# Effects of Population Aging on Economic Growth: A Panel Analysis

**Hyun-Hoon Lee*, Hyeon-seung Huh, Young-Youn Lee, and Jae-Young Lim**

This paper aims to assess the effects of population aging on economic growth. We adopt the partial-adjustment model to regress the per capita GDP growth rates of 80 countries from 1960 to 2005 against a set of independent variables including the levels and changes in the proportions of the young and elderly population. Unlike the young population, the segment of the elderly population in the total population (or relative to the working-age population) does not indicate a "demographic burden" and does not inhibit economic growth in the short and long terms. Thus, in many countries, behavior responses to population aging occur in the form of high retirement savings, high labor force participation, and increased immigration of workers from developing countries. Thus, appropriate policies can be implemented to mitigate the adverse consequences of population changes.

*Keywords*: Economic growth, Population, Age structure, Demographic transition

*JEL Classification*: J10, O10, O15, O49

* Professor, Division of Economics and International Trades, Kangwon National University, Chuncheon 200-701, Korea, (Tel) +81-33-250-6186 (Fax) +81-33-256-4088, (E-mail) hhlee@kangwon.ac.kr; Professor, School of Economics, Yonsei University, Yonsei-ro, Seodaemun-gu, Seoul, Korea, (Tel) +81-2-2123-5499 (Fax) +81-2-2123-8638 (E-mail) hshuh@yonsei.ac.kr; Professor, Department of International Trade and Business, Kangwon National University, Chuncheon 200-701, Korea, (Tel) +81-33-250-6185 (Fax) +81-33-256-4088, (E-mail) yylee@kangwon.ac.kr; Associate Professor, Department of Food and Resource Economics, Korea University, Anam-dong 5 ga, Seongbuk-gu, Seoul, Korea, (Tel) +81-2-3290-3038 (Fax) +81-2-953-0737, (E-mail) jylimecon@korea.ac.kr, respectively.
[**Seoul Journal of Economics** 2013, Vol. 26, No. 4]

## I. Introduction

Most countries in the world have undergone an unprecedented transition in demographic behavior from high to low fertility and mortality rates after the end of World War II. This transition has resulted in rapid changes in the age structure of the population.

However, different countries are in different stages of an equally rapid transition in age structures. Many developed countries have populations that are among the oldest in the world, such as Japan, with a median age of nearly 45.9 years in 2013 (United Nations 2013). Many high-income countries, including Germany, Italy, Bulgaria, Greece, Austria, Croatia, Slovenia, Hong Kong, and Finland, are also among the 10 countries with the oldest population as of 2013.

Japan is projected to remain the oldest in the world with a median age of 55.8 years in 2050. Korea has a relatively younger population with a median age of 39.4 years in 2013. However, Korea is projected to become one of the five countries with the oldest population with a median age of 53.5 years in 2050.[1]

Most developed countries face a rapid increase in the number of elderly citizens. The populations of most developing countries are also poised to enter a period of rapid population aging (United Nations 2013). Given that population aging will decreases labor force participation and saving rates, population changes raise a valid concern on the possible deceleration of economic growth (Bloom, Canning, and Fink 2011).[2]

This paper assesses the effects of demographic transition on economic growth. Most literature on population focuses on the effects of the working-age population on economic growth (*e.g.*, Bloom, and Williamson 1998; Bloom, Canning, and Sevilla 2001; Bloom, Craig, and Malaney 2000; Bloom, Canning, and Sevilla 2003; Mason 2007; Bloom, David, Gunther, and Jocelyn 2009) By contrast, the current paper compares the long- and short-term effects of an aging and youthful population on economic growth.

To the best of our knowledge, 2 studies have estimated the statistical association of the proportions of young and elderly populations with

[1] By contrast, the 10 countries with the youngest population as of 2013 are mostly from Africa, such as Niger, Mali, Zambia, Somalia, Nigeria, Burundi, Uganda, Chad, Gambia, and Tanzania. African countries are projected to have the youngest populations in 2050.

[2] By contrast, Prettner (2013) develops an endogenous growth model wherein population aging fosters long-term growth.

**TABLE 1**

TEN COUNTRIES/AREAS WITH THE OLDEST AND YOUNGEST POPULATIONS IN 1980, 2013, AND 2060 (MEDIUM VARIANT)

| 1980 | | 2013 | | 2050 | |
|---|---|---|---|---|---|
| Country or area | Median age (years) | Country or area | Median age (years) | Country or area | Median age (years) |
| A. Oldest populations | | | | | |
| 1. Germany | 36.7 | 1. Japan | 45.9 | 1. Qatar | 55.8 |
| 2. Sweden | 36.3 | 2. Germany | 45.5 | 2. Other non-specific areas | 54.5 |
| 3. Luxembourg | 35.0 | 3. Italy | 44.3 | | |
| 4. Latvia | 35.0 | 4. Bulgaria | 43.0 | 3. Cuba | 54.1 |
| 5. Channel Islands | 34.9 | 5. Greece | 42.8 | 4. China, Hong Kong | 53.9 |
| 6. Austria | 34.9 | 6. Austria | 42.7 | 5. Republic of Korea | 53.5 |
| 7. Switzerland | 34.6 | 7. Croatia | 42.6 | 6. Japan | 53.4 |
| 8. Hungary | 34.4 | 8. Slovenia | 42.4 | 7. Portugal | 52.5 |
| 9. United Kingdom | 34.4 | 9. China, Hong Kong | 42.4 | 8. Germany | 51.5 |
| 10. Denmark | 34.3 | | | 9. Thailand | 51.1 |
| | | 10. Finand | 42.3 | 10. Oman | 50.8 |
| B. Youngest populations | | | | | |
| 1. Kenya | 15.0 | 1. Niger | 15.0 | 1. Niger | 17.5 |
| 2. State of Palestine | 15.1 | 2. Uganda | 15.8 | 2. Mali | 19.7 |
| 3. Mayotte | 15.4 | 3. Chad | 15.8 | 3. Zambia | 20.1 |
| 4. Jordan | 15.5 | 4. Angola | 16.3 | 4. Somalia | 21.3 |
| 5. Yemen | 15.5 | 5. Mali | 16.3 | 5. Nigeria | 21.4 |
| 6. Zimbabwe | 15.5 | 6. Somalia | 16.3 | 6. Burundi | 22.0 |
| 7. Swaziland | 15.6 | 7. Afghanistan | 16.5 | 7. Uganda | 22.0 |
| 8. Syrian Arab Republic | 15.6 | 8. Timor-Leste | 16.6 | 8. Chad | 22.0 |
| | | 9. Zambia | 16.6 | 9. Gambia | 22.1 |
| 9. Rwanda | 16.0 | 10. Gambia | 17.0 | 10. United Rep. of Tanzania | 22.3 |
| 10. Uganda | 16.2 | | | | |
| World | 22.6 | World | 29.2 | World | 36.1 |

Note: Only countries or areas with 90,000 persons or more in 2013 are considered.

Source: United Nations (2013), World Population Prospects The 2013 Revision: Key Findings and Advance Tables, ESA/P/WP.227, Department of Economic and Social Affairs, New York" United Nations.

economic growth. The study conducted by Huh, Lee, and Lee (2003, 2007) uses a partial-adjustment model on the 1993 data of 77 countries for 2 years. The results indicate that a relatively large population of children and elderly has a negative effect on economic growth. They find that the relative size of the elderly in the total population has a greater

negative effect on economic growth than an increase in the relative number of children. By contrast, Bloom, Canning, and Fink (2008) construct a panel dataset and show in a first-difference model that the rate of aging negatively and insignificantly affects growth in the short and long terms, respectively. This finding is caused by the mitigation of the negative effect of aging by behavioral responses, such as high retirement savings, high labor force participation, and increased immigration of workers from developing countries. This argument can also be found in Bloom, Canning, and Fink (2011) and Bloom, Canning, and Finlay (2008).

This paper re-evaluates the effects of population aging by using the partial-adjustment model in a panel framework comprising the 1960~2005 data of 80 countries. Unlike the youth population, the proportion of the elderly in the total population (or relative to the working-age population) does not constitute a "demographic burden" and does not inhibit economic growth the short and long terms.

This paper is organized as follows. Section II provides a theoretical model of economic growth and explains the proportion of the young and elderly population. Conventional facts regarding the relation between the demographic factors and economic growth and the relation among the demographic factors are also provided in Section II. Section III presents an empirically testable model of economic growth that distinguishes the effect of the young and elderly population. Section IV shows the empirical results. Section V discusses the implications of the major findings of the paper.

## II. Theory and conventional facts

### *A. Theoretical model*

Demographic patterns are closely associated with labor supply and savings, that is, labor supply and savings are higher among working-age adults than among the elderly (Park and Lee 2007; Bloom, Caning, and Fink 2008). Therefore, a country with a significant number of the working-age population is likely to experience faster economic growth than a country with large groups of young and elderly populations.

To show theoretically the effect of age structure on economic growth, we present a growth model that incorporates age structure.

We assume that the aggregate output corresponds to a three-factor Cobb-Douglas production function:

$$Y = AK^{\alpha}H^{\phi}L^{1-\alpha-\phi}, \tag{1}$$

where $Y$ is the gross domestic product, $K$ is the physical capital, $H$ is the human capital, $L$ is the labor force, and $A$ is the productivity level.

Dividing both sides by population P yields Equation (2):

$$y = AK^{\alpha}H^{\phi}(L / P)^{1-\alpha-\phi}P^{-\alpha-\phi}, \tag{2}$$

where $y=Y/P$ and denotes income per capita.

By taking the natural logarithm of both sides, we obtain the following:

$$\ln y = \ln A + \alpha \ln K + \phi \ln H + (1 - \alpha - \phi)\ln(L / P) - (\alpha + \phi)\ln P, \tag{3}$$

By defining the population $P$ as the sum of the young population $C$, labor force $L$ (proxied by the working-age population), and elderly population $O$, we obtain the following:

$$\ln y = \ln A + \alpha \ln K + \phi \ln H + (1 - \alpha - \phi)\ln\left(\frac{P - C - O}{P}\right) - (\alpha + \phi)\ln P. \tag{4}$$

An implication of Equation (3) is that the sign of coefficient on the proportion of the working-age population is positive. Equation (4) implies that the signs of coefficients on the proportions of young and elderly populations are negative and that their sizes should be the same. On one hand, a country with a large proportion of working-age population is likely to experience faster economic growth than a country with large groups of youth and elderly populations. On the other hand, a country with large young or elderly populations is likely to develop slower than a country with a large proportion of working-age population.

However, this model assumes that age-specific behavior remains unchanged. If behavior responses change with varying expectations on life cycle and demographic shifts, empirical analysis shows that the magnitudes of the coefficients on the young and elderly proportion are different. (*i.e.*, the young and elderly proportions have different effects on income per capita).

