with sub-Saharan African countries being projected to have most of the increase. Population momentum plays an important role in determining the future population growth in many countries and areas where fertility is in a rapid transition. With declines in fertility, the world's population is unprecedentedly aging, and the numbers of households with smaller sizes are growing. International migration is also on the rise since the beginning of this century. The world's population is also urbanizing due to increased internal rural to urban migration. Nevertheless, there are uncertainties in future population growth, not only because there are uncertainties in the future trends in fertility, mortality, and migration, but also because there are many other factors that could affect these trajectories. International consensus on climate change and ecosystem protections may trigger population control policies, and the ongoing pandemic is likely to have some impact on mortality, migration, or even fertility.

The future trend of a population is an outcome of the interactive dynamics between its existing age structure and its future trends in fertility, mortality, and migration. An abundance of scientific evidence shows that population growth in a country is connected to socioeconomic growth, environmental protection, health promotion, quality of life, and social stability. Understanding the growth dynamics and future trends of populations around the world is crucial to achieving the 2030 Agenda for Sustainable Development Goals (SDGs) and other long-term development goals. This article reviews the main features of recent and future trends in population growth for the world, major regions, and selected countries. We mainly rely on the estimates and projections of the 2019 Revision of the World Population Prospects (WPP 2019) produced by the United Nations Population Division (*1*) to focus on 201 countries and areas with 90,000 inhabitants or more in mid-2020.

MAJOR TRENDS IN POPULATION GROWTH

Continuing Gowth of the World Population at a Slowing Pace

The world's population continues to grow, reaching 7.8 billion by mid-2020, rising from 7 billion in 2010, 6 billion in 1998, and 5 billion in 1986. The average annual growth rate was around 1.1% in 2015–2020, which steadily decreased after it peaked at 2.3% in the late 1960s. Among 201 countries and areas, 73 countries had a smaller growth rate in 2010–2020 compared with the previous decade; and out of these 73 countries, more than 60 are developing countries. The slowing pace of the population growth is closely related to declines in fertility. Globally, the total fertility rate was 2.4 births per woman of reproductive age in 2020, decreasing from 2.7 in 2000, 3.7 in 1980, and 5.0 in 1950. In high-income and upper-middle-income countries, the total fertility rate has been below replacement level (2.1 births per woman) for a few decades, which is the level required to ensure the replacement of generations in low-mortality countries. In a few of these countries, total fertility rates have even fallen to extremely low levels, 1.5 births per woman, and even below 1.5 in some countries, for the past several decades.

There is a myriad of reasons for the slowing pace of population growth that can be attributed to declining fertility in the context of a demographic transition mainly caused by modernization. In the process of modernization, improved food security, nutrition, and public health, advances in medical technology and socioeconomic development, coupled with improved safe and effective family planning methods and services

have largely improved child survival, which has enabled couples to have a desired number of children without having too many births. Improved education, enhanced women's empowerment, increased financial security in old age, and personal aspirations for more opportunities regarding self-career development and a better life have all reshaped young couples' views and behaviors about postponements of marriage and childbearing, and the numbers and timing of childbirths (*2*–*3*). All of these forces have led to reductions in fertility, and eventually triggered a demographic transition. By 2020, all countries and areas either have completed their demographic transition or are in the middle of the transition.

However, even if fertility levels declined rapidly, the world population would likely continue to grow because of the momentum of population growth — a force that drives future population growth resulting from the existing age structure. Globally, more than two-thirds of the projected increase of 1.9 billion in population from 2020 to 2050 could be attributable to population momentum. In other words, population momentum is projected to produce 1.3 billion more people between 2020 and 2050, or 17% of the total in 2020. The contributions of above-replacement level fertility and declining mortality to the projected increase in 2020–2050 are 317 million (16% of the total increase) and 295 million (15%), respectively. The increases attributable to above-replacement level fertility and mortality are roughly equal to 4% each of the total in 2020.

