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Impact of Demographic Changes on Inflation and the Macroeconomy†

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Ongoing demographic changes have brought about a substantial shift in the size and age composition of the population, which are having a significant impact on the global economy. Despite potentially grave consequences, demographic changes usually do not take center stage in many macroeconomic policy discussions or debates. This paper illustrates how demographic variables move over time and analyzes how they influence macroeconomic variables such as economic growth, inflation, savings and investment, and fiscal balances, from an empirical perspective. Based on empirical findings—particularly regarding inflation—we discuss their implications on macroeconomic policies, including monetary policy. We also highlight the need to consider the interactions between population dynamics and macroeconomic variables in macroeconomic policy decisions.

Key Word: Demographic Changes, Population Aging, Inflation, Macroeconomic Impact, Savings and Investment, Monetary Policy, Fiscal Policy
JEL Code: J11, E31, E21

I. Introduction

Demographic change is one of the most important determinants of the future economic and social landscape. Many researchers have looked into how changes in the *size* and *composition* of an economy's population influence macroeconomic outcomes. The channels through which demographic changes affect an economy typically include savings and investment behaviors, labor market decisions, and aggregate demand and supply responses. In the medium to

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long term, both changes in the labor supply and changes in productivity—either viewed as exogenous or caused by demographic changes—could significantly alter an economy's aggregate supply and thereby economic growth, as demographic changes affect the amount and combination by which its factor inputs are utilized. Over the short term, demographic transitions are likely to affect aggregate demand given that the amount of consumption and investment would depend critically on structural changes in the population's age-earnings profiles.

This paper intends to analyze the macroeconomic effects of demographic changes from an empirical perspective and to discuss their policy implications—particularly regarding inflation. Effects of demographic changes would depend on the extent of the anticipation of the demographic changes, nominal and real friction, institutional aspects, and behavioral responses. For example, aggregate supply or demand responses may be more flexible when demographic changes are fully anticipated in advance. Macroeconomic dynamics would also be based on the specific types of friction assumed to that are built into a model. In an economy with significant bottlenecks to deter real or nominal adjustments, aggregate supply responses are more likely to lag aggregate demand responses, leading to slower output and price adjustments from the supply side.

We attempt to identify the impact of demographic changes on inflation and the macroeconomy using two types of proxies to capture demographic changes. Changes in the total size of the population are captured by its growth rate. With regard to the composition of the population, multiple measures have been proposed to reflect the degree of population aging, such as the percentages of the working-age and elderly in the population, dependency ratios, and life expectancy. We follow earlier empirical work based on these proxies and identify empirical evidence on the impact of demographic changes on economic growth, savings and investment, the external current account balance, and the fiscal balance. Monetary aspects of economic outcomes have received less attention in analyses of demographic changes; here, we pay particular attention to how inflation behavior is affected by demographic changes.

This paper proceeds as follows. Section 2 describes a number of stylized facts pertaining to the driving forces of demographic changes and their projections into the near future, including fertility and mortality ratios, population growth, and the shares of the working-age and elderly in the population. Section 3 provides a brief review of the related literature, covering both theoretical and empirical discussions of the impact of demographic changes on macroeconomic variables, including inflation. In Section 4, we elaborate on the data, methodology, and empirical findings with regard to inflation and the macroeconomic impact of demographic changes. The final section concludes the paper and offers some discussion on policy implications.

II. Description of Demographic Changes

The world is about to experience a drastic shift in the size and composition of the population. Such demographic changes have already begun in some countries,

including Japan, and will become conspicuous for many other countries in the coming decades. Two fundamental driving forces that underlie such demographic changes are related to birth and death, i.e., fertility and mortality.[1] According to work published by the United Nations (United Nations 2014), the total fertility rate was around 5 on average around the world in the 1960s. This number has decreased consistently over the last fifty years and is currently around 2.5. It is projected to settle just above 2 by the end of the 21st century.[2]

There is, however, a significant difference between more developed areas and less developed regions, as illustrated in Figure 1. The fertility rate was as high as about 6 around 1960 in less developed regions, and in such regions the fertility rate is currently higher than the world average. Even in the 1950s, the fertility rate in more developed areas was less than 3 and currently; it has remained below 2 for nearly thirty years, since approximately 1985. Over the long term, the United Nations projects this to move back up to around 2.

Figure 2 provides information about country-wide total fertility rates for several countries. The fertility rate for five industrialized countries (the US, the UK, France, Germany, and Japan) remained between 2 and 4 in the 1950s and 60s and has fluctuated around 2 from the 1970s onward. However, in Korea in the 1950s through to the 1970s, the fertility rate exceeded 4 before taking a rapid downward trajectory afterward.[3] It dropped to less than 2 in the 1990s before stabilizing at

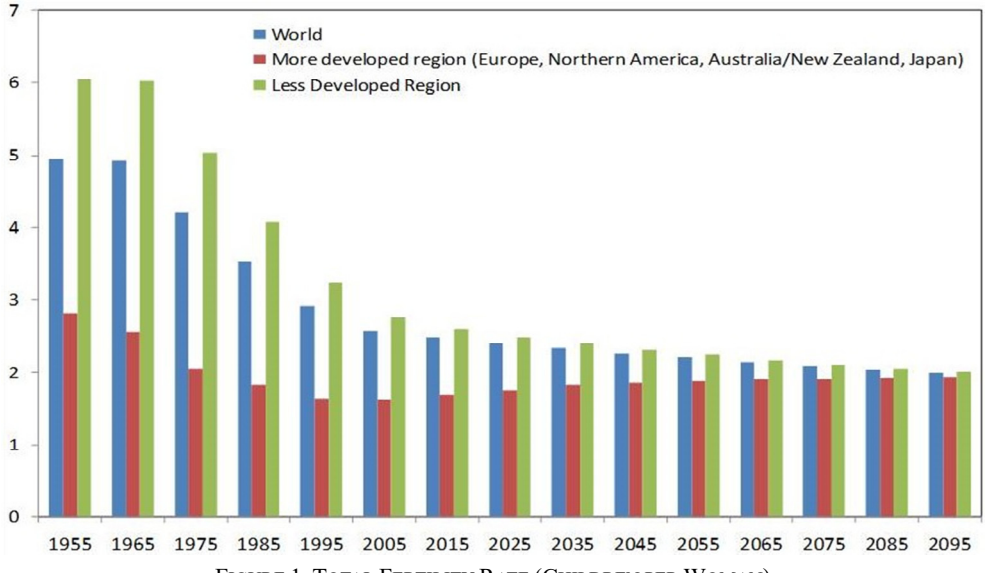

FIGURE 1. TOTAL FERTILITY RATE (CHILDREN PER WOMAN)

Source: UN Population Prospects, 2012 revision.

[1]While past variations in birth/death rates or immigration factors may also trigger demographic changes, they were not included in the description given their relatively weak significance.

[2]Our assessments are based solely on baseline projections according to the United Nations (2014). Demographic trends could change depending on various policy efforts, such as those affecting immigration.

[3]Japan and Korea were emphasized based on their rapid population aging and lowest fertility levels. China, the country with the largest population in the world, has also been experiencing significant demographic changes, similar to those of Korea, during the last few decades, as summarized in Figure A1.

approximately 2 since then. In particular, Korea's fertility rate has remained significantly below 1.5 in the last couple of decades and declined recently to about 1.2, one of the lowest rates in the world.

Besides the decrease in the fertility rate, mortality has been another factor affecting recent demographic changes. Figure 3 captures the change in mortality by life expectancy as averaged over a cohort group born each year. The world-average

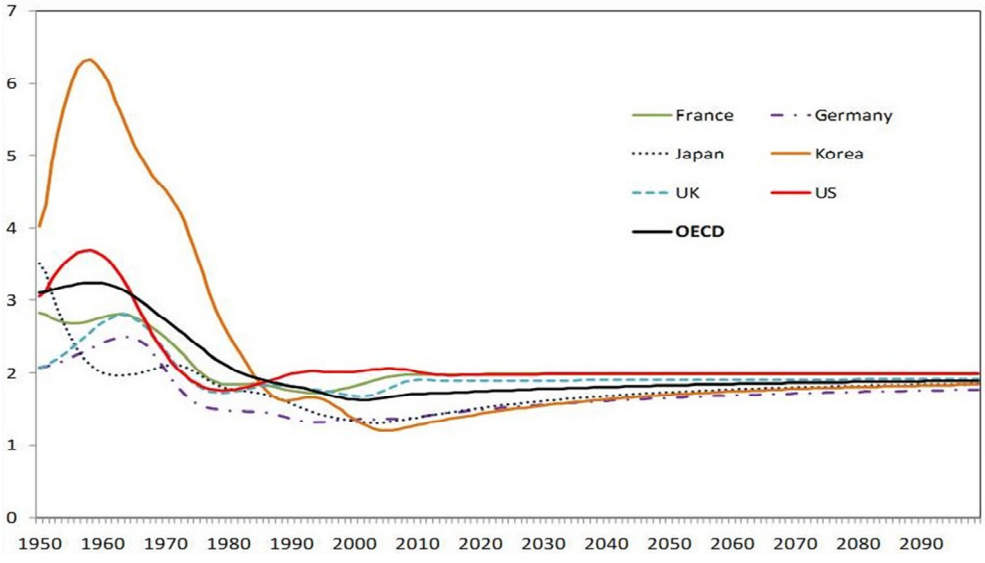

FIGURE 2. TOTAL FERTILITY BY MAJOR ECONOMIES (CHILDREN PER WOMAN)

Source: UN Population Prospects, 2012 revision.

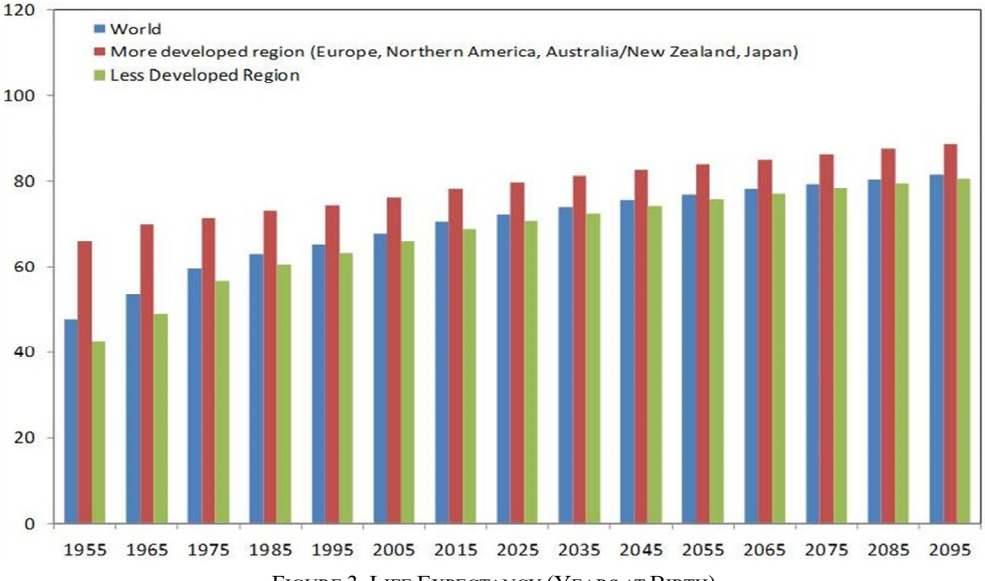

FIGURE 3. LIFE EXPECTANCY (YEARS AT BIRTH)

Source: UN Population Prospects, 2012 revision.

life expectancy of someone who was born in 1955 is close to 50 years, while life expectancy for more developed regions is significantly above 60 years. The life expectancy increases as we move to later cohorts, as one would expect. The increase in life expectancy, together with the decrease in the fertility rate as shown in Figures 1 and 2, caused both a change in the size of the world population and an aging phenomenon in the composition of the population.

The demographic consequences brought about by the above drivers include changes in the size and the composition of the population. Elevated fertility rates in the 1950s and 60s—combined with an increase in life expectancy—caused the population to grow, and the growth rate picked up as well in more developed countries. Figure 4 shows that the growth rate of the total population has been following a decreasing trend since then. Though the population growth rate will remain in the positive range for the world as a whole according to United Nations projections, the total population growth for the OECD in total is expected to enter negative territory around 2050. In particular, Figure 4 indicates that the total population began to decline in Japan from 2009, and this occurred in Germany from the mid-2000s with Korea expected to follow suit from the mid-2030s. Such declines in the population size could have disproportionate ramifications on the macroeconomy.

Having as much influence on macroeconomic dynamics as the size of population is the composition of the population. Figure 5 displays changes in the share of the working-age population relative to the total population. High fertility rates in the 1950s and 60s were in the background of an increasing trend in the working-age share of the total population in OECD countries until shortly after 2000. Since then, a decrease in fertility and an increase in longevity have caused the working-age population share to decline steadily. We can observe the turnaround in the trend of the working age population share in the recent decade, which divides the rising

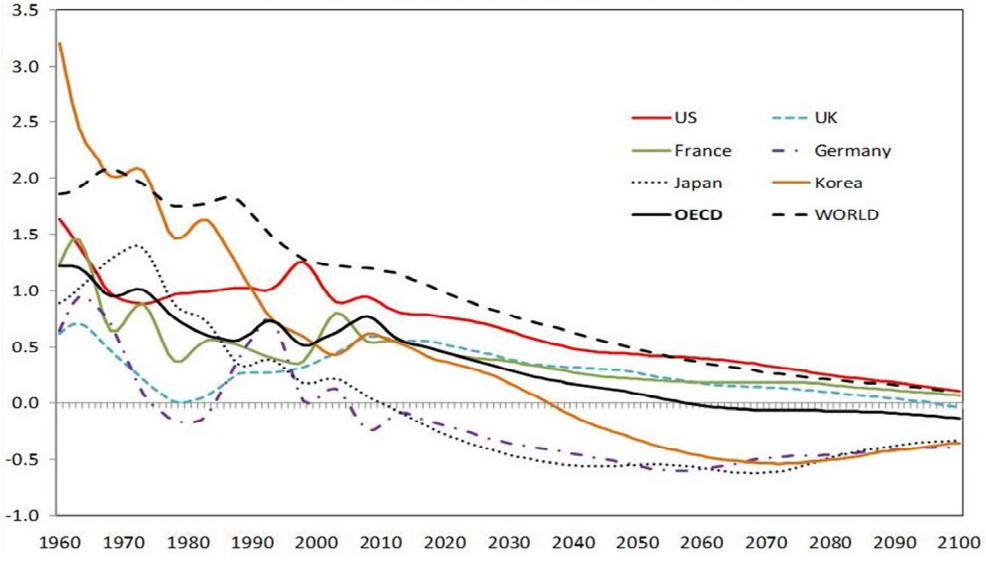

FIGURE 4. TOTAL POPULATION GROWTH (PERCENT)

Source: UN Population Prospects, 2012 revision.

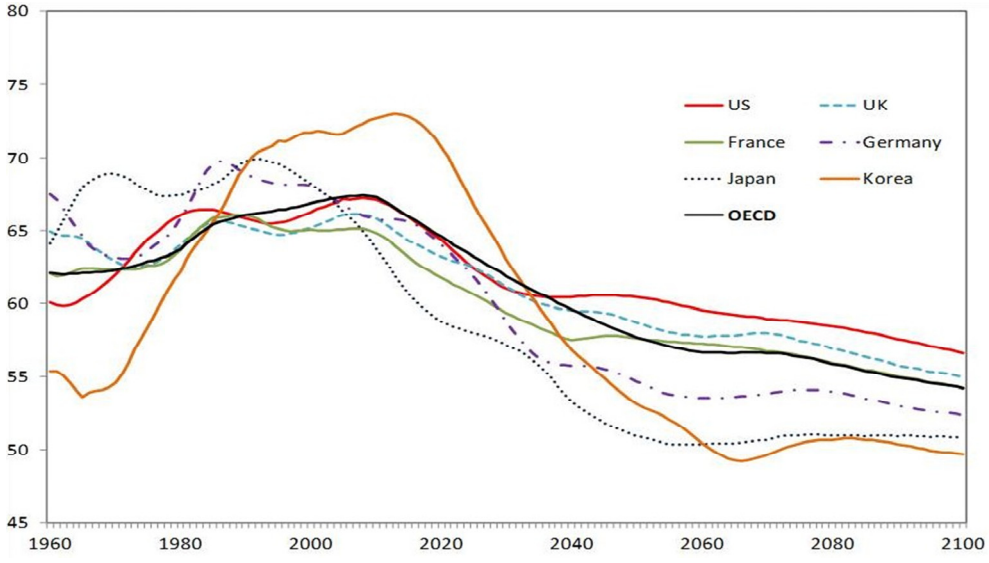

FIGURE 5. WORKING-AGE POPULATION SHARE OF THE TOTAL POPULATION (PERCENT)

Source: UN Population Prospects, 2012 revision.

trend until the 1990s and the declining trend from about the 2010s. The declines in working-age population share are particularly rapid in Japan and Korea, where the total fertility rates have declined very rapidly.