Bloom, Canning, and Fink (2008) note that behavior responses to population aging can occur in the form of high retirement savings, high labor

force participation, and increased immigration of workers from developing countries. They also note that appropriate policies can mitigate the adverse consequences of population changes.

Thus, the extent of behavioral implications on mitigating the negative effects of population aging is an empirical question. Huh, Lee, and Lee (2007) show that the elderly population has an adverse effect on economic growth, thus implying that the negative effects of aging is not mitigated significantly by behavioral response. By contrast, the regression analysis of Bloom, Canning, and Fink (2008) indicate that the elderly population negatively and insignificantly affects growth in the short and long terms, respectively.

For the dynamics of economic growth, suppose that the steady state of the log of income per capita $\ln y$ at time $t$ is $\ln y^*$. The relationship between the actual and steady state of $\ln y$ can be specified as follows:

$$(\ln y_t - \ln y_{t-1}) = \delta(\ln y_t^* - \ln y_{t-1}), \tag{5}$$

where $\delta$ is the rate of adjustment (or speed of conversion) and is bounded by zero and one.

Given that $\ln y_t^*$ is not observed, the implementation of Equation (5) requires the development of empirical analogues for the steady state of income per capita at time $t$.

One formula assumes that $\ln y_t^*$ is determined by the $\ln y$ determinant level in period $t-1$ and the difference forms, which incorporate changes in the long-term extent of $\ln y$ between periods $t-1$ and $t$. Thus, the equation for changes in $\ln y$ is expressed as follows:

$$(\ln y_t - \ln y_{t-1}) = -\delta \ln y_{t-1} + X_{t-1}\lambda_1 + (X_t - X_{t-1})\lambda_2 + \mu_t, \tag{6}$$

where $X$ is a vector of explanatory variables, which are summarized in Equation (4); $\mu_t$ is an error term.

This partial-adjustment model can be found in the works of Stone and Lee (1995) and Hayakawa *et al.* (2013). The $\lambda$ coefficients on each variable level represent the long-term coefficient ($\beta$), whereas the $\lambda$ coefficients on the first-difference variables represent the short-term adjustments to contemporaneous changes in the $\ln y$ determinants.

Equation (7) can be written as follows:

$$\ln y_t = (1 - \delta) \ln y_{t-1} + X_{t-1}\lambda_1 + (X_t - X_{t-1})\lambda_2 + \mu_t. \tag{7}$$

By including a lagged dependent variable on the right-hand side of the regression equations, the error terms of Equations (6) and (7) may be correlated again with the lagged dependent variables. Therefore, we also estimate Equation (7) by using the system generalized method of moment (GMM) estimator of Blundell and Bond (1998).

In the empirical analysis in the following section, we attempt to evaluate this estimation by using an empirically robust estimation procedure.

### *B. Conventional facts*

Before we present the empirical specifications, we describe some of the major features of the cross-country relationship between economic growth and changes in age structure. We also present the relationship among demographic factors. Our goal is to identify the salient patterns that must be considered in formal regression analysis.

Similar to most empirical literature on growth, we focus on the period between 1960 and 2005.[3] Moreover, we use GDP data from the Penn World Table (PWT) Version 6.3, specifically the real GDP per capita calculated by using the Laspeyres price index. Data on age structure are obtained from the World Bank Development Indicators.

Figure 1 is a scatter diagram that shows the general pattern of cross-country relationship between economic growth (first difference of logs of GDPs per capita between 1960 and 2005; lrgdpl_c) and the average proportion of working-age population aged between 15 and 64 (Pop1564_av) from 1960 to 2005. Figure 2 is a scatter diagram that shows the relationship between economic growth and changes in the working-age proportion (Pop1564_c) during the same period. A positive relation in both figures is noted; thus, these two figures support the general perception that countries with greater working-age populations tend to grow faster.

Figure 3 is a scatter diagram that shows the relationship between economic growth and the average proportion of young population (Pop0014_av) during the same period. Figure 4 is a corresponding diagram that shows the relationship between growth and changes in the young population (Pop0014_c). These two figures reveal a negative relation between growth and a young population, thus implying that countries with high proportions of young populations grow slowly.

By contrast, Figures 5 and 6 represent the cross-country relations between economic growth and the average proportion of elderly population

[3] The year 1960 is the point wherein national account data for large groups of countries start to become available.

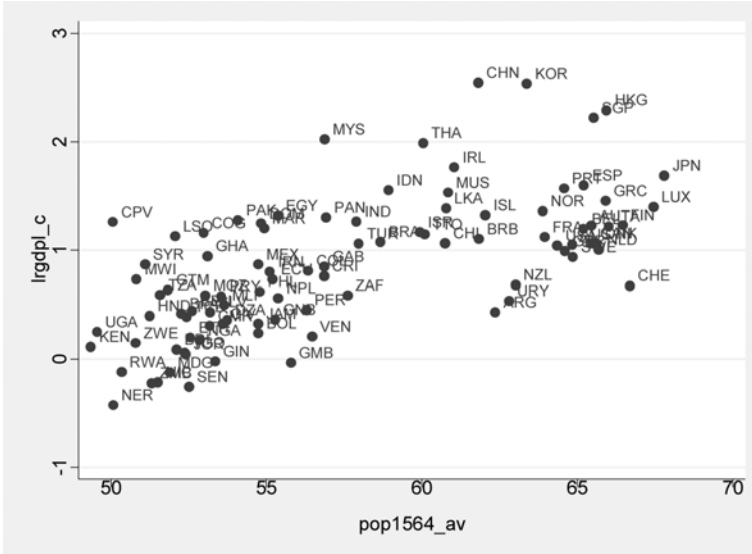


**FIGURE 1**

ECONOMIC GROWTH VERSUS THE AVERAGE PROPORTION OF WORKING-AGE POPULATION (1960-2005).

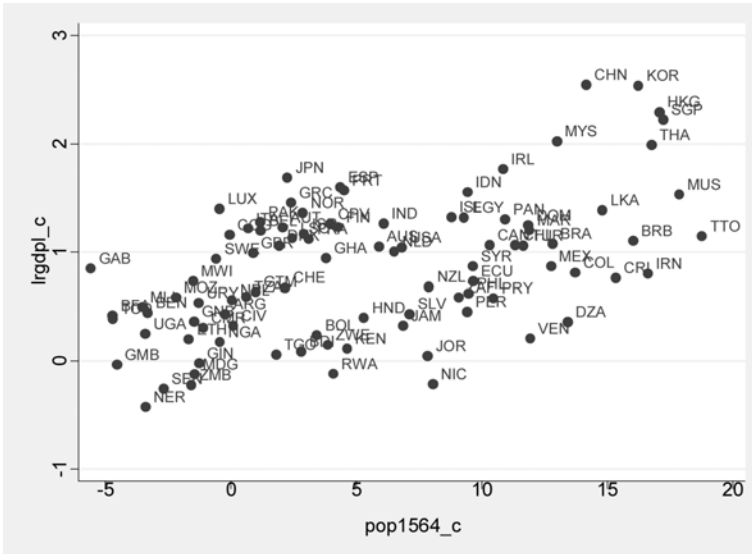


**FIGURE 2**

ECONOMIC GROWTH VERSUS CHANGES IN THE PROPORTION OF THE WORKING-AGE POPULATION (1960-2005).