Although the growing trend in the world population is expected to continue throughout this century at a slowing pace, there is uncertainty about future trends, and the uncertainty gets wider with time. For example, the world population is projected to reach 9.7 billion by 2050 and 10.9 billion by 2100, but their 95% projection intervals could be between 9.4 and 10.1 billion for 2050 and between 9.4 and 12.7 billion for 2100 (Figure 1).

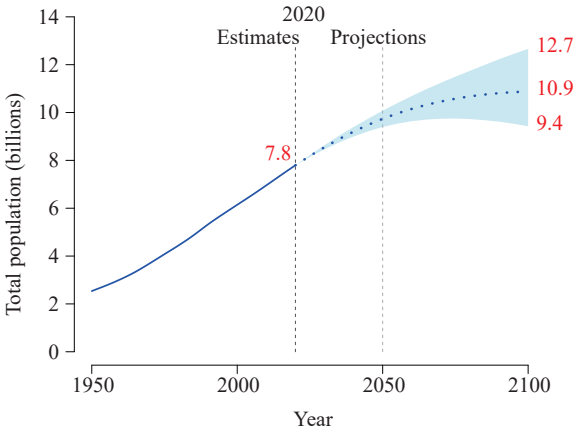

FIGURE 1. Growth of the world population, 1950–2100.
Note: The solid blue line is an estimate, whereas the dotted blue line is a projection under the medium variant and the shadow is the 95% projection intervals.
Source: Drawn from the World Population Prospects 2019 (*1*).

Large Variations in Growth Patterns Across Regions and Countries

There are substantial variations in the future trends of populations across regions and countries. Overall, most countries and areas in the world are projected to continue growing in 2020–2050. However, in the second half of the century, more than half of the countries and areas are projected to witness a decline. Among eight SDG regions, sub-Saharan Africa is expected to account for most of the increase in the world's population throughout the century, and its global share of the population is projected to increase steadily. By contrast, the global shares of the population by other SDG regions are projected to decrease over time. Globally, there are 54 countries which have an annual growth rate twice as fast as the world average rate in 2020–2050, and 41 of these countries, or slightly more than three-fourths, are located in sub-Saharan Africa. Indeed, more than a half of the global additional 2.0 billion people projected increase between 2020 and 2050 are from countries in sub-Saharan Africa (regardless of scenarios), and such a proportion is projected to be about 90% in 2050–2100. Overall, about 23–38 million more people annually from sub-Saharan countries are projected to be added to the world's total population. As a result, the current total population of sub-Saharan African countries, which was 1.1 billion in 2020 (or similar to the Europe and Northern America combined), is projected to climb to 3.8 billion by 2100 with a 95% projection interval between 3.0 and 4.8 billion. By contrast, the total population of Europe and Northern America combined will maintain its current level by 2100 (Figure 2).

Although a fast-growing population in some developing countries provides a large young population base, which could be a favorable factor for economic growth when this young population enters the labor force, these countries are facing challenges associated with a large young population, such as low access to education among children (especially among girls),

