The effects of demographic dynamics on economic growth in EU economies: A panel vector autoregressive approach

Taguchi, Hiroyuki and Latjin, Mirani

Saitama University

2022

The Effects of Demographic Dynamics on Economic Growth in EU Economies: A Panel Vector Autoregressive Approach

Hiroyuki Taguchi*
Mirani Latjin

Graduate School of Humanities and Social Sciences, Saitama University, Saitama, Japan
* Corresponding author: htaguchi@mail.saitama-u.ac.jp; ORCID: 0000-0002-6426-772X

Abstract

This study estimates the effects of demographic dynamics on economic growth, with a focus on the working-age population and life expectancy in 19 European Union economies for 1970–2020 and 2020–2050, using a panel vector autoregressive (PVAR) model as the analytical methodology. The main findings are as follows. First, the PVAR estimation identifies positive effects of the growth of the working-age population share and the extension of life expectancy on economic growth. Second, the contribution ratio of the demographic effects to economic growth for past population bonus periods is approximately 15% on average in this study, which is comparable to the ratios found in previous studies. Third, the projection for 2020–2050 shows that the magnitude of the negative demographic effect on annual economic growth due to the population onus is -0.385 on average among all sample economies. The main policy implication of this study is that the EU economies that have already entered the population onus phase of the demographic transition need to mitigate the negative effects of the decline in the working-age population share.

Keywords: demographic dynamics, economic growth, European Union, working-age population, life expectancy, panel vector autoregressive model

JEL Classification: J11, O52

1. Introduction

The nexus between demographic dynamics and economic growth has been intensively investigated from both the theoretical and empirical viewpoints in the literature because demographic dynamics are an important determinant of economic growth. The relationship of the population size with economic growth has been an issue of debate for a long time. While this debate has continued, a critical variable, the age structure of the population represented by the working-age and dependent populations has attracted more attention in recent studies since the age structure is considered to capture the overall impact of demographic changes more appropriately than the population size itself (e.g., Kelley & Schmidt, 2005; Macunovich, 2012).

The dynamic change in the age structure stems from the demographic transition, characterized by the following three phases when fertility falls followed by a mortality decline: from a high dependency ratio of the young population, through a high proportion of the working-age population, to a high dependency ratio of the aged population. Among these phases, the second phase with a higher proportion of the working-age population is assumed to produce a positive impact on economic growth, whereas the phases characterized by higher dependency ratios of the young and the aged have a negative economic impact. The growth associated with a growing proportion of the working-age population is referred to as the demographic dividend by Bloom et al. (2003a) and the population bonus by Mason (1997), whereas the burdens associated with a declining proportion of the working-age population and a rise in the youth and/or elderly dependency ratio are often called the population onus. The effects of the population bonus and onus on economic growth have been examined empirically in several studies (e.g., Bloom & Finlay, 2009; Bloom & Williamson, 1998; Bloom et al., 2000, 2003a; Headey & Hodge, 2009).

In Europe, the striking demographic changes during recent decades have been the secular rise in life expectancy and the decline in the fertility rate. Their combination, resulting in population ageing, is considered to exert downwards pressure on economic growth (e.g., Cooley et al., 2019; Gaag & Beer, 2015). Regarding the fertility rate, Europe started experiencing its second demographic transition (SDT) in the 1970s. Under the SDT, as initially proposed by Lesthaeghe and van de Kaa (1986), subreplacement fertility is sustained and does not recover to replacement fertility. Under this SDT and due to the increase in longevity, most European countries entered a chronic and persistent phase of population onus after the 1990s–2000s, showing both a decline in their working-age population shares and an increase in their population ageing rates, as seen in Figure 1. Therefore, it is worthwhile to re-examine the quantitative relationships between demographic factors and economic growth along with their long-term projections for European countries.

This study thus aims to estimate the effects of demographic dynamics on economic growth, with a focus on the working-age population and life expectancy in 19 European Union (EU) countries for the past (1970–2020) and the future (2020–2050), by using a panel vector autoregressive (PVAR) model. The research questions are twofold: (i) to what extent the increases in the working-age population share (the population bonus) and life expectancy contributed to economic growth during the past decades in EU countries and (ii) how serious the negative effect of the decline in the working-age population share on economic growth will be during 2020–2050 in these EU countries under the persistent population onus with ageing.

There are a limited number of empirical studies on the economic effects of demographic dynamics focusing on EU countries with a wide coverage of sample economies and a long range of sample periods including the projected period. On the one hand, Cooley et al. (2019) quantified the growth effects of ageing by using a general equilibrium overlapping generations model for the past (1975–2015) and the future (2020–2040), focusing on the four largest

European economies. On the other hand, Gaag and Beer (2015) examined the impact of ageing on economic growth for EU countries over 2000–2020 in descriptive analyses focusing on the employment perspective. Thus, there is a large empirical space between a pure assumption-based approach (a general equilibrium overlapping generations model) and a pure descriptive one. Our study using the PVAR model contributes to filling this empirical space by taking a position between the two methods above to provide a trade-off between the two extreme approaches.

The PVAR model has the following methodological advantages: allowing potential and highly likely endogeneity among estimation variables (working-age population, life expectancy and economic growth), identifying the dynamic responses of the explained variables to shocks to a set of explanatory variables, and incorporating shared information between the sample countries in the panel settings (e.g., Abrigo & Love, 2016). In fact, the VAR approach has been applied for the analysis of demographic effects in different regions and from different perspectives. Taguchi et al. (2021), for instance, applied a PVAR model with the same approach as the one used in this study to examine the effects of demographic dynamics on economic growth targeting Asian economies. For individual economies, Lopreite & Mauro (2017) and Lopreite & Zhu (2020) investigated the effects of population ageing on health care expenditure and economic growth by using a Bayesian VAR analysis on Italy and China, respectively. In short, this type of VAR model has been useful in studies of demographic impacts and also provides added value by enriching the empirical evidence on the economic effects of demographic dynamics in EU countries.

The remainder of the study is structured as follows. The next section conducts an empirical analysis through simple observation of the trend in the age structure in the 19 EU countries and a PVAR model estimation. The last section summarizes and concludes the paper.

2. Empirics

This section conducts an empirical analysis by first observing the trend in demographic dynamics with a focus on the age structure in the 19 EU countries and presents a PVAR estimation describing the methodology, data, and results.

2.1 Trend in Demographic Dynamics

Figure 1 shows the trend in the age structure, namely, the share of the young (1–14 years old), working-age (15–64), and elderly (65 and over) populations for 1950–2020 and 2020–2050 for the 19 EU countries. The data, including the projections, are retrieved from the 2019 Revision of World Population Prospects by the United Nations.[1] The sample countries are 19 EU economies: Austria, Belgium, Bulgaria, Cyprus, Denmark, Finland, France, Greece, Hungary, Ireland, Italy, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Spain, and Sweden.[2]

The common findings from Figure 1 are that all sample countries have already experienced a population bonus characterized by an increase in their working-age population shares over the past decades but that the bonus periods differed among countries. They have since entered the chronic and persistent phase of population onus, with a decline in their working-age

---

[1] See https://population.un.org/wpp/.

[2] Among the 27 EU members, Croatia, Czechia, Estonia, Germany, Latvia, Lithuania, Slovakia, and Slovenia were excluded from the sample due to lack of data for 1970–1980.

population shares and an increase in their population ageing rates. Regarding life expectancy, the sample countries all show steady extensions of longevity from 1950 through 2020 and then to 2050 by approximately 20 years.