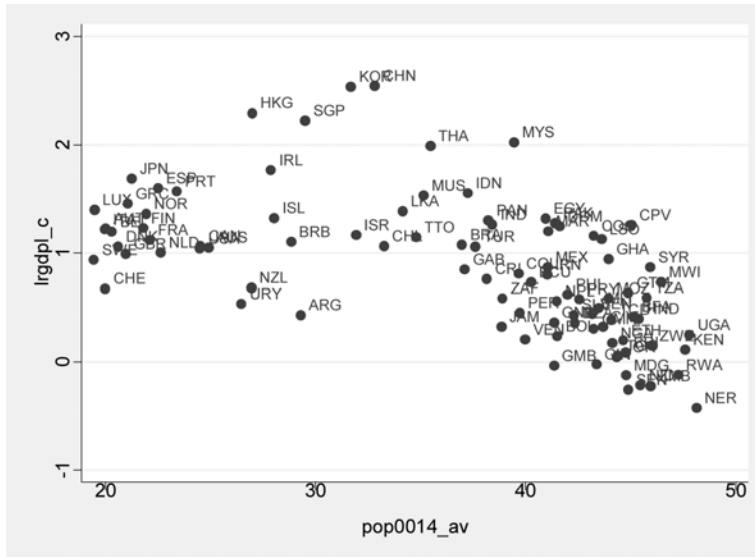


**FIGURE 3**
ECONOMIC GROWTH VERSUS THE AVERAGE PROPORTION OF THE YOUNG POPULATION (1960-2005).

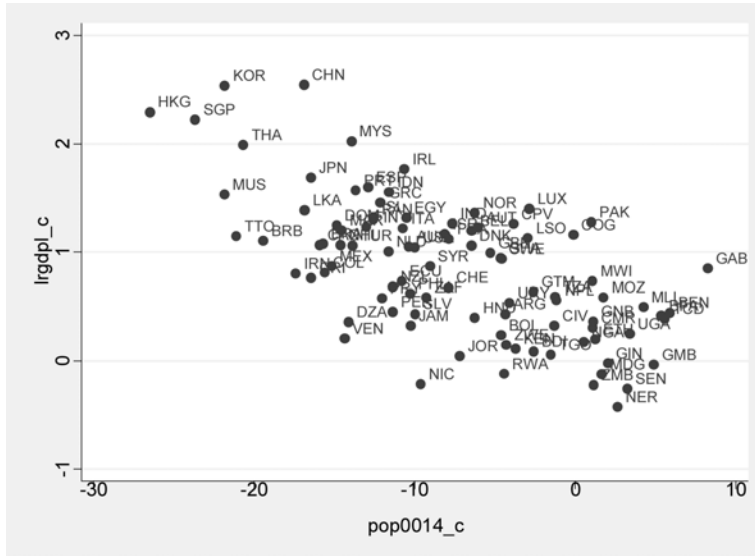


**FIGURE 4**
ECONOMIC GROWTH VERSUS CHANGES IN THE PROPORTION OF YOUNG POPULATION (1960-2005).

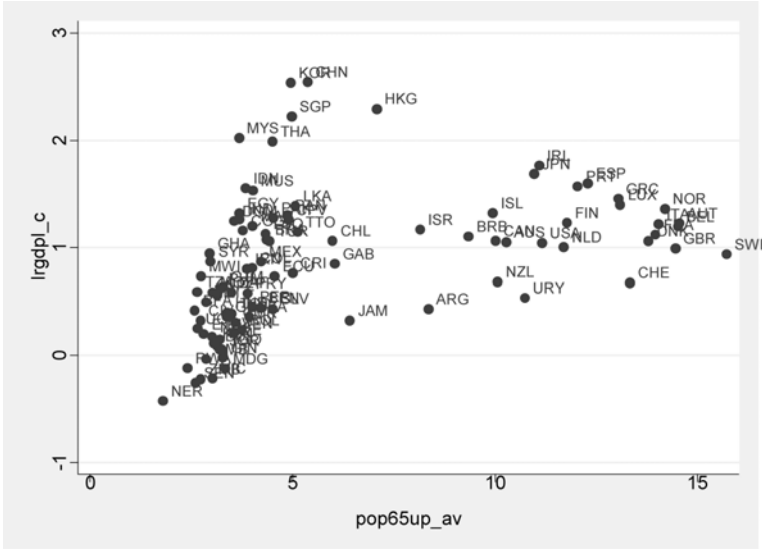


**FIGURE 5**
ECONOMIC GROWTH VERSUS THE AVERAGE PROPORTION OF ELDERLY PROPORTION (1960-2005).

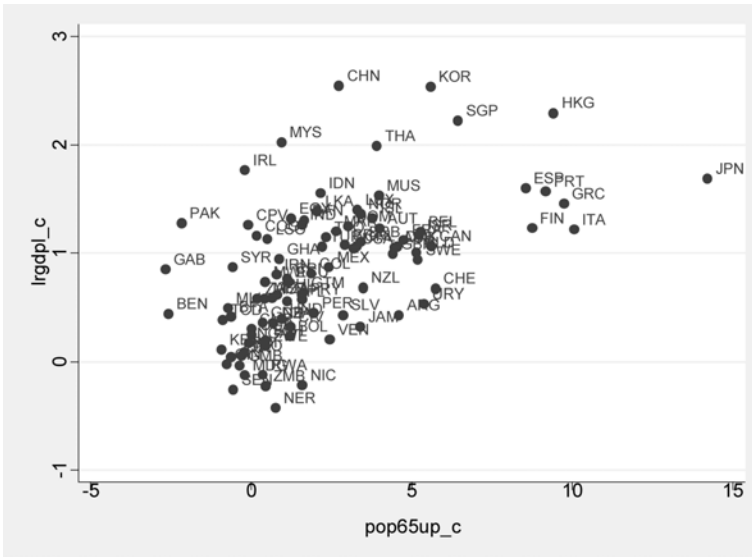


**FIGURE 6**
ECONOMIC GROWTH VERSUS CHANGES IN THE PROPORTION OF ELDERLY POPULATION (1960-2005).

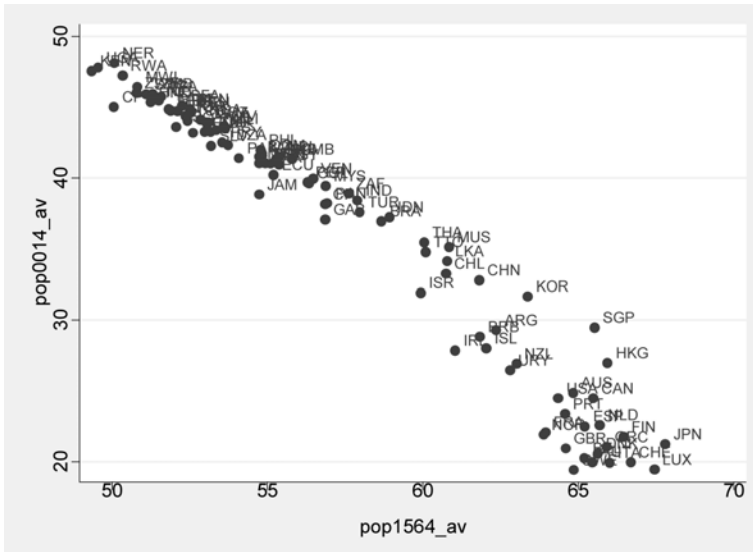


**FIGURE 7**
AVERAGE PROPORTION OF YOUNG POPULATION VERSUS THE AVERAGE PROPORTION OF WORKING-AGE POPULATION (1960-2005).

(Pop65_av), as well as between growth and changes in the proportion of elderly population (Pop65_c). Both figures reveal a positive relation between economic growth and the proportion of elderly population. Thus, countries with large and fast growing percentages of elderly tend to progress rapidly.

However, this does not necessarily suggest that behavioral changes are significant enough to offset the adverse consequences of increases in the proportion of elderly population on economic growth. The proportion of elderly population increases with increasing income. Thus, causality may also encompass income and demographic patterns because life expectancy increases with increasing income, which in turn increases the proportion of elderly population.

Although a high proportion of young people leads to small proportions of working-age population, a high proportion of elderly population does not coincide with small proportion of working-age population. Figures 7 and 10 support this view. Figure 7 reveals that countries with high proportions of young populations also have small proportions of working-age populations. Figure 8 reveals that countries with rapidly decreasing pro-

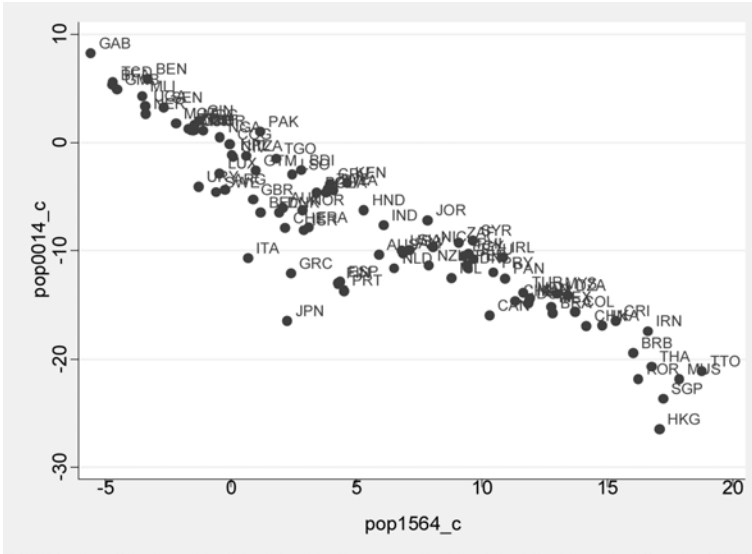


**FIGURE 8**
CHANGES IN THE PROPORTION OF THE YOUNG POPULATION VERSUS CHANGES IN THE PROPORTION OF THE WORKING-AGE POPULATION (1960-2005).

portions of young populations also experience a rapid increase in the proportions of working-age populations. By contrast, Figure 9 reveals that countries with high proportions of elderly populations also have high proportions of working-age populations. Figure 10 suggests that countries with rapidly increasing proportions of elderly populations do not witness a rapid decrease in the proportions of working-age populations. Thus, a simple cross-country relation can reveal a positive association between the proportion of elderly population and economic growth because a positive association exists between the proportion of working-age population and economic growth.

Other factors may also influence both GDP growth rate and demographic transition. Therefore, a simple correlation without considering such factors may be subjective.

An empirical specification investigating the partial effects of demographic transition on growth should be designed to address these possibilities.

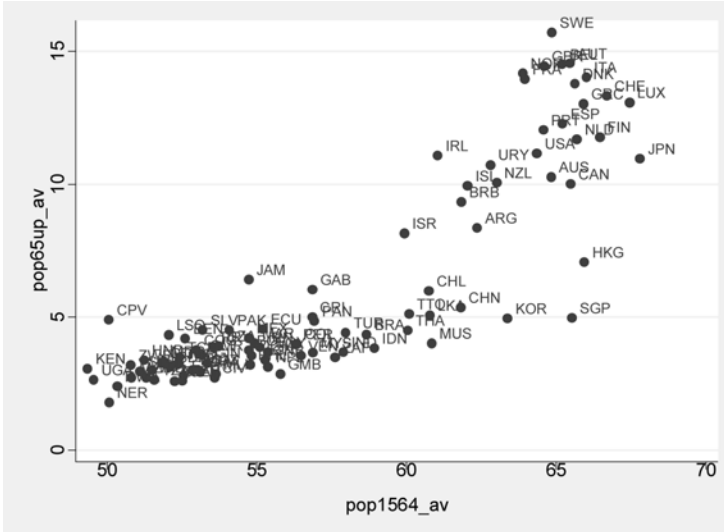


**FIGURE 9**

AVERAGE PROPORTION OF ELDERLY PROPORTION VERSUS THE AVERAGE PROPORTION OF WORKING-AGE POPULATION (1960-2005).

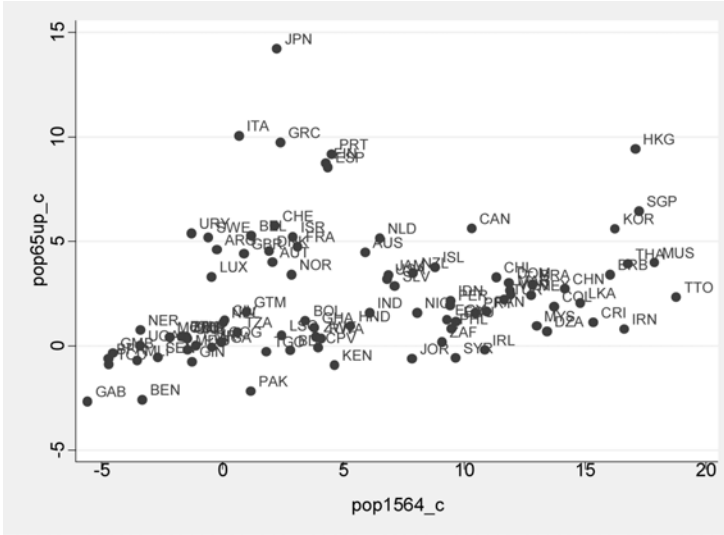


**FIGURE 10**

CHANGES IN THE PROPORTION OF ELDERLY POPULATION VERSUS CHANGES IN THE PROPORTION OF WORKING-AGE POPULATION (1960-2005)

## III. Empirical specification

Unlike most studies on cross-country regression that investigates the role of age structure on growth (Bloom and Canning 2004; Bloom, Canning, and Sevilla 2003; Bloom, Canning, Fink, and Finlay 2007), we use a panel data set of 80 countries observed every 5 years from 1960 to 2005.

We control the country-fixed effects and include year dummies to consider factors, such as world business cycle and global capital market shocks. We assume that the productivity of the economy $\ln(A)$ is a function of openness, population, and time-invariant country-fixed effects.