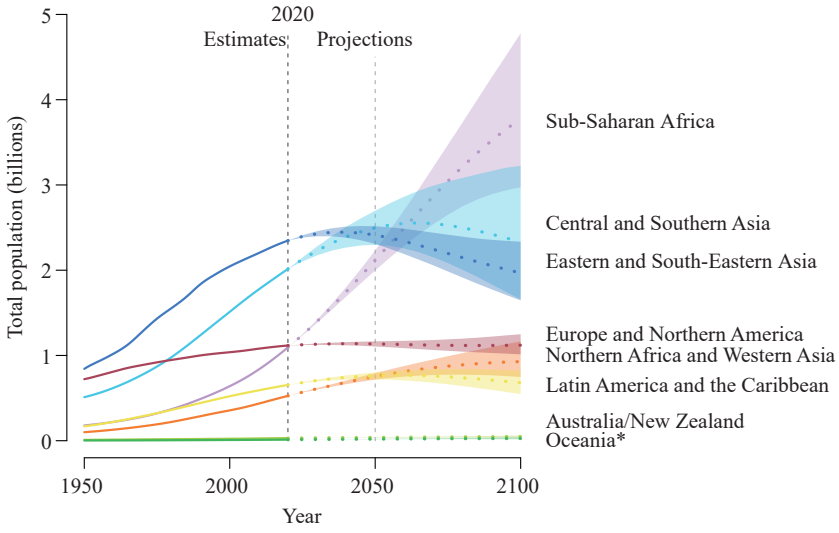

FIGURE 2. Population growth by Sustainable Development Goals region, 1950–2100.
*: excluding Australia and New Zealand.
Note: The solid color lines are estimates, whereas the dotted color lines are projections under the medium variant and the color shadows are the 95% projection intervals.
Source: Drawn from the World Population Prospects 2019 (*1*).

relatively high levels of infant, child, and maternal mortality, and relatively high unmet needs in family planning services. High fertility has also caused young couples to have unwanted pregnancies and births that otherwise could relieve them of childbearing and childrearing obligations for other opportunities of human development (*2*).

Another major feature of the world's future population growth is that the majority of the projected increase in the world's total population is attributed to a very few populous (or fast growing) countries. For example, under the medium variant of WPP 2019, nine countries (India, United States, Indonesia, Pakistan, Nigeria, Ethiopia, Egypt, Democratic Republic of the Congo, and the United Republic of Tanzania) are projected to account for more than half of the increase in global population between 2020 and 2050. Except for the United States, all are developing countries and are low-income or low-middle-income countries. Low education among children, high fertility levels, high maternal mortality, and high unmet needs in family planning services in many of these countries are major obstacles for achieving SDGs (*4*).

In contrast to most countries where populations are projected to increase in 2020–2050, populations in some countries are projected to decline. There were 18 countries and areas, mostly in Europe, that had a negative population growth rate in the last 3 decades (1990–2020), and the number of countries and areas with a negative growth rate is projected to reach 46 in the next 3 decades (2020–2050), including several Asian countries. Almost all countries in Latin American and the Caribbean are projected to continue to grow in 2020–2050, but many of them are projected to be on a declining track in 2050–2100.

China, the most populated country in the contemporary world, had a total population of 1.43 billion in 2020 and was a major contributor to the world's population growth over the past several decades. Under the medium variant of WPP 2019 (Figure 3), China is projected to have some loss in its total population, with 1.40 billion by 2050, after peaking at 1.46 billion around 2030. Japan has seen the largest losses in population size since the beginning of this century; however, China is projected to eclipse this and will become the largest country with a decreasing population (of 30 million by 2050). By 2100, China is projected to have a loss of more than a quarter of its current size. For India, the world's second most populous country in the contemporary world, it is projected to continue to grow and will overtake China as the largest population in 2025–2030, reaching 1.64 billion by 2050. However, India is projected to witness population decline after reaching its peak around 1.65 billion in 2055–2060 due to falling fertility. By 2100, India is projected to reach 1.45 billion and to have the second largest loss in population in 2050–2100 after China, followed by Brazil and Bangladesh, ranking the third and fourth

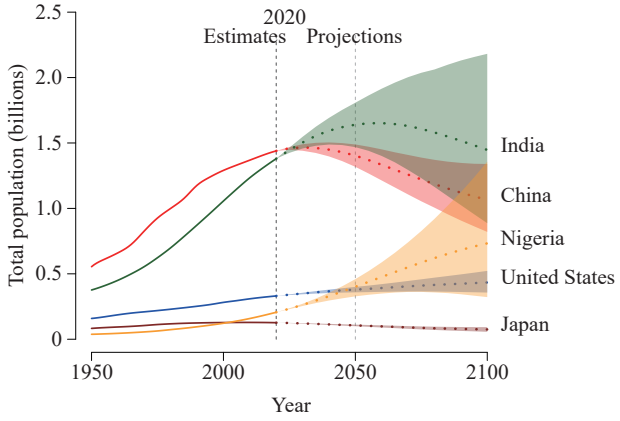

FIGURE 3. Population growth for selected populous countries, 1950–2100.
Note: The solid color lines are estimates, whereas the dotted color lines are projections under the medium variant and color shadows are the 95% projection intervals.
Source: Drawn from the World Population Prospects 2019 (*1*).

largest losses in population, respectively.

