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ABSTRACT

While there are growing concerns about population aging, some studies explore the possibility that population aging can give rise to a silver dividend that contributes to economic growth (ADB 2019). While the demographic dividend refers to the increase of the working-age population, the silver dividend points to increased longevity and longer working life as potential sources of growth in an aging society. Extending Lee and Shin (2021) to include developing countries, we examine the potential for a silver dividend by investigating the channels through which population aging affects economic growth. We find that lower total factor productivity growth is the main mechanism through which population aging harms economic growth. Labor shortage caused by population aging is mostly offset by higher labor force participation rates of males, females, and older workers. In particular, the labor force participation rate of the older people increases the most.

Keywords: aging, growth, labor force participation, total factor productivity, silver dividend

JEL codes: J10, O40, J21, O47, E2

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1. Introduction

It has been argued that the demographic dividend—the expansion of working-age population during the demographic transition—was essential for the fast growth of East Asian economies (Bloom and Williamson 1998). However, a number of Asian economies are experiencing rapid population aging, slower growth or even contraction of workforce, and slower economic growth (Park and Shin 2012, 2022; Mason and Lee 2012). However, there is also some optimism that population aging can yield a silver dividend which can offset the reduction of the demographic dividend (Ogawa et al. 2021, ADB 2019). While the demographic dividend refers to the increase in the working-age population, the silver dividend points to longevity and longer working life as potential sources of growth in an aging society. In particular, encouraging older people to continue to learn can motivate them to participate in the labor market.[1]

The estimation of both demographic dividend and the silver dividend in most existing studies assume that population aging affects economic growth mainly through its effect on the workforce. Theoretically, however, the negative growth effects of aging operate through other channels as well. An aging population lowers the saving rate (Park, Shin, and Whang 2010; Horioka and Niimi 2017), slowing capital accumulation and consequently lowering economic growth. The decline in the number of children also affects the accumulation of human capital by affecting the motivation to invest in their human capital (Becker and Nigel 1973). Finally, aging

[1] The recent development of new technologies such as robots and artificial intelligence can be friendlier toward old workers and help them become more productive. (Park, Shin, and Kikkawa 2021; 2022).

has a negative effect on the growth rate of total factor productivity (TFP) since older people tend to be less innovative, leading to lower technological progress (Jones 2010).[2]

Empirical studies on the various channels through which aging affects economic growth find that lower TFP growth is the most important channel.[3] For example, Maestas, Mullen, and Powell (2022) find that two-thirds of the negative effect of aging is explained by slower productivity growth. More recently, based on data from 35 Organisation for Economic Co-operation and Development (OECD) countries, Lee and Shin (2021) investigated six channels through which population aging affects the growth rate of per capita gross domestic product (GDP). The six channels are changes in: (i) physical capital; (ii) human capital; (iii) average working hours; (iv) labor participation rate; (v) the share of population aged 15 and over; and (vi) TFP. They find that population aging harms economic growth primarily through slower TFP growth.

We extend Lee and Shin (2021) to include developing countries and examine whether population aging has a different impact on economic growth depending on the characteristics of each economy. Based on our panel data set of countries, we investigate how countries differ in the relative importance of the different channels depending on the value of the following characteristics: (i) old dependency ratio, (ii) human capital, (iii) life expectancy, (iv) labor market flexibility, (v) government size, (vi) trade openness, and (vii) capital market openness. We find that the main channel of the negative growth effect of

[2] Liang, Wang, and Lazear (2018) argue that as an economy gets aged, older workers occupy high-level positions and block younger workers from acquiring skills, which eventually impedes innovation. Derrien, Kecskés, and Nguyen (2018); Aksoy et al. (2019); and Lee and Shin (2021) provide evidence that aging lowers the growth rate of TFP based on advanced-economy data.

[3] More generally, even for the other determinants of economic growth, Wong (2007) shows that TFP growth is the main channel.

population aging is reduced TFP growth. Previous studies find these results based mostly on data from advanced countries. However, we confirm this finding even using a much broader sample of 166 countries encompassing both advanced and developing economies. Labor shortage caused by population aging is mostly offset by higher labor force participation rates of males, females, and old workers. In particular, the shortage seems to cause a remarkable increase in the labor force participation rate among older people. Significantly, labor shortage due to aging does not seem to be a problem in most countries due to higher labor force participation.

We find that higher life expectancy, human capital, and trade openness amplify the mitigating effect of the increased labor force participation rate among older people. Grouping countries according to the values of the seven characteristics listed previously, we find nonlinear effects of population aging. In particular, the effect of population aging is not even negative for countries with low values of some characteristics. In addition, we find that the mitigating effect of higher labor force participation rate is not enough to offset the negative growth effect of population aging. Although the shortage of labor force can be completely offset by higher labor force participation, the primary channel for the negative growth effect of aging is reduced TFP growth, which is difficult to offset. This is especially true for countries with high-value characteristics, which are mostly advanced countries. The rest of the paper is organized as follows: Section 2 explains the empirical specification, Section 3 reports our main empirical results, and Section 4 concludes.

2. Empirical Specification and Data

In this section, we describe our empirical framework and data. The empirical specification follows Lee and Shin (2021). Assuming a Cobb-Douglas production function, output per capita is represented as:

$$\mathrm{y} = A^{1/\alpha} k^{(1-\alpha)/\alpha} hvpn_{15} \quad (1)$$

where $\mathrm{y} = \frac{Y}{N}$, $k = \frac{K}{Y}$, $n_{15} = \frac{N_{15}}{N}$, A is the TFP level, α is labor income share, h is average human capital, v is average working hours, p is the labor force participation rate, N_{15} is population aged 15 and over, and N is the total population. As emphasized by Lee and Shin (2021), k is the capital-output ratio rather than the capital–labor ratio. Here we follow Hall and Jones (1999) to allow the steady state of capital–output ratio to be independent of the level of TFP.

By taking log difference of equation (1), we obtain the following equation:

$$\Delta \ln \mathrm{y} = \frac{1-\alpha}{\alpha} \Delta \ln k + \Delta \ln h + \Delta \ln v + \Delta \ln p + \Delta \ln n_{15} + \frac{1}{\alpha} \Delta \ln A \quad (2)$$

where Δ represents the time difference.

Equation (2) implies that any determinant of output growth per capita works through six channels: changes in (i) physical capital-output ratio, (ii) per capita human capital, (iii) average working hours, (iv) labor participation rate, (v) the share of 15 and above (the share of population aged 15 and over), and (vi) TFP. Lee and Shin (2021) noted that the six channels can be divided into two groups depending on whether or not the channel can affect growth permanently. The first group, which can change the growth rate of per capita output permanently, comprises channels (i), (ii), and (iv). The second

group, which does not have a permanent growth effect, includes channels, (iii), (iv), and (v). The key difference between the two groups is whether each component can grow without any limit. For example, average hours, the labor participation rate, and the share of 15 and above, which constitute the second group, cannot grow forever. However, since the time interval in the empirical specification is either five or ten years, we believe that even group 2 channels can affect the growth rate of per capita output in the intermediate run. The share of 15 and above is not the same as the conventional working-age population that is defined as the share of population aged between 15 and 64. Hence, Lee and Shin (2021) further decompose the share of 15 and above into two parts. Then the final equation for the estimation becomes:

$$\Delta \ln \mathrm{y} = \frac{1-\alpha}{\alpha}\Delta \ln k + \Delta \ln h + \Delta \ln v + \Delta \ln p + \Delta \ln n_{15-6} \; + \Delta \ln n_{15-6}^{15} \; + \frac{1}{\alpha}\Delta \ln A \quad (3)$$

Note that $\Delta \ln n_{15}$ is decomposed into $\Delta \ln n_{15-6}$ and $\Delta \ln n_{15-64}^{15}$, where the first component is the change in the share of working-age population and the second, the change in the share of 15 and above to the working-age population. While these two components are estimated separately, they will be combined and regarded as one channel when we interpret our empirical results later. We collect data from various sources, as summarized in the Appendix. Output, population, capital stock, human capital stock, average working hours, and TFP are collected from the Penn World Table (PWT) 10.0 update (18 June 2021). Output growth per capita is calculated using the PWT's national-accounts real GDP ($RGDP^{NA}$).[4] The country sample includes 166 countries. The

[4] There are five different GDP variables calculated in PWT 10.0. See https://www.rug.nl/ggdc/productivity/pwt/. Among these, the national-accounts real GDP ($RGDP^{NA}$) is recommended for cross-country growth regressions.

sample period is 1960 to 2019 and the growth rate is calculated by using 5-year averages: (Period 1: 1960–1964), (Period 2: 1965–1969), …, and (Period 12: 2015–2019).[5] The old-age dependency and youth dependency ratios are retrieved from the World Bank's World Development Indicators. The labor force participation rates are modelled estimates from the statistics database of the International Labour Organization (ILO), ILOStat.