Thus, Equation (6) becomes the following empirically tested equation:

$$\begin{aligned}(\ln y_{it} - \ln y_{it-1}) &= -\delta \ln y_{it-1} + \beta_1 Cap\_inv_{it-1} + \beta_2 Tyr_{it-1} + \beta_3 Open_{it-1} \\ &+\beta_4 Pop0014_{it-1} + \beta_5 Pop65up_{it-1} + \beta_6 \ln Pop_{it-1} + \beta_7 \ln \tau_i \\ &+\beta_8 (Cap\_inv_{it} - Cap\_inv_{it-1}) + \beta_9 (Tyr_{it} - Tyr_{it-1}) + \beta_{10} (Open_{it} - Open_{it-1}) \\ &+\beta_{11} (Pop0014_{it} - Pop0014_{it-1}) + \beta_{12} (Pop65up_{it} - Pop65up_{it-1}) \\ &+\beta_{13} (\ln Pop_{it} - \ln Pop_{it-1}) + \mu_i + \mu_t + \xi_t,\end{aligned} \tag{8}$$

where

$\ln y_{it-1}$ = ln_gdp_1 = Log of GDP per capita in the previous period

*Cap_inv* = Gross Capital Formation (% of GDP) (World Bank Development Indicators)

*Tyr* = Average schooling years in the total population (Barro and Lee 2010)

ln*Pop* = Log of total population; World Bank Development Indicators

*Pop*0014 = share of young population = population aged below 15 (% of total) (World Bank Development Indicators)

*Pop*65*up* = share of elderly population = population aged above 65 (% of total) (World Bank Development Indicators)

$\tau_i = Airdist_i^{\delta_1} \exp(\delta_2 Landlocked_i + \delta_3 Oil_i + \delta_4 Colonyy_i + \delta_5 EAsia_i)$

*Open* = openness (total trade divided by GDP) − PWT

*Landlocked* = Landlocked dummy − CEPII (www.cepii.fr)

*Oil* = Oil-producing country dummy

*Airdist* = Log of air distance to big cities

*Colony* = Colony dummy

*EAsia* = East Asian country dummy

As shown above, GDP per capita data are obtained from PWT 6.3. To verify the robustness, we use real GDP per capita obtained online from the World Bank Development Indicators. We restrict our analysis to countries that have interest series available throughout the sample period (1960-2005); hence, a panel of 80 countries. The Appendix Table provides a complete list of countries with age structure.

Most empirical models include regional dummies, usually for East Asia and Sub-Saharan Africa, and note the poor performance of Africa and the exceptional performance of East Asia, which cannot be explained within the model. We follow literature by including regional dummies for East Asian and Sub-Saharan countries. Regional dummies for European and Latin American countries are also included.

## IV. Estimation results

Before examining the effects of the proportions of young and elderly populations on economic growth, we present the estimated results in Table 2 when the proportion of working-age population is included in the growth equation where the dependent variable is the real GDP per capita from PWT 6.3. The results are obtained by four different models, namely, ordinary least squares (OLS), random effects, fixed effects, and system GMM.

By referring to the estimates in Column 1 of the OLS model, the coefficient on the initial level of income per capita is negative and significant at the 1% level, thus indicating that high-income countries develop slower than low-income countries. Countries with significant proportions of capital investment in GDP have high economic growth rates. By contrast, landlocked countries grow slowly. Furthermore, East Asian countries progress rapidly, whereas sub-Saharan African countries develop slowly. Bloom, Canning, and Malaney (2000) argue that when age structure variables are introduced into an economic growth model, the statistical significance of the regional dummy variables disappears. Our finding does not support this argument.

The coefficient on the log of population has a negative but insignificant coefficient. By contrast, both the proportion of working-age population in the base year (five years ago) and its changes over the five-year period have positive coefficients that are significant at the 1% level. Therefore, an increase in the proportion of working-age population fosters economic growth in the short and long terms. This finding confirms the

**TABLE 2**

EFFECTS OF THE PROPORTION OF WORKING-AGE POPULATION ON ECONOMIC GROWTH

| | Dep Var: Real GDP per capita, Laspeyres | | | |
|---|---|---|---|---|
| | OLS | Random effects | Fixed effects | System GMM |
| | (1) | (2) | (3) | (4) |
| Log real GDP per capita in the base year | -0.066*** | -0.076*** | -0.289*** | 1.041*** |
| | (0.017) | (0.019) | (0.027) | (0.037) |
| Log total population in the base year | 0.000 | -0.000 | -0.255*** | -0.010 |
| | (0.005) | (0.006) | (0.047) | (0.014) |
| Working age share in the base year | 0.009*** | 0.010*** | 0.011*** | 0.010*** |
| | (0.002) | (0.002) | (0.002) | (0.003) |
| Capital-GDP ratio in the base year | 0.005*** | 0.005*** | 0.008*** | 0.007*** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Average schooling years of population in the base year | 0.002 | 0.004 | 0.015 | -0.001 |
| | (0.004) | (0.005) | (0.011) | (0.016) |
| Openness in the base year | 0.000 | 0.000 | 0.000 | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.001) |
| Change in total population | -0.029 | 0.007 | 0.129 | 0.027 |
| | (0.139) | (0.132) | (0.163) | (0.120) |
| Change in working age share | 0.014*** | 0.013*** | 0.004 | 0.012** |
| | (0.004) | (0.004) | (0.004) | (0.005) |
| Change in capital-GDP ratio | 0.007*** | 0.007*** | 0.007*** | 0.011*** |
| | (0.001) | (0.002) | (0.001) | (0.002) |
| Change in average schooling years | -0.009 | -0.009 | 0.002 | -0.013 |
| | (0.012) | (0.012) | (0.013) | (0.013) |
| Change in openness | -0.000 | -0.000 | 0.000 | -0.001** |
| | (0.000) | (0.001) | (0.000) | (0.000) |
| Landlocked | -0.035** | -0.040** | | |
| | (0.016) | (0.018) | | |
| Oil producer | -0.038 | -0.035* | | |
| | (0.031) | (0.020) | | |
| Log air distance form big cities | -0.004 | -0.006 | | |
| | (0.007) | (0.007) | | |
| Colony | 0.004 | 0.003 | | |
| | (0.023) | (0.018) | | |

*(Table 2 Continued)*

**TABLE 2**
(CONTINUED)

| | Dep Var: Real GDP per capita, Laspeyres | | | |
|---|---|---|---|---|
| | OLS | Random effects | Fixed effects | System GMM |
| | (1) | (2) | (3) | (4) |
| East Asia | 0.046** | 0.047 | | |
| | (0.021) | (0.031) | | |
| Sub-Saharan Africa | -0.045** | -0.048** | | |
| | (0.020) | (0.024) | | |
| Europe | 0.031 | 0.038 | | |
| | (0.022) | (0.027) | | |
| Latin America | -0.000 | 0.005 | | |
| | (0.017) | (0.022) | | |
| Constant | 0.009 | 0.102 | 5.687*** | -0.856** |
| | (0.168) | (0.225) | (0.838) | (0.337) |
| Country dummy | No | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes |
| R2 | 0.388 | 0.387 | 0.382 | |
| Number of observations | 603 | 603 | 603 | 616 |
| Number of countries | | 78 | 78 | 80 |
| Arellano-Bond test | | | | |
| AR(1) | | | | -3.114 |
| p-value | | | | 0.002 |
| AR(2) | | | | 1.005 |
| p-value | | | | 0.315 |
| Overidentification test (Sargan) | | | | |
| Chi-squared | | | | 19.955 |
| p-value | | | | 0.174 |

Notes: Shown in parentheses are standard errors. ***, **, and * denote one, five, and ten percent level of significance, respectively. R2 for random effects model is overall R2 and for fixed effects model is within R2.

demographic shares found in other studies. This finding remains robust not only in the random and fixed effects model but also in the system GMM model.

Table 3 presents the estimates by using the proportions of young and elderly populations in the total population in place of the proportion of working-age population. Columns 1 to 4 and Columns 5 to 8 report the results when the dependent variable is the real GDP per capita obtained

**TABLE 3**

EFFECTS OF POPULATION AGING ON ECONOMIC GROWTH
(DEMOGRAPHIC VARIABLES: PROPORTION IN THE TOTAL POPULATION)

| | Dep Var: Real GDP per capita, Laspeyres | | | | Dep Var: Real GDP per capita, World Bank | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | Random effects | Fixed effects | System GMM | OLS | Random effects | Fixed effects | System GMM |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Log real GDP per capita in the base year | -0.069*** (0.018) | -0.080*** (0.020) | -0.289*** (0.027) | 1.014*** (0.046) | -0.031*** (0.007) | -0.038*** (0.008) | -0.259*** (0.023) | 1.015*** (0.026) |
| Log total population in the base year | -0.000 (0.005) | -0.001 (0.006) | -0.270*** (0.061) | -0.017 (0.015) | -0.001 (0.004) | -0.002 (0.005) | -0.258*** (0.050) | -0.026 (0.021) |
| Youth age share in the base year | -0.010*** (0.002) | -0.010*** (0.002) | -0.010*** (0.003) | -0.009*** (0.002) | -0.008*** (0.002) | -0.008*** (0.002) | -0.010*** (0.002) | -0.008*** (0.003) |
| Old age share in the base year | -0.004 (0.003) | -0.003 (0.004) | -0.013 (0.008) | -0.003 (0.007) | -0.001 (0.003) | -0.000 (0.003) | -0.011 (0.007) | -0.003 (0.006) |
| Capital-GDP ratio in the base year | 0.005*** (0.001) | 0.005*** (0.001) | 0.008*** (0.001) | 0.007*** (0.001) | 0.005*** (0.001) | 0.006*** (0.001) | 0.008*** (0.001) | 0.009*** (0.001) |
| Average schooling years of population in the base year | 0.000 (0.005) | 0.002 (0.005) | 0.016 (0.011) | 0.003 (0.016) | -0.003 (0.004) | -0.001 (0.004) | 0.016* (0.009) | -0.008 (0.014) |
| Openness in the base year | 0.000 (0.000) | 0.000 (0.000) | 0.000 (0.000) | -0.000 (0.001) | 0.000 (0.000) | 0.000 (0.000) | 0.001** (0.000) | -0.000 (0.000) |
| Change in total population | 0.003 (0.141) | 0.039 (0.140) | 0.132 (0.168) | -0.003 (0.096) | 0.038 (0.136) | 0.068 (0.137) | 0.133 (0.138) | -0.180 (0.156) |
| Change in youth age share | -0.016*** (0.005) | -0.015*** (0.005) | -0.004 (0.004) | -0.014*** (0.005) | -0.019*** (0.004) | -0.018*** (0.004) | -0.009** (0.004) | -0.017*** (0.005) |
| Change in old age share | -0.031*** (0.011) | -0.027** (0.011) | 0.002 (0.015) | 0.007 (0.016) | -0.034*** (0.009) | -0.031*** (0.009) | -0.005 (0.012) | -0.007 (0.012) |
| Change in capital-GDP ratio | 0.007*** (0.001) | 0.007*** (0.001) | 0.007*** (0.001) | 0.011*** (0.002) | 0.008*** (0.001) | 0.008*** (0.001) | 0.008*** (0.001) | 0.012*** (0.002) |
| Change in average schooling years | -0.009 (0.011) | -0.008 (0.011) | 0.003 (0.013) | -0.009 (0.013) | -0.011 (0.009) | -0.010 (0.009) | 0.006 (0.011) | -0.011 (0.011) |
| Change in openness | -0.000 (0.000) | -0.000 (0.000) | 0.000 (0.000) | -0.001** (0.000) | 0.000 (0.000) | 0.000 (0.000) | 0.000* (0.000) | -0.000 (0.000) |
| Landlocked | -0.034** (0.016) | -0.039** (0.018) | | | -0.029** (0.014) | -0.032** (0.016) | | |
| Oil producer | -0.039 (0.030) | -0.034 (0.035) | | | -0.068*** (0.024) | -0.065** (0.028) | | |
| Log air distance form big cities | -0.004 (0.006) | -0.006 (0.007) | | | -0.007 (0.005) | -0.009 (0.006) | | |