Nevertheless, it is worth noting that there is uncertainty in the future growth of populations and the uncertainty gets wider in the more distant future. For example, the 95% projected low and high bounds for China could be 1.32 to 1.50 billion by 2050, and 0.82 to 1.33 billion by 2100, respectively. The corresponding figures for India are 1.47 to 1.81 billion by 2050, and 8.87 to 2.18 billion by 2100 (Figure 3).

Contributions of Population Momentum, Fertility, and Mortality to Population Growth

Future population growth depends on population momentum, future fertility, mortality, and migration trends. The population momentum refers to an inherent driving force for population growth resulted from the existing age structure. A young age structure leads to increases in population even if fertility is kept constantly at replacement level, whereas an older age structure could lead slower growth or even decreases in population (*5*).

There is a large variation in the contribution of these components to future population growth for individual countries and regions. For example, in sub-Saharan Africa, relative to the total population in 2020, the total increase in population due to population momentum between 2020 and 2050 is projected to be equal to 40% of the 2020 total; the increase in population due to higher fertility (above replacement level) is projected to be equal to 53% of the 2020 total. The contributions by mortality and migration are very small. In Europe, both low fertility and population momentum are projected to cause population losses between 2020 and 2050. Although improvements in mortality and increasing migration are projected to offset some of the population losses in this period, the overall trend in population size is projected to decline. In Northern America, the population is expected to continue to grow in 2020–2050 largely fueled by declines in mortality and positive net migration, and, to a lesser extent, by positive population momentum. This growth is expected to be partially dampened by the negative contribution of low fertility.

In Eastern and South-Eastern Asia, the increases in population between 2020 and 2050 due to population momentum and improved mortality are projected to be equal to 5% and 3% of its current total, respectively; whereas low fertility in the regions is projected to bring negative population growth by 5% of its current total. The contribution of migration is negligible. Trends in China are similar to this regional pattern, although the actual levels are somewhat different. In Japan, however, the overall pattern is close to that of Europe rather than that of their geographical region.

In Central and Southern Asia, while fertility is projected to bring zero growth to the future population, population momentum is projected to add one-quarter of its population to the current total. The contributions of mortality and migration in this region are negligible. In Latin America and the Caribbean, the increases in population are driven mostly by population momentum, with an additional (although small) contribution of improved mortality. Fertility is projected to contribute significantly to population decline, about 5% of the current population size.

Unprecedented Challenges of Population Aging in Many Countries

With progress along the demographic transition, coupled with other societal developments, most countries have experienced declining fertility and improved mortality, marked by the elimination/reduction of many fatal infectious diseases that have prolonged life expectancy. Global life expectancy at birth has reached 73 years in 2020, 7 years more than that in 2000, and nearly 30 years more than that in 1950. It has been documented that life expectancy at birth for the best performing countries in

history have witnessed an increase of 2.0–2.5 years per decade over the last few centuries (*4*). It is now projected that global life expectancy at birth will reach 77 years by 2050 and 82 years by 2100. Life expectancy at birth could even be over 95 years by 2100 in Japan, Republic of Korea, Singapore, and Spain, although it is projected to remain below 80 years in some African countries.

Paralleling the unprecedented rise in life expectancy is the unprecedented growth of population aging (*6*). A population is typically considered an aging population if the proportion of its adults aged 65 or older (or old-age proportion) is over 7%. Likewise, it is called an aged, a super-aged, and an ultra-aged population if the old-age proportion is over 14%, 21%, and 28%, respectively (*7*). Globally, the proportion of people aged 65 or older reached 9.3% in 2020, rising from 6.9% in 2000, and 5.1% in 1950 (Table 1). The global old-age proportion is projected to reach 15.9% in 2050 and 22.4% in 2100.

