Educational Gradients in Disability among Asia's Future Elderly: Projections for the Republic of Korea and Singapore

Cynthia Chen, Jue Tao Lim, Ngee Choon Chia, Daejung Kim, Haemi Park, Lijia Wang, Bryan Tysinger, Michelle Zhao, Alex R. Cook, Ming Zhe Chong, Jian-Min Yuan, Stefan Ma, Kelvin Bryan Tan, Tze Pin Ng, Koh Woon-Puay, Joanne Yoong, Jay Bhattacharya, and Karen Eggleston*

Asia is home to the most rapidly aging populations in the world. This study focuses on two countries in Asia that are advanced in terms of their demographic transition: the Republic of Korea and Singapore. We developed a demographic and economic state-transition microsimulation model based on the Korean Longitudinal Study of Aging and the Singapore Chinese Health Study. The model was employed to compare projections of functional status and disability among future cohorts of older adults, including disparities in

*Cynthia Chen: Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore; and Schaeffer Center for Health Policy and Economics, University of Southern California, United States (US). E-mail: phchc@nus.edu.sg; Jue Tao Lim: Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore. E-mail: juetao@nus.edu.sg; Ngee Choon Chia: Department of Economics, National University of Singapore, Singapore. E-mail: ecscnc@nus.edu.sg; Daejung Kim (corresponding author): Department of Health Care Policy Research, Korea Institute for Health and Social Affairs, Republic of Korea. E-mail: kimdj07@kihasa.re.kr; Haemi Park: Department of Social Welfare, Daejeon University, Republic of Korea; Lijia Wang: Department of Statistics and Actuarial Science, University of Waterloo, Canada; Bryan Tysinger: Schaeffer Center for Health Policy and Economics, University of Southern California, US; Michelle Zhao: Stanford University, US; Alex R. Cook: Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore; Ming Zhe Chong: Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore; Jian-Min Yuan: Department of Epidemiology, Graduate School of Public Health, University of Pittsburgh, US; and Division of Cancer Control and Population Sciences, UPMC Hillman Cancer Center, US; Stefan Ma: Epidemiology and Disease Control Division, Ministry of Health, Singapore;

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disability prevalence by educational attainment. The model also projects increasing disparities in the prevalence of activities-of-daily-living disability and other chronic diseases between those with low and high educational attainment. Despite overall increases in educational attainment, all elderly, including those with a college degree, experience an increased burden of functional disability and chronic diseases because of survival to older ages. These increases have significant economic and social implications, including increased medical and long-term care expenditures, and an increased caregiver burden.

Keywords: ADL disability, microsimulation model, Republic of Korea, Singapore

JEL code: I14

I. Introduction

The Republic of Korea and Singapore are home to the most rapidly aging populations in the world and are projected to have continually increasing proportions of older adults in the coming decades. These countries are projected to be "top-heavy" societies because of continued increase in life expectancy coupled with low, below-replacement fertility rates. Although the changes in population size and demographics in these countries have been studied, the complex evolution of the health and functional disparities of the future elderly has not been fully explored. These changes will have important implications for social protection systems, including the financing and delivery of long-term care and health care.

Both Singapore and the Republic of Korea experienced rapid industrialization, with exceptionally high average annual real gross domestic product growth rates of

Kelvin Bryan Tan: Policy Research and Economics Office, Ministry of Health, Singapore; Tze Pin Ng: Yong Loo Lin School of Medicine, National University of Singapore, Singapore; Koh Woon-Puay: Healthy Longevity Translational Research Programme, Yong Loo Lin School of Medicine, National University of Singapore, Singapore; and Singapore Institute for Clinical Sciences, Agency for Science Technology and Research, Singapore; Joanne Yoong: Center for Economic and Social Research, University of Southern California, US; Jay Bhattacharya: School of Medicine, Stanford University, US; Karen Eggleston: Shorenstein Asia Pacific Research Center, Stanford University, US. We thank Kenwin Maung for the helpful discussions and statistical support that have contributed to this work. The research was supported by the National Medical Research Council (MOH-HSRGMH18may-0001) and the National Institute on Aging of the National Institutes of Health (P30AG024968). The Singapore Chinese Health Study was supported by US National Institutes of Health (R01CA144034 and UM1CA182876). Koh Woon-Puay was supported by the National Medical Research Council, Singapore (NMRC/CSA/0055/2013). The funding sources had no role in the design and conduct of the study; collection, management, analysis, or interpretation of the data; preparation, review, or approval of the paper; and decision to submit the paper for publication. The Asian Development Bank recognizes "China" as the People's Republic of China and "Korea" and "South Korea" as the Republic of Korea.

7.38% and 7.42%, respectively, from 1960 to 2017 (World Bank 2017). They transited from low-income to high-income economies within 50 years. Out of 188 economies ranked in the Human Development Index, Singapore and the Republic of Korea are considered to be highly developed economies with Human Development Index values of 0.925 (ranked 4th) and 0.901 (ranked 18th), respectively (United Nations Development Programme 2018). Their high scores are in part due to good universal health care accessibility and high levels of educational attainment.

Our conceptual framework for studying the Republic of Korea and Singapore is based on hypotheses and evidence from a large literature showing that human capital accumulation is associated with broad socioeconomic development (Lee and Mason 2010) and can have a large effect on individuals and the economy. Good health allows for more schooling and better absorption of knowledge, and education provides people with the skills that translate into higher labor productivity and wages (Barro 2013). Thus, higher educational attainment can affect health directly (e.g., through better knowledge of how lifestyle choices impact health) as well as through its association with higher socioeconomic status, including (depending on the health system) improved financial access to quality health care and health insurance (Cutler and Lleras-Muney 2010; Leopold and Engelhartdt 2012; Basu, Jones, and Dias 2018). While many studies have examined the return-on-investment from education, few have investigated how health disparities across education groups vary across time in Asia. This endeavor may be challenging given the complex economic and social interdependence between demographic change and population health. The Republic of Korea and Singapore are both fast-growing industrialized countries, with sparse mineral resources and human capital as their primary resource. While both the Republic of Korea and Singapore are aging rapidly, they have differing trends in educational attainment across genders. As the formation of human capital developed differently over time in each country, this might have had different impacts on health. Therefore, a study involving both countries allows us to examine human capital's comparative impacts on population health and the consequent disparities over time. This may provide supporting evidence to aid policy makers in formulating effective responses, especially for disadvantaged groups.

Education is linked to prevention of chronic disease (Harris 2007), disability (Lutz et al. 2007, K. C. and Lentzner 2010) and mortality (Baker et al. 2011). Higher-educated and wealthier individuals are less prone to physical disability later in life (Gjonça, Tabassum, and Breeze 2009), and they possess longer disability-free life expectancy (Minicuci and Noale 2005, Nogueira and Reis 2014). Thus, health

differences by educational attainment are expected, although it is not clear if these educational gradients in health are steepening as the average education or human capital of a society increases. Moreover, other factors might crowd out education's beneficial impact on health outcomes (Behrman and Wolfe 1987; Fuchs 2004; Conti, Heckman, and Urzua 2010). A recent study in the People's Republic of China found steepening educational gradients in health, although the gradient flattens with age and is mediated by economic and social resource variables (Chen et al. 2017). Lastly, age and income also have a complex interplay with morbidity and mortality (McDonough et al. 1997, Schnittker 2004, Kennedy et al. 2014). As such, a projection of the health and functional disability of the middle-aged and elderly population needs to account for socioeconomic and demographic trends, as well as competing risk factors to provide an accurate picture for policy making.

Improvements in the educational composition of the population can also have a considerable impact on decreasing the future prevalence of disability at any given age (Lutz et al. 2007). There are many mechanisms. For example, Caldwell (1996) showed that women's education has a direct effect on the health status of the population through improved maternal–child health. Gender disparities in education also narrowed as educational attainment increased in the Republic of Korea and Singapore. In the past, women were unlikely to be formally employed and had fewer educational opportunities. However, much has changed and both countries have made great strides in education; for example, in Singapore, female literacy rates rose from 34% in 1957 to 94% in 2010 (Moi 2010). This resulted in increased female wages (median income rose from $2,863 in 2010 to $3,518 in 2014) and labor force participation (21.6% in 1957 to 58.6% in 2014), and induced better health outcomes, as an increase in literacy rates is associated with increases in health-care access and utilization (Sudore et al. 2006, Bustamante et al. 2012). In addition, higher education is associated with lower mortality, an improvement in psychosocial health, a reduction in bad lifestyle habits, and lower occupational and health risks from jobs that demand manual labor such as agriculture or construction (Currie and Hyson 1999, Deaton and Paxson 1999, National Research Council 2012). Lower mortality among the better-educated, in turn, implies survival to older ages. As a result, our conceptual framework suggests that the increasing educational attainment of the Korean and Singaporean populations will lead to lower age-standardized disability rates but higher overall disability rates because of a higher proportion of the oldest-old and their associated disabilities. The educational gradient in disability may decline or increase, depending on the relative health benefit of better education among the low- versus high-educated groups.

To take into consideration the dynamic interplay between a rapidly aging population, increases in educational attainment, age-dependent susceptibility to health conditions, and functional disability in Asia, we develop a Future Elderly Model (FEM) for the Republic of Korea and Singapore. The FEM is a sociodemographic and economic state-transition microsimulation model with flexibility as a key strength: it can take into account the evolving educational attainment of future elderly cohorts and competing risks when projecting functional disability outcomes for the future elderly population. We employ these models to project and compare functional disability across the two countries, including disparities in functional disability prevalence by educational attainment and gender, up to 2050. The models in this paper are similar in spirit to the American FEM (Goldman et al. 2005), but with country-specific prevalence rates of diseases, demographic trends, and transition probabilities for different health states. The Republic of Korea's estimates are based on the harmonized version of the Korean Longitudinal Study of Aging (KLoSA), while the Singapore model is based on the Singapore Chinese Health Study (SCHS).

We find that from 2015 to 2050, the educational gradient in health and functional status will steepen, with a wider gap in the prevalence of functional disability between those with low and high educational attainment. For example, in Singapore, the disparity in functional disability prevalence, as measured by limitation in at least one activity of daily living (ADL), starts at a difference of 9.5 percentage points in 2015 and climbs by 2050 to a difference of over 23 percentage points (31.9% among those with low education, compared to 8.7% among the college-educated). Functional disability as measured by instrumental activities of daily living (IADL) shows a similar pattern. The Republic of Korea's model projects even larger disparities by 2050, as exemplified by a difference of 41.7 percentage points in the prevalence of any functional disability between low- and high-educational attainment groups (i.e., 51.7% among those with less than a high school education, compared to 10.0% among the college-educated). These disparities are driven almost entirely by population aging and increasing education so that the population in the lower educational attainment group is a small, selected disadvantaged group. Improved survival of those with low education and their declining share of the population leads to their concentration among the oldest-old (therefore with the highest disability burden), especially in the Republic of Korea.