*(Table 3 Continued)*

**TABLE 3**
(CONTINUED)

| | Dep Var: Real GDP per capita, Laspeyres | | | | Dep Var: Real GDP per capita, World Bank | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | Random effects | Fixed effects | System GMM | OLS | Random effects | Fixed effects | System GMM |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Colony | 0.013 | 0.014 | | | 0.010 | 0.009 | | |
| | (0.025) | (0.028) | | | (0.019) | (0.022) | | |
| East Asia | 0.052** | 0.052** | | | 0.055*** | 0.055*** | | |
| | (0.021) | (0.024) | | | (0.019) | (0.021) | | |
| Sub-Saharan Africa | -0.044** | -0.047** | | | -0.049*** | -0.050** | | |
| | (0.020) | (0.022) | | | (0.017) | (0.020) | | |
| Europe | 0.008 | 0.011 | | | -0.012 | -0.008 | | |
| | (0.023) | (0.026) | | | (0.020) | (0.023) | | |
| Latin America | -0.000 | 0.004 | | | -0.012 | -0.008 | | |
| | (0.017) | (0.020) | | | (0.015) | (0.017) | | |
| Constant | 0.974*** | 1.063*** | 6.989*** | 0.537 | 0.569*** | 0.619*** | 6.282*** | 0.673 |
| | (0.258) | (0.283) | (1.074) | (0.428) | (0.165) | (0.182) | (0.883) | (0.457) |
| Country dummy | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| R2 | 0.392 | 0.391 | 0.382 | | 0.478 | 0.477 | 0.467 | |
| Number of observations | 603 | 603 | 603 | 616 | 598 | 598 | 598 | 610 |
| Number of countries | | 78 | 78 | 80 | | 78 | 78 | 80 |
| Arellano-Bond test | | | | -3.094 | | | | |
| AR(1) | | | | 0.002 | | | | -3.643 |
| p-value | | | | 0.938 | | | | 0.000 |
| AR(2) | | | | 0.348 | | | | 0.719 |
| p-value | | | | | | | | 0.472 |
| Overidentification test (Sargan) | | | | | | | | |
| Chi-squared | | | | 21.108 | | | | 14.429 |
| p-value | | | | 0.133 | | | | 0.493 |

Notes: Shown in parentheses are standard errors. ***, **, and * denote one, five, and ten percent level of significance, respectively. R2 for random effects model is overall R2 and for fixed effects model is within R2.

from PWT 6.3 and the World Bank Development Indicators, respectively. The results are obtained by four different models, namely, OLS, random effects, fixed effects, and system GMM.

Column 1 reveals that economic growth is negatively associated with the population of children. By contrast, the proportion of elderly population has negative coefficient but is statistically insignificant. The increase in the proportion of both the young and elderly populations is

negatively associated with income growth. Thus, the simple OLS model suggests that a large share of the young population hampers economic growth not only in the short and long terms. Alternately, a large proportion of elderly population may delay economic growth in the short term but not in the long term. A similar result is obtained with the random effects model (Column 2).

By contrast, when the country-fixed effects are included (Column 3) in the model, the elderly population does not hamper economic growth in the short and long terms. The young population is negatively associated with economic growth only in the long term. Even if the system GMM model is employed (Column 4), the elderly population does not have a statistically significant negative coefficient for either form of level or changes. The young population is negatively associated with economic growth both in the short and long terms.

To validate the robustness, we also estimate the same equation by using real GDP data obtained from the World Bank Development Indicators Online database. We also consider that growth determinants are sensitive to income differences across datasets (Ciccone and Jarocinski 2008).[4] The discussed findings are robust to the different measure of GDP per capita (Columns 5 to 8).

Given that our theoretical prediction does not specify the exact functional form of the age proportion in the growth equation, we attempt various robustness checks by using different forms of population age structures. Table 4 reports the results when the young and elderly populations are in natural logs. Table 5 shows the results when the youth dependency proportion (youth population relative to the working-age population) and elderly dependency proportion (elderly population relative to the working-age population) are included instead of the proportions of young and elderly populations.

Table 6 summarizes the results for the demographic structure variables from Tables 2 to 4. The elderly population when expressed in natural logarithm is not negatively associated with economic growth in the short and long terms in any of the models applied. When the elderly dependency proportion is used, the results are similar to some extent to the results on the proportion of elderly population (elderly population to the total population), that is, an increase in the elderly population is negatively associated only in the short term in the OLS and random effect models.

[4] We also use GDP per capita on PPP terms and found similar results.

**TABLE 4**

EFFECTS OF POPULATION AGING ON ECONOMIC GROWTH
(DEMOGRAPHIC VARIABLES: LOG OF PROPORTION IN THE TOTAL POPULATION)

| | Dep Var: Real GDP per capita, Laspeyres | | | | Dep Var: Real GDP per capita, World Bank | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | Random effects | Fixed effects | System GMM | OLS | Random effects | Fixed effects | System GMM |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Log of real GDP per capita in the base year | -0.072*** (0.018) | -0.089*** (0.021) | -0.289*** (0.027) | 1.020*** (0.048) | -0.033*** (0.007) | -0.043*** (0.008) | -0.261*** (0.024) | 1.005*** (0.026) |
| Log of total population in the base year | 0.004 (0.006) | 0.002 (0.006) | -0.179*** (0.052) | -0.005 (0.015) | 0.003 (0.005) | 0.001 (0.005) | -0.175*** (0.043) | -0.013 (0.019) |
| Log of youth age share in the base year | -0.136* (0.073) | -0.174** (0.079) | -0.368*** (0.094) | -0.261*** (0.090) | -0.041 (0.060) | -0.065 (0.063) | -0.258*** (0.079) | -0.224** (0.097) |
| Log of old age share in the base year | 0.029 (0.035) | 0.021 (0.038) | -0.090 (0.062) | -0.053 (0.071) | 0.064* (0.033) | 0.060 (0.036) | -0.033 (0.051) | 0.002 (0.070) |
| Capital-GDP ratio in the base year | 0.005*** (0.001) | 0.005*** (0.001) | 0.009*** (0.001) | 0.008*** (0.001) | 0.005*** (0.001) | 0.006*** (0.001) | 0.009*** (0.001) | 0.010*** (0.001) |
| Average schooling years of population in the base year | 0.005 (0.004) | 0.007 (0.005) | 0.016 (0.011) | 0.006 (0.016) | 0.001 (0.003) | 0.004 (0.004) | 0.020** (0.009) | -0.012 (0.014) |
| Openness in the base year | 0.000 (0.000) | 0.000 (0.000) | 0.000 (0.000) | -0.000 (0.001) | 0.000 (0.000) | 0.000 (0.000) | 0.001** (0.000) | -0.000 (0.000) |
| Change in total population | -0.011 (0.151) | 0.043 (0.149) | 0.134 (0.170) | 0.037 (0.087) | 0.036 (0.142) | 0.080 (0.143) | 0.139 (0.140) | -0.161 (0.145) |
| Change in log of youth age share | -0.486*** (0.132) | -0.472*** (0.134) | -0.349** (0.138) | -0.492*** (0.167) | -0.521*** (0.111) | -0.509*** (0.112) | -0.409*** (0.115) | -0.522*** (0.151) |
| Chgange in log of old age share | 0.043 (0.115) | 0.036 (0.116) | -0.023 (0.114) | 0.190 (0.116) | -0.023 (0.095) | -0.023 (0.095) | -0.057 (0.094) | 0.107 (0.099) |
| Change in capital-GDP ratio | 0.007*** (0.001) | 0.008*** (0.001) | 0.008*** (0.001) | 0.011*** (0.002) | 0.008*** (0.001) | 0.008*** (0.001) | 0.008*** (0.001) | 0.011*** (0.002) |
| Change in average schooling years | -0.005 (0.011) | -0.005 (0.011) | 0.001 (0.013) | -0.009 (0.013) | -0.007 (0.010) | -0.006 (0.009) | 0.008 (0.011) | -0.016 (0.012) |
| Change in openness | -0.000 (0.000) | -0.000 (0.000) | 0.000 (0.000) | -0.001** (0.000) | 0.000 (0.000) | 0.000 (0.000) | 0.000 (0.000) | -0.000 (0.000) |

*(Table 4 Continued)*

**TABLE 4**
(CONTINUED)

| | Dep Var: Real GDP per capita, Laspeyres | | | | Dep Var: Real GDP per capita, World Bank | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | Random effects | Fixed effects | System GMM | OLS | Random effects | Fixed effects | System GMM |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Landlocked | -0.042*** | -0.049** | | | -0.034** | -0.039** | | |
| | (0.016) | (0.019) | | | (0.013) | (0.016) | | |
| Oil producer | -0.033 | -0.028 | | | -0.060** | -0.058* | | |
| | (0.030) | (0.036) | | | (0.024) | (0.030) | | |
| Log air distance form big cities | 0.001 | -0.002 | | | -0.004 | -0.006 | | |
| | (0.007) | (0.008) | | | (0.006) | (0.007) | | |
| Colony | 0.008 | 0.010 | | | 0.000 | 0.000 | | |
| | (0.025) | (0.029) | | | (0.020) | (0.023) | | |
| East Asia | 0.049** | 0.046* | | | 0.057*** | 0.057** | | |
| | (0.022) | (0.025) | | | (0.020) | (0.023) | | |
| Sub-Saharan Africa | -0.046** | -0.051** | | | -0.047** | -0.049** | | |
| | (0.021) | (0.025) | | | (0.019) | (0.022) | | |
| Europe | 0.002 | 0.008 | | | -0.016 | -0.011 | | |
| | (0.025) | (0.029) | | | (0.022) | (0.025) | | |
| Latin America | -0.001 | 0.006 | | | -0.009 | -0.004 | | |
| | (0.017) | (0.020) | | | (0.014) | (0.018) | | |
| Constant | 0.919** | 1.326*** | 6.544*** | 0.922* | 0.224 | 0.526 | 5.508*** | 1.021* |
| | (0.449) | (0.504) | (0.925) | (0.525) | (0.327) | (0.357) | (0.773) | (0.596) |
| Country dummy | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| R2 | 0.379 | 0.377 | 0.384 | | 0.467 | 0.465 | 0.462 | |
| Number of observations | 603 | 603 | 603 | 616 | 598 | 598 | 598 | 610 |
| Number of countries | | 78 | 78 | 80 | | 78 | 78 | 80 |
| Arellano-Bond test | | | | | | | | |
| AR(1) | | | | -3.171 | | | | -3.843 |
| p-value | | | | 0.002 | | | | 0.000 |
| AR(2) | | | | 0.854 | | | | 0.647 |
| p-value | | | | 0.393 | | | | 0.518 |
| Overidentification test (Sargan) | | | | | | | | |
| Chi-squared | | | | 22.688 | | | | 14.429 |
| p-value | | | | 0.091 | | | | 0.493 |

Notes: Shown in parentheses are standard errors. ***, **, and * denote one, five, and ten percent level of significance, respectively. R2 for random effects model is overall and for fixed effects model is within R2.

**TABLE 5**

EFFECTS OF POPULATION AGING ON ECONOMIC GROWTH
(DEMOGRAPHIC VARIABLES: DEPENDENCY RATIO)

| | Dep Var: Real GDP per capita, Laspeyres | | | | Dep Var: Real GDP per capita, World Bank | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | Random effects | Fixed effects | System GMM | OLS | Random effects | Fixed effects | System GMM |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Log real GDP per capita in the base year | -0.066*** | -0.076*** | -0.279*** | 1.030*** | -0.030*** | -0.036*** | -0.250*** | 1.022*** |
| | (0.017) | (0.019) | (0.027) | (0.043) | (0.007) | (0.008) | (0.023) | (0.026) |
| Log total population in the base year | 0.000 | -0.000 | -0.278*** | -0.018 | -0.001 | -0.001 | -0.264*** | -0.028 |
| | (0.005) | (0.006) | (0.058) | (0.015) | (0.004) | (0.005) | (0.048) | (0.022) |
| Youth dependency ratio in the base year | -0.334*** | -0.331*** | -0.251*** | -0.327*** | -0.268*** | -0.266*** | -0.274*** | -0.265*** |
| | (0.070) | (0.073) | (0.087) | (0.082) | (0.056) | (0.059) | (0.073) | (0.095) |
| Old age dependency ratio in the base year | -0.018 | 0.037 | -0.686 | -0.016 | 0.144 | 0.179 | -0.448 | -0.011 |
| | (0.196) | (0.213) | (0.471) | (0.407) | (0.179) | (0.193) | (0.387) | (0.358) |
| Capital-GDP ratio in the base year | 0.005*** | 0.005*** | 0.008*** | 0.007*** | 0.005*** | 0.006*** | 0.008*** | 0.009*** |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Average schooling years of population in the base year | 0.000 | 0.002 | 0.019* | -0.002 | -0.003 | -0.002 | 0.018** | -0.007 |
| | (0.005) | (0.005) | (0.011) | (0.016) | (0.004) | (0.004) | (0.009) | (0.014) |
| Openness in the base year | 0.000 | 0.000 | 0.000 | -0.000 | 0.000 | 0.000 | 0.001** | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.001) | (0.000) | (0.000) | (0.000) | (0.000) |
| Change in total population | -0.007 | 0.023 | 0.089 | 0.003 | 0.027 | 0.053 | 0.095 | -0.215 |
| | (0.139) | (0.138) | (0.168) | (0.095) | (0.133) | (0.135) | (0.138) | (0.150) |
| Change in youth dependency ratio | -0.348** | -0.318* | 0.042 | -0.382** | -0.483*** | -0.464*** | -0.215 | -0.509*** |
| | (0.163) | (0.165) | (0.153) | (0.188) | (0.148) | (0.148) | (0.132) | (0.176) |
| Change in old age dependency ratio | -1.343** | -1.175* | -0.196 | 0.726 | -1.514*** | -1.344** | -0.438 | -0.105 |
| | (0.641) | (0.654) | (0.831) | (0.979) | (0.530) | (0.538) | (0.681) | (0.709) |
| Change in capital-GDP ratio | 0.008*** | 0.008*** | 0.007*** | 0.011*** | 0.008*** | 0.008*** | 0.008*** | 0.012*** |
| | (0.001) | (0.001) | (0.001) | (0.002) | (0.001) | (0.001) | (0.001) | (0.002) |
| Change in average schooling years | -0.008 | -0.008 | 0.005 | -0.011 | -0.011 | -0.010 | 0.008 | -0.009 |
| | (0.011) | (0.011) | (0.013) | (0.013) | (0.009) | (0.009) | (0.011) | (0.011) |
| Change in openness | -0.000 | -0.000 | 0.000 | -0.001** | 0.000 | 0.000 | 0.000* | -0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |
| Landlocked | -0.033** | -0.037** | | | -0.028** | -0.031* | | |
| | (0.016) | (0.018) | | | (0.014) | (0.016) | | |
| Oil producer | -0.039 | -0.035 | | | -0.067*** | -0.064** | | |
| | (0.030) | (0.035) | | | (0.024) | (0.028) | | |

*(Table 5 Continued)*

**TABLE 5**
(CONTINUED)

| | Dep Var: Real GDP per capita, Laspeyres | | | | Dep Var: Real GDP per capita, World Bank | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | Random effects | Fixed effects | System GMM | OLS | Random effects | Fixed effects | System GMM |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Log air distance form big cities | -0.005<br>(0.007) | -0.006<br>(0.007) | | | -0.008<br>(0.005) | -0.009<br>(0.006) | | |
| Colony | 0.012<br>(0.025) | 0.012<br>(0.028) | | | 0.008<br>(0.019) | 0.008<br>(0.022) | | |
| East Asia | 0.058***<br>(0.021) | 0.058**<br>(0.024) | | | 0.059***<br>(0.019) | 0.060***<br>(0.021) | | |
| Sub-Saharan Africa | -0.042**<br>(0.020) | -0.045**<br>(0.022) | | | -0.046***<br>(0.018) | -0.047**<br>(0.020) | | |
| Europe | 0.010<br>(0.023) | 0.013<br>(0.026) | | | -0.011<br>(0.020) | -0.008<br>(0.022) | | |
| Latin America | 0.000<br>(0.017) | 0.005<br>(0.020) | | | -0.011<br>(0.015) | -0.008<br>(0.017) | | |
| Constant | 0.781***<br>(0.231) | 0.950***<br>(0.252) | 6.796***<br>(1.025) | 0.293<br>(0.382) | 0.428***<br>(0.146) | 0.591***<br>(0.159) | 6.103***<br>(0.848) | 0.518<br>(0.445) |
| Country dummy | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Year dummy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| R2 | 0.387 | 0.386 | 0.376 | | 0.473 | 0.473 | 0.459 | |
| Number of observations | 603 | 603 | 603 | 616 | 598 | 598 | 598 | 610 |
| Number of countries | | 78 | 78 | 80 | | 78 | 78 | 80 |
| Arellano-Bond test | | | | -3.100 | | | | |
| AR(1) | | | | 0.002 | | | | -3.605 |
| p-value | | | | 0.955 | | | | 0.000 |
| AR(2) | | | | 0.339 | | | | 0.748 |
| p-value | | | | | | | | 0.455 |
| Overidentification test (Sargan) | | | | 19.562 | | | | |
| Chi-squared | | | | 0.189 | | | | 13.643 |
| p-value | | | | | | | | 0.477 |

Notes: Shown in parentheses are standard errors. ***, **, and * denote one, five, and ten percent level of significance, respectively. R2 for random effects model is overall R2 and for fixed effects model is within R2.

**TABLE 6**

SUMMARY EFFECTS OF DEMOGRAPHIC TRANSITION ON ECONOMIC GROWTH

| | Dep Var: Real GDP per capita, Laspeyres | | | | Dep Var: Real GDP per capita, World Bank | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | Random effects | Fixed effects | System GMM | OLS | Random effects | Fixed effects | System GMM |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Demographic Variables: Share | | | | | | | | |
| Youth age share in the base year | -0.010*** (0.002) | -0.010*** (0.002) | -0.010*** (0.003) | -0.009*** (0.002) | -0.008*** (0.002) | -0.008*** (0.002) | -0.010*** (0.002) | -0.008*** (0.003) |
| Old age share in the base year | -0.004 (0.003) | -0.003 (0.004) | -0.013 (0.008) | -0.003 (0.007) | -0.001 (0.003) | -0.000 (0.003) | -0.011 (0.007) | -0.003 (0.006) |
| Change in youth age share | -0.016*** (0.005) | -0.015*** (0.005) | -0.004 (0.004) | -0.014*** (0.005) | -0.019*** (0.004) | -0.018*** (0.004) | -0.009** (0.004) | -0.017*** (0.005) |
| Change in old age share | -0.031*** (0.011) | -0.027** (0.011) | 0.002 (0.015) | 0.007 (0.016) | -0.034*** (0.009) | -0.031*** (0.009) | -0.005 (0.012) | -0.007 (0.012) |
| Demographic Variables: Log of Share | | | | | | | | |
| Log of youth age share in the base year | -0.136* (0.073) | -0.174** (0.079) | -0.368*** (0.094) | -0.261*** (0.090) | -0.041 (0.060) | -0.065 (0.063) | -0.258*** (0.079) | -0.224** (0.097) |
| Log of old age share in the base year | 0.029 (0.035) | 0.021 (0.038) | -0.090 (0.062) | -0.053 (0.071) | 0.064* (0.033) | 0.060 (0.036) | -0.033 (0.051) | 0.002 (0.070) |
| Change in log of youth age share | -0.486*** (0.132) | -0.472*** (0.134) | -0.349** (0.138) | -0.492*** (0.167) | -0.521*** (0.111) | -0.509*** (0.112) | -0.409*** (0.115) | -0.522*** (0.151) |
| Change in log of old age share | 0.043 (0.115) | 0.036 (0.116) | -0.023 (0.114) | 0.190 (0.116) | -0.023 (0.095) | -0.023 (0.095) | -0.057 (0.094) | 0.107 (0.099) |
| Demographic Variables: Dependency Ratio | | | | | | | | |
| Youth dependency ratio in the base year | -0.334*** (0.070) | -0.331*** (0.073) | -0.251*** (0.087) | -0.327*** (0.082) | -0.268*** (0.056) | -0.266*** (0.059) | -0.274*** (0.073) | -0.265*** (0.095) |
| Old age dependency ratio in the base year | -0.018 (0.196) | 0.037 (0.213) | -0.686 (0.471) | -0.016 (0.407) | 0.144 (0.179) | 0.179 (0.193) | -0.448 (0.387) | -0.011 (0.358) |
| Change in youth dependency ratio | -0.348** (0.163) | -0.318* (0.165) | 0.042 (0.153) | -0.382** (0.188) | -0.483*** (0.148) | -0.464*** (0.148) | -0.215 (0.132) | -0.509*** (0.176) |
| Change in old age dependency ratio | -1.343** (0.641) | -1.175* (0.654) | -0.196 (0.831) | 0.726 (0.979) | -1.514*** (0.530) | -1.344** (0.538) | -0.438 (0.681) | -0.105 (0.709) |

Notes: Estimates are taken from Tables 3-5.

## V. Concluding remarks

The 2013 Revision of the World Population Prospects confirms that despite the slowdown of growth of the overall population size in most countries, age structure is in the midst of an unprecedented transition. A rapid growth in the number of elderly people is experienced by many countries. Population aging requires research that can accurately predict the consequences of population aging.

The empirical evidence obtained in this study demonstrates that an increase in the young population constitutes a "demographic burden" and inhibits economic growth compared with the elderly population in the short and long terms. Therefore, the behavior responses of countries to population aging occur in the form of high retirement savings, high labor force participation, and increased immigration of workers from developing countries. Thus, appropriate policies can mitigate the adverse consequences of population changes.

However, this paper does not directly assess how such behavior changes occur in response to demographic transition and how such behavior changes affect economic growth. For example, population aging may affect savings and investment (Park and Rhee, 2007), which may affect economic growth. Such an indirect association between population aging and economic growth is not fully considered in the present study. Therefore, further analyses are required to assess the effect of demographic transition on economic growth by investigating the implications of population changes on savings, labor force participation, and so on.

(*Received 17 October 2012; Revised 31 July 2013; Accepted 1 August 2013*)

## Appendix

**APPENDIX TABLE 1**
LIST OF 80 COUNTRIES

| | | Youth age share | | Old age share | | Real GDP per capita (USD) | |
|---|---|---|---|---|---|---|---|
| Country | Isocode | 1960 | 2005 | 1960 | 2005 | 1960 | 2005 |
| Algeria | DZA | 43.8 | 29.6 | 3.9 | 4.5 | 4,388 | 6,291 |
| Argentina | ARG | 30.6 | 26.2 | 5.7 | 10.3 | 8,825 | 13,603 |
| Australia | AUS | 30.1 | 19.7 | 8.5 | 12.9 | 12,003 | 34,323 |
| Austria | AUT | 22.0 | 16.0 | 12.2 | 16.2 | 9,812 | 33,450 |
| Barbados | BRB | 38.1 | 18.7 | 6.7 | 10.1 | 7,895 | 23,792 |
| Belgium | BEL | 23.5 | 17.1 | 12.0 | 17.3 | 9,584 | 31,750 |
| Benin | BEN | 37.8 | 43.7 | 5.7 | 3.1 | 885 | 1,380 |
| Bolivia | BOL | 42.7 | 38.1 | 3.3 | 4.5 | 2,829 | 3,577 |
| Brazil | BRA | 43.3 | 27.5 | 3.3 | 6.2 | 3,067 | 9,000 |
| Cameroon | CMR | 40.6 | 41.7 | 3.5 | 3.6 | 1,900 | 2,579 |
| Canada | CAN | 33.5 | 17.6 | 7.5 | 13.1 | 11,942 | 34,590 |
| Chile | CHL | 39.5 | 24.9 | 4.8 | 8.1 | 5,860 | 16,966 |
| China | CHN | 38.9 | 22.0 | 4.8 | 7.6 | 507 | 6,483 |
| Colombia | COL | 46.4 | 30.8 | 3.2 | 5.1 | 3,170 | 7,127 |
| Congo, Republic of | COG | 41.3 | 41.2 | 3.7 | 3.8 | 1,159 | 3,683 |
| Costa Rica | CRI | 44.8 | 28.4 | 4.7 | 5.8 | 4,998 | 10,694 |
| Denmark | DNK | 25.2 | 18.8 | 10.6 | 15.1 | 11,120 | 32,162 |
| Dominican Republic | DOM | 47.9 | 33.0 | 2.6 | 5.6 | 2,346 | 8,159 |
| Ecuador | ECU | 43.4 | 32.6 | 4.7 | 5.9 | 2,763 | 5,756 |
| Egypt | EGY | 43.9 | 33.3 | 3.2 | 4.5 | 1,399 | 5,230 |
| El Salvador | SLV | 45.1 | 35.1 | 3.7 | 6.6 | 3,428 | 5,288 |
| Finland | FIN | 30.4 | 17.4 | 7.2 | 16.0 | 8,696 | 29,761 |
| France | FRA | 26.3 | 18.4 | 11.7 | 16.5 | 9,385 | 28,779 |
| Gambia, The | GMB | 37.9 | 42.8 | 3.1 | 2.8 | 1,440 | 1,386 |
| Ghana | GHA | 44.3 | 39.7 | 2.6 | 3.5 | 594 | 1,530 |
| Greece | GRC | 26.5 | 14.4 | 8.3 | 18.0 | 5,944 | 25,467 |
| Guatemala | GTM | 45.8 | 43.2 | 2.7 | 4.3 | 3,021 | 5,712 |
| Honduras | HND | 46.1 | 39.8 | 3.2 | 4.1 | 2,265 | 3,368 |
| Hong Kong | HKG | 40.9 | 14.4 | 2.8 | 12.2 | 3,849 | 38,156 |
| Iceland | ISL | 34.7 | 22.1 | 8.0 | 11.7 | 10,153 | 38,143 |
| India | IND | 40.7 | 33.1 | 3.0 | 4.6 | 949 | 3,365 |
| Indonesia | IDN | 40.0 | 28.4 | 3.4 | 5.5 | 1,036 | 4,884 |
| Iran | IRN | 43.8 | 26.4 | 4.2 | 5.0 | 4,263 | 9,498 |
| Ireland | IRL | 31.1 | 20.4 | 11.2 | 11.0 | 6,616 | 38,659 |

*(Appendix Table 1 Continued)*

**APPENDIX TABLE 1**
(CONTINUED)

| | | Youth age share | | Old age share | | Real GDP per capita (USD) | |
|---|---|---|---|---|---|---|---|
| Israel | ISR | 36.1 | 27.9 | 4.9 | 10.1 | 6,968 | 22,327 |
| Italy | ITA | 24.9 | 14.2 | 9.6 | 19.6 | 8,240 | 27,795 |
| Japan | JPN | 30.3 | 13.8 | 5.7 | 19.9 | 5,493 | 29,780 |
| Jordan | JOR | 44.4 | 37.2 | 4.1 | 3.5 | 4,558 | 4,762 |
| Kenya | KEN | 46.5 | 42.8 | 3.7 | 2.7 | 1,806 | 2,017 |
| Korea, Republic of | KOR | 40.9 | 19.1 | 3.7 | 9.3 | 1,744 | 22,048 |
| Lesotho | LSO | 43.1 | 40.1 | 4.3 | 4.8 | 671 | 2,070 |
| Malawi | MWI | 45.7 | 46.8 | 2.6 | 3.0 | 567 | 1,180 |
| Malaysia | MYS | 45.3 | 31.3 | 3.4 | 4.4 | 2,178 | 16,481 |
| Mali | MLI | 40.3 | 44.5 | 3.1 | 2.4 | 765 | 1,254 |
| Mauritius | MUS | 46.6 | 24.7 | 2.5 | 6.5 | 3,968 | 18,342 |
| Mexico | MEX | 45.9 | 30.7 | 3.4 | 5.8 | 4,421 | 10,546 |
| Mozambique | MOZ | 42.3 | 44.1 | 2.8 | 3.2 | 1,110 | 1,988 |
| Nepal | NPL | 40.2 | 39.0 | 2.6 | 3.8 | 1,078 | 1,886 |
| Netherlands | NLD | 30.0 | 18.3 | 9.0 | 14.2 | 11,961 | 32,638 |
| New Zeland | NZL | 32.9 | 21.5 | 8.6 | 12.1 | 12,394 | 24,551 |
| Nicaragua | NIC | 47.4 | 37.8 | 2.5 | 4.1 | 2,614 | 2,112 |
| Niger | NER | 46.3 | 48.9 | 1.2 | 2.0 | 1,307 | 851 |
| Norway | NOR | 25.9 | 19.6 | 11.1 | 14.5 | 11,715 | 45,694 |
| Pakistan | PAK | 37.5 | 38.5 | 6.0 | 3.8 | 910 | 3,269 |
| Panama | PAN | 42.9 | 30.4 | 4.3 | 6.0 | 2,164 | 7,945 |
| Paraguay | PRY | 47.9 | 35.8 | 3.2 | 4.8 | 2,582 | 4,591 |
| Peru | PER | 43.3 | 31.9 | 3.4 | 5.4 | 3,646 | 5,734 |
| Philippines | PHL | 45.9 | 35.6 | 3.0 | 3.9 | 2,191 | 4,063 |
| Portugal | PRT | 29.3 | 15.6 | 7.9 | 17.1 | 4,071 | 19,562 |
| Rwanda | RWA | 46.9 | 42.5 | 2.3 | 2.6 | 1,260 | 1,116 |
| Senegal | SEN | 41.2 | 44.4 | 3.0 | 2.4 | 2,415 | 1,869 |
| Singapore | SGP | 43.2 | 19.6 | 2.1 | 8.5 | 4,151 | 38,441 |
| South Africa | ZAF | 40.9 | 31.7 | 3.9 | 4.1 | 5,366 | 9,610 |
| Spain | ESP | 27.4 | 14.5 | 8.2 | 16.8 | 5,879 | 29,150 |
| Sri Lanka | LKA | 41.5 | 24.6 | 4.7 | 6.8 | 1,330 | 5,329 |
| Sweden | SWE | 22.0 | 17.4 | 12.0 | 17.2 | 12,020 | 30,657 |
| Switzerland | CHE | 24.0 | 16.1 | 10.2 | 16.0 | 18,103 | 35,444 |
| Syria | SYR | 45.9 | 36.9 | 3.7 | 3.1 | 1,087 | 2,596 |
| Thailand | THA | 43.6 | 22.9 | 3.2 | 7.1 | 1,184 | 8,666 |
| Togo | TGO | 42.8 | 41.3 | 3.7 | 3.4 | 840 | 889 |
| Trinidad & Tobago | TTO | 43.0 | 21.9 | 4.0 | 6.3 | 6,815 | 21,403 |

*(Appendix Table 1 Continued)*

**APPENDIX TABLE 1**
(CONTINUED)

| | | Youth age share | | Old age share | | Real GDP per capita (USD) | |
|---|---|---|---|---|---|---|---|
| Turkey | TUR | 42.4 | 28.5 | 3.4 | 5.7 | 2,469 | 7,133 |
| Uganda | UGA | 45.9 | 49.3 | 2.6 | 2.6 | 910 | 1,167 |
| United Kingdom | GBR | 23.3 | 18.0 | 11.7 | 16.1 | 11,238 | 30,276 |
| United States | USA | 30.8 | 20.8 | 9.2 | 12.4 | 14,737 | 41,870 |
| Uruguay | URY | 27.9 | 23.8 | 8.2 | 13.5 | 6,555 | 11,157 |
| Venezuela | VEN | 45.7 | 31.3 | 2.5 | 5.0 | 8,926 | 10,973 |
| Zambia | ZMB | 44.9 | 46.0 | 2.5 | 3.0 | 2,237 | 1,792 |
| Zimbabwe | ZWE | 45.3 | 41.0 | 3.3 | 3.8 | 1,851 | 2,146 |
| Italy | ITA | 24.9 | 14.2 | 9.6 | 19.6 | 8,240 | 27,795 |
| Japan | JPN | 30.3 | 13.8 | 5.7 | 19.9 | 5,493 | 29,780 |
| Jordan | JOR | 44.4 | 37.2 | 4.1 | 3.5 | 4,558 | 4,762 |
| Kenya | KEN | 46.5 | 42.8 | 3.7 | 2.7 | 1,806 | 2,017 |
| Korea, Republic of | KOR | 40.9 | 19.1 | 3.7 | 9.3 | 1,744 | 22,048 |
| Lesotho | LSO | 43.1 | 40.1 | 4.3 | 4.8 | 671 | 2,070 |
| Malawi | MWI | 45.7 | 46.8 | 2.6 | 3.0 | 567 | 1,180 |
| Malaysia | MYS | 45.3 | 31.3 | 3.4 | 4.4 | 2,178 | 16,481 |
| Mali | MLI | 40.3 | 44.5 | 3.1 | 2.4 | 765 | 1,254 |
| Mauritius | MUS | 46.6 | 24.7 | 2.5 | 6.5 | 3,968 | 18,342 |
| Mexico | MEX | 45.9 | 30.7 | 3.4 | 5.8 | 4,421 | 10,546 |
| Mozambique | MOZ | 42.3 | 44.1 | 2.8 | 3.2 | 1,110 | 1,988 |
| Nepal | NPL | 40.2 | 39.0 | 2.6 | 3.8 | 1,078 | 1,886 |
| Netherlands | NLD | 30.0 | 18.3 | 9.0 | 14.2 | 11,961 | 32,638 |
| New Zeland | NZL | 32.9 | 21.5 | 8.6 | 12.1 | 12,394 | 24,551 |
| Nicaragua | NIC | 47.4 | 37.8 | 2.5 | 4.1 | 2,614 | 2,112 |
| Niger | NER | 46.3 | 48.9 | 1.2 | 2.0 | 1,307 | 851 |
| Norway | NOR | 25.9 | 19.6 | 11.1 | 14.5 | 11,715 | 45,694 |
| Pakistan | PAK | 37.5 | 38.5 | 6.0 | 3.8 | 910 | 3,269 |
| Panama | PAN | 42.9 | 30.4 | 4.3 | 6.0 | 2,164 | 7,945 |
| Paraguay | PRY | 47.9 | 35.8 | 3.2 | 4.8 | 2,582 | 4,591 |
| Peru | PER | 43.3 | 31.9 | 3.4 | 5.4 | 3,646 | 5,734 |
| Philippines | PHL | 45.9 | 35.6 | 3.0 | 3.9 | 2,191 | 4,063 |
| Portugal | PRT | 29.3 | 15.6 | 7.9 | 17.1 | 4,071 | 19,562 |
| Rwanda | RWA | 46.9 | 42.5 | 2.3 | 2.6 | 1,260 | 1,116 |
| Senegal | SEN | 41.2 | 44.4 | 3.0 | 2.4 | 2,415 | 1,869 |
| Singapore | SGP | 43.2 | 19.6 | 2.1 | 8.5 | 4,151 | 38,441 |
| South Africa | ZAF | 40.9 | 31.7 | 3.9 | 4.1 | 5,366 | 9,610 |
| Spain | ESP | 27.4 | 14.5 | 8.2 | 16.8 | 5,879 | 29,150 |

*(Appendix Table 1 Continued)*

**APPENDIX TABLE 1**
(CONTINUED)

| | | Youth age share | | Old age share | | Real GDP per capita (USD) | |
|---|---|---|---|---|---|---|---|
| Sri Lanka | LKA | 41.5 | 24.6 | 4.7 | 6.8 | 1,330 | 5,329 |
| Sweden | SWE | 22.0 | 17.4 | 12.0 | 17.2 | 12,020 | 30,657 |
| Switzerland | CHE | 24.0 | 16.1 | 10.2 | 16.0 | 18,103 | 35,444 |
| Syria | SYR | 45.9 | 36.9 | 3.7 | 3.1 | 1,087 | 2,596 |
| Thailand | THA | 43.6 | 22.9 | 3.2 | 7.1 | 1,184 | 8,666 |
| Togo | TGO | 42.8 | 41.3 | 3.7 | 3.4 | 840 | 889 |
| Trinidad & Tobago | TTO | 43.0 | 21.9 | 4.0 | 6.3 | 6,815 | 21,403 |
| Turkey | TUR | 42.4 | 28.5 | 3.4 | 5.7 | 2,469 | 7,133 |
| Uganda | UGA | 45.9 | 49.3 | 2.6 | 2.6 | 910 | 1,167 |
| United Kingdom | GBR | 23.3 | 18.0 | 11.7 | 16.1 | 11,238 | 30,276 |
| United States | USA | 30.8 | 20.8 | 9.2 | 12.4 | 14,737 | 41,870 |
| Uruguay | URY | 27.9 | 23.8 | 8.2 | 13.5 | 6,555 | 11,157 |
| Venezuela | VEN | 45.7 | 31.3 | 2.5 | 5.0 | 8,926 | 10,973 |
| Zambia | ZMB | 44.9 | 46.0 | 2.5 | 3.0 | 2,237 | 1,792 |
| Zimbabwe | ZWE | 45.3 | 41.0 | 3.3 | 3.8 | 1,851 | 2,146 |

## References

Barro, Robert J., and Jong-Wha Lee. A New Data Set of Educational Attainment in the World. NBER Working Papers 15902, 2010.

Bloom, David E., and David Canning. "Global Demographic Change: Dimensions and Economic Significance." *Global Demographic Change: Economic Impacts and Policy Challenges*, Sponsored by the Federal Reserve Bank of Kansas City Jackson Hole, Wyoming, August 2004.

Bloom, David E., and David Canning. Global Demographic Change: Dimensions and Economic Significance. National Bureau of Economic Research, 2004.

Bloom, David E., David Canning, Gunther Fink and Jocelyn Finlay. Does Age Structure Forecast Economic Growth. PGDA Working Paper No. 20, 2007.

Bloom, David E., David Canning, and Jocelyn Finlay "Population Aging and Economic Growth in Asia," mimeo, Harvard School of Public Health, 2008.

Bloom, David E., David Canning, and Jocelyn. Population aging and economic growth in Asia. The Economic Consequences of Demographic Change in East Asia NBER-EASE Volume 19, University of Chicago Press, 2010. 61-89.

Bloom, David E., and David Canning, Günther Fink, Population Aging and Economic Growth. PGDA Working Paper No. 31, 2008.

Bloom, David E., and David Canning, Günther Fink. Implications of Population Aging for Economic Growth. PGDA Working Paper No. 64, 2011.

Bloom, David E., David Canning, Gunther Fink, and Jocelyn E. Finlay "Fertility, Female Labor Force Participation, and the Demographic Dividend" *Journal of Economic Growth* 14 (No. 2 2009): 79-101

Bloom, David E., David Canning, and P. Malaney. "Population Dynamics and Economic Growth in Asia." *Population and Development Review* 26 (2000): 257-90.

Bloom, David E., David Canning, and Jaypee Sevilla. Economic Growth and the Demographic Transition. NBER Working Paper No. 8685, 2001.

Bloom, David E., David Canning, and Jaypee Sevilla. *The Demographic Dividend: A New Perspective on the Economic Consequences of Population Change, Santa Monica*. California: RAND Corporation,

2003.

Bloom, David E., and J. G. Williamson "Demographic Transitions and Economic Miracles in Emerging Asia." *World Bank Economic Review* 12 (No. 3 1998): 419-55.

Ciccone, Antonio, and Marek Jarocinski. Determinants of Economic Growth: Will Data Tell?. Working Paper Series No. 852, 2008.

Hayakawa, Kazunobu, Fukunari Kumura, and Hyun-Hoon Lee "How Does Country Risk Matter for Foreign Direct Investment?" *The Developing Economies* 51 (No. 1 2013): 60-78.

Heston, Alan, Robert Summers, and Bettina Aten. Penn World Table Version 6.3, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, August 2009.

Huh, Hyeon-seung, Hyun-Hoon Lee, and Young-Youn Lee. Demographic Shift and its Impact on Economic Growth. Korea and the World Economy VI Conference, University of Wollongong, 2007.

Mason, Andrew. "Demographic Dividends: The Past, the Present, and the Future." In Mitoshi Yamaguchi (ed.), *Contributions to Economic Analysis*, Vol. 281, Bingley, U.K.: Emerald Group Publishing Limited, pp. 75-98, 2007.

Park, Daekeun, and Changyong Rhee. "Population Aging an Financial Markets: A Cross-Country Study." *Seoul Journal of Economics* 20 (No. 3 2007): 333-54.

Prettner, Klaus. "Population Aging and Endogenous Economic Growth." *Journal of Population Economics* 26 (No. 2 2013): 811-34.

Stone, Joe, and Hyun-Hoon Lee. "Determinants of Intra-Industry Trade: A Longitudinal, Cross-Country Analysis" *Weltwirtschaftliches Archiv* 131 (No. 1 1995): 67-85.

United Nations Publications. *World Population Prospects The 2013 Revision: Key Findings and Advance Tables*, ESA/P/Working paper 227, Department of Economic and Social Affairs, New York" United Nations, 2013.