In some developed countries (or countries with rapid fertility declines), the proportion of older people is much higher. For example, the old-age proportion in Japan, the most aged population in the contemporary world, was 28.4% in 2020, rising from 17.0% in 2000, and 4.9% in 1950. Table 1 shows that by 2050, nearly 58% of the 201 countries are projected to be in an aged society, and nearly 15% of these countries are projected to be in an ultra-aged society; in comparison to the less than 30% of countries in an aged society in 2020 and only one country in an ultra-aged society (Japan). By 2100, nearly 90% of these countries are projected to be an aged society, and more than half are project to be an ultra-aged society.

Population aging has had a profound impact on old-age care, pension and social security systems, housing, savings, labor supplies, social services, and in many other sectors (*6*). These challenges are more pressing for developing countries because they are facing these challenges within a much shorter time frame, and long before they become economically well off, to prepare for such rapid population aging ("aging before rich"). With few exceptions (e.g., Japan), most developed countries took 40 to 120 years to transform from an aging population (7%) to an aged population (14%) and took (or will take) 20 to 50 years to transform from an aged society (14%) to a super-aged society (21%). In contrast, most developing countries will take 15–35 years to transform from an aging population to an aged population and 10–30 years to transform from an aged population to a super-aged population. Based on some empirical evidence, and potential trajectories of mortality and fertility, it is projected that the number of years to transform from a super-aged population into an ultra-aged population will be shorter than the number of years transforming from an aged society to a super-aged society for both developed and developing countries. Such an unprecedented growth of older populations in the world has required reforms in pension systems and statutory retirement ages in many countries, especially in more developed countries in order to maintain fiscal sustainability of existing public pension systems (*8*).

However, rapid population aging can also open additional windows of opportunity for economic growth — such as a "second economic dividend" when low fertility and prolonged longevity stimulate human capital investments (*9*). This is especially the case when population aging is accompanied by better health (i.e., "compression of morbidity") that has been observed in many older populations (*10*). Better health and prolonged longevity could allow labor force participation among older adults to offset downward pressures on economic growth (*6*). Research has shown

TABLE 1. Distribution of countries by the percent of the population aged 65 or older for selected years.

Percent of the old-age population	1950	2000	2020	2050	2100
Levels					
<7	76.6	66.2	49.7	22.9	0.0
7–14	23.4	22.4	21.4	19.4	13.4
14–21	0.0	11.4	23.9	20.4	15.9
21–28	0.0	0.0	4.5	22.4	19.5
≥28	0.0	0.0	0.5	14.9	51.2
Total	100.0	100.0	100.0	100.0	100.0
The world	5.1	6.9	9.3	15.9	22.4

Note: The distributions are calculated among 201 countries and areas. The old-age percentages refer to the proportion shared by the population aged 65 or older out of the total population.

that the benefits of a second dividend are estimated to be larger and more lasting than the first dividend (*9*), leaving policymakers an opportunity to optimize transitory economic growth from the first dividend into a sustained one.

Growing Role of International Migration

It is estimated that the number of persons who live outside of their countries of birth reached 281 million in 2020 globally, an increase from 108 million over the amount in 2000 (*11*). Although international migration does not have a direct impact on the world's population growth, and its impact on population growth is usually negligible in most countries compared to other demographic components, it has contributed significantly to the growth of populations in some countries. For example, in the past few decades, international labor migration inflows in several Gulf States have contributed to rapid population growth in these countries. It was estimated that labor immigrants accounted for more than three-fourths of the working-age population in Bahrain, United Arab Emirates, and Qatar in the last couple of decades.