3. Empirical Findings

In this section, we report and discuss our empirical findings. Table 1 presents the summary statistics of the variables we used in this study. The average growth rate of per capita output is 2%. The average per capita GDP in 2017 constant United States dollars is $13,387. The average old-age ratio is 0.11 and 0.61 for youth dependency. The average old-aged population share is 0.07 and 0.34 for the youth-aged population. The average share of the working age population is 0.59. The average labor force participation rate for population aged 15+ is 0.62. The average annual growth rates of capital–output ratio is 0.55% and 0.91% for human capital. The average annual growth rate of TFP is 0.48%.

Table 1: Summary Statistics

Variables	Count	Mean	SD	Minimum	Maximum
Annual GDP growth rate per capita, national accounts	1,649	2.02%	3.20%	-22.08%	21.47%
Real per capita GDP, output side	1,818	13,387	20,279	457	277,563
Youth dependency ratio	1,746	0.61	0.25	0.15	1.12
Old-age dependency ratio	1,746	0.11	0.07	0.02	0.45
Youth-aged population share	1,746	0.34	0.11	0.11	0.51
Old-age population share	1,746	0.07	0.05	0.01	0.27
Working aged population share	1,746	0.59	0.07	0.46	0.80
Share of 55–64 ages in total population	1,746	0.07	0.03	0.02	0.16

[5] Calculating the growth rate between the averages after calculating the 5-year average reduces the randomness associated with setting arbitrary intervals. Other growth rates are calculated similarly.

Variables	Count	Mean	SD	Minimum	Maximum
Labor force participation rate (15+, both sex)	942	0.62	0.10	0.32	0.89
Annual growth rate of capital–output ratio	1,187	0.55%	2.66%	-11.12%	17.61%
Annual growth rate of human capital	1,317	0.91%	0.60%	-2.32%	4.34%
Annual growth rate of average working hours	565	-0.29%	0.49%	-1.98%	1.12%
Annual growth of labor force participation rate (15+ population)	785	-0.04%	0.36%	-1.95%	1.50%
Annual growth of ratio of 15–64 years old population	1,584	0.25%	0.49%	-1.32%	2.49%
Annual growth of ratio of +15 years old over 15–64 years old	1,584	0.07%	0.15%	-0.34%	0.79%
Annual growth rate of TFP	1,649	0.48%	2.16%	-17.46%	11.29%
Annual growth rate of life expectancy at birth (Total)	1,591	0.53%	0.78%	-10.57%	12.04%

GDP = gross domestic product, SD = standard deviation, TFP = total factor productivity.

Note: Definitions of variables and data sources are in the Appendix. The 5-year average growth rates are calculated and then annualized. Other variables are measured at the beginning of each period. The sample period is from 1960 to 2019: (Period 1: 1960–1964), (Period 2: 1965–1969) ,…, (Period 12: 2015–2019).

Source: Authors' calculations.

Table 2.1 presents the panel estimation results with country fixed effects when we regress the growth rates of per capita output and the variable representing each of the six channels on the old-age and youth dependency ratios.[6] We include period dummies, but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. As shown in equation (3), since $\frac{1-\alpha}{\alpha}$ and $\frac{1}{\alpha}$ are multiplied $\Delta \ln k$ and $\Delta \ln A$, respectively, we report the estimated coefficients in columns (2) and (8) after multiplying these values by the dependent variables. The sum of the coefficients of the old-age dependency ratio in columns (2) to (8) should be identically equal to that the coefficient in column (1). However, since the number of observations differs across columns due to data availability, this

[6] Since we estimate equation (3) rather than equation (2), there are seven channels in the table. However, the fifth and sixth channels are combined as $\Delta \ln n_{15}$.

identity does not hold exactly. In line with Lee and Shin (2021), the coefficient of the old-age dependency ratio is negative and statistically significant in column (1) where the dependent variable is the growth rate of per capita output. This negative effect of aging on economic growth is explained by the six channels reported in columns (2) to (8). Again, in line with Lee and Shin (2021), the negative effect is mostly explained by the decrease in TFP growth in column (8).[7] Note that aging has a negative impact on the share of working age population [column (6)], but more than two-thirds of the impact is offset by the increase in the labor force participation [column (5)]. Aging also has a negative and statistically significant impact on human capital accumulation [column (3)].

In Table 2.2, we report the same panel estimation results when we use old and youth population shares instead of old-age and youth dependency ratios as explanatory variables. The results are consistent with those in Table 2.1. In particular, the coefficient of the old population share is negative and statistically significant in column (1) and the negative impact of aging is more than fully explained by lowered TFP growth. Aging also has a negative impact on the share of working age population [column (6)], but more than three-fourths of the impact is offset by an increase in the labor force participation [column (5)]. In addition, we find a negative and statistically significant impact of aging on human capital accumulation [column (3)].

[7] In fact, the coefficient reported in column (8) is greater than that in column (1), indicating that lowered TFP is more than enough to explain the negative effect of aging on economic growth.

Table 2: The Effects of Aging on GDP Growth and its Eight Channels When the Initial Per Capita GDP is Not Controlled

Table 2.1: Dependency Ratios

Variables	(1) GDP per capita	(2) K/Y	(3) Human capital	(4) Work hour	(5) LF participation	(6) 15–64 population	(7) Share of 15 and above	(8) TFP
Old-age dependency ratio	-0.170***	0.005	-0.045***	-0.004	0.044***	-0.061***	0.003	-0.263***
	[0.053]	[0.075]	[0.012]	[0.012]	[0.011]	[0.006]	[0.004]	[0.097]
Youth dependency ratio	0.012	-0.002	0.009*	0.016**	-0.009***	0.011***	-0.002***	-0.024
	[0.014]	[0.029]	[0.005]	[0.007]	[0.003]	[0.002]	[0.001]	[0.040]
Observations	1,584	1,165	1,306	554	780	1,584	1,584	1,055
R-squared	0.093	0.061	0.106	0.152	0.050	0.260	0.155	0.106
Number of countries	162	125	129	66	156	162	162	109

GDP = gross domestic product, K/Y = capital–output ratio, LF = labor force, TFP = total factor productivity.

Notes: The dependent variable is annualized log-difference of 5-year periods of the variable listed in the first row. Panel regression results with country fixed effects are reported. Period dummies are included but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

Table 2.2: Population Shares

Variables	(1) GDP per capita	(2) K/Y	(3) Human capital	(4) Work hour	(5) LF participation	(6) 15–64 population	(7) Share of 15 and above	(8) TFP
Old population share	-0.293 ***	0.036	-0.066***	0.015	0.066***	-0.085***	0.002	-0.534**
	[0.094]	[0.179]	[0.025]	[0.020]	[0.019]	[0.011]	[0.007]	[0.217]
Youth population share	0.018	-0.009	0.018	0.042 **	-0.019**	0.031***	-0.005***	-0.095
	[0.039]	[0.091]	[0.015]	[0.016]	[0.008]	[0.005]	[0.002]	[0.114]
Observations	1,584	1,165	1,306	554	780	1,584	1,584	1,055
R-squared	0.097	0.061	0.109	0.155	0.058	0.301	0.160	0.110
Number of countries	162	125	129	66	156	162	162	109

GDP = gross domestic product, K/Y = capital–output ratio, LF = labor force, TFP = total factor productivity.

Notes: The dependent variable is annualized log-difference of 5-year periods of the variable listed in the first row. Panel regression results with country fixed effects are reported. We include period dummies but their coefficients are not reported. Robust standard errors are in brackets. *** and ** represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

In Table 3.1, we add the initial level of GDP per capita as an additional variable and report panel estimation results with fixed effects. While it makes sense to add the initial level of GDP per capita in column (1) and possibly in column (8), it may not be entirely appropriate to add it in other columns. However, to preserve the identity that the sum of the coefficients of columns (2) to (8) is equal to the coefficient of column (1), we added it to other columns as well. We use output-side real GDP at chained purchasing power parity (PPPs) as the initial level of GDP per capita.[8] Although the coefficient of the old-age dependency ratio is negative, it is no longer statistically significant [column (8)].[9] However, we still observe that the negative impact of aging on the working age population is substantially offset by an increase in the labor for participation rate. Note that the coefficient of the old-age dependency ratio is negative and largest in absolute value in column (2). This suggests that in this specification, reduced capital accumulation is the largest channel for the negative impact of aging.