The remainder of this paper is organized as follows. Section II describes the data and method for operationalizing the FEM for the Republic of Korea and Singapore. Section III presents the results on functional disability and the associated educational gradient in the future elderly by country. The last section identifies economic and

policy implications, as well as areas for mutual learning and improvement. Further details on the models for individual countries are reported in the appendixes.[1]

II. Method

A. Data

Data were drawn from comprehensive longitudinal surveys of older adults from two rapidly aging economies, the Republic of Korea and Singapore. The KLoSA is a longitudinal study of individuals over age 45 years old in the Republic of Korea. It was designed to help researchers and policy makers better understand the socioeconomic determinants and consequences of aging. The survey includes a rich set of questions regarding the economic standing, physical and psychological health, demographics, and social networks of aged persons. We used the harmonized KLoSA dataset, which contains Waves 1, 2, 3, and 4 as of October 2015. The first wave of the KLoSA survey was conducted in 2006 and included 10,254 respondents aged 45 years and over. The second wave was done in 2008 with 8,688 respondents. The third wave was done in 2010 with 7,920 respondents. The fourth wave was done in 2012 with 7,486 respondents.

The SCHS is a prospective cohort study of ethnic Chinese men and women aged 45–74 years old in the baseline who were followed up for a mean duration of 12 years. Inclusion criteria were similar to an earlier study (Chen et al. 2019b), with respondents being either citizens or permanent residents, residing in government-built housing, and belonging to either of the two major dialect groups of Chinese in Singapore (Hokkien and Cantonese). The baseline study ($n = 63,257$) was collected between 1993 and 1999, follow-up 1 ($n = 52,325$) was collected between 1999 and 2004, and follow-up 2 ($n = 39,528$) was collected between 2006 and 2010. At baseline, each participant completed an in-person interview at their home using a structured questionnaire that requested information about demographic characteristics, self-reported height and weight, smoking status, current physical activity, occupational exposure, medical history, and family history of cancer. A follow-up telephone interview asked participants for an update on their tobacco and alcohol use as well as medical history. We used the Singapore Longitudinal Aging Study (SLAS)—a smaller cohort that consists of 2,804 subjects aged 55 years or above interviewed in 2004–2005,

[1]The online Appendixes can be accessed at: https://sph.nus.edu.sg/wp-content/uploads/2022/03/Appendix_FEM_SGSK_v2.pdf.

2007–2008, and 2010–2011—to model functional disability. Older adults who were citizens or permanent residents aged 55 years or above were identified by door-to-door census and invited to participate voluntarily in the study.

B. Microsimulation Model

The FEM microsimulation model includes disease transitions and accounts for population aging within the middle-aged and elderly population. Using the FEM, we are able to model individual-level longitudinal dynamics, allowing for greater heterogeneity than cell-based approaches. Moreover, populations entering the microsimulation reflect current trends in sociodemographic characteristics and health status based on data from population surveys. The FEM was successfully implemented first to support decision-making related to Medicare and Medicaid, the public health insurance and welfare programs for the elderly and needy, respectively, in the United States (Goldman et al. 2005). Since then, the FEM has been used for dozens of important papers for informing health and social issues in aging societies such as the United States, European Union, and Japan (Michaud et al. 2011, Chen et al. 2016, Chen et al. 2019b). Its ongoing development is supported by the National Institute on Aging through the University of Southern California's Roybal Center for Health Policy Simulation (University of Southern California 2019). In using the same FEM model to project functional disability for Singapore and the Republic of Korea, we aim to: (i) highlight potential differences in the aging experience by gender and education in each country to inform social and health-care policy, and (ii) provide a common platform for international comparison to identify and compare challenges across countries.

Individuals in the FEM are characterized by their socioeconomic status and health states. From period to period, they transit from one health state to another with probabilities that are estimated from the data (see Section II.C). The Singapore FEM is modeled with a 6-year time step, as the SCHS was surveyed with a mean of 6 years between each study wave. The Republic of Korea's FEM model follows a 2-year time step mirroring the mean time between waves of the KLoSA study. We then interpolate linearly the outcomes to yearly rates. As there was no difference in results when presenting with 6-year compared to 5-year intervals, we reported the 5-year charts for ease of interpretation. Also, a replenishing cohort is introduced every period at the default starting age, set at 55–60 years old for Singapore and 51–52 years old for the Republic of Korea. Individuals within the simulation exit from the model at the time of death. Hence, although some individuals are lost to mortality, the population expands

with renewal. KLoSA and SCHS are post-stratified by age group, gender, and education. They are then rebalanced with the corresponding population weights using population projections obtained from the International Institute for Applied Systems Analysis and the Vienna Institute of Demography projections for Singapore. In the Republic of Korea, the education profile was rebalanced using the Barro–Lee projections. This adjustment is made for both the initial cohort as well as the replenishing cohorts over the simulation cycles. The distribution of socioeconomic status, particularly education, and health status vary across the new cohorts depending on the trends derived from the data and on the time of their introduction. In each simulation cycle, the population moves forward in time and individuals transit to new states probabilistically; this results in an observable distribution of health in the population at the end of each cycle. The replenishing cohort model, which determines the distribution of states among individuals in the new cohorts, is estimated in Stata, while the overarching simulation is implemented in C++ for computational efficiency. To calculate the Monte Carlo confidence intervals, we repeated the sample process described above 1,000 times and used the 2.5th and 97.5th percentiles as the prediction interval, similar to other studies (Pericchi and Walley 1991, O'Brien et al. 2009, Chen et al. 2019a).

C. Health Transition Model

The FEM uses a discrete piecewise linear hazard model on longitudinal data to estimate transitional probabilities for selected measures of health status. The hazard of getting a disease, dying, or becoming disabled depends on risk factors such as gender, education, lifestyle, comorbidities, functional status, and age (Appendix 4). The resulting hazards will then be used as parameters in the microsimulation model to determine how individuals transit between health states from one period to the next. The health transition model is estimated in Stata. We used probit regressions to estimate the probability of transition to each health condition, controlling for education, demographic variables, and comorbidities at the previous period. We treated all diseases as an absorbing state—as there is currently no cure for chronic diseases such as diabetes, hypertension, heart disease, or stroke—in reflection of the question asked: "Have you ever been told . . . by a doctor?" In the Republic of Korea, variables were measured with a 2-year lag in the KLoSA (Jang 2016). In Singapore, all independent variables were measured with a 6-year lag in the SCHS and represent the respondent's characteristics from 1993 to 2010 (National University of Singapore 2018). In both countries, as diseases were treated as an absorbing state, we assumed that those with a chronic condition in the previous wave would continue

to have that disease in the current wave. As such, transition probabilities were only estimated on those who did not suffer from a specific condition at the time of the previous survey wave.

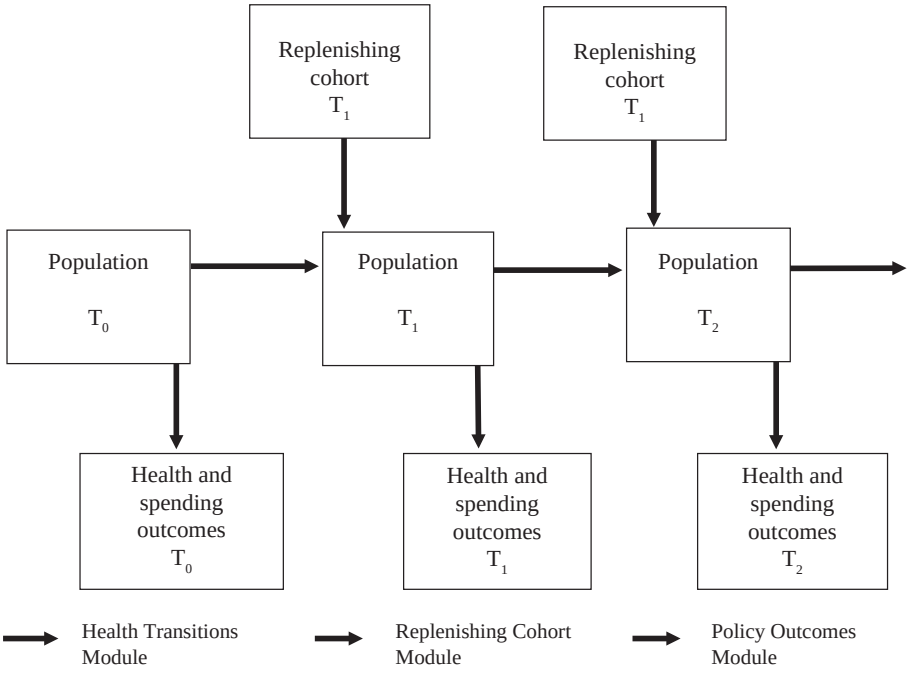
The transition model is the core of the FEM. The transition model describes the health status of individuals and how it evolves between periods over the course of the simulation. The model's main variables consist of sociodemographic and behavioral variables denoted as AGE_{it}, $GENDER_i$, $EDUCATION_i$, $MARITAL_STATUS_i$, $SMOKE_CURRENT_{it}$, $SMOKE_EVER_{it}$, and BMI_{it}, as well as a set of indicator variables for diseases: $DISEASE_{it} = \{DISEASE1_{it}, \ldots, DISEASEN_{it}\}$ with reference to the N chronic conditions, where i refers to the individual and t refers to the time. In addition, a mortality indicator variable denoted $DIED_{it}$ was created and is equal to 1 if the simulated individual i dies at time t during the simulation or 0 otherwise. The baseline cohort is defined at the initial time period ($t = 1$). The variables of AGE_{it}, $GENDER_i$, $EDUCATION_i$, $MARITAL_STATUS_i$, $SMOKE_CURRENT_{it}$, $SMOKE_EVER_{it}$, BMI_{it}, and $DISEASE_{it}$ in the baseline cohort are retrievable from the KloSA and SCHS datasets. All of these samples are allocated with a specific weight such that the number of individuals in each age, sex, and education level category is consistent with that of the population distribution in each country.

Figure 1 provides a schematic overview of the model. The FEM simulation starts from 2008 with initial populations aged 51 years and above in the Republic of Korea and Singapore. We then predict outcomes using our estimation for the initial cohort (Appendix 4) to begin the simulation. Individuals who survive are defined as those for whom the transition model predicts $DIED_{it}$ not equal to 1 (nondecedents) at the end of the corresponding year. Projections on policy outcomes are then made for that year. Thereafter, the FEM moves to the following time period within the simulation cycle when a new cohort enters. The current cohort and the replenishing cohort form the new population of those aged 51 years and above (Republic of Korea) or 55 years and above (Singapore), which then proceeds through the transition module as before. The replenishing cohort enters the simulation every 2 years for the Republic of Korea and every 6 years for Singapore. This process of replenishing new cohorts and transiting across various health states is repeated until we reach the final year of the simulation. Each individual module is explained in more detail in Appendix 4.