The demographic trend above in the EU countries is somewhat different from that in Asian countries. Taguchi et al. (2021) demonstrated that some latecomer developing countries in Asian regions are still enjoying the population bonus phase and that saving rates rather than life expectancy are an influential factor affecting economic growth in the region.

2.2 PVAR Analysis

This subsection conducts a PVAR estimation focusing on the working-age population and life expectancy. It starts with the model specification, followed by the data description, a block exogeneity test, an impulse response test, and discussion of the estimation results.

2.2.1 Model Specification

We first show a standard convergence model in growth regressions, as per Bloom et al. (2000), Kelley and Schmidt (2005), and Bloom and Finlay (2009). The purpose of constructing the theoretical growth model here is to identify and justify the usage of the variables for the subsequent PVAR model estimation. The model is specified as follows:

$$g_{pcy} = g_{pwy} + g_{was},$$

$$g_{pwy} = \lambda\,(pwy^* - pwy_0), \qquad (1)$$

where the first equation is a growth identity assuming that the number of workers is equal to that of the working-age population. g denotes the economic growth rate, pcy is GDP per capita, *pwy* is GDP per worker, and *was* is the ratio of the working-age population to the total population. The second equation indicates a convergence model, where λ is the speed of convergence, pwy^* is the steady state of GDP per worker, and pwy_0 is the initial value of GDP per worker.

The neoclassical Solow-Swan growth model (Solow, 1956; Swan, 1956) argues that the steady state of GDP per worker (pwy^*) is determined by population growth and the saving rate. Population growth itself is the subject of a long-lasting debate over its effect on economic growth. Researchers disagree on whether population growth restricts (e.g., Barro, 1991; Solow, 1956), promotes (e.g., Kremer, 1993; Kuznets, 1960), or is independent of economic growth (e.g., Ehrlich & Lui, 1997; Feyrery, 2002). Post neoclassical endogenous growth theory has argued for a role of saving, as a determinant of steady state growth in the Solow-Swan model, in that a rise in saving produces a continuously higher rate of growth through capital accumulation (e.g., Barro, 1990; Barro & Sala-i-Martin, 1995; Lucas, 1988; Romer, 1986, 1990). Saving is, however, considered to be a dependent variable affected by the age structure and economic growth. The effect of the age structure on saving has been studied based on the life-cycle hypothesis (e.g., Horioka & Terada-Hagiwara, 2012; Kelley & Schmidt, 1996; Mason, 1981; Modigliani & Brumberg, 1954) and on the dependency hypothesis (e.g., Coale & Hoover, 1958; Higgins & Williamson, 1997; Leff, 1969). The effect of economic growth on saving has also been verified, for instance, by a model of consumption with habit formation (Carroll & Weil, 1994; Carroll et al., 2000).

Another demographic variable affecting economic variables is life expectancy. Barro and Sala-i-Martin (1995), for instance, showed a positive correlation between life expectancy and the growth rate of per capita GDP in their empirical analysis of a cross section of countries. From a theoretical viewpoint, there are two channels whereby life expectancy may influence economic growth: a direct channel and an indirect channel through saving. Regarding the direct channel, longer life expectancy creates a higher return on human capital, thereby encouraging more investment in education and health and thus stimulating economic growth. This channel has been verified by overlapping generation models (Kalemli-Ozcan et al., 2000; Yakita, 2006) and growth models (Hickson, 2009; Zhang et al., 2001). Under the indirect channel, longevity affects the saving rate and further influences capital investment and the growth rate. The effect of life expectancy on saving has been empirically studied based on the life-cycle hypothesis (e.g., Bloom et al., 2003b; Lee & Mason, 2006; Li et al., 2007). Another sophisticated argument is that there is a nonlinear relationship between life expectancy and economic growth. For instance, Cervellati and Sunde (2011) and Hansen and Lonstrup (2015) demonstrated that an increase in life expectancy primarily increases the population before the demographic transition but reduces population growth and fosters human capital accumulation and, thus, economic growth after the demographic transition.

The feedback effects from economic growth to demographic variables (the age structure and life expectancy) have also been investigated. For instance, Bloom et al. (2000) found that the feedback effect from economic growth to age-structure change facilitated the impact of the age structure on economic growth. Regarding the effect of income on life expectancy, Preston (1975, 2007) demonstrated the eponymous Preston curve, whereby there is a strong effect of increasing income on life expectancy in countries with low income levels but a small effect in countries with high income levels, where life expectancy depends more on health technology than income.

Based on the above discussion, candidate variables for a PVAR model estimation are growth of GDP per capita (g_{pcy}), growth of the working-age population share (g_{was}), the saving rate to GDP (*sav*), population growth (g_{pop}), life expectancy (*lfe*), and the initial value of GDP per worker (pwy_0). All these variables, except for the initial value of GDP per worker (pwy_0), may endogenously interact, as discussed above. Hence, it is necessary to apply a PVAR model instead of growth regressions because this model allows for potential and highly likely endogeneity among the estimated variables. The PVAR model for estimation can be specified as follows:

$$y_{it} = \alpha + \beta\, y_{it-1} + \gamma\, pwy_0 + \varepsilon_{it}, \quad (2)$$

where y_{it} is a column vector of the endogenous variables with economy i and year t: $y = (g_{pcy}, g_{was}, sav, g_{pop}, lfe)'$; y_{it-1} is a vector of lagged variables; α, β, and γ are coefficient matrices; and ε_{it} is a vector of the random error terms in the system. The lag length (-1) is chosen by the Schwarz information criterion (SIC)[3], with the maximum number of lags being four under the limited time-series data.[4] The estimation includes two time-dummies for 2000–2020 (*dm00*) and 2010–2020 (*dm10*) since the dotcom crisis (1998–1999) and the subprime crisis (2007-2008) are supposed to be the events to cause the structural changes thereafter. The next step is to examine Granger causalities among the endogenous variables by a block exogeneity test based on the PVAR model estimation of Equation (2).

---

[3] The Akaike information criterion (AIC) was also applied, and it indicated a lag length of (-4) as the optimal lag order, which is equivalent to too long lags of 20 years. Green (2008) argues that both SIC and AIC have their virtues, and that SIC, with its heavier penalty for degrees of freedom lost, will lean toward a simple model. Since this study's model is structured rather simple, this study applies SIC.

[4] In this study, the VAR residual heteroskedasticity tests and residual normality tests could not confirm the absence of heteroskedasticity and multivariate normality, while the VAR residual serial correlation tests could identify no serial correlation. Thus, this study has room for improvements in the model specification, for instance, by adding omitted variables.

2.2.2 Data

For the estimation, this study builds a panel dataset of the 19 EU countries (as shown in Section 2.1) with every five years from 1970 to 2020 based on data availability. Data at five-year intervals are used to avoid short-term disturbances, business cycle fluctuations, and serial correlations, as suggested by Islam (1995).

The data details of the variables selected in the previous section are described as follows. The data on GDP per capita (*pcy*) in real terms and the saving rate to GDP (*sav*) are retrieved from UNCTADSTAT: the GDP per capita (*pcy*) data are from the series 'Gross domestic product per capita, US dollars at constant (2015) prices', and the saving rate to GDP (*sav*) data are calculated by subtracting 'Final consumption expenditure' from 'Gross domestic product (GDP)', and dividing it by GDP. The working-age population share (*was*), total population (*pop*), and life expectancy (*lfe*) are from the 2019 Revision of World Population Prospects by the United Nations. The initial value of GDP per worker (pwy_0) in thousand US dollars is computed by dividing the GDP per capita in 1970 by the working-age population in 1970. The growth term (g_{pcy}, g_{was}, g_{pop}) is represented by an annual growth rate on average for every five years starting from 1975. The saving rate to GDP (*sav*) and life expectancy (*lfe*) are the averages for five years.