In Table 3.2, when we use the old and youth population shares and the initial level of per capita GDP as explanatory variables, the coefficient of the old population share is negative and statistically significant in column (1). Again, the negative impact of aging on economic growth is more than fully explained by reduced TFP in column (8). In addition, the negative impact of aging on the working age population is substantially offset by an

[8] Note that we use national-accounts real GDP per capita ($RGDP^{NA}$) when calculating the growth rate. Since we use output-side real GDP per capita ($RGDP^{O}$) as the initial level of real GDP per capita, our panel specification in column (1) is not suitable for dynamic panel estimations. PWT recommends $RGDP^{O}$ comparing per capita GDP across countries Hence, it is appropriate to use it as the initial level of per capita GDP.

[9] While the coefficient of the old-age dependency ratio is not statistically significant, we find evidence of the negative impact of aging elsewhere. As shown in Table 3.2, the coefficient of the old population share is negative and statistically significant. When we use 10-year period instead of 5-year period (not reported), even the coefficient of the old-age dependency ratio is negative and statistically significant in the same specification. More importantly we find the coefficient of the old-age dependency ratio to be negative and statistically significant in the instrumental-variable (IV) estimation reported in Table 4.1.

increase in the labor for participation rate. Interestingly, the coefficient of the old population share is negative and large in magnitude but it is not statistically significant.

Table 3: The Effects of Aging on GDP Growth and its Eight Channels when the Initial Per Capita GDP is Controlled

Table 3.1: Dependency Ratios

Variables	(1) GDP per capita	(2) K/Y	(3) Human capital	(4) Work hour	(5) LF participation	(6) 15–64 population	(7) Share of 15 and above	(8) TFP
Old-age dependency ratio	-0.047 [0.053]	-0.132 ** [0.062]	-0.048 *** [0.012]	-0.001 [0.012]	0.044*** [0.011]	-0.059*** [0.007]	0.002 [0.004]	-0.082 [0.072]
Youth dependency ratio	-0.035** [0.016]	0.054 [0.042]	0.010 * [0.005]	0.011* [0.006]	-0.008** [0.003]	0.010*** [0.002]	-0.002*** [0.001]	-0.101* [0.052]
Initial GDP per capita	-0.033*** [0.004]	0.042*** [0.014]	0.001 [0.001]	-0.003** [0.002]	0.001 [0.001]	-0.000 [0.001]	0.000 [0.000]	-0.057*** [0.016]
Observations	1,584	1,165	1,306	554	780	1,584	1,584	1,055
R-squared	0.216	0.169	0.107	0.170	0.056	0.262	0.156	0.220
Number of countries	162	125	129	66	156	162	162	109

GDP = gross domestic product, K/Y = capital–output ratio, LF = labor force, TFP = total factor productivity.

Notes: The dependent variable is annualized log-difference of 5-year periods of the variable listed in the first row. We add the initial level of GDP per capita, calculated from output-side real GDP per capita, as an additional regressor. Panel regression results with country fixed effects are reported. We include period dummies but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

Table 3.2: Population Shares

Variables	(1) GDP per capita	(2) K/Y	(3) Human capital	(4) Work hour	(5) LF participation	(6) 15–64 population	(7) Share of 15 and above	(8) TFP
Old population share	-0.160 *	-0.111	-0.070 ***	0.014	0.067***	-0.086 ***	0.002	-0.342 **
	[0.086]	[0.132]	[0.025]	[0.019]	[0.019]	[0.011]	[0.007]	[0.150]
Youth population share	-0.116**	0.159	0.021	0.029*	-0.017**	0.032***	-0.005***	-0.323**
	[0.046]	[0.126]	[0.015]	[0.015]	[0.008]	[0.004]	[0.002]	[0.151]
Initial GDP per capita	-0.034***	0.043***	0.001	-0.003*	0.001	0.000	0.000	-0.059***
	[0.004]	[0.014]	[0.001]	[0.002]	[0.001]	[0.001]	[0.000]	[0.016]
Observations	1,584	1,165	1,306	554	780	1,584	1,584	1,055
R-squared	0.218	0.172	0.111	0.169	0.063	0.301	0.160	0.225
Number of countries	162	125	129	66	156	162	162	109

GDP = gross domestic product, K/Y = capital–output ratio, LF = labor force, TFP = total factor productivity.

Notes: The dependent variable is annualized log-difference of 5-year periods of the variable listed in the first row. We add the initial level of GDP per capita, calculated from output-side real GDP per capita, as an additional regressor. Panel regression results with country fixed effects are reported. We include period dummies but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

While the results in Tables 2 and 3 are suggestive, they may suffer from endogeneity. For instance, as the economy matures and economic growth rate stagnates, the demographic structure also matures, and the share of older population tends to increase. Another possibility is that if young workers who feel pessimistic about economic prospects emigrate, expectations of lower future GDP growth can induce the old dependency ratio and the older population share to increase. Hence, we cannot be sure about the direction of causality of the results in Tables 2 and 3. In Table 4.1, by using the same empirical specification as in Table 3.1, we report instrumental-variables (IV) panel regression results with country fixed effects. We use 10-year lagged values of the old and youth dependency ratios and the birth rate as instruments for the current old dependency ratio. We include period dummies but their coefficients are not reported. In most columns, the first stage F statistics indicate that our instrumental variables are appropriate. However, some caution is warranted since the regression does not pass the Hansen's J-test in columns (1), (3), (6), and (7). In column (1) of Table 4.1, unlike in Table 3.1, the coefficient of the old-age dependency is highly statistically significant, indicating that aging adversely affects economic growth. However, in column (8), the coefficient of the old-age dependency ratio is negative and large in magnitude but not statistically significant. The negative impact of aging on the working age population in column (6) is almost entirely offset by the increase in the labor force participation rate in column (5). We also observe that aging has a negative impact on human capital accumulation in column (3).

In Table 4.2, we report the same IV panel regression results with fixed effects but with the old and young population shares replacing the old-age and youth dependency ratios as regressors. The results are consistent with those in Table 4.1 except that the

coefficient of the older population share is highly statistically significant in column (8). The estimated coefficient in column (8) more than fully explains the negative growth effect of aging in column (1). Again, the negative impact of aging on the working age population in column (6) is almost entirely offset by the increase in the labor force participation rate in column (5). Aging also negatively affects human capital accumulation.

Table 4: The Effects of Aging on GDP Growth and its Eight Channels When the Initial Per Capita GDP is Controlled: IV Regressions

Table 4.1: Dependency Ratios

Variables	(1) GDP per capita	(2) K/Y	(3) Human capital	(4) Work hour	(5) LF participation	(6) 15–64 population	(7) Share of 15 and above	(8) TFP
Old-age dependency ratio	-0.094 **	-0.068	-0.035 ***	-0.007	0.054***	-0.059 ***	-0.006 *	-0.057
	[0.043]	[0.058]	[0.008]	[0.012]	[0.011]	[0.007]	[0.003]	[0.082]
Youth dependency ratio	-0.022 *	0.034	0.007**	0.014***	-0.009 ***	0.015***	-0.002 ***	-0.117 **
	[0.011]	[0.033]	[0.003]	[0.004]	[0.003]	[0.002]	[0.000]	[0.047]
Initial GDP per capita	-0.032***	0.034***	-0.000	-0.003 ***	0.001	-0.000	0.000**	-0.062 ***
	[0.003]	[0.009]	[0.001]	[0.001]	[0.001]	[0.000]	[0.000]	[0.012]
Observations	1,417	1,060	1,173	521	758	1,417	1,417	961
R-squared	0.222	0.140	0.083	0.174	0.044	0.249	0.154	0.212
Number of countries	161	125	129	66	156	161	161	109
First stage F-statistic	721.2	600.2	700.8	291.2	225.3	721.2	721.2	609.2
Hansen's J-test (P-value)	0.000353	0.240	4.25e-07	0.248	0.896	0	4.56e-09	0.0662

GDP = gross domestic product, K/Y = capital–output ratio, LF = labor force, TFP = total factor productivity.