D. Functional Disability Model

We defined functional disability as having any ADL disability such as limitation in washing, dressing, feeding, toileting, mobility, and transferring

Figure 1. **Schematic Overview of Future Elderly Model Simulation in the Republic of Korea and Singapore**



Source: Authors' illustration.

(Ministry of Health 2018), or having any IADL disability such as limitation in taking transportation, shopping, managing money, making phone calls, doing household chores, and meal preparation. The former measures an individual's physical ability to perform basic tasks, whereas the latter includes higher-order tasks that measure an individual's engagement and management of resources. We projected future functional disability using probit regressions for any ADL and IADL disability, and ordered probit regressions for disability measured on an ordinal scale. In the ordered probit regression for each country, we summed the number of ADL functional disabilities in washing, dressing, feeding, toileting, mobility, and transferring. We then modeled *adlstat* as three categories: (i) having no disability, (ii) having one or two disabilities, or (iii) having three or more disabilities. We modeled *adlstat* as an ordinal outcome using ordered probit regression. Similar analysis was performed for IADL. The covariates included were age, gender, educational attainment, body mass index, marital status, and chronic diseases.

E. Educational Attainment

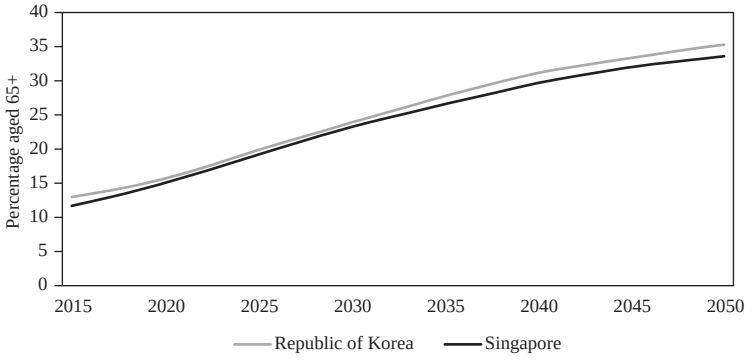
Only educational attainment was modeled according to countries' specific categorization. In the Republic of Korea, low attainment is defined as less than high school, middle attainment is defined as high school, and high attainment is defined as having a college education. In Singapore, low attainment is defined as having a primary education or less (6 years of education or less); middle attainment as having a secondary school education, technical education, or diploma (7–15 years of education); and high attainment as having a college education or above (at least 15 years of education). We wanted to capture each country's specific distribution of relative educational attainment, as this distribution better captures each country's dispersion in human capital and helps us therefore to understand the relationship between educational differences and health disparities. Given this categorization, those with low educational attainment in the Republic of Korea are on average more educated than those categorized as low educational attainment in Singapore, whereas high educational attainment is comparable across the two countries. Our appendixes also include figures depicting the model projections when using a consistent definition of low educational attainment for both countries, defined as having less than a college education. Education was used as a measure of socioeconomic status, and we used these two terms interchangeably.

III. Results

A. Country Characteristics

The United Nations (UN) has projected both the Republic of Korea and Singapore to age rapidly in the future (Figure 2). This aging within the middle-aged and older population reflects the large post-war baby boomer cohorts, subsequent low fertility, and improved survival (lower age-specific mortality) across the population. Using UN data, the proportion aged 65 years and above in 2015 was 13.0% in the Republic of Korea and 11.7% in Singapore; in 2050, these shares will have increased to 35.3% and 33.6%, respectively. The old-age support ratio, defined as the population aged 20–64 years (working age) divided by the population aged 65 years and above, declines at similar rates in both countries from about 6 working adults per elderly person in 2015 to about 1.5 working adults per elderly person in 2050. Using the UN projections, Figure 3 shows that both countries will have an increasing percentage of the elderly with a college education among both men and

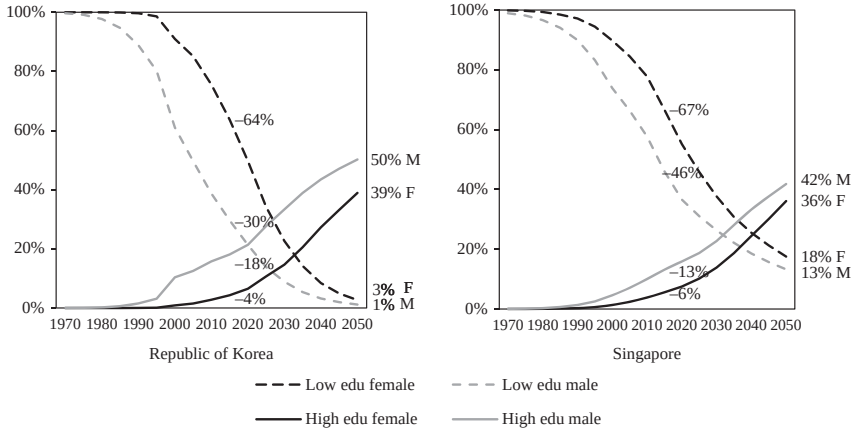
Figure 2. **Share of Population Aged 65 Years and Above**



Source: United Nations Department of Economic and Social Affairs. 2017. *World Population Prospects: The 2017 Revision.* https://www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html.

women. The projection also shows that the number of the elderly with low or no education will decrease continuously. Using UN data, in 2015 the percentage of older adults with low or no formal education was higher in females compared to males: for the Republic of Korea, 64% (females) and 30% (males); for Singapore,

Figure 3. **Percentage of Low and High Educational Attainment among Those Aged 65 Years and Above**



edu = education, M = male, F = female.

Source: International Institute for Applied Systems Analysis and the Vienna Institute of Demography projection extracted from United Nations Department of Economic and Social Affairs. 2017. *World Population Prospects: The 2017 Revision.* https://www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html.

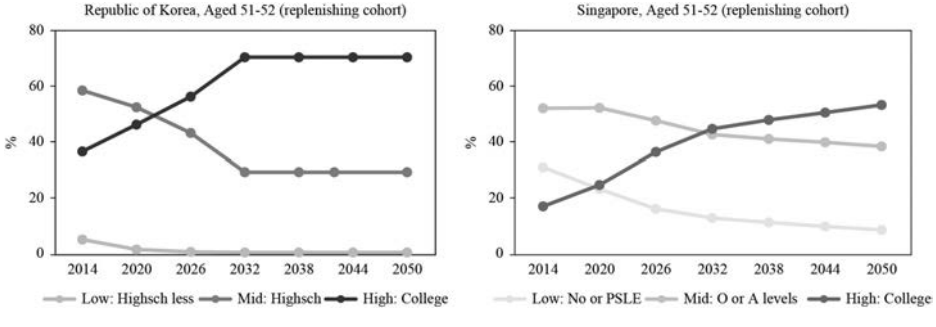
67% (females) and 46% (males). By 2050, the percentage is projected to have decreased substantially for both countries: for the Republic of Korea, 3% (females) and 1% (males); for Singapore, 18% (females) and 13% (males). Over the same period, there will be a sharper increase in college education among women than men: for females, from 4.3% in 2015 to 38.9% in 2050 in the Republic of Korea and from 6.0% in 2015 to 36.1% in 2050 in Singapore; compared with males, from 18.1% in 2015 to 50.2% in 2050 in the Republic of Korea and from 13.1% in 2015 to 41.8% in 2050 in Singapore.

Thus, educational attainment among our replenishing cohorts was projected to increase (Figure 4). In the Republic of Korea, the proportion of primary school graduates entering middle school was 99.9% in 2000, and the proportion of middle school graduates entering high school was 99.7% (Ministry of Education 2000). Our model captures how this change in educational attainment of future older adults will shape trends in health, incorporating both differences in mortality and morbidity. Based on our FEM simulations, Figure 5 shows the aging pyramid in both countries with growing numbers of elderly with college education.

In both countries, chronic conditions and functional disability were projected to rise during the review period. IADL disability is projected to be much higher in Singapore than the Republic of Korea in 2050 (Figure 6). The prevalence of chronic disease burden for diabetes, stroke, and heart disease will be higher in the Republic of Korea.

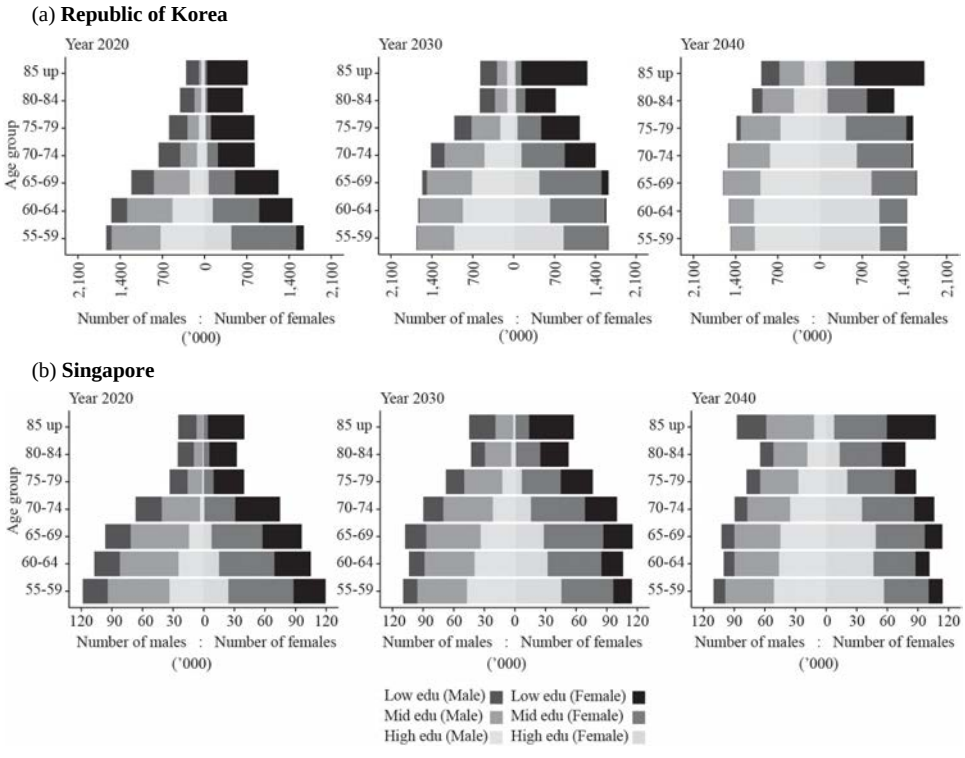
By 2050, the total number of people with any ADL disability was projected to increase to 275,000 (18.9%) in Singapore and 2.48 million (15.9%) in the Republic of

Figure 4. **Educational Attainment among Future Middle-Aged and Elderly in Singapore and the Republic of Korea: Trends in the Replenishing Cohorts in the Future Elderly Model**



Highsch = high school, PSLE = primary school leaving examination.
Source: Authors' calculations using the Future Elderly Model based on data from the Korean Longitudinal Study of Aging and the Singapore Chinese Health Study.