Prior to the PVAR estimation, we check the stationarity of the panel data by employing panel unit root tests: the Levin, Lin, and Chu test (Levin et al., 2002) as a common unit root test and the Fisher–ADF and Fisher–PP tests (Choi, 2001; Maddala & Wu, 1999) and the Im, Pesaran, and Shin test (Im et al., 2003) as individual unit root tests. The common unit root test assumes the existence of a common unit root process across cross-sections, while the individual unit root test allows individual unit root processes that differ across cross-sections. We conduct these tests with the null hypothesis that a series of panel data in levels has a unit root by including 'intercept' and 'trend and intercept' in the test equations. Table 1 shows that the Levin, Lin, and Chu test rejects the null hypothesis of a unit root at the 99% significance level for all variables in both test equations. The individual unit root tests do not necessarily reject the null hypothesis in all cases, but the Fisher–ADF test rejects it at the 99% level for all variables in the test equation, including the trend and intercept. Therefore, we assume that there is no serious problem of the existence of unit roots in the panel data and use the panel data in levels for the estimation.

2.2.3 Block Exogeneity Test

The block exogeneity test is a method used to judge whether a variable should be either included or excluded from an estimation model based on the existence of Granger causality in a VAR framework.[5] Granger causality is confirmed by rejection of the null hypothesis that the variable is excluded from a VAR model.

Table 2 presents the test results of Equation (2) with a one-period lag as the baseline and with a two-period lag as a robustness check. Granger causalities are identified from the growth in the working-age population share (g_{was}) and life expectancy (lfe) to the growth in GDP per capita (g_{pcy}). The causality running from the working-age population share to GDP per capita is consistent with findings in previous studies such as Bloom et al. (2003a) and Headey and Hodge (2009). Regarding the causality from life expectancy to GDP per capita, this result is considered to capture their direct effects through the education channel as verified by Kalemli-

[5] In this study, no specialised testing procedure as in Lopez and Weber (2017) is used.

Ozcan et al. (2000) and Zhang et al. (2001) because the saving rate has no causal relationship with GDP per capita. The result is also consistent with the nonlinearity hypothesis proposed by Cervellati and Sunde (2011) because all EU sample countries have already entered the post-demographic transition phase.

We should note that the saving rate to GDP (*sav*) and population growth (g_{pop}) do not Granger-cause the growth in GDP per capita (g_{pcy}). The result of no impact of the saving rate to GDP on per capita GDP growth can be explained by the diminishing returns to capital accumulation in growth models because all the sample EU countries except for Bulgaria and Romania have high incomes according to the 2020 World Bank income classification.[6] The finding of no causal effect from population growth to the growth in GDP per capita reflects the argument that the age structure (represented by the working-age population share) rather than population growth captures the overall impact of demographic changes on economic growth, as in Kelley and Schmidt (2005) and Macunovich (2012). Regarding the feedback effects from economic growth to demographic variables represented by the causal relationship from the growth in the GDP per capita to the growth in the working-age population share and life expectancy, both are insignificant at the 95% level. These results contradict Bloom et al. (2000) and Preston (1975, 2007).

Based on the preliminary block exogeneity test above, the saving rate to GDP (*sav*) and population growth (g_{pop}) can be excluded from the PVAR estimation, and we thus conduct an alternative PVAR estimation by focusing only on the three endogenous variables, namely, $y = (g_{pcy}, g_{was}, lfe)'$ in Equation (2). Table 3 shows the alternative test results: growth of the

---

[6] See https://datahelpdesk.worldbank.org/knowledgebase/articles/906519.

working-age population share (g_{was}) and life expectancy (*lfe*) Granger-cause the growth of GDP per capita (g_{pcy}), and there are no feedback effects from g_{pcy} to g_{pcy} and *lfe*, consistent with the preliminary test. Therefore, the subsequent estimation is based on this three-variable estimation.

2.2.4 Impulse Response Test

Table 4 reports the outcomes of the three-variable PVAR model estimation, and shows significantly negative coefficients of the time-dummy for 2010–2020 (*dm10*) in the equations of g_{pcy} and g_{was} as dependent variables, suggesting the existence of structural changes after the subprime crisis (2007-2008) on the growth of GDP per capita and the working-age population.

Based on the PVAR model estimation, this section conducts an impulse response test to trace out the dynamic responses of a variable to a one-unit shock of a set of variables.

Table 5 and Figure 2 indicate the test results as follows. If the response (solid line) with a 95% error ban (dotted line) is beyond zero, the response is considered significant at the 95% level; otherwise, it is considered insignificant. In the combination between the growth of GDP per capita (g_{pcy}) and growth of the working-age population share (g_{was}), g_{pcy} responds positively with a 95% error band to a one-unit (one-percentage-point) shock of g_{was} in a continuous way from the shock to the fourth period, whereas the opposite response from g_{pcy} to g_{was} is ambiguous, with zero in the error bands. Thus, the response of per capita GDP growth (g_{pcy}) to a shock of the growth of the working-age population share (g_{was}) is positively significant, and the opposite response from g_{pcy} to g_{was} is insignificant. In the combination between per capita GDP growth (g_{pcy}) and life expectancy (*lfe*), g_{pcy} responds positively with a 95% error band (thus significantly) to a one-unit shock of *lfe* in a continuous way after the shock, whereas the opposite response from g_{pcy} to *lfe* is insignificant. These results are consistent with those of the block exogeneity test in Section 2.2.3: positive effects of the working-age population share and life expectancy on the growth in GDP per capita, and no feedback effects from the growth in GDP per capita to the working-age population share or life expectancy. The magnitude of the g_{pcy} response from g_{was} peaks in the second period by 0.908 percentage points and that of the g_{pcy} response from *lfe* reaches 0.036 in the fourth period and levels off thereafter.

2.2.5 Factor Analyses

This section demonstrates the quantitative effects of the changes in the working-age population share and the extension in life expectancy on per capita GDP growth for the population bonus period during 1970–2020 and the population onus period for 2020–2050.

The analysis uses the elasticity values obtained by the impulse response test in Table 5: 0.908 as the response value of g_{pcy} to a one-unit (one-percentage-point) shock of g_{was} in the second period and 0.036 as the response value of g_{pcy} to a one-unit (one-year) shock of *lfe* in the fourth period. Then, the variables' relationship is described as follows:

$$G_{pcy} = 0.908\, g_{was} + 0.036\, lfe. \qquad (3)$$

The first term on the right-hand side of Equation (3) is the effect of the changes in the working-age population share on per capita GDP growth, and the second term is the effect of the extension in life expectancy on per capita GDP growth.