Globally, about two-thirds of international migrants are concentrated in just 20 countries — with the United States as the largest destination country, followed by Germany, Saudi Arabia, the Russian Federation, and the United Kingdom, which all have over 10 million immigrants. On the other hand, about one-third of all global migrants originated in only 10 countries — with India as the largest out-migration country, followed by Mexico, China, and the Russian Federation, which have over 10 million emigrants. Overall, high-income countries host nearly two-thirds of all international migrants, and Europe continues to host the largest number of migrants in the world, followed by Northern America. The number of male international migrants is slightly higher than that of female migrants. Most international migration is for labor or family reasons. However, the number of forcibly displaced migrants due to humanitarian crises in many parts of the world grew rapidly, reaching 34 million in 2020, an increase from 17 million compared with 2000 (*11*).

Migration can contribute to sustainable development in both origin and destination countries, which has been widely acknowledged in the 2030 Agenda for Sustainable Development and the Global Compact for Safe, Orderly, and Regular Migration (*11*). As most migrants are working-age adults, positive net migration can also offset a shortage of labor supply and population decline, as well as slow down population aging in destination countries. For countries and areas of origin, as migrants are mostly healthy, highly educated, and skilled young adults, a large scale of out-migration may cause possible brain drains and accelerate population aging. However, migrants' remittances to countries and areas of origin could improve the livelihood and education of population left behind, boost socioeconomic development, and reduce mortality. All these promote sustainable development in origin countries and areas (*11*). Nevertheless, as migrants often face many disadvantages — including language barriers, low social integration and isolation, and a low likelihood of being eligible for pensions, healthcare, and/or education compared with those who are native born — how to better protect their rights and remove obstacles that prevent them from discrimination is a key goal for achieving SDGs and leaving no one behind.

An Urbanizing World

Urbanization, usually measured by the percentage urban (i.e., urban population as a percentage of the total population), is the spatial re-distribution of the population of a country or an area, mainly resulting from internal or domestic migration. Given the close relationships among urbanization, socioeconomic development, and the environment, it is crucial to understand the long-term trends in urbanization in addition to the trends in population size and composition. Just like international migration will not change the world's population, internal or domestic migration within a country will not change the population of that country. However, internal migration, especially rural-to-urban migration can have a huge impact on the total population in both the origin and destination cities of a given country, which is normally a major driving force for rapid urbanization, such as in the case of China (*12*).

The world's population is urbanizing rapidly. The percentage urban was 56% in 2020, rising from 50% in 2007, 43% in 1990, and less than 30% in 1950 (Table 2). It is projected to reach more than 68% in 2050 (*13*). There are large variations in urbanization levels and growth rates across regions and countries, with the percentage urban more than 80% in Northern America and, Latin America and the Caribbean, 75% in Europe, and around 40% in sub-Saharan Africa in 2020. From 2000 to 2020, with the exception of a very few countries, all other countries witnessed an increase

TABLE 2. Distribution of countries by percentage urban for selected years.

Percentage urban	1950	2000	2020	2050
Levels				
<20	38.3	7.5	4.0	0.0
20–30	18.9	12.4	9.0	3.5
30–50	22.4	23.4	19.9	12.9
50–70	13.9	27.4	28.9	24.9
≥70	6.5	29.4	38.3	58.7
Total	100.0	100.0	100.0	100.0
By selected regions				
World	29.6	46.7	56.2	68.4
More developed regions	54.8	74.2	79.1	86.6
Less developed regions	17.7	40.1	51.7	65.6
Europe	51.7	71.1	74.9	83.7
Northern America	63.9	79.1	82.6	89.0
Australia/New Zealand	76.2	84.5	86.3	91.0
Latin American and the Caribbean	41.3	75.5	81.2	87.8
South-Eastern Asia	15.6	37.9	50.0	66.0
Sub-Saharan Africa	11.1	31.4	41.4	58.1

Note: The distributions are calculated among 201 countries and areas. The percentage urban refers to the proportion shared by the urban population out of the total population.
Source: United Nations (2018) (*11*).

in urbanization — with nearly 40 countries having an annual growth rate greater at 1.5%; and all countries are projected to continue to urbanize from 2020 to 2050, albeit with different annual growth rates ranging from 0.01% to over 2.0%. Most developing countries are projected to have a much faster growth rate than developed countries. China has been the biggest contributor to global urbanization from 2000 to 2020, thanks to its massive scale of rural-to-urban migration. From 2020 to 2050, China is projected to continue to play a major role in global urbanization, although India will overtake China as the largest contributor. Nigeria is projected to be the third largest contributor to the world's urbanization growth in the next three decades (*13*).