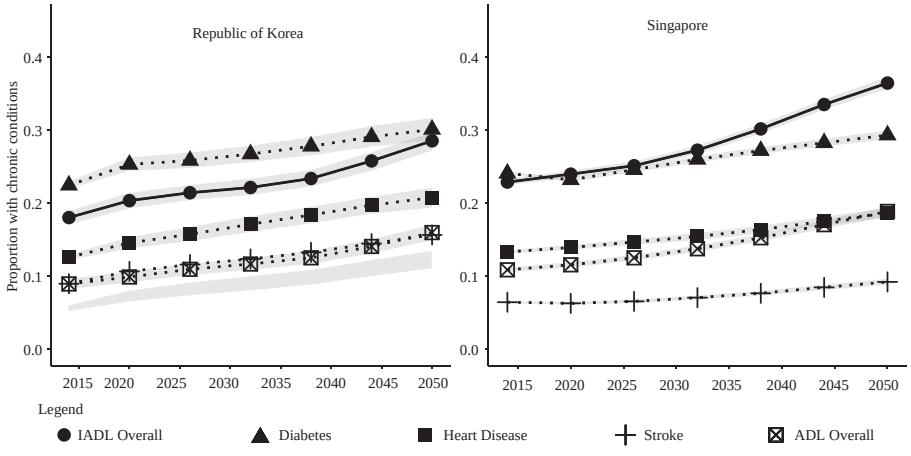
Figure 5. **Population Pyramids by Education for the Middle-Aged and Elderly, 2020–2040**



edu = education.
Source: Authors' calculations using the Future Elderly Model based on data from the Korean Longitudinal Study of Aging and the Singapore Chinese Health Study.

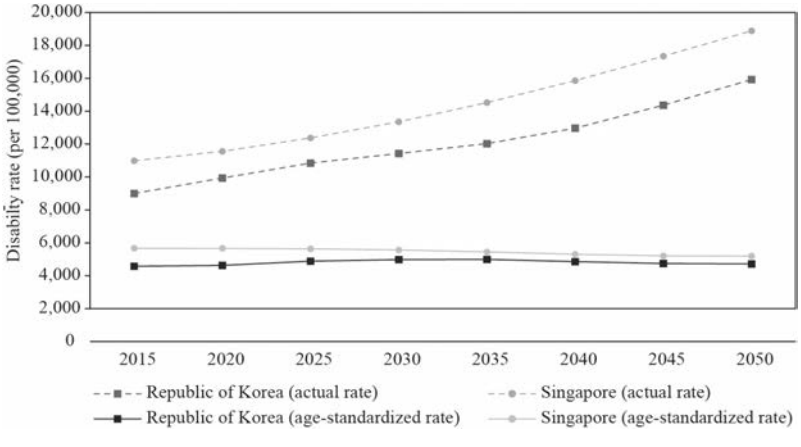
Korea, with an increasing rate of disability among those aged 65 years and above (Figure 7). To adjust for the differences in the age structure and account for the strong influence of age on the risk of ADL disability, the prevalence rates were age-standardized to the combined populations of the Republic of Korea and Singapore in 2015 and expressed as 100,000 person-years for the elderly aged 65 years and above. Data were analyzed using 5-year age groups (65–69, 70–74, 75–79, 80–84, and 85+ years) for both countries. After changes in the age structure were removed, both countries exhibit very similar trends. The age-standardized rates (ASRs) for both countries remained stable across time, with slight declines in age-standardized rates in later years that partly reflect the increase in the share with a college education, who are in better health.

Figure 6. **Proportion of Those Aged 65 Years and Above with Disability and Chronic Conditions, 2050**



ADL = activities of daily living, IADL = instrumental activities of daily living.
Note: Confidence bounds represent the 95% prediction interval from 1,000 Monte Carlo simulation.
Source: Authors' calculations using the Future Elderly Model based on data from the Korean Longitudinal Study of Aging and the Singapore Chinese Health Study.

Figure 7. **Disability Rates (Actual and Age-Standardized) per 100,000 People Aged 65 Years and Above**



Source: Authors' calculations using the Future Elderly Model based on data from the Korean Longitudinal Study of Aging and the Singapore Chinese Health Study.

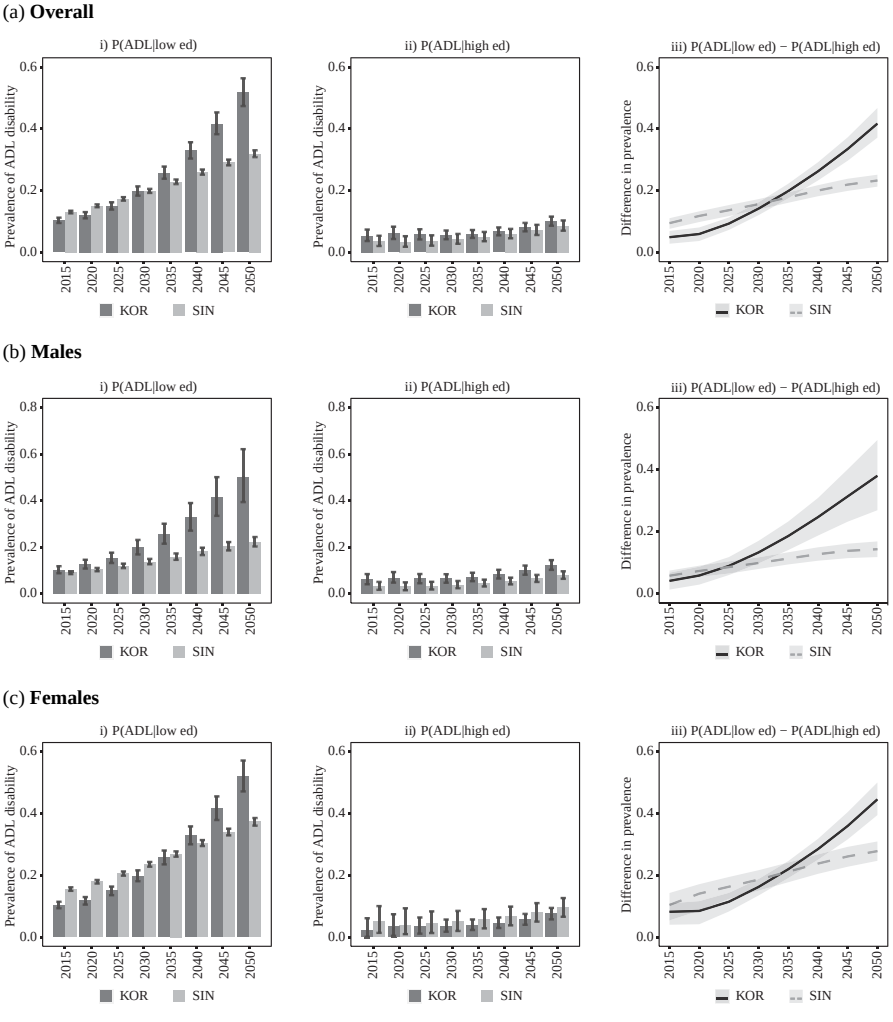
B. Educational Gradients in Disability

The model projects a continuing—and in some cases steepening—educational gradient in disability and chronic conditions, with those of lower education experiencing a higher prevalence of disability and chronic diseases. This result was consistent across genders, although varying in magnitude across countries over time. For men in Singapore, in 2015, the difference in the prevalence of poor health between elderly with low and high educational attainment was largest for IADL disability (21.3 percentage points), followed by diabetes (6.4 percentage points) and ADL (5.8 percentage points). For women in Singapore, the difference was largest for IADL disability (16.7 percentage points), followed by diabetes (15.5 percentage points) and hypertension (15.2 percentage points). For men in the Republic of Korea, in 2015 the absolute difference in the prevalence between elderly with low and high educational attainment was largest for IADL disability (7.0 percentage points), followed by heart disease (5.2 percentage points), and ADL disability (4.1 percentage points). For women, the difference was largest for hypertension (20.0 percentage points), followed by IADL disability (12.2 percentage points) and diabetes (10.7 percentage points).

Over time, ADL disability is projected to rise sharply for the elderly with low educational attainment in the Republic of Korea from 10.3% in 2015 to 51.7% in 2050, while increasing at a slower pace in Singapore from 13.1% to 31.9% over the same period (Figure 8a). In part, this reflects the fact that low-educated Koreans will be concentrated exclusively among the oldest-old by 2050 (see Figures 2 and 3), rather than also including those in their 60s and 70s as in Singapore. For female elderly with high educational attainment, the prevalence of ADL disability was projected to be higher in Singapore compared to the Republic of Korea. The disparities in the burden of ADL disability appeared larger for the Republic of Korea and are projected to increase in the future as the low-education group becomes a tiny fraction of the population, whereas the difference is projected to stabilize for Singapore in the future. Similar trends were observed in both males (Figure 8b) and females (Figure 8c). Also, the difference in ADL disability among low- and high-education groups is projected to be larger for females than males in both countries.

IADL disability is projected to rise sharply for elderly with low education in the Republic of Korea from 19.9% in 2015 to 71.8% in 2050, while it increases less quickly for Singapore from 27.2% to 57.0% during the same period (Figure 9a). Although the overall projected prevalence of IADL disability is lower in Singaporean elderly with high education, this is driven mainly by males (Figures 9b and 9c).