Notes: The dependent variable is annualized log-difference of 5-year periods of the variable listed in the first row. We add the initial level of GDP per capita, calculated from output-side real GDP per capita, as an additional regressor. We report instrumental-variables panel regression results with country fixed effects by using 10-year lagged values of the old and youth dependency ratios and the birth rate as instruments for the current old dependency ratio. We include period dummies but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

Table 4.2: Population Shares

Variables	(1) GDP per capita	(2) K/Y	(3) Human capital	(4) Work hour	(5) LF participation	(6) 15–64 population	(7) Share of 15 and above	(8) TFP
Older population share	-0.227 ***	-0.045	-0.051***	0.011	0.080***	-0.081***	-0.010 *	-0.319*
	[0.067]	[0.117]	[0.015]	[0.018]	[0.018]	[0.010]	[0.005]	[0.167]
Youth population share	-0.071 **	0.090	0.016	0.035***	-0.018**	0.045***	-0.007***	-0.338**
	[0.032]	[0.100]	[0.010]	[0.012]	[0.007]	[0.004]	[0.001]	[0.139]
Initial GDP per capita	-0.032***	0.034***	0.000	-0.003**	0.000	0.000	0.000	-0.064***
	[0.004]	[0.009]	[0.001]	[0.001]	[0.001]	[0.000]	[0.000]	[0.013]
Observations	1,417	1,060	1,173	521	758	1,417	1,417	961
R-squared	0.224	0.140	0.084	0.171	0.053	0.297	0.168	0.217
Number of countries	161	125	129	66	156	161	161	109
First stage F-statistic	1092	937.6	1094	550.0	330.6	1092	1092	973.8
Hansen's J-test (P-value)	0.000568	0.215	2.42e-05	0.137	0.705	0	4.12e-10	0.0668

GDP = gross domestic product, K/Y = capital–output ratio, LF = labor force, TFP = total factor productivity.

Notes: The dependent variable is annualized log-difference of 5-year periods of the variable listed in the first row. We add the initial level of GDP per capita, calculated from output-side real GDP per capita, as an additional regressor. We report instrumental-variables panel regression results with country fixed effects by using 10-year lagged values of the old and youth population shares and the birth rate as instruments for the current older population share. We include period dummies but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

This section summarizes our findings thus far. Aging has a negative impact on economic growth but this negative impact is not due to a decrease in the labor force. The decline of the working-age population is mostly offset by the increase in the labor market participation rate. Instead, the negative growth effect of aging was mainly driven by the decline in TFP growth. Most existing studies of silver dividend took labor shortage for granted and focused on how to mitigate the labor shortage. However, our study shows that reducing the negative effects of aging on TFP growth matters more for reducing the negative effect of aging on economic growth.

The economy can offset the labor shortage caused by population aging by increasing the labor force participation rate of three groups, namely working-age males, working-age females, and among older people. In Table 5, we estimate the impact of aging on the three groups' labor force participation rates. In Table 5.1, we use old-age dependency ratio as a proxy of aging and report the ordinary least squares (OLS) panel regression results with fixed effects in columns (1), (2), and (3) where the dependent variable is the labor force participation rate of males, females, and old-age population, respectively.[10] The equation specification follows those in Tables 3 and 4, and includes the youth dependency ratio and initial GDP per capita as additional control variables. We find that the coefficient of old-age dependency ratio is positive and highly statistically significant in all three columns. This indicates that the shortage of labor due to aging is offset by higher force participation rate. The estimated coefficient in column (3) is three to

[10] While it is desirable to use the labor force participation rate of males and females of the working age population, the ILO statistics report the labor force participation of males and females of the whole population aged 15+. Hence our estimates are likely to overstate the impact of aging on the labor force participation rate of working-age males and females. However, the coefficient of the old-age population still remains by far the largest.

four times larger than the corresponding figures for column (1) or (2), suggesting that higher labor force participation among older people is the strongest antidote to labor shortage. In columns (4) to (6), we report the IV panel regression results with fixed effects. The results are consistent with those reported in columns (1) to (3). The coefficient of old-age dependency ratio is positive and highly statistically significant in all three columns and the estimated coefficient reported in column (3) is five to six times as large as those in columns (4) and (5).

In Table 5.2, we report the same set of regression results as in Table 5.1, but with old-age population share replacing old-age dependency ratio. The estimation results are consistent with those in Table 5.1. The coefficient of old-age population share is positive and highly statistically significant in both OLS and IV panel regressions. Again, the coefficient of old-age population share, shown in columns (3) and (6), is much larger than that of working-age males and females, shown in columns (1), (2), (4), and (5). Again, higher labor force participation rate among older people plays the most important role in offsetting labor shortage.

Table 5: The Impact of Population Aging on the Labor Force Participation Rate

Table 5.1: Dependency Ratios

	(1)	(2)	(3)	IV (4)	IV (5)	IV (6)
Variables	**Female**	**Male**	**Older people**	**Female**	**Male**	**Older people**
Old-age dependency ratio	0.089 ***	0.067***	0.243**	0.100***	0.086***	0.511***
	[0.028]	[0.018]	[0.111]	[0.026]	[0.019]	[0.124]
Youth dependency ratio	0.012	-0.014***	0.067**	0.005	-0.016***	0.054*
	[0.016]	[0.004]	[0.032]	[0.012]	[0.004]	[0.031]
Initial GDP per capita	-0.000	0.002*	0.011	-0.000	0.001	0.004
	[0.003]	[0.001]	[0.007]	[0.002]	[0.001]	[0.004]
Observations	780	780	780	758	758	758
R-squared	0.034	0.074	0.062	0.015	0.066	0.073
Number of countries	156	156	156	156	156	156
First stage F-statistic				225.3	225.3	225.3
Hansen's J-test (P-value)				0.972	0.153	0.0131

GDP = gross domestic product, IV = instrumental-variable.

Notes: The dependent variable is annualized log-difference of 5-year periods of the labor force participation rate for the group denoted in the first row. We add the initial level of GDP per capita, calculated from output-side real GDP per capita, as an additional regressor. We report instrumental-variables panel regression results with country fixed effects by using 10-year lagged values of the old and youth dependency ratios and the birth rate as instruments for the current old dependency ratio. We include period dummies but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

Table 5.2: Population Shares

Variables	(1) Female	(2) Male	(3) Older people	IV (4) Female	IV (5) Male	IV (6) Older people
Old-age population share	0.178 *** [0.050]	0.100*** [0.030]	0.532*** [0.197]	0.181*** [0.043]	0.128*** [0.031]	0.983*** [0.220]
Youth population share	0.025 [0.037]	-0.030*** [0.011]	0.150 [0.093]	0.023 [0.028]	-0.032*** [0.010]	0.158 * [0.088]
Initial GDP per capita	-0.001 [0.003]	0.002 [0.001]	0.010 [0.008]	-0.000 [0.002]	0.001 [0.001]	0.003 [0.005]
Observations	780	780	780	758	758	758
R-squared	0.035	0.081	0.060	0.018	0.078	0.075
Number of countries	156	156	156	156	156	156
First stage F-statistic				330.6	330.6	330.6
Hansen's J-test (P-value)				0.988	0.423	0.00422

GDP = gross domestic product, IV = instrumental-variable.

Notes: The dependent variable is annualized log-difference of 5-year periods of the labor force participation rate for the group denoted in the first row. We add the initial level of GDP per capita, calculated from output-side real GDP per capita, as an additional regressor. We report instrumental-variables panel regression results with country fixed effects by using 10-year lagged values of the old and youth dependency ratios and the birth rate as instruments for the current old dependency ratio. We include period dummies but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

In Tables 6 to 8, we investigate the determinants of the increase in the labor force participation rate in response to aging. Tables 6.1 and 6.2 show the role of life expectancy. We expect that as life expectancy increases, individuals work more because they are healthier. In Table 6.1, we report both OLS and IV panel regression results for the same set of equations as in Table 5.1, except we add life expectancy and its interaction term with old-age dependency ratio as additional explanatory variables. The first stage F statistics and Hansen's J test indicate that our instrumental variables are appropriate. Both coefficients of the interaction term in the OLS estimation of column (3) and the IV estimation of column (6) are positive and highly statistically significant. This suggests that in countries with higher life expectancy, labor force participation rate among older people increases more in response to population aging. In Table 6.2, we replace old-age dependency ratio with old-age population share and find qualitatively similar results.

Table 6: Life Expectancy and the Impact of Population Aging on the Labor Force Participation Rate

Table 6.1: Dependency Ratios

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	**Female**	**Male**	**Older people**	**Female**	**Male**	**Older people**
Old-age dependency ratio	0.226	-0.173	-3.371 ***	-0.139	-0.250	-2.905*
	[0.250]	[0.129]	[1.045]	[0.398]	[0.224]	[1.545]
Youth dependency ratio	0.015	-0.017***	0.018	0.000	-0.022***	-0.006
	[0.018]	[0.004]	[0.031]	[0.015]	[0.005]	[0.033]
Initial GDP per capita	0.000	0.002*	0.011	-0.000	0.001	0.003
	[0.003]	[0.001]	[0.008]	[0.002]	[0.001]	[0.004]
Life expectancy x old dependency ratio	-0.002	0.003*	0.045***	0.003	0.004	0.042**
	[0.003]	[0.002]	[0.013]	[0.005]	[0.003]	[0.019]
Life expectancy	-0.000	-0.000**	-0.003***	-0.000	-0.000**	-0.003***
	[0.000]	[0.000]	[0.001]	[0.000]	[0.000]	[0.001]
Observations	780	780	780	758	758	758
R-squared	0.037	0.084	0.099	0.015	0.078	0.104
Number of countries	156	156	156	156	156	156
First stage F-statistic				26.58	26.58	26.58
Hansen's J-test (P-value)				0.706	0.491	0.0839

GDP = gross domestic product, IV = instrumental-variable, OLS = ordinary least squares.