Table 6 reports the analytical results of the demographic effects on economic growth in the 19 EU economies for the population bonus period during 1970–2020. The second column displays the population bonus period in each sample economy, that is, the period when the working-age population share was increasing. Column (a) denotes the annual growth of GDP per capita for the population bonus period. Columns (b) and (d) indicate the annual growth of the working-age population share and the annual extension of life expectancy for the period, and Columns (c) and (e) show their effects on per capita GDP growth, computed by the first and second terms of Equation (3), respectively. Column (f) is the contribution ratio of the sum of Columns (c) and (e) to Column (a). The contribution ratio ranges from 0.053 for Malta to 0.259 for the Netherlands, with an average of 0.145 among the 19 sample economies. This ratio is comparable to the findings of Bloom and Williamson (1998) and Bloom and Finlay (2009): a contribution of approximately one-third of the change in the working age population share to economic growth on average for Asian economies.

Table 7 reports the projection of the demographic effects on economic growth in the 19 EU economies for 2020–2050. Columns (g) and (i) indicate the annual growth of the working-age population share and the annual extension of life expectancy for the projected period using the 2019 Revision of World Population Prospects by the United Nations, and Columns (h) and (j) show their projected effects on per capita GDP growth computed by the first and second terms of Equation (3), respectively. Column (k) is the total effect calculated by the sum of Columns (h) and (j). According to Column (k), the total projected effect on annual growth of GDP per capita ranges from -0.132 for Sweden to -0.758 for Spain, with an average of -0.385 among the 19 sample economies. The reason for the negative demographic effect in all sample economies for the projected period is that all countries have already entered the population onus phase, with a decline in the working-age population share stemming from the ongoing SDT; this negative effect far exceeds the positive effect of the projected extension of life expectancy on economic growth. This projection implies that the EU economies under the population onus need to mitigate the negative working-age effects to sustain their economic growth.

Figure 3 visualizes the factor analyses shown in Table 6 and 7: the right bar charts display the population bonus effects and the growth of GDP per capita during the past bonus period, and the left bar charts show the population onus effects for 2020–2050 in the 19 EU economies. It should be moted that the average magnitude of the population onus effects, -0.385, is larger that that of the bonus effects, 0.328, in terms of the absolute values, while the degree of both effects differs depending on the sample economies.

3. Concluding Remarks

This study estimated the effects of demographic dynamics on economic growth, with a focus on the working-age population share and life expectancy in 19 EU economies in the past (1970–2020) and the future (2020–2050), by applying a PVAR model as an analytical methodology considering endogenous interactions among the variables involved. The main findings are as follows. First, the PVAR estimation identified positive effects of growth in the working-age population share and the extension of life expectancy on economic growth. Second, the contribution ratio of the demographic effects to economic growth for the past population bonus period, at approximately 15% on average in this study, is comparable to the ratios found in the previous studies by Bloom and Williamson (1998) and Bloom and Finlay (2009). Third, in the projection for 2020–2050, the magnitude of the negative demographic effect on annual economic growth due to the population onus with a decline in the working-age population share stemming from the ongoing SDT is -0.385 on average among all sample economies.

References

Abrigo, M. R. M., & Love, I. (2016). Estimation of panel vector autoregression in Stata. *The Stata Journal*, *16*, 778–804. https://doi.org/10.1177/1536867X1601600314

Barro, R. J. (1990). Government spending in a simple model of endogenous growth. *Journal of Political Economy*, *98*, S103–S125. https://doi.org/10.1086/261726

Barro, R. J. (1991). Economic growth in a cross section of countries. *Quarterly Journal of Economics*, *106*, 407–443. https://doi.org/10.2307/2937943

Barro, R. J., & Sala-i-Martin, X. (1995). *Economic growth*. McGraw-Hill.

Bloom, D. E., & Williamson, J. G. 1998. Demographic transitions and economic miracles in emerging Asia. *World Bank Economic Review*, *12*, 419–455. https://doi.org/10.1093/wber/12.3.419

Bloom, D. E., Canning, D., & Malaney, P. N. (2000). Population dynamics and economic growth in Asia. *Population and Development Review*, *26*, 257–290.

Bloom, D. E., Canning, D., & Sevilla, J. (2003a). *The demographic dividend: A new perspective on the economic consequences of population change*. Rand. https://doi.org/10.7249/MR1274

Bloom, D. E., Canning, D., & Graham, B. (2003b). Longevity and life cycle savings. *Scandinavian Journal of Economics*, *105*, 319–338. https://doi.org/10.1111/1467-9442.t01-1-00001

Bloom, D. E., & Finlay, J. (2009). Demographic change and economic growth in Asia. *Asian Economic Policy Review*, *4*, 45–64. https://doi.org/10.1111/j.1748-3131.2009.01106.x

Carroll, C. D., & Weil, D. N. (1994). Saving and growth: A reinterpretation. *Carnegie-*

Rochester Conference Series on Public Policy, *40*, 133–192. https://doi.org/10.1016/0167-2231(94)90006-X

Carroll, C. D., Overland, J., & Weil, D. N. (2000). Saving and growth with habit formation. *American Economic Review*, *90*, 341–355. https://doi.org/10.1257/aer.90.3.341

Cervellati, M., & Sunde, U. (2011). Life expectancy and economic growth: The role of the demographic transition. *Journal of Economic Growth*, *16*, 99–133. https://doi.org/10.1007/s10887-011-9065-2

Choi, I. (2001). Unit root tests for panel data. *Journal of International Money and Finance*, *20*, 249–272. https://doi.org/10.1016/S0261-5606(00)00048-6

Coale, A. J., & Hoover, E. (1958). *Population growth and economic development in low-income countries*. Princeton University Press.

Cooley, T. F., Henriksen, E., & Nusbaum C. (2019). Demographic obstacles to European growth. *NBER Working Paper*, No. 26503. https://doi.org/10.3386/w26503

Ehrlich, I., & Lui, F., (1997). The problem of population and growth: A review of the literature from Malthus to contemporary models of endogenous population and endogenous growth. *Journal of Economic Dynamics and Control*, *21*, 205–242. https://doi.org/10.1016/0165-1889(95)00930-2

Feyrery, J. (2002). Demographics and productivity. *Dartmouth College Working Paper: Proceedings of the Midwest Business Economics Association, Dartmouth College*.

Green, W. H. (2008). *Econometric Analysis (Sixth Edition)*. Pearson Prentice Hall.

Van der Gaag, N., & Beer, J. (2015). From demographic dividend to demographic burden: The impact of population aging on economic growth in Europe. *Tijdschrift voor Economische* *en Sociale Geografie*, *106*(1), 94–109. https://doi.org/10.1111/tesg.12104

Hansen, C. W., & Lonstrup, L. (2015). The rise in life expectancy and economic growth in the 20th century. *Economic Journal*, *125*, 838–852. https://doi.org/10.1111/ecoj.12261

Headey, D. D., & Hodge, A. (2009). The effect of population growth on economic growth: A metaregression analysis of the macroeconomic literature. *Population and Development Review*, *35*, 221–248. https://doi.org/10.1111/j.1728-4457.2009.00274.x

Hickson, K. J. (2009). The contribution of increased life expectancy to economic development in twentieth century Japan. *Journal of Asian Economics*, *20*, 489–504. https://doi.org/10.1016/j.asieco.2009.04.006

Higgins, M., & Williamson, J. G. (1997). Age structure dynamics in Asia and dependence on foreign capital. *Population and Development Review*, *23*, 261–293. https://doi.org/10.2307/2137546

Horioka, C. Y., & Terada-Hagiwara, A. (2012). The determinants and long-term projections of saving rates in developing Asia. *Japan and World Economy*, *24*, 128–137. https://doi.org/10.1016/j.japwor.2012.01.006

Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels, *Journal of Econometrics*, *115*, 53–74. https://doi.org/10.1016/S0304-4076(03)00092-7

Islam, N. (1995). Growth empirics: A panel data approach. *The Quarterly Journal of Economics*, *110*, 1127–1170. https://doi.org/10.2307/2946651

Kalemli-Ozcan, S., Ryder, H. E., & Weil, D. N. (2000). Mortality decline, human capital investment, and economic growth. *Journal of Development Economics*, *62*, 1–23. https://doi.org/10.1016/S0304-3878(00)00073-0

Kelley, A. C., & Schmidt, R. M. (1996). Saving, dependency and development. *Journal of Population Economics*, *9*, 365–386. https://doi.org/10.1007/BF00573070

Kelley, A. C., & Schmidt, R. M. (2005). Evolution of recent economic-demographic modeling: A synthesis. *Journal of Population Economics*, *18*, 275–300. https://doi.org/10.1007/s00148-005-0222-9

Kremer, M. (1993). Population growth and technological change: One million B.C. to 1990. *Quarterly Journal of Economics*, *108*, 681–716. https://doi.org/10.2307/2118405

Kuznets, S. (1960). Population change and aggregate output. In G. Roberts (ed.), *Demographic and economic change in developed countries*. 324-351, NBER.

Lee, R. D., & Mason, A. (2006). What is the demographic dividend?. *Finance and Development*, *43*, 16–17.

Leff, N. H. (1969). Dependency rates and savings rates. *American Economic Review*, *59*, 886–896.

Lesthaeghe, R., & van de Kaa, D. (1986). Twee demografische transities?, in R. Lesthaeghe, & D. van de Kaa (Eds.), *Bevolking–Groei en Krimp, Mens en Maatschappij*. 9-24, Van Loghum Slaterus, Deventer.

Levin, A., Lin, C. F., & Chu, C. (2002). Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics*, *108*, 1–24. https://doi.org/10.1016/S0304-4076(01)00098-7

Li, H., Zhang, J., & Zhang, J. (2007). Effects of longevity and dependency rates on saving and growth: Evidence from a panel of cross countries. *Journal of Development Economics*, *84*, 138–154. https://doi.org/10.1016/j.jdeveco.2006.10.002

Lopez, K., and Weber, S. (2017). Testing for Granger causality in panel data. *The Stata Journal*, *4*, 972–984.

Lopreite, M., & Mauro, M. (2017). The effects of population ageing on health care expenditure: A Bayesian VAR analysis using data from Italy. *Health Policy*, *121*, 663-674.

Lopreite, M., & Zhu, Z. (2020). The Effects of Ageing Population on Health Expenditure and Economic Growth in China: A Bayesian-VAR Approach. *Social Science and Medicine*, *265*, 1-12.

Macunovich, D. J. (2012). The role of demographics in precipitating economic downturns. *Journal of Population Economics*, *25*, 783–807. https://doi.org/10.1007/s00148-010-0329-5

Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*, *61*, 631–652. https://doi.org/10.1111/1468-0084.0610s1631

Mason, A. (1981). An extension of the life-cycle model and its application to population growth and aggregate saving. *East-West Population Institute Working Paper*, No. 4.

Mason, A. (1997). Population and the Asian economic miracle. *Asia-Pacific Population & Policy*, *43*.

Modigliani, F., & Brumberg, R. (1954). Utility analysis and the consumption function: An interpretation of cross section data. In K. K. Kurihara (Ed.), *Post-Keynesian economics*. 388-436, Rutgers University Press.

Preston, S. H. (1975). The changing relation between mortality and level of economic development. *Population Studies*, *29*, 231–248. https://doi.org/10.1080/00324728.1975.10410201

Preston, S. H. (2007). The changing relation between mortality and level of economic development. *International Journal of Epidemiology*, *36*, 484–490. https://doi.org/10.1093/ije/dym075

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of Political Economy*, *94*, 1002–1037. https://doi.org/10.1086/261420

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy*, *98*, S71–S102. https://doi.org/10.1086/261725

Solow, R. M. (1956). A contribution to the theory of economic growth. *Quarterly Journal of Economics*, *70*, 65–94. https://doi.org/10.2307/1884513

Swan, T. W. (1956). Economic growth and capital accumulation. *Economic Record*, *32*, 334–361. https://doi.org/10.1111/j.1475-4932.1956.tb00434.x

Taguchi, H. Ni Lar, & Ky, S. (2021). Revisiting the Effects of Demographic Dynamics on Economic Growth in Asia: A Panel Vector-Autoregressive Approach with a Saving Channel, *Asian-Pacific Economic Literature*, *35*, 77-94.

Yakita, A. (2006). Life expectancy, money, and growth. *Journal of Population Economics*, *19*, 579–592. https://doi.org/10.1007/s00148-005-0017-z

Zhang, J., Zhang, J., & Lee, R. (2001). Mortality decline and long-run economic growth. *Journal of Public Economics*, *80*, 485–507. https://doi.org/10.1016/S0047-2727(00)00122-5

Table 1 Panel Unit Root Tests

	g_{pcy}	g_{was}	*lfe*	*sav*	g_{pop}
[Intercept]					
Levin, Lin & Chu Test	-4.587 ***	-6.922 ***	-4.981 ***	-4.738 ***	-7.762 ***
Fisher ADF Chi-square	59.036 **	64.019 ***	29.047	55.991 **	70.625 ***
Fisher PP Chi-square	79.257 ***	24.376	49.110	75.650 ***	49.380
Im, Pesaran and Shin W-stat	-1.763	-2.512 ***	2.387	-1.681	-3.104 ***
[Intercept & Trend]					
Levin, Lin & Chu Test	-10.149 ***	-11.907 ***	-10.105 ***	-6.917 ***	-13.659 ***
Fisher ADF Chi-square	83.854 ***	78.193 ***	70.591 ***	63.725 ***	82.173 ***
Fisher PP Chi-square	117.949 ***	43.781	32.431	91.228 ***	79.502 ***
Im, Pesaran and Shin W-stat	-2.554 ***	-1.956 **	-0.872	-1.161	-2.306 **

Note: *, **, and *** denote rejection of the null hypothesis at the 10%, 5%, and 1% levels of significance. The critical values of the tests at 10%, 5%, and 1% are as follows:

Levin, Lin, and Chu test and Im, Pesaran, and Shin test: -1.77, -1.84, and -2.00

Fisher–ADF and Fisher–PP tests: 51.81, 55.76, and 63.69.

Source: Authors' estimations.

Table 2 Block Exogeneity Test on Five Endogenous Variables

[One-period lag]

Dependent Variable: g_{pcy}			
Excluded	Chi-sq	df	Probability
g_{was}	9.160	1	0.003
lfe	12.768	1	0.000
sav	0.925	1	0.336 (negative)
g_{pop}	0.040	1	0.841 (negative)
Dependent Variable: g_{was}			
Excluded	Chi-sq	df	Probability
g_{pcy}	0.222	1	0.638
lfe	4.361	1	0.037 (negative)
sav	2.458	1	0.117
g_{pop}	0.636	1	0.425
Dependent Variable: *lfe*			
Excluded	Chi-sq	df	Probability
g_{pcy}	2.744	1	0.098
g_{was}	3.230	1	0.072
sav	8.819	1	0.003 (negative)
g_{pop}	0.601	1	0.438

[Two-period lags]

Dependent Variable: g_{pcy}			
Excluded	Chi-sq	df	Probability
g_{was}	6.815	2	0.033
lfe	8.842	2	0.012
sav	0.231	2	0.891
g_{pop}	2.064	2	0.356 (negative)
Dependent Variable: g_{was}			
Excluded	Chi-sq	df	Probability
g_{pcy}	0.251	2	0.061
lfe	11.372	2	0.003 (negative)
sav	4.743	2	0.093
g_{pop}	9.153	2	0.010
Dependent Variable: *lfe*			
Excluded	Chi-sq	df	Probability
g_{pcy}	0.251	2	0.882
g_{was}	7.912	2	0.019
sav	2.676	2	0.262 (negative)
g_{pop}	7.489	2	0.024 (negative)

Source: Authors' estimations.