Fast Growing Numbers of Households with Decreasing Size

All human beings are connected to others by blood or marriage, and generally live together in families or households. Dynamic changes in household size and composition over time are indeed another form of population growth. Households are often a more relevant unit for analyzing energy-related consumption, human impacts on the environment, and likewise sustainable development because energy-related commodities such as water, food, vehicles, housing, and social services are often purchased and consumed by households, rather than by individuals (*14–15*). There is ample empirical evidence showing that the average size of households has declined steadily over the past several decades for most countries in the world (*16*). For example, in Brazil, the average household size declined from 5.1 persons per household in 1960 to 3.3 persons per household in 2010. The corresponding figures were 3.8 and 3.2 for the United Kingdom, and 3.5 and 2.6 for the United States. The average household size for India also declined from 5.8 persons per household in 1980 to around 4.5 persons per household in 2010. China's household size decreased from 4.7 in 1981 to 3.2 in 2010, and further down to 2.62 in 2020 (*17*).

Such decreases in household size have led to faster growth in the number of households as compared to the growth of the population (*18*). The faster growth of households will likely persist in the foreseeable future. Globally, the average household size for all countries was around 4 persons per household in 2010, ranging from 2.1 in Finland and Germany to 8 persons per household in Afghanistan (*16*). It was estimated that if the average household size had been 2.5 people globally in 2010, the number of households in the

world would be 2.7 billion, 0.8 billion more (or a 41% increase) than the current total of 1.9 billion (*14*). In addition to declining fertility, higher divorce rates, more internal and international migration, and the diminishing norms of co-residence have all contributed to the growth of smaller household sizes (*16*).

The living arrangements of older adults is an important component of household composition, which have been receiving increasing attention. The living arrangements of older adults are the result of a nexus of personal preferences, needs, available resources, and culture. Coresidence with adult children and/or grandchildren is very common in many countries and areas in Asia, Africa, and Latin America and the Caribbean, where coresidence is usually over 40% (and even reaches over 80% in some countries). In contrast, coresidence is relatively low among older adults in Europe and Northern America, where the most common living arrangement of older adults is living with a spouse only or living alone (*19*). With the progress of modernization and advances in socioeconomic development, the number of older adults in many developing countries preferring to live with their spouses only and/or live alone is growing in most countries. In China, for instance, the percentage of those living with only a spouse or alone witnessed a steady increase over the last several decades, from 25% in 1982 to 35% in 2010 (*20–21*). Research has shown that the living arrangement of older adults is linked to various health outcomes and the use of (in)formal services; which implies that the fast growing trend in the numbers of households coupled with its reducing size could have important implications for the planning of long-term care, housing, and social services in the context of rapid population aging.

Overall, the trends in household size and composition and older adult living arrangements are important for sustainable development, especially when such trends are connected with energy-related consumption and old-age care.

DISCUSSION

The world's population is projected to continue to grow at a slowing pace during this century. Such a trend of decelerating growth is mainly due to fertility declines in a growing number of countries. However, many sub-Saharan African countries are projected to have much faster growth than countries in other regions of the world — because many sub-Saharan African countries still have high fertility rates and reductions in fertility have been stalling in recent years. In these countries, more effort is needed to prioritize the enhancement and empowerment of women, improve the availability of safe and effective methods of contraception, promote compulsory education among children, and reduce poverty.

Rapid and sustained declines in fertility could result in a large labor force relative to the number of children and older people in some period(s), creating a window of opportunity for socioeconomic growth, commonly known as the "first demographic dividend (population bonus)" (*9*). With progress along the demographic transition in a country, the young bulk of the labor force enters the late stages of the labor force. This leads to higher per capita consumption due to this population's greater resources, and eventually creating another window of opportunity for economic growth in that country, or the "second demographic dividend" (*9*). Most developing countries are (or will be) in their first window of opportunity, and many developed countries are (or will be) in their second window of opportunity.

However, it should be emphasized that the demographic dividends are opportunities for economic growth and should not be taken for granted. The duration of each window of opportunity is limited and does not last forever. Instead, the realization of demographic dividends depends on appropriate policies adopted in other related sectors and the country's ability to implement these policies (*22*). Research has shown that female labor force participation, educational attainment of the labor force, the potentiality of the old-age population entering the workforce, people's health and wellbeing, urbanization, investments (especially foreign direct invests), high technology, and international trades are all important factors determining the outcomes of demographic dividends (*22*). It is thus important for different countries to formulate socioeconomic policy packages that are consistent with their own population trends and characteristics to reap the maximum benefits of the demographic dividends. For countries in the first (window) stage, promoting quality education, enhancing women's empowerment, creating more jobs, and attracting more foreign direct investments may be a priority. For aging countries, especially aged and super-aged countries, postponing the retirement age, developing a sound long-term care system, promoting home- and community-based social services, and creating social environments without ageism are effective solutions to ensure that all adults

achieve healthy aging and age in the right place. However, it is also worth noting that with prolonged life expectancy and improvements in the health of all people, the threshold of old age will likely increase, which means the size, the length, and the timing of these (window) periods could be prolonged.

Nevertheless, there are uncertainties in future population growth, not only because there are uncertainties in the future trends for the three demographic components (fertility, mortality, and migration), but also because many other factors can affect a population's future trajectories. For example, the ongoing coronavirus disease 2019 (COVID-19) pandemic has impacted almost every nation and profoundly affected every member of a society. By mid-2021, the pandemic has caused more than 3.8 million deaths worldwide — with older people being the hardest hit. The excess deaths across countries range from 5 deaths per million population to more than 1,000 deaths per million population in the past 1.5 years. The lockdown policies implemented in most countries have greatly reduced both internal and international migration; and it may take years to reach pre-COVID-19 pandemic levels. For the pandemic's impact on fertility, it is too early to draw any reliable conclusions at this point. Some evidence suggests that there is an increase in child marriages and adolescent fertility, yet evidence in some countries shows a decrease in fertility in 2020, the first year of the pandemic. Based on historical evidence, we would expect a relatively high level of fertility in the post-disaster or post-pandemic period (*23*). The future trends in population growth of a country are also affected by the birth policies of a country. China recently relaxed its birth policies to allow couples to have up to three children (*24*). Given its large share of the world's population, such a relaxation in its birth policy will not only influence China's own population growth in the future, but also influence the trajectory of the world's population.

In analyzing future population growth, it is crucial to consider the trends in the size and composition of households. With trends toward smaller households in the near future, how to transform our consumption behaviors to ensure a responsible and sustainable consumption pattern towards achieving SDG should be a priority (*16*). Furthermore, given the global trends in urbanization, policies to manage urban growth are needed to ensure equal access to housing, education, healthcare, decent jobs, and friendly living and working environments — with a focus on the needs of the urban poor and other vulnerable groups — so that the benefits of urbanization can be shared by all.

Climate change and environmental degradation are major global concerns in the contemporary world. There is a consensus that population growth, urbanization, unsustainable consumption patterns are important drivers of emissions that have been a cause of the worsening climate and ecosystem (*25*). Rapid population growth is one of the key drivers of growing emissions and one of the determinants of vulnerability to its impact (*2*). Consequently, slowing population growth could be key to lessen climate risks facing human beings by reducing global emissions in the long-term and by freeing up resources for adaptation (*2*).

In summary, the world's population is projected to grow throughout the century, albeit at a decreasing rate. Given large variations in population trends across countries, different countries should develop sound policies specific to their own situation to scientifically address the unique challenges related to population growth for achieving SDGs and other long-term socioeconomic development goals.

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