Note: The dependent variable is annualized log-difference of 5-year periods of the labor force participation rate for the group denoted in the first row. We add the initial level of GDP per capita, calculated from output-side real GDP per capita, as an additional regressor. We report instrumental-variables panel regression results with country fixed effects by using 10-year lagged values of the old and youth dependency ratios and the birth rate as instruments for the current old dependency ratio and the interaction term with life expectancy. We include period dummies but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

Table 6.2: Population Shares

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	**Female**	**Male**	**Older people**	**Female**	**Male**	**Older people**
Old-age population share	0.346	-0.231	-6.320***	-0.465	-0.554	-7.993 **
	[0.361]	[0.208]	[1.683]	[1.021]	[0.449]	[3.218]
Youth population share	0.034	-0.039***	-0.070	-0.004	-0.059***	-0.183
	[0.043]	[0.012]	[0.097]	[0.046]	[0.019]	[0.128]
Initial GDP per capita	-0.000	0.002	0.009	-0.000	0.001	-0.001
	[0.003]	[0.001]	[0.008]	[0.002]	[0.001]	[0.005]
Life expectancy x old population share	-0.002	0.004	0.082***	0.007	0.008	0.105***
	[0.004]	[0.002]	[0.021]	[0.012]	[0.005]	[0.038]
Life expectancy	-0.000	-0.000**	-0.003***	-0.000	-0.000**	-0.004***
	[0.000]	[0.000]	[0.001]	[0.000]	[0.000]	[0.001]
Observations	780	780	780	758	758	758
R-squared	0.038	0.089	0.113	0.012	0.086	0.117
Number of countries	156	156	156	156	156	156
First stage F-statistic				18.79	18.79	18.79
Hansen's J-test (P-value)				0.566	0.888	0.104

GDP = gross domestic product, IV = instrumental-variable, OLS = ordinary least squares.

Notes: The dependent variable is annualized log-difference of 5-year periods of the labor force participation rate for the group denoted in the first row. We add the initial level of GDP per capita, calculated from output-side real GDP per capita, as an additional regressor. We report instrumental-variables panel regression results with country fixed effects by using 10-year lagged values of the old and youth dependency ratios and the birth rate as instruments for the current old dependency ratio and the interaction term with life expectancy. We include period dummies but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

We investigate the role of human capital in Tables 7.1 and 7.2. We expect workers with more human capital to have stronger incentive to participate in the labor market. Again, we report both OLS and IV panel regression results for the same set of equations as in Tables 5.1 and 5.2, except we add human capital and its interaction term with old-age dependency ratio or older population share as additional explanatory variables. The IV estimation results pass the first stage F test and the Hansen's J test at the conventional level. We find that higher human capital helps to offset labor shortage by boosting the labor force participation rates of both males and older workers. The coefficients of the interaction term are positive and highly statistically significant in columns (2), (3), (5), and (6). In Table 7.2, we replace old-age dependency ratio with old-age population share and find qualitatively similar results. Interestingly, however, we do not observe the same effect for females in either Table 7.1 or 7.2.

Table 7: Human Capital and the Impact of Population Aging on Labor Force Participation Rate

Table 7.1: Dependency Ratios

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	**Female**	**Male**	**Older people**	**Female**	**Male**	**Older people**
Old-age dependency ratio	-0.010	-0.293 ***	-1.918***	-0.106	-0.206*	-1.633*
	[0.232]	[0.086]	[0.679]	[0.221]	[0.113]	[0.925]
Youth dependency ratio	0.012	-0.025***	0.010	0.000	-0.025***	-0.008
	[0.026]	[0.005]	[0.040]	[0.019]	[0.005]	[0.038]
Initial GDP per capita	-0.004	0.001	0.008	-0.003	0.000	-0.002
	[0.004]	[0.001]	[0.008]	[0.002]	[0.001]	[0.005]
Human capital x old dependency ratio	0.028	0.107***	0.646***	0.058	0.087***	0.622**
	[0.066]	[0.025]	[0.199]	[0.064]	[0.033]	[0.274]
Human capital	0.012	-0.003	-0.043*	0.006	-0.001	-0.033
	[0.013]	[0.004]	[0.024]	[0.010]	[0.004]	[0.028]
Observations	640	640	640	626	626	626
R-squared	0.049	0.140	0.107	0.031	0.127	0.136
Number of countries	128	128	128	128	128	128
First stage F-statistic				21.89	21.89	21.89
Hansen's J-test (P-value)				0.897	0.884	0.113

GDP = gross domestic product, IV = instrumental-variable, OLS = ordinary least squares.

Notes: The dependent variable is annualized log-difference of 5-year periods of the labor force participation rate for the group denoted in the first row. We add the initial level of GDP per capita, calculated from output-side real GDP per capita, as an additional regressor. We report instrumental-variables panel regression results with country fixed effects by using 10-year lagged values of the old and youth dependency ratios and the birth rate as instruments for the current old dependency ratio and the interaction term with human capital. We include period dummies but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

Table 7.2: Population Shares

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	**Female**	**Male**	**Older people**	**Female**	**Male**	**Older people**
Old-age population share	-0.068	-0.437***	-3.565***	-0.440	-0.356*	-3.816**
	[0.331]	[0.144]	[1.191]	[0.545]	[0.214]	[1.804]
Youth population share	0.012	-0.067***	-0.133	-0.025	-0.069***	-0.204
	[0.063]	[0.016]	[0.148]	[0.054]	[0.020]	[0.145]
Initial GDP per capita	-0.004	0.001	0.007	-0.003	-0.000	-0.004
	[0.004]	[0.001]	[0.008]	[0.002]	[0.001]	[0.005]
Human capital x old population share	0.067	0.148***	1.135***	0.164	0.132**	1.285***
	[0.085]	[0.039]	[0.325]	[0.148]	[0.056]	[0.485]
Human capital	0.009	-0.003	-0.060**	0.001	-0.002	-0.060**
	[0.013]	[0.004]	[0.027]	[0.011]	[0.005]	[0.030]
Observations	640	640	640	626	626	626
R-squared	0.050	0.138	0.119	0.029	0.137	0.158
Number of countries	128	128	128	128	128	128
First stage F-statistic				17.76	17.76	17.76
Hansen's J-test (P-value)				0.731	0.557	0.120

GDP = gross domestic product, IV = instrumental-variable, OLS = ordinary least squares.

Notes: The dependent variable is annualized log-difference of 5-year periods of the labor force participation rate for the group denoted in the first row. We add the initial level of GDP per capita, calculated from output-side real GDP per capita, as an additional regressor. We report instrumental-variables panel regression results with country fixed effects by using 10-year lagged values of the old and youth dependency ratios and the birth rate as instruments for the current old dependency ratio and the interaction term with human capital. We include period dummies but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

Finally, we investigate the role of trade openness in Tables 8.1 and 8.2. We add trade openness and its interaction term with old-age dependency ratio or old population share as additional explanatory variables. We find that higher trade openness increases the labor force participation response among older people. We find the same effect for working age males in OLS estimation in both Tables 8.1 and 8.2 but not in the IV estimation. For working-age females, we do not observe such effect.

Table 8: Trade Openness and the Impact of Population Aging on Labor Force Participation Rate

Table 8.1: Dependency Ratios

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	**Female**	**Male**	**Older people**	**Female**	**Male**	**Older people**
Old-age dependency ratio	0.060	0.015	-0.271	0.026	-0.010	-0.331
	[0.039]	[0.021]	[0.176]	[0.107]	[0.059]	[0.374]
Youth dependency ratio	0.010	-0.017***	0.036	-0.001	-0.024***	-0.012
	[0.016]	[0.004]	[0.029]	[0.015]	[0.005]	[0.035]
Initial GDP per capita	0.000	0.002*	0.013*	-0.000	0.001	0.002
	[0.003]	[0.001]	[0.007]	[0.002]	[0.001]	[0.005]
Trade openness x old dependency ratio	0.022	0.045***	0.438***	0.057	0.082	0.688*
	[0.027]	[0.016]	[0.130]	[0.096]	[0.054]	[0.353]
Trade openness	0.001	-0.003*	-0.026*	-0.004	-0.008	-0.060
	[0.004]	[0.002]	[0.014]	[0.013]	[0.007]	[0.047]
Observations	780	780	780	758	758	758
R-squared	0.039	0.108	0.138	0.016	0.089	0.142
Number of countries	156	156	156	156	156	156
First stage F-statistic				7.802	7.802	7.802
Hansen's J-test (P-value)				0.835	0.393	0.0832

GDP = gross domestic product, IV = instrumental-variable, OLS = ordinary least squares.