Table 3 Block Exogeneity Test on Three Endogenous Variables

Dependent Variable: g_{pcy}			
Excluded	Chi-sq	df	Probability
g_{was}	9.887	1	0.002
lfe	20.688	1	0.000
Dependent Variable: g_{was}			
Excluded	Chi-sq	df	Probability
g_{pcy}	0.000	1	0.992
lfe	1.519	1	0.218 (negative)
Dependent Variable: *lfe*			
Excluded	Chi-sq	df	Probability
g_{pcy}	1.095	1	0.295
g_{was}	4.496	1	0.034

Source: Authors' estimations.

Table 4 PVAR Model Estimation

	g_{pcy}	g_{was}	*ife*
g_{pcy} (-1)	0.238 ***	-0.019 *	0.029 *
	[3.413]	[-1.761]	[1.932]
g_{was} (-1)	0.908 **	0.424 ***	0.278 ***
	[2.164]	[6.439]	[3.045]
lfe (-1)	0.025 ***	0.002 **	1.009 ***
	[4.095]	[2.410]	[769.045]
pwy_0	-0.020 *	0.000	0.006 **
	[-1.657]	[0.259]	[2.348]
dm00	0.773 *	-0.071	0.173 *
	[1.892]	[-1.107]	[1.953]
dm10	-1.496 ***	-0.335 ***	0.099
	[-3.423]	[-4.885]	[1.045]
adj. R^2	0.186	0.434	0.986

Note: *, **, and *** denote the rejection of the null hypothesis at the 90%, 95%, and 99% significance levels, respectively. T statistics are in parentheses.

Source: Authors' estimations.

Table 5 Impulse Response Test

	Combination between g_{pcy} and g_{was}		Combination between g_{pcy} and lfe	
	from g_{was} *to* g_{pcy}	*from* g_{pcy} *to* g_{was}	*from* lfe *to* g_{pcy}	*from* g_{pcy} *to* lfe
1st	0.000	0.000	0.000	0.000
2nd	0.908 **	-0.019	0.025 **	0.029
3rd	0.608 **	-0.013	0.033 **	0.031
4th	0.303 **	-0.006	0.036 **	0.029
5th	0.137	-0.002	0.037 **	0.028
6th	0.064	-0.001	0.037 **	0.027
7th	0.035	-0.000	0.038 **	0.027
8th	0.024	-0.000	0.038 **	0.027

Note: ** denotes the rejection of the null hypothesis at the 95% significance level.

Source: Authors' estimations.

Table 6 Analysis of Demographic Effects in Periods of Population Bonus

Country	Population Bonus Period	Growth of *pcy* [annual, %] (a)	Growth of *was* [annual, %] (b)	Effect of g_{was} on g_{pcy} (c)	Increase in *lfe* [annual] (d)	Effect of *lfe* on g_{pcy} (e)	(c+e)/(a) (f)
Austria	1972–1989	2.443	0.630	0.573	0.271	0.010	0.238
Belgium	1970–1986	2.315	0.442	0.401	0.239	0.009	0.177
Bulgaria	1979–2005	1.938	0.174	0.158	0.059	0.002	0.083
Cyprus	1970–2010	3.697	0.456	0.415	0.171	0.006	0.114
Denmark	1974–1993	1.737	0.277	0.252	0.077	0.003	0.147
Finland	1970–1984	3.039	0.202	0.183	0.303	0.011	0.064
France	1972–1988	2.187	0.358	0.325	0.245	0.009	0.153
Greece	1972–1999	1.191	0.282	0.256	0.252	0.009	0.223
Hungary	1981–2010	1.381	0.246	0.224	0.181	0.006	0.167
Ireland	1970–2005	4.083	0.497	0.451	0.224	0.008	0.113
Italy	1976–1990	2.603	0.543	0.493	0.271	0.010	0.193
Luxembourg	1970–2020	2.266	0.142	0.129	0.249	0.009	0.061
Malta	1970–2008	4.819	0.274	0.249	0.239	0.009	0.053
Netherlands	1970–1989	1.872	0.528	0.480	0.162	0.006	0.259
Poland	1988–2010	2.815	0.431	0.392	0.255	0.009	0.142
Portugal	1970–2000	3.024	0.317	0.288	0.314	0.011	0.099
Romania	1980–2006	1.396	0.357	0.324	0.111	0.004	0.235
Spain	1972–2005	2.205	0.320	0.291	0.243	0.009	0.136
Sweden	1996–2009	2.105	0.215	0.196	0.183	0.007	0.096

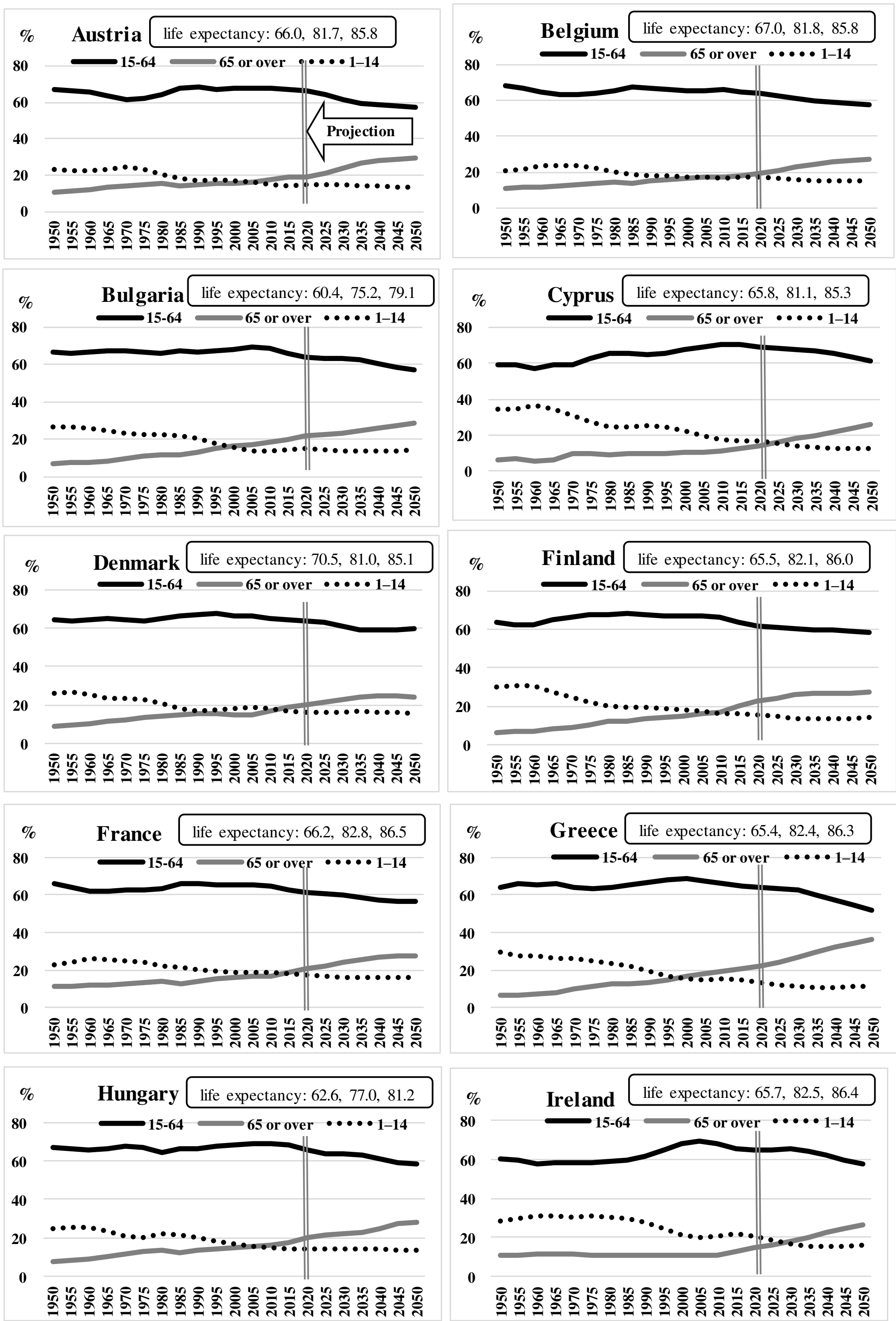
Source: Authors' estimations.