Figure 8. **Disparities in Activities of Daily Living Disability by Country, Education, and Gender**



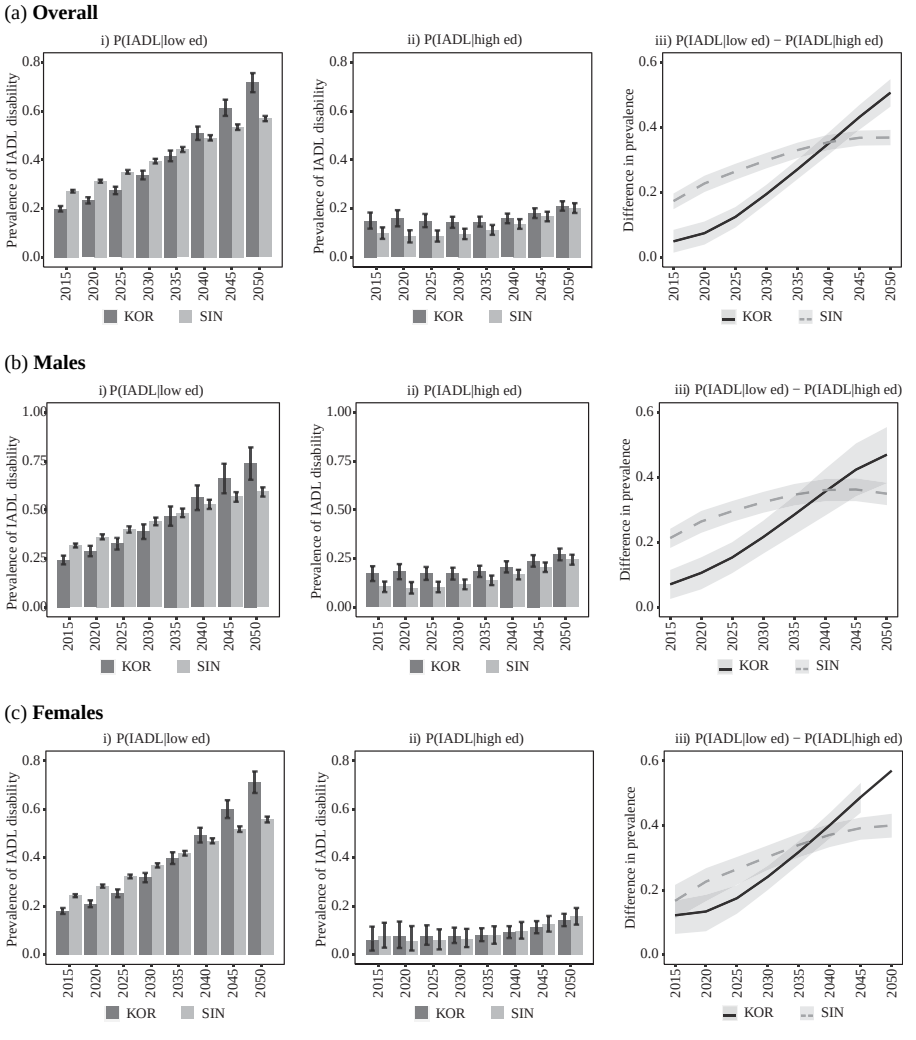
ADL = activities of daily living, high ed = high education, KOR = Republic of Korea, low ed = low education, SIN = Singapore.

Notes: From left to right, by country:

1. Proportion of ADL disability among elderly with low education from 2015 to 2050.
2. Proportion of ADL disability among elderly with high education from 2015 to 2050.
3. Absolute difference in proportion of ADL disability between elderly in high- and low-education groups from 2015 to 2050. Lines represent the mean difference in ADL disability prevalence between high- and low-education for the Republic of Korea and Singapore. Confidence bounds represent the 95% prediction interval from Monte Carlo uncertainty of 1,000 simulation.

Source: Authors' calculations using the Future Elderly Model based on data from the Korean Longitudinal Study of Aging and the Singapore Chinese Health Study.

Figure 9. **Disparities in Instrumental Activities of Daily Living Disability by Country, Education, and Gender**



IADL = Instrumental activities of daily living, high ed = high education, KOR = Republic of Korea, low ed = low education, SIN = Singapore.

Notes: From left to right, by country:

1. Proportion of IADL disability among elderly with low education from 2015 to 2050.
2. Proportion of IADL disability among elderly with high education from 2015 to 2050.
3. Absolute difference in proportion of IADL disability between elderly in high- and low-education groups from 2015 to 2050. Lines represent the mean difference in IADL disability prevalence between high- and low-education for the Republic of Korea and Singapore. Confidence bounds represent the 95% prediction interval from Monte Carlo uncertainty of 1,000 simulation.

Source: Authors' calculations using the Future Elderly Model based on data from the Korean Longitudinal Study of Aging and the Singapore Chinese Health Study.

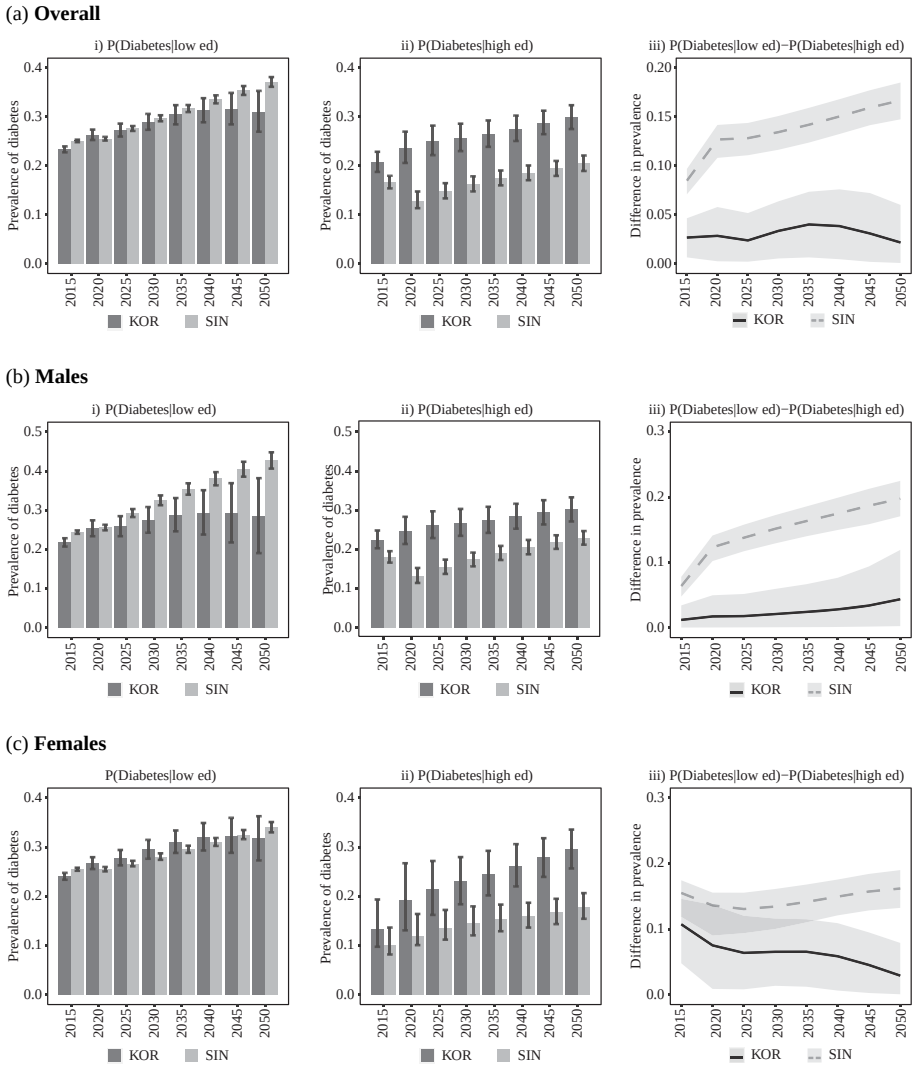
The educational disparities in the burden of IADL disability is projected to increase in the Republic of Korea in the future, whereas the difference is projected to stabilize for Singapore. Also, the educational disparities appeared larger for females in both countries.

For the most part, diabetes prevalence is projected to increase among elderly in both the low-education group (Republic of Korea: 23.3% in 2015 to 31.0% in 2050; Singapore: 25.1% in 2015 to 37.1% in 2050) and the high-education group (Republic of Korea: 20.7% in 2015 to 29.9% in 2050; Singapore: 16.6% in 2015 to 20.4% in 2050) (Figure 10a). However, in the Republic of Korea, there is a decline in the growth rate of diabetes prevalence among elderly with low education in both males (Figure 10b) and females (Figure 10c). As such, there is a decreasing trend in the difference in diabetes prevalence among the low- and high-education groups for the Republic of Korea, but a greater difference in diabetes prevalence in Singapore. Low-educated males in Singapore have a higher prevalence of diabetes compared to the Republic of Korea.

While stroke prevalence is projected to increase rapidly in the Republic of Korea among the low-educated (9.3% in 2015 to 21.8% in 2050) and high-educated (9.6% in 2015 to 15.2% in 2050) elderly, Singapore's prevalence is projected to increase at a much slower rate for both the low educated (7.1% in 2015 to 13.1% in 2050) and high educated (4.7% in 2015 to 6.6% in 2050) (Figure 11a). A similar pattern is seen for both males (Figure 11b) and females (Figure 11c). The educational difference in stroke prevalence increased in the Republic of Korea and remained stable in Singapore during the review period.

Heart disease prevalence is projected to increase in both the Republic of Korea and Singapore among the low-education group (Republic of Korea: from 12.9% in 2015 to 22.3% in 2050; Singapore: from 13.7% in 2015 to 24.7% in 2050) and in the high-education group in the Republic of Korea from 14.8% in 2015 to 19.9% in 2050. In Singapore, there is a slight decline from 12.3% in 2015 to 12.1% in 2050 (Figure 12a). In the Republic of Korea, males were less likely to experience heart disease than their female compatriots, but the converse was found in Singapore. As such, while the overall growth in heart disease prevalence in the Republic of Korea tapers off during the review period, the decline was driven by the drop in prevalence among males (Figure 12b), as heart disease in females continued to increase (Figure 12c). By contrast, in Singapore the overall disparities in the prevalence of heart disease were projected to increase. The difference in heart disease prevalence among the low and high educated is projected to decrease in the later years in the Republic of Korea and remain stable in Singapore.

Figure 10. **Disparities in Diabetes Prevalence by Country, Education, and Gender**



high ed = high education, KOR = Republic of Korea, low ed = low education, SIN = Singapore.

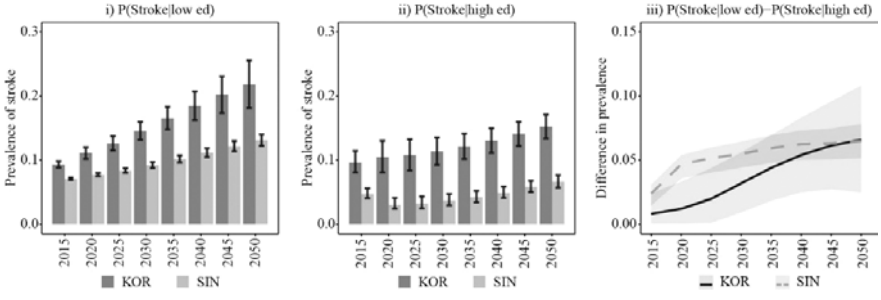
Notes: From left to right, by country:

1. Proportion of diabetes among elderly with low education from 2015 to 2050.
2. Proportion of diabetes among elderly with high education from 2015 to 2050.
3. Absolute difference in proportion of diabetes between elderly in high- and low-education groups from 2015 to 2050. Lines represent the mean difference in diabetes prevalence between high- and low-education for the Republic of Korea and Singapore. Confidence bounds represent the 95% prediction interval from Monte Carlo uncertainty of 1,000 simulation.

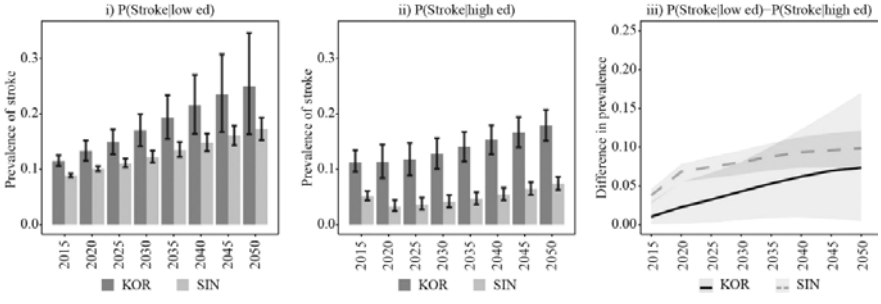
Source: Authors' calculations using the Future Elderly Model based on data from the Korean Longitudinal Study of Aging and the Singapore Chinese Health Study.

Figure 11. **Disparities in Stroke Prevalence by Country, Education, and Gender**

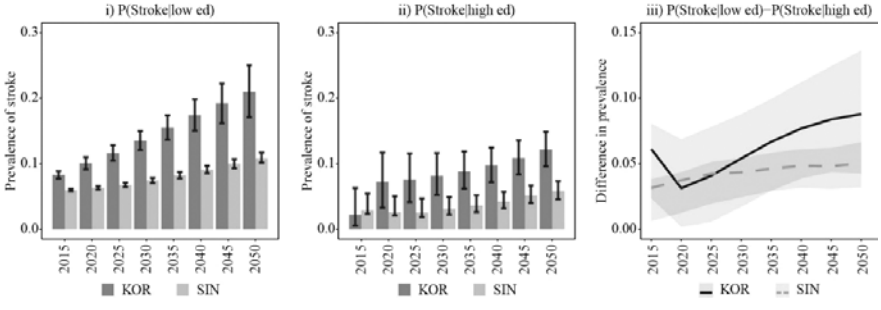
(a) **Overall**



(b) **Males**

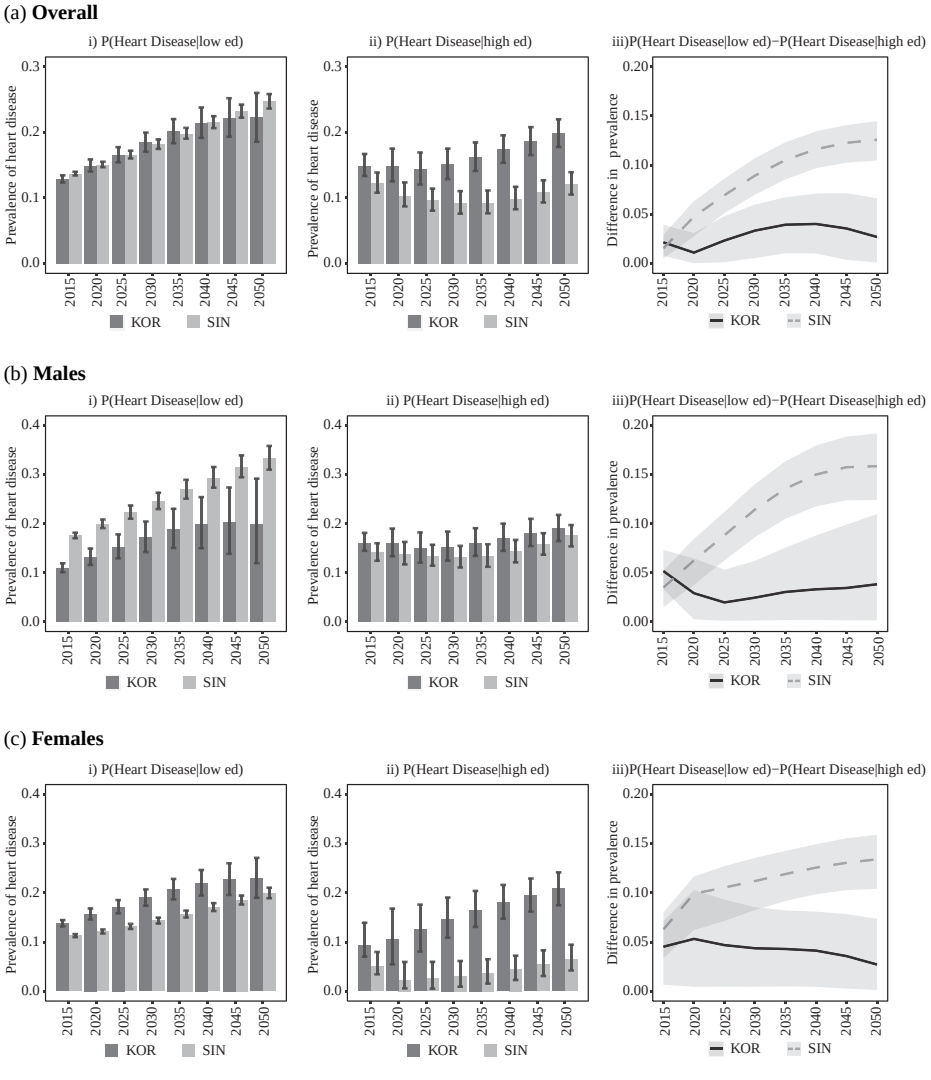


(c) **Females**



high ed = high education, KOR = Republic of Korea, low ed = low education, SIN = Singapore.
Notes: From left to right, by country:
1. Proportion of stroke among elderly with low education from 2015 to 2050.
2. Proportion of stroke among elderly with high education from 2015 to 2050.
3. Absolute difference in proportion of stroke between elderly in high- and low-education groups from 2015 to 2050. Lines represent the mean difference in stroke prevalence between high- and low-education for the Republic of Korea and Singapore. Confidence bounds represent the 95% prediction interval from Monte Carlo uncertainty of 1,000 simulation.
Source: Authors' calculations using the Future Elderly Model based on data from the Korean Longitudinal Study of Aging and the Singapore Chinese Health Study.

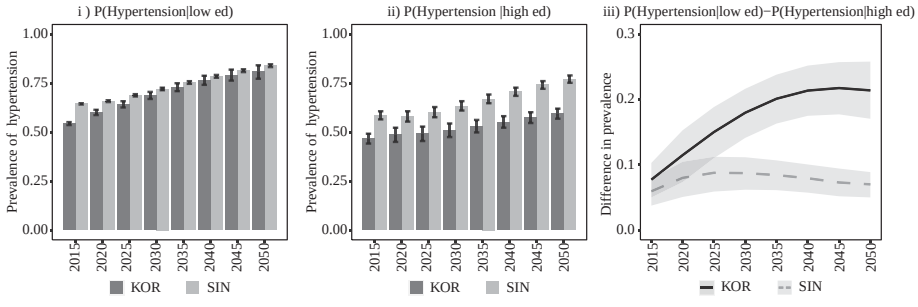
Figure 12. **Disparities in Heart Disease Prevalence by Country, Education, and Gender**



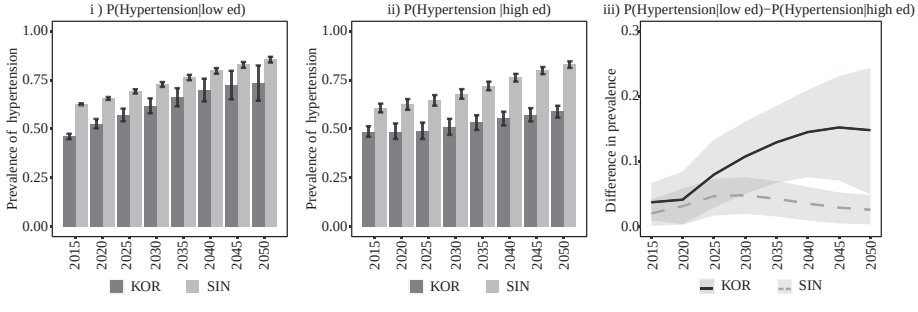
high ed = high education, KOR = Republic of Korea, low ed = low education, SIN = Singapore.
Notes: From left to right, by country:
1. Proportion of heart disease among elderly with low education from 2015 to 2050.
2. Proportion of heart disease among elderly with high education from 2015 to 2050.
3. Absolute difference in proportion of heart disease between elderly in high- and low-education groups from 2015 to 2050. Lines represent the mean difference in heart disease prevalence between high- and low-education for the Republic of Korea and Singapore. Confidence bounds represent the 95% prediction interval from Monte Carlo uncertainty of 1,000 simulation.
Source: Authors' calculations using the Future Elderly Model based on data from the Korean Longitudinal Study of Aging and the Singapore Chinese Health Study.

Figure 13. **Disparities in Hypertension Prevalence by Country, Education, and Gender**

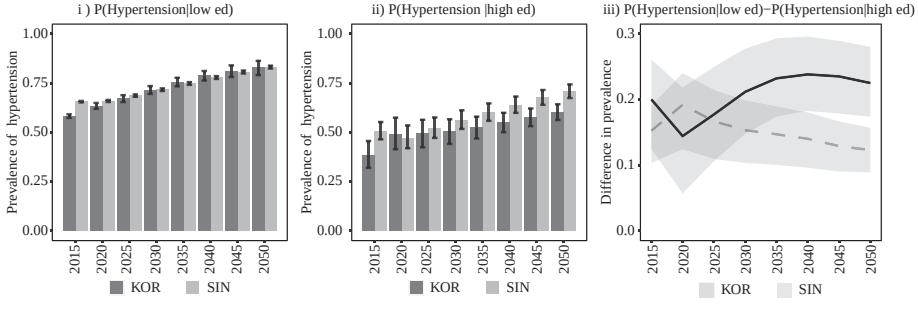
(a) **Overall**



(b) **Males**



(c) **Females**



high ed = high education, KOR = Republic of Korea, low ed = low education, SIN = Singapore.
Notes: From left to right, by country:
1. Proportion of hypertension among elderly with low education from 2015 to 2050.
2. Proportion of hypertension among elderly with high education from 2015 to 2050.
3. Absolute difference in proportion of hypertension between elderly in high- and low-education groups from 2015 to 2050. Lines represent the mean difference in hypertension prevalence between high- and low-education for the Republic of Korea and Singapore. Confidence bounds represent the 95% prediction interval from Monte Carlo uncertainty of 1,000 simulation.
Source: Authors' calculations using the Future Elderly Model based on data from the Korean Longitudinal Study of Aging and the Singapore Chinese Health Study.

Table 1. **Prevalence of Conditions in 2050 for those Age 65 years and Above by Country, Education, and Gender**

	Singapore		Republic of Korea		Difference in Prevalence (Low versus High Education)	
Condition	**Low Education**	**High Education**	**Low Education**	**High Education**	**Singapore**	**Republic of Korea**
			Overall			
ADL disability	0.319	0.087	0.517	0.100	0.233	0.417
IADL disability	0.570	0.201	0.718	0.211	0.369	0.507
Diabetes	0.371	0.204	0.310	0.299	0.167	0.022
Stroke	0.131	0.066	0.218	0.152	0.065	0.066
Heart disease	0.247	0.121	0.223	0.199	0.126	0.027
Hypertension	0.840	0.770	0.809	0.595	0.070	0.214
			Female			
ADL disability	0.373	0.094	0.521	0.075	0.278	0.446
IADL disability	0.558	0.158	0.712	0.142	0.400	0.569
Diabetes	0.340	0.179	0.317	0.297	0.162	0.029
Stroke	0.108	0.058	0.210	0.122	0.050	0.088
Heart disease	0.199	0.065	0.229	0.209	0.134	0.027
Hypertension	0.832	0.709	0.828	0.603	0.123	0.225
			Male			
ADL disability	0.223	0.079	0.503	0.122	0.144	0.380
IADL disability	0.593	0.243	0.740	0.270	0.350	0.470
Diabetes	0.427	0.229	0.285	0.302	0.198	−0.044
Stroke	0.172	0.074	0.250	0.179	0.098	0.073
Heart disease	0.334	0.176	0.200	0.191	0.159	0.038
Hypertension	0.855	0.829	0.736	0.588	0.026	0.148

ADL = activities of daily living, IADL = instrumental activities of daily living.
Source: Authors' calculations using the Future Elderly Model based on data from the Korean Longitudinal Study of Aging and the Singapore Chinese Health Study.

Interestingly, while hypertension prevalence is similar in the Republic of Korea and Singapore among elderly with low education, elderly with high education in Singapore have a higher prevalence of hypertension compared to the Republic of Korea (Figure 13a). The increase in the educational gradient for hypertension tapers off in both countries between 2015 and 2050, driven in the Republic of Korea more by decreasing growth in male hypertension prevalence, while in Singapore it is driven by both genders (Figures 13b and 13c).

Table 1 summarizes the projected prevalence rate of all conditions in 2050 (Figures 7–12). The respective results were described in the above paragraphs. Diabetes is the only chronic condition for which there is a projected decline in the educational gradient such that among men in the Republic of Korea in 2050 the prevalence of diabetes is higher among those with a college education than among men with less than a high school education.

Sensitivity analysis was performed comparing the elderly aged 55–64, 65–74, and 75–84 years, where low education was recorded as having no college education (high school or less) and high education was having at least a college education. Overall, we found decreasing trends in disparities for both the Republic of Korea and Singapore (Appendix 7). In general, the elderly with a college education had a lower prevalence of diseases compared to the elderly without a college education, except for diabetes (aged 65–74 and 75–84 years) and stroke in the Republic of Korea. While disparities in diabetes increase in Singapore, this was driven by the sharper rise in prevalence among elderly without a college education.

IV. Discussion

These findings show associations between education and health for two rapidly aging countries in East Asia. Overall, despite increases in educational attainment, we project an increasing prevalence of functional disability as well as chronic conditions from 2015 to 2050, due entirely to survival to older ages and thus population aging within the over-50 population in each country. The elderly with high educational attainment are projected to have a lower prevalence of functional disability and chronic diseases compared to the elderly with low educational attainment across time. This was found to be consistent across gender in both the Republic of Korea and Singapore. After stratification by age group (55–64, 65–74, and 75–84 years old), we found disparities in functional disability between low- and high-education groups in each age group. However, these disparities decrease across time in both countries.

Individuals with high educational attainment also experience an increasing burden of functional disability and chronic diseases. This is consistent with studies that found diminishing marginal health returns to education (Harris 2007). While those with high educational attainment are more efficient producers of health and may have greater ability to pay for life-protection activities, their lower age-specific mortality and hence survival to older ages leads to greater functional disability and chronic disease burden. Those with relatively lower education also benefited from individual and social investments that lowered age-specific morbidity less than age-specific mortality, relative to their better-educated counterparts. If we remove these survival improvements by holding age structure constant through age standardization, we find that functional disability remains stable across time.

By comparing disease projections by education and across population groups, we can better understand how health disparities change dynamically. In what follows, we discuss in more detail the underlying factors that may be responsible for the dynamic pattern of changes in survival and disability projected by our simulation, including differential self-protective behaviors and early-life exposures shaping life expectancy and age-specific health across different groups, as well as the economic and social implications of our results.

Our simulation model builds on a rich literature that shows that mortality and morbidity are partially endogenous choices of human capital rather than biological endowments. Public health measures, prevention, and primary care have supported a rapid demographic transition in both Singapore and the Republic of Korea, representing what a complementary literature characterize as investments in life protection at the individual, community, and national levels (Ehrlich 2000, Ehrlich and Yin 2005). These activities include control of infectious diseases, better nutrition, and enhanced access to the technological frontier in treating acute conditions, as well as screening for and treating chronic disease, through organized financing and universal health coverage in both countries. Thus, the primary finding from our projections is that in both countries, across men and women of different educational attainment, improved survival will lead to population aging within the over-65 population, a pattern intensified within successive cohorts and compressed over a shorter period than in many other parts of the world.

The significant increase in the proportion of younger cohorts with a college education itself represents substantial individual, household, and social investments in self-protective behaviors in both countries (through public schools, private tutoring, and subsidized access to other educational programs). These populations clearly invested in human capital at earlier stages of the life course, which contributed to the

observed lower age-specific mortality rates, as demonstrated by successive cohorts rapidly increasing the proportion with higher educational attainment (see Figures 3–5). This significant increase in educational attainment in both countries, especially among women, is important to take into account when considering the health needs of the future elderly. As shown in Figure 3, the percentage of women with a college education increased steadily across birth cohorts; in the Republic of Korea, women with less than a high school education will represent only 3% of women aged 65 years and above by 2050. In Singapore, gender parity in education predates the compulsory education policy in 2000 (Attorney-General's Chambers Compulsory Education Act 2000). There has been a huge transition into higher education among females. By 2007, parity was achieved at all levels of education, and women in college now outnumber men by a 10% margin (Pan 2013, Thong 2017). This trend is not isolated to Asia but also observed in other high-income economies (Fiske 2012). While women have seen a faster increase in college education, they have yet to catch up with men on some other aspects of socioeconomic status (SES) such as earnings, which might contribute to a delay in seeking medical or long-term care. Women tend to live longer, incur higher health-care expenditures, and utilize more health-care resources. Empowering females through education leads to better outcomes in health and income. As a larger proportion of women reach old age with greater education, they benefit from longer survival. Moreover, we find that health disparities between the shrinking group of low-educated women and the growing group of high-educated women for certain chronic diseases (e.g., hypertension) are projected to decline. The projected male–female differences in functional disability shown in our simulations also reflect changing social norms and opportunities for wage-income streams over the life course—both because of greater formal sector female labor force participation conditional on educational attainment and because of greater increases in human capital for females (starting from a lower base of schooling among the oldest female cohorts). Increased educational attainment and the associated growth in the age-earning profiles of women relative to those of men may allow future elderly women to afford the increased amount of health care necessary for them in old age, perhaps contributing to a further narrowing of disparities (Owens 2008; Vaidya, Partha, and Karmakar 2012; Doumas et al. 2013).

Our results do not permit an interpretation of causality as our FEM model uses a reduced form equation to estimate the association between educational attainment and mortality. However, studies have shown that education may enhance knowledge on living a healthy life, leading to improved choices that affect health and shape mortality risks over the life span through self-protective behavior and life-protection investments

over the life cycle (Kenkel 1991, Ehrlich 2000, Ehrlich and Yin 2005). Age-specific mortality risk is lowered through self-protective inputs such as medical care services, diet, and exercise, collectively termed as life-protection (Ehrlich and Yin 2005). Higher-educated adults also possess higher wealth and have a higher incentive to protect this wealth by insuring more against mortality risk through life insurance and annuities (Ehrlich and Yin 2005). Thus, they may benefit more from these cumulative or persistent effects of life-protection outlay earlier in their lives, where the existence of insurance increases the likelihood of larger health endowments (Ehrlich 2000, Ehrlich and Yin 2005). In addition, when focusing on the middle-aged and elderly as we do, one could argue that it is more likely that education influences choices of use of time and goods that affect health (Kenkel 1991). Our simulations suggest a generally increasing educational disparity, with ADL and IADL disability showing stark differences in prevalence between the high- and low-education groups in both Singapore and the Republic of Korea—larger than disparities in chronic diseases such as hypertension and diabetes.

These results are consistent with the current body of the literature on educational disparities on health outcomes in both Eastern and Western countries. Higher educational attainment of both males and females in the Republic of Korea led to comparatively lower odds of having ADLs or IADLs (Kye et al. 2014), and a Singapore-based projection showed that individuals with higher education have lower risk of functional disability status over their life course (Ansah et al. 2015). There are numerous reasons why those with higher education may enjoy better health status (Cubbin and Winkleby 2005, Chandola et al. 2008, Berkman 2009). The elderly with higher socioeconomic status is more efficient producers of health due to more informed health choices and better network effects, which lead to better health outcomes (Cutler and Lleras-Muney 2010). Higher educational attainment early in life is usually correlated with healthier lifestyle choices in adulthood such as less smoking, more physical activity, better weight management, and greater accumulation of healthy years of life over the life span (Clarke et al. 2009; Basu, Jones, and Dias 2018). The elderly with low educational attainment may not benefit as much from advances in medicine due to poorer adherence to treatment (Goldman and Lakdawalla 2001), in addition to barriers from the financial and time investments required (Goldman and Lakdawalla 2001). The positive association between SES inequality and poorer health outcomes supports the general notion that inequality affects health negatively (Kawachi, Kennedy, and Wilkinson 1999). Disparities in life expectancy between the well-educated and those with less education are also well documented (Olshansky et al. 2012; Goldring, Lange, and Richards-Shubik 2016; Sasson 2016).

Subgroup analysis done on the 65–74 and 74–85 year-old age groups showed that disparities in chronic conditions, ADL disability, and IADL disability by education exist but decrease over time (Appendix 7). Our result is consistent with the existing literature showing that compositional changes in education can have considerable impact on decreasing future disability prevalence (Lutz et al. 2007). We find that increasing educational attainment among the populations of the Republic of Korea and Singapore will lead to decreasing age-standardized disability rates. However, due to the rapidly aging population in both countries, the overall crude disability rates will increase because of a higher proportion of the oldest-old and their associated disability. While elderly with a college education had fewer diseases compared to those without a college education, the disparities are projected to decline over time as survival continues to improve among the least advantaged and disparities converge among the oldest-old. Nevertheless, disparities persist, in part because several beneficial assets accumulate with education: more effective coping skills, better access to preventative services, better use of resources, and the network of family and friends where adaptation of positive health behavior is being reinforced (Winkleby, Fortmann, and Barrett 1990). Thus, improving human capital through the improvement of the educational composition may offer a way to avoid some of the possible negative consequences associated with rapid aging (Lutz et al. 2007).

In addition to the evolving educational gradient in disability, our simulations capture the likely future differential health impacts of social developments over the past half century in both countries. Younger cohorts have also been exposed over a larger share of their life span to social safety nets and expanding social welfare systems—such as the Republic of Korea's National Health Insurance since 1989 and long-term care insurance since 2008—that provide greater insurance value to those of low SES, helping to smooth consumption and lower the cost of self-protective behaviors such as preventive care. This growth of the social protection system may help to explain the dynamic pattern of improved survival to older ages for both low and high SES individuals, as well as the decreasing educational gradient in some chronic diseases.

Since a substantial share of life-protection investments occur at earlier ages than we model, our estimates must take as given the young-adult choices and investments that determined heterogeneity of age-specific mortality and morbidity by sex and educational attainment of our modeled populations. These earlier investments could explain a large share of the disparities we document and project. For example, modeling the United States, Ehrlich and Yin (2005) find that the impact of life protection on life expectancy at age 30 accounted for a higher percentage of remaining

life expectancy, and a greater share of the educational disparities in life expectancy, than at age 65.

Our results also indicate an increase in functional disability among the future elderly in both countries, across genders and education groups, primarily because of an increase in the number of oldest-old. Depending on whether current cohorts' self-protection activities decrease morbidity risks at the same rate as mortality risk, the future elderly may experience compression of morbidity at older ages (i.e., reductions in age-specific morbidity) that may reduce projected disability at older ages. Such activities should be encouraged since increased prevalence of functional disability has significant economic implications. First, functional disability has direct medical costs, impedes extension of labor force participation and work productivity, and may negatively impact standards of living (Fried et al. 2001, Loyalka et al. 2014). Indirect costs from caregiver burden can be significant. Managing disability could mean substantial increases in primary and secondary medical care and long-term care expenditure for both individuals and health-care systems. In the low-education group for both Singapore and the Republic of Korea, we projected a drastic increase in functional disability compared to the high-education group. Compared to their better educated peers, individuals in the low-education group are less likely to benefit from human capital accumulation through employment (Redding 1996). They are also more likely to experience functional disability that induces early retirement or suspension of work with limited likelihood of reentering the workforce permanently (Dahl, Nilsen IV, and Vaage 2000).

With rapidly aging populations, both the Republic of Korea and Singapore face a higher proportion of their respective populations at a period in life when life-protection efforts are reaching diminishing returns (given higher biological risk of mortality at older ages), so spending in self-protection may decrease. Yet, as noted, the future elderly of both countries will also be much wealthier with more human capital than earlier cohorts, especially among women; this latter pattern pushes in the opposite direction toward higher investments in health and life protection. Similarly, although higher health endowments of the current young cohorts might seem to suggest that we would expect lower life-protection efforts in the future, models such as Ehrlich and Yin (2005) point out that longer life expectancies also generate a wealth effect that increases the value of life-protection investments. Thus, our estimates might be conservative to the extent that such investments generate a further compression of morbidity not included in our projections. Policies that encourage prevention and healthy lifestyles, especially supporting the vulnerable, could help both countries narrow the gap by education and sex in healthy life expectancy.

A. Limitations

Modeling in this complex environment necessarily reflects only the best available information and is subject to certain limitations. Our study uses data from surveys that only included community-dwelling individuals and did not include those in nursing homes or other institutionalized patients, thus underestimating the disability and chronic disease burden in both the Republic of Korea and Singapore. Nevertheless, our results are still relevant for policy planning to cater to the growing needs of the elderly with disabilities living in the community. The number of nursing home beds per 1,000 population aged 65 years and over is 24 for the Republic of Korea and 26 for Singapore, or 2.4% and 2.6% of the over-65 population, respectively. Although our forecast of dependency is an underestimate, the risk of institutionalization is low in the Republic of Korea and Singapore. Due to small numbers, we were also unable to model the severity of disability after adjusting for individual heterogeneity in Singapore. While similar ADL tasks were assessed in both the Republic of Korea and Singapore, Singapore had an additional question on IADL tasks. Specifically, the question was whether the respondent needs help using transportation. As such, Singapore has one more IADL task compared to the Republic of Korea and would have a slightly overestimated prevalence for IADL disability. Nevertheless, among older adults who needed help with any IADL tasks, only 2% of older adults needed help with transportation only. The rest of the older adults required help in IADL tasks as captured in surveys in both the Republic of Korea and Singapore.

From 2010 to 2015, Singapore had a racial composition of around 74% Chinese, 14% Malay, 9% Indian, and 3% other races (Department of Statistics 2012). As a result, our chronic disease projections may be an underestimate as minority groups have a greater chronic disease burden (Venketasubramaniam et al. 2005, Williams and Mohammed 2009, Lee et al. 2009, Sharma et al. 2012). Transition models were estimated using panel data, which suffer from issues of nonresponse and attrition. Recall bias may be possible as health status is reported in 2-year and 6-year surveys for the Republic of Korea and Singapore, respectively. We were also unable to model shorter disease dynamics in Singapore as our transitional probabilities were estimated based on the survey with a 6-year median follow-up. However, as we are comparing the disparity in socioeconomic standing between the low- and high-educational attainment groups, the difference in years between survey waves may not bias our results. Singapore has a quota for college education (Toh 2017), which makes the proportion of individuals in that group perhaps more selective compared to the Republic of Korea, although a nontrivial fraction of individuals in both countries can

also obtain education abroad. In addition, the Republic of Korea's improvement in education has been so dramatic that the country will no longer have elderly with less than a high school education in the replenishing cohort by 2030 (see Figure 4); therefore, the higher disparities we found in the Republic of Korea are largely driven by the fact that those with low education in the Republic of Korea are older on average than those with low education in Singapore. We also assumed that the protective effect of college education on functional disability is maintained over time. However, as it was harder for post-war generation elderly to attain a college degree compared to the more recent replenishing cohorts, we might have overestimated the disparities since we assumed the same protective effect of college education across time.

In addition, older adults born after industrialization spend their childhood in a more affluent society than previous generations. As such, an increase in health problems in the future could be overestimated. Nevertheless, these birth cohorts are also less involved in physically laborious work and tend to have diets with a higher composition of fat and sodium. The changes in work, lifestyle, and diet may lead to higher incidence of health problems in the future, as shown for example by the increased prevalence and declining educational gradient in diabetes, especially evident for the Republic of Korea. Lastly, Singapore's incoming cohort is slightly older, starting at aged 55 years and above, whereas the Republic of Korea's cohort is aged 51 years and above. Nevertheless, as most diseases tend to occur later in life, we do not expect our disparity projections to be significantly biased by that difference. We are also unable to tease apart the difference between educational attainment versus the selection of high-ability people due to entrance exams to enter high school, thus the effect of improved educational attainment on old-age health could be overestimated. It would be valuable to extend these microsimulation results with more detailed data to estimate the dynamic evolution of age-specific hazards of mortality, morbidity, and functional disability by sex and educational attainment.

B. Conclusion

Our work allows comparisons of the challenges rapidly aging countries in Asia face by providing a common platform (FEM) to derive projections. Although similar microsimulations have been conducted in projecting elderly health and functional disability for Japan (Fukawa 2007), the Republic of Korea (Kye et al. 2014), and Singapore (Ansah et al. 2015), it is unclear whether valid cross-country comparisons can be made given the underlying differences in model estimation, assumptions, and projection timelines. Previous research comparing elderly health in Asia tended to

report trends without modeling the micro-dynamics (Lee and Shinkai 2003, Ofstedal et al. 2007). Thus, our comparison of future developments in elderly functional disability and diseases, along with the associated educational gradient, contributes to the literature on each country and to the literature comparing aging internationally, especially because of the marked differences in health-care and social support systems across countries.[2]

Our microsimulation analyses indicate that from 2015 to 2050, the educational gradient in health and functional status will steepen, with a wider gap in the prevalence of disability between older adults with low and high educational attainment. For example, in Singapore, the disparity in functional disability prevalence—as measured by limitation in at least one ADL—starts at 9.0 percentage points in 2015 and is projected to increase to 23.3 percentage points by 2050. The Republic of Korea's model projects even larger disparities by 2050, despite having more years of schooling among the low-education group (i.e., high school versus primary school), with a 41.7-percentage-point difference in the prevalence of ADL disability between low- and high-educational attainment groups (51.7% compared to 10%). These disparities also hold across most other chronic diseases such as heart disease. For the Republic of Korea, the low-educational attainment group by 2050 represents only 1% of men and 3% of women, and these most-disadvantaged elderly are entirely concentrated in the oldest-old group (Figure 3). Their rates of disability are higher than in a population aged 65 years and above that includes "young-old" in their 60s and 70s as well as those in their 80s and 90s such as Singapore. Age-standardized disability rates are constant or declining in both countries (Figure 7).

Overall, the model projects an increasing prevalence of functional disability as well as chronic conditions from 2015 to 2050. Elders with high educational attainment are projected to have a lower prevalence of functional disability and chronic conditions compared to elderly with low educational attainment. Even with increases in educational attainment, reduced mortality and improved survival lead to greater disease prevalence among the elderly across all educational groups due to a higher proportion of over-80 within the over-65 population. While both the Republic of Korea and Singapore have universal health coverage, and the Republic of Korea has long-term care insurance, there might be differences in the out-of-pocket burden for medical care and gaps in the provision of and access to long-term care services that exacerbate disparities. Health insurance enhances access to care and reduces the risk of

[2]For example, Singapore employs a compulsory savings plan linked to an individual retirement account without social risk pooling, while schemes in East Asia are characterized by employer-based pay-as-you-go plans.

catastrophic medical expenditures, lowering the cost of health investments through self-protection. Nevertheless, medical care in adulthood may be imperfectly able to compensate for the exposures to less healthy environments in childhood that cumulate through differential education and other human capital. Moreover, the benefits of consumption smoothing from universal health-care coverage may be offset somewhat by the moral hazard of low out-of-pocket costs for care, leading to fewer preventive activities (ex ante moral hazard) and overuse of curative services (ex post moral hazard), as evident in our projections by the increase in some chronic diseases among the high-SES group.

To the best of our knowledge, our study is the first to compare the progression of educational disparities in disability across two rapidly aging Asian societies, accounting for their complex interrelationship with sociodemographic and health behaviors as covariates that evolve across time. By studying these evolving patterns of morbidity and disability, our study complements the literature on life-protection activities that endogenizes mortality while abstracting from effects on morbidity (Ehrlich and Yin 2005), further underscoring the importance of investment in healthy aging and control of chronic disease so that added years of life can be relatively healthy ones. We projected a widening disparity in health outcomes across education and between genders for both Singapore and the Republic of Korea. Lastly, we delineated possible mechanisms explaining the education–gender disparity in health outcomes and suggested possible policy actions to narrow those disparities in super-aging societies.

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