Notes: The dependent variable is annualized log-difference of 5-year periods of the labor force participation rate for the group denoted in the first row. We add the initial level of GDP per capita, calculated from output-side real GDP per capita, as an additional regressor. We report instrumental-variables panel regression results with country fixed effects by using 10-year lagged values of the old and youth dependency ratios and the birth rate as instruments for the current old dependency ratio and the interaction term with trade openness. We include period dummies but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

Table 8.2: Population Shares

	OLS			IV		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	**Female**	**Male**	**Older people**	**Female**	**Male**	**Older people**
Old-age population share	0.133**	0.024	-0.380	-0.016	-0.056	-1.104
	[0.065]	[0.035]	[0.279]	[0.262]	[0.110]	[0.758]
Youth population share	0.022	-0.038***	0.056	-0.008	-0.060***	-0.132
	[0.038]	[0.011]	[0.088]	[0.042]	[0.017]	[0.119]
Initial GDP per capita	-0.000	0.002*	0.012*	-0.001	0.001	-0.000
	[0.003]	[0.001]	[0.007]	[0.002]	[0.001]	[0.005]
Trade openness x old population share	0.027	0.054**	0.647***	0.133	0.130	1.440***
	[0.037]	[0.022]	[0.168]	[0.196]	[0.079]	[0.553]
Trade openness	0.001	-0.002	-0.026**	-0.008	-0.009	-0.098*
	[0.003]	[0.002]	[0.012]	[0.017]	[0.007]	[0.050]
Observations	780	780	780	758	758	758
R-squared	0.040	0.107	0.141	(0.001)	0.074	0.081
Number of countries	156	156	156	156	156	156
First stage F-statistic				6.265	6.265	6.265
Hansen's J-test (P-value)				0.650	0.955	0.110

GDP = gross domestic product, IV = instrumental-variable, OLS = ordinary least squares.

Notes: The dependent variable is annualized log-difference of 5-year periods of the labor force participation rate for the group denoted in the first row. We add the initial level of GDP per capita, calculated from output-side real GDP per capita, as an additional regressor. We report instrumental-variables panel regression results with country fixed effects by using 10-year lagged values of the old and youth dependency ratios and the birth rate as instruments for the current old dependency ratio and the interaction term with trade openness. We include period dummies but their coefficients are not reported. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

In Tables 2 to 4, we assumed that the decomposition of the channels is identical across countries. In Tables 6 to 8, we investigated the possibility that countries differ in the degree to which labor participation rates change in response to population aging. However, it is expected that the relative importance of the channels varies depending on how each country responds to population aging. Investigating how each country responds to population aging is beyond the scope of this paper. Instead, we will examine how the relative importance of each channel differs as country characteristics vary.

We select seven country characteristics, which are (i) old dependency ratio, (ii) human capital, (iii) life expectancy, (iv) labor market flexibility, (v) government size, (vi) trade openness, and (vii) capital market openness.[11] The definition and source of the characteristics are listed in the Appendix. For each characteristic, we divide the entire sample into three groups and examine how the decomposition of channels varies as the value of the characteristic changes.[12] For example, for the first characteristic, which is the old-age dependency ratio, we divided the sample into three groups based on average magnitude. One-third of the countries have high values, another third of the countries have low values, and the remaining third have middle values. We estimate IV panel regressions with fixed effects as in Table 4.1 for each group and report the coefficients of old-age dependency ratio in Table 9.1.[13] To save space, we do not report the estimated coefficients of other variables. An important caveat of our analysis is that it does not gauge

[11] We also divided the sample by income level. While the negative impact of aging is found only in advanced economies, the offsetting effect of the labor participation rate is observed in both advanced and developing economies. When we divide the sample by time period, the compensating effect of the labor participation rate is more pronounced in more recent periods.

[12] We use the average value over the entire sample period in classifying countries into the three groups.

[13] The OLS panel regression results are consistent with the IV panel regression results and hence not reported. The results are available upon request.

causality. Instead, our analysis simply shows that the effect of aging differs across countries with different characteristics. Determining whether such differences are due to country characteristics requires more in-depth analysis.

Table 9: The Effects of Aging on GDP Growth and its Eight Channels
Instrumental Variable Regressions for Three Sub-samples

Table 9.1: Old-age Dependency Ratio

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Factors	**Groups**	**GDP per capita**	**K/Y**	**Human capital**	**Work hour**	**LF participation**	**15–64 population**	**Share of 15 and above**	**TFP**
Old dependency ratio	Low	0.636 ***	0.549	0.261***	-0.706*	-0.098**	0.003	-0.045***	-0.774
		[0.229]	[0.229]	[0.593]	[0.054]	[0.421]	[0.041]	[0.030]	[0.004]
	Middle	0.04	0.048	0.021	-0.033	-0.006	-0.040**	0.008**	-0.093
		[0.118]	[0.177]	[0.031]	[0.045]	[0.026]	[0.017]	[0.004]	[0.228]
	High	-0.092*	-0.043	-0.013	-0.012	0.075***	0.003	-0.029***	-0.082
		[0.052]	[0.046]	[0.010]	[0.013]	[0.018]	[0.009]	[0.005]	[0.078]
Human capital	Low	0.719***	-0.538	0.082**	0.074	0.025	-0.018	-0.034***	0.842*
		[0.199]	[0.337]	[0.032]	[0.103]	[0.041]	[0.024]	[0.004]	[0.478]
	Middle	0.147	0.019	0.015	0.013	-0.063*	-0.069***	-0.006	0.19
		[0.106]	[0.207]	[0.031]	[0.037]	[0.033]	[0.018]	[0.004]	[0.277]
	High	-0.159***	0.017	-0.01	-0.014	0.089***	-0.003	-0.023***	-0.198**
		[0.050]	[0.051]	[0.010]	[0.013]	[0.018]	[0.008]	[0.004]	[0.082]
Life expectancy	Low	0.843***	-0.379	0.107***	0.047	-0.083***	-0.011	-0.022***	1.345***
		[0.191]	[0.325]	[0.039]	[0.211]	[0.028]	[0.021]	[0.003]	[0.467]
	Middle	0.157	0.203	-0.001	-0.097**	0.051	-0.077***	-0.006	-0.371*
		[0.111]	[0.151]	[0.029]	[0.042]	[0.035]	[0.020]	[0.005]	[0.208]
	High	-0.120**	-0.008	-0.007	-0.012	0.076***	-0.002	-0.027***	-0.181
		[0.053]	[0.096]	[0.011]	[0.012]	[0.018]	[0.008]	[0.004]	[0.129]
Labor market efficiency	Low	-0.153*	-0.022	-0.030**	0.02	0.042*	-0.060***	-0.013***	-0.257*
		[0.092]	[0.092]	[0.013]	[0.023]	[0.022]	[0.012]	[0.004]	[0.156]
	Middle	-0.012	-0.129	-0.030	-0.027	0.098***	-0.076***	0.007*	-0.177
		[0.091]	[0.147]	[0.019]	[0.024]	[0.020]	[0.013]	[0.004]	[0.235]
	High	-0.145***	-0.009	-0.036***	-0.007	0.045***	-0.055***	-0.012*	-0.053
		[0.047]	[0.069]	[0.011]	[0.015]	[0.017]	[0.011]	[0.006]	[0.078]
Government size	Low	-0.220***	-0.105	-0.052***	0.008	0.043**	-0.062***	-0.014***	0.005
		[0.082]	[0.093]	[0.017]	[0.018]	[0.019]	[0.012]	[0.004]	[0.130]
	Middle	-0.127**	-0.12	-0.021	-0.024*	0.015	-0.075***	0.004	0.013
		[0.056]	[0.104]	[0.016]	[0.014]	[0.015]	[0.010]	[0.003]	[0.145]