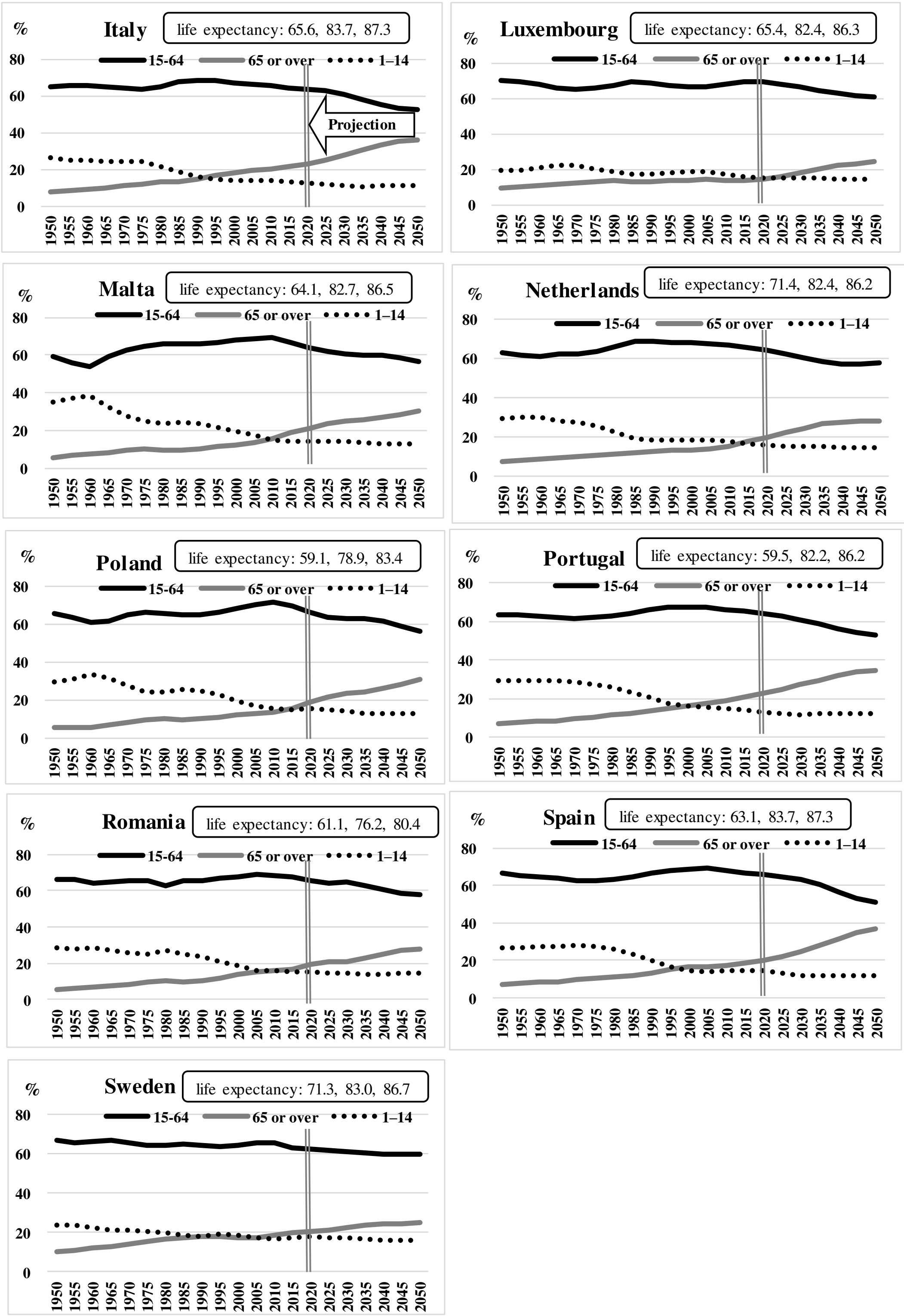
Table 7 Analysis of Demographic Effects over 2020–2050

Country	Growth of *was* [annual, %] (g)	Effect of g_{was} on g_{pcy} (h)	Increase in *lfe* [annual] (i)	Effect of *lfe* on g_{pcy} (j)	(h)+(j) (k)
Austria	-0.496	-0.450	0.138	0.005	-0.445
Belgium	-0.331	-0.301	0.135	0.005	-0.296
Bulgaria	-0.362	-0.329	0.131	0.005	-0.324
Cyprus	-0.398	-0.361	0.139	0.005	-0.357
Denmark	-0.193	-0.175	0.137	0.005	-0.170
Finland	-0.175	-0.159	0.129	0.005	-0.154
France	-0.292	-0.265	0.125	0.004	-0.261
Greece	-0.683	-0.621	0.128	0.005	-0.616
Hungary	-0.393	-0.357	0.139	0.005	-0.352
Ireland	-0.381	-0.346	0.131	0.005	-0.341
Italy	-0.652	-0.592	0.122	0.004	-0.588
Luxembourg	-0.460	-0.418	0.131	0.005	-0.414
Malta	-0.408	-0.371	0.128	0.005	-0.366
Netherlands	-0.363	-0.330	0.127	0.005	-0.325
Poland	-0.549	-0.499	0.150	0.005	-0.493
Portugal	-0.631	-0.574	0.133	0.005	-0.569
Romania	-0.396	-0.360	0.140	0.005	-0.355
Spain	-0.839	-0.762	0.120	0.004	-0.758
Sweden	-0.150	-0.136	0.125	0.004	-0.132

Source: Authors' estimations.

Figure 1 Demographic Dynamics in Europe during 1950–2050

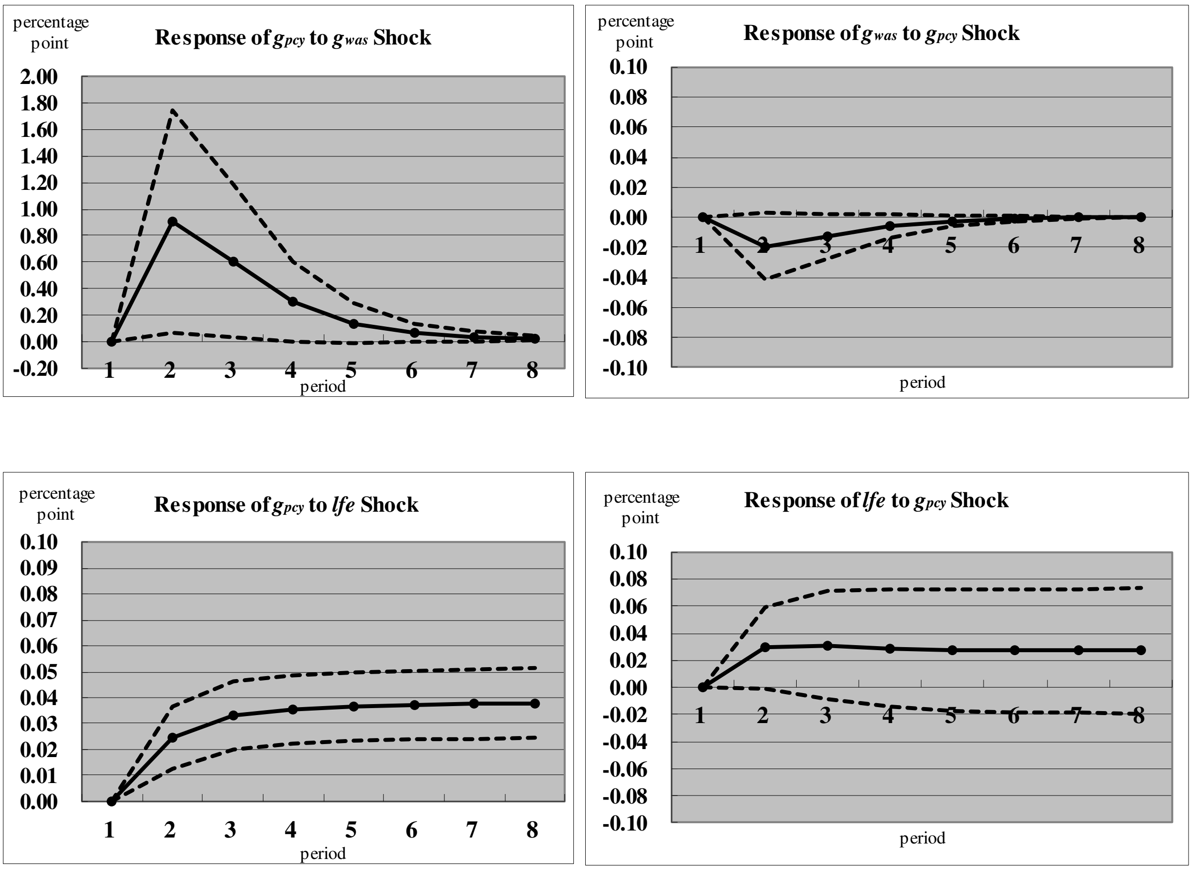




Note: The figures for life expectancy on each graph are those for 1950, 2020, and 2050.

Source: Created by the authors based on the 2019 Revision of World Population Prospects by the United Nations.

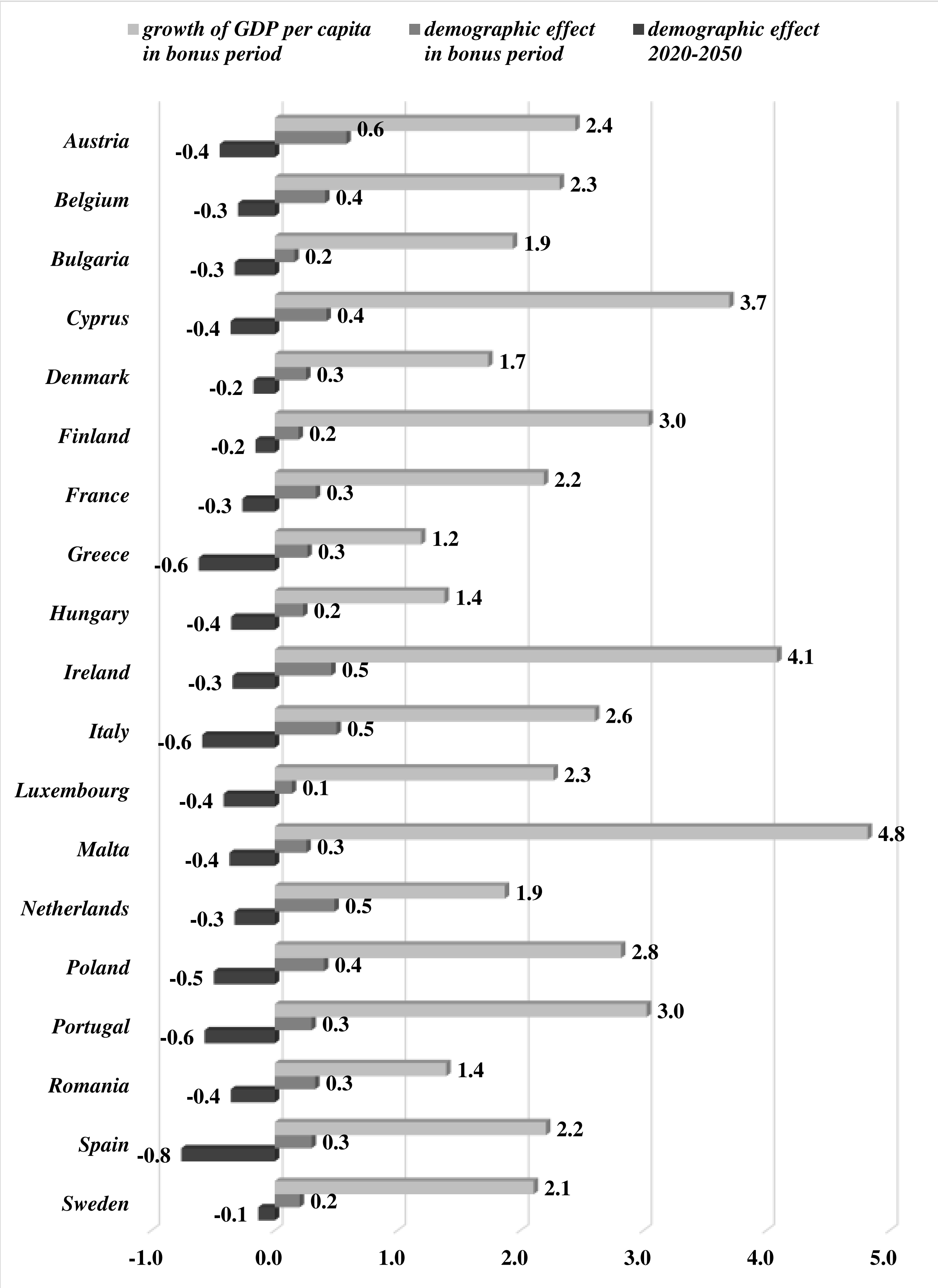
Figure 2 Impulse Response Test



Note: The dotted lines denote the 95% error bands over eight periods.

Source: Authors' estimations.

Figure 3 GDP growth and demographic effects



Source: Authors' estimations.