Factors	Groups	(1) GDP per capita	(2) K/Y	(3) Human capital	(4) Work hour	(5) LF participation	(6) 15–64 population	(7) Share of 15 and above	(8) TFP
	High	0.007	-0.167	-0.048**	-0.193**	0.115***	-0.040***	-0.020***	0.046
		[0.106]	[0.143]	[0.019]	[0.078]	[0.021]	[0.013]	[0.005]	[0.198]
Trade openness	Low	-0.090	-0.079	-0.033**	0	0.053***	-0.046***	0.005**	0.038
		[0.064]	[0.076]	[0.014]	[0.016]	[0.016]	[0.010]	[0.002]	[0.111]
	Middle	-0.131*	-0.129	-0.073***	-0.023	0.041*	-0.074***	0	-0.202
		[0.079]	[0.098]	[0.017]	[0.028]	[0.022]	[0.011]	[0.003]	[0.143]
	High	-0.012	0.155	0.004	0.001	0.086***	-0.072***	-0.028***	-0.221
		[0.086]	[0.157]	[0.018]	[0.021]	[0.021]	[0.013]	[0.005]	[0.211]
Capital market openness	Low	0.133	-0.371	0.124***	0.057	-0.049	-0.032	-0.012**	0.576
		[0.196]	[0.311]	[0.046]	[0.063]	[0.031]	[0.025]	[0.006]	[0.537]
	Middle	0.021	-0.125	-0.044***	-0.053	0.059***	-0.065***	-0.007*	0.126
		[0.077]	[0.091]	[0.016]	[0.036]	[0.019]	[0.011]	[0.004]	[0.125]
	High	-0.086	0.007	-0.012	-0.006	0.065***	-0.038***	-0.017***	-0.203
		[0.060]	[0.106]	[0.014]	[0.012]	[0.018]	[0.010]	[0.004]	[0.136]

GDP = gross domestic product, K/Y = capital–output ratio, LF = labor force, TFP = total factor productivity.

Notes: The dependent variable is annualized growth rate of the variable listed in the first row. We divide the entire sample into three groups based on the magnitude of each factor listed in the first column: Low, middle and High groups. We report the same IV regression results as in Table 4.1 for each group separately. To save space, we report the coefficient of the old-age dependency ratio only. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

Table 9.2: Older Population Share

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	**Groups**	**GDP per capita**	**K/Y**	**Human capital**	**Work hour**	**LF participation**	**15–64 population**	**Share of 15 and above**	**TFP**
Old dependency ratio	Low	1.213 ***	1.919*	0.592***	-1.092	-0.261***	0.059	-0.094***	-3.085*
		[0.446]	[1.147]	[0.106]	[0.710]	[0.078]	[0.057]	[0.009]	[1.710]
	Middle	-0.039	0.257	0.05	-0.052	-0.012	0.007	0.007	-0.547
		[0.224]	[0.321]	[0.057]	[0.076]	[0.042]	[0.031]	[0.007]	[0.408]
	High	-0.144*	-0.120	-0.017	-0.006	0.118***	0.004	-0.043***	-0.146
		[0.087]	[0.081]	[0.017]	[0.024]	[0.032]	[0.014]	[0.008]	[0.138]
Human capital	Low	1.232***	-1.125	0.187***	0.088	0.027	-0.008	-0.076***	1.536
		[0.401]	[0.695]	[0.065]	[0.162]	[0.079]	[0.048]	[0.008]	[0.988]
	Middle	0.1	0.279	0.006	0.035	-0.112**	-0.050*	-0.013**	-0.206
		[0.177]	[0.347]	[0.051]	[0.052]	[0.052]	[0.028]	[0.007]	[0.463]
	High	-0.364***	0.047	-0.008	-0.004	0.141***	0.006	-0.038***	-0.471***
		[0.084]	[0.087]	[0.016]	[0.024]	[0.030]	[0.014]	[0.007]	[0.141]
Life expectancy	Low	1.632***	-0.757	0.271***	0.096	-0.194***	0.023	-0.050***	2.851***
		[0.382]	[0.652]	[0.078]	[0.376]	[0.056]	[0.041]	[0.006]	[0.930]
	Middle	0.166	0.217	-0.071	-0.136**	0.063	-0.093***	-0.011	-0.686**
		[0.170]	[0.229]	[0.045]	[0.063]	[0.048]	[0.029]	[0.007]	[0.318]
	High	-0.212**	0.109	-0.013	-0.007	0.123***	-0.001	-0.038***	-0.518**
		[0.085]	[0.157]	[0.019]	[0.022]	[0.031]	[0.013]	[0.007]	[0.212]
Labor market efficiency	Low	-0.222	-0.027	-0.044**	0.021	0.047	-0.076***	-0.026***	-0.324
		[0.149]	[0.128]	[0.020]	[0.035]	[0.040]	[0.020]	[0.007]	[0.214]
	Middle	-0.182	-0.099	-0.008	0	0.134***	-0.099***	0.011	-0.631
		[0.143]	[0.349]	[0.031]	[0.034]	[0.032]	[0.020]	[0.007]	[0.530]
	High	-0.342***	0.022	-0.052**	0.015	0.074***	-0.079***	-0.016*	-0.268*
		[0.076]	[0.110]	[0.020]	[0.025]	[0.028]	[0.017]	[0.009]	[0.138]
Government size	Low	-0.439***	-0.148	-0.087***	0.022	0.038	-0.090***	-0.021***	-0.097
		[0.137]	[0.157]	[0.028]	[0.029]	[0.031]	[0.019]	[0.006]	[0.217]
	Middle	-0.304***	-0.076	-0.034	-0.001	0.009	-0.109***	0.008*	-0.285
		[0.090]	[0.166]	[0.025]	[0.024]	[0.026]	[0.016]	[0.005]	[0.232]
	High	0.019	-0.147	-0.046	-0.325**	0.189***	-0.042**	-0.032***	-0.213
		[0.172]	[0.215]	[0.029]	[0.139]	[0.032]	[0.020]	[0.007]	[0.297]

Variables	Groups	(1) GDP per capita	(2) K/Y	(3) Human capital	(4) Work hour	(5) LF participation	(6) 15–64 population	(7) Share of 15 and above	(8) TFP
Trade openness	Low	-0.230**	-0.104	-0.038	-0.004	0.091***	-0.056***	0.005	-0.066
		[0.109]	[0.129]	[0.023]	[0.025]	[0.028]	[0.016]	[0.004]	[0.187]
	Middle	-0.229*	-0.149	-0.135***	0.032	0.054	-0.103***	-0.002	-0.435**
		[0.130]	[0.153]	[0.026]	[0.042]	[0.033]	[0.018]	[0.005]	[0.221]
	High	-0.109	0.343	0.023	0.022	0.115***	-0.111***	-0.033***	-0.679**
		[0.134]	[0.244]	[0.029]	[0.038]	[0.032]	[0.020]	[0.008]	[0.333]
Capital market openness	Low	-0.016	-0.550	0.198**	0.061	-0.093*	-0.021	-0.029***	0.602
		[0.364]	[0.563]	[0.084]	[0.117]	[0.054]	[0.046]	[0.011]	[0.988]
	Middle	-0.059	-0.227	-0.034	-0.038	0.080**	-0.068***	-0.016**	0.049
		[0.131]	[0.153]	[0.027]	[0.054]	[0.032]	[0.019]	[0.006]	[0.210]
	High	-0.205**	0.141	-0.034	0.002	0.094***	-0.077***	-0.018***	-0.656***
		[0.092]	[0.161]	[0.021]	[0.021]	[0.030]	[0.015]	[0.006]	[0.209]

GDP = gross domestic product, K/Y = capital–output ratio, LF = labor force, TFP = total factor productivity.

Notes: The dependent variable is annualized growth rate of the variable listed in the first row. We divide the entire sample into three groups based on the magnitude of each factor listed in the first column: Low, middle and High groups. We report the same IV regression results as in Table 4.2 for each group separately. To save space, we report the coefficient of the older population share only. Robust standard errors are in brackets. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' calculations.

In the first panel of Table 9.1, we report the coefficients of old-age dependency ratio for low, middle and high old-age dependency ratio groups. The dependent variable is denoted in the first row. For the low old-age dependency group, the coefficient of old-age dependency ratio is positive and statistically significant in column (1). On the other hand, the coefficient is not significant for the middle group and negative and significant for the high group. This implies that the impact of aging on economic growth may be nonlinear as argued by Lee and Shin (2019), i.e. the negative effect of aging is more pronounced in more aged economies. In addition, we find that the coefficient of the labor force participation rate is positive and significant only for the high group, which suggests that the offsetting role of the labor force participation rate is more evident in more aged economies. On the other hand, the positive impact of human capital accumulation is visible only in the low group.

In the second panel, we report the coefficients of the old-age dependency ratio for the low, middle, and high human capital groups. Again, we observe a nonlinear effect in the sense that the negative effect of aging on economic growth is more pronounced for economies with high human capital. Further, the negative effect of aging on labor shortage and the offsetting role of the labor force participation rate are more pronounced in the high group. On the other hand, the positive impact of human capital accumulation is visible only in the low group.

In the third panel, related to life expectancy, we again find a nonlinear effect of population aging on economic growth. The coefficient of old-age dependency ratio is positive and statistically significant in the low life expectancy group but negative and significant in the high life expectancy group. The negative effect of aging on labor shortage and the mitigating role of the labor force participation rate is visible only in the high group. We observe a negative effect of aging on TFP growth only in the middle

group. The coefficient for TFP growth is also negative in the high group although it is not precisely estimated. The evidence in the second and third panels suggest that lowered TFP growth is the main channel through which population aging harms economic growth, especially in the high group.

In the fourth panel, we report the coefficients of the old-age dependency ratio for countries with low, middle, and high labor market efficiency or flexibility. The negative effect of aging on economic growth in column (1) does not differ substantially across groups. The negative effect of aging and the offsetting role of labor force participation rate are equally visible in all three groups. Interestingly, the effect of aging on TFP growth is negative and statistically significant only in the low group. In the fifth panel, the size of government, defined as the ratio of government expenditures to GDP, is the defining country characteristic. We find that the negative effect of population aging on economic growth is highest in the low group. The effect is almost zero in the high group. We find a negative effect of aging on labor shortage and a mitigating role of the labor force participation rate only in the high group. Our results suggest that the negative effect of population aging on economic growth is smallest in countries with the largest governments.

The sixth characteristic is trade openness. We do not see much difference across groups. The coefficient of the old-age dependency ratio is negative and large only in the middle group. In line with Table 8, we find that the mitigating effect of increasing labor force participation rate is largest in the high group. The seventh panel reports the results for country groups with different degrees of capital openness. While not precisely estimated, the coefficient of old-age dependency ratio is negative in columns (1) and (8) only in the high group. At the same time, the mitigating effect of labor force participation rate is also largest in the high group.

Table 9.2 reports the same results as in Table 9.1, except we replace old-age dependency ratio with old-age population share. The results are consistent. In general, we find even stronger results. Some coefficients that were not statistically significant in Table 9.1 become statistically significant. For example, for trade openness, the coefficient of old-age population share is negative and statistically significant in the low group. For capital market openness, it is negative and statistically significant only in the high group. The results in Table 9.2 suggest that the negative growth effect of population aging is larger if trade is less open and capital market is more open. However, the coefficient of old-age population share is negative, large, and highly statistically significant in the high trade group and high capital market openness group. The mitigating effect of higher labor force participation rate is also strongest in those two groups.

Overall, our findings in Tables 9.1 and 9.2 suggest that the mitigating effect of higher labor force participation rate is not enough to offset the negative effect of population aging. The shortage of labor can be completely nullified by higher labor force participation. But the primary channel for the negative growth effect of aging is lowered TFP growth, which is difficult to offset. This is especially true in countries with high values of country characteristics, which are mostly advanced countries.

4. Conclusion

There are growing concerns about the negative impact of population aging on economic growth. Such concerns are especially pronounced in advanced economies and some Asian economies that are experiencing rapid aging. They are also relevant to many developing economies that are still relatively young but are already experiencing a demographic transition. The one ray of hope in this gloomy demographic landscape is the silver dividend, or increased longevity and longer working life. That is, older workers working longer can augment the labor supply and thus boost growth, offsetting the negative growth effects of a smaller working-age population.

In this paper, we investigated the extent to which the silver dividend can support economic growth in the face of population aging. To do so, we followed the framework of Lee and Shin (2021) and investigated six channels through which population aging potentially affects the growth rate of per capita GDP. The six channels are changes in: (i) physical capital, (ii) human capital, (iii) average working hours, (iv) labor participation rate, (v) the share of population aged 15 and over, and (vi) TFP. It is important to note that changes in the working-age population is only one of several economic effects of population aging.

Our analysis yielded some interesting findings. Above all, we found that the primary channel through which population aging harms economic growth is lowered TFP growth. Labor shortage caused by aging is mostly offset by higher labor force participation rates of males, females, and especially older workers. Higher life expectancy, human capital, and trade openness amplify the mitigating effect of the labor force participation rate among older people. While most of the concern about the

economic impact of aging centers on shortage of workers, our analysis suggested that more workers entering the workforce eliminates the shortage in most countries. However, the increase in labor force participation is not enough to completely offset the negative effect of aging on growth, which is largely driven by a decline in TFP growth.

To investigate how country characteristics affect the impact of population aging on economic growth, we divided countries into three groups—low value, medium value, and high value. The country characteristics are (i) old dependency ratio, (ii) human capital, (iii) life expectancy, (iv) labor market flexibility, (v) government size, (vi) trade openness, and (vii) capital market openness. For instance, low value of human capital refers to countries with relatively little human capital. Our analysis indicated that population aging has a nonlinear effect on economic growth, i.e., the negative effect of aging is more pronounced in more aged economies.

To conclude, our analysis indicated that contrary to conventional wisdom, the primary channel through which population aging harms economic growth is through lower TFP growth rather than a shortage of workers. We found that there is a substantial silver dividend—i.e., more older workers entering the labor market—in the face of population aging. In fact, this silver dividend is the driving force behind the increase in labor force participation that offsets the labor shortage due to aging in most countries. However, the silver dividend and the broader increase in labor force participation is not enough to nullify the negative impact of population aging on growth. This is because reducing the negative effects of aging on TFP growth matters more for reducing the negative effect of aging on economic growth.

Appendix: Definitions of Variables and Data Sources

Variables	Description and Construction	Data Source
Aggregate GDP (national price)	Real GDP at constant 2017 national prices (in million 2017 US$)	Penn World Table 10.0
Aggregate GDP (output side)	Output-side real GDP at chained PPPs (in million 2017 US$)	Penn World Table 10.0
Population	Population in millions	Penn World Table 10.0
Average hours worked	Average annual hours worked by persons engaged in employment	Penn World Table 10.0
Total factor productivity (national price)	Total factor productivity at constant national prices (2017=1)	Penn World Table 10.0
Education/human capital	Human Capital Index	Penn World Table 10.0
Labor compensation share	Share of labor compensation in GDP at current national prices	Penn World Table 10.0
Trade openness (at current PPPs)	Share of merchandise exports – Share of merchandise imports	Penn World Table 10.0
Government size	Share of government consumption at current PPPs	Penn World Table 10.0
Labor force participation rate, official data	Labor force participation rate for age group 15+, official data collected by ILO	ILO. ILOStat. https://ilostat.ilo.org/data/
Labor force participation rate, ILO modeled estimate	Labor force participation rate for age group 15+, ILO modeled estimate	ILO. ILOStat. https://ilostat.ilo.org/data/
Labor force participation rate, males, ILO modeled estimate	Labor force participation rate for males of age group 15+, ILO modeled estimate	ILO. ILOStat. https://ilostat.ilo.org/data/
Labor force participation rate, females, ILO modeled estimate	Labor force participation rate for females of age group 15+, ILO modeled estimate	ILO. ILOStat. https://ilostat.ilo.org/data/
Older people participation	Labor force participation rate, official data, 65+	The International Labour Organization‘s Office of Statistics LABORSTA database
Capital Market Openness	Chinn–Ito Index; a country’s degree of capital account openness (normalized to one)	Chinn and Ito. 2006. “What Matters for Financial Development? Capital Controls, Institutions, and Interactions.” *Journal of Development Economics* 81 (1): 163–192.

Variables	Description and Construction	Data Source
Old-age dependency	Annual old-age dependency ratio. (Population age 65+ / population age 15–64)	UN DESA. 2017. *World Population Prospects: The 2017 Revision*.
Youth dependency	Annual child dependency ratio. (Population age 0–14 / population age 15–64)	UN DESA. 2017. *World Population Prospects: The 2017 Revision*.
Working-age population ratio	Annual working-age population ratio. (Population age 15–64 / total population)	UN DESA. 2017. *World Population Prospects: The 2017 Revision*.
Life expectancy	Life expectancy at birth, total (years)	World Bank's World Development Indicators
Labor market efficiency	Labor Market Efficiency, Index (1–7)	World Economic Forum, Global Competitiveness Index (GCI)

GDP = gross domestic product, ILO = International Labour Organization, PPP = purchasing power parity, UN DESA = United Nations Department of Economic and Social Affairs, US = United States.

Source: Authors' compilations.

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Population Aging, Silver Dividend, and Economic Growth

The silver dividend refers to increased longevity and longer working life becoming potential sources of growth in an aging society. The authors examine the potential for a silver dividend by empirically investigating the channels through which population aging affects economic growth. They find that lower total factor productivity growth is the main mechanism through which population aging harms economic growth. Labor shortage caused by aging is mostly offset by higher labor force participation rates among older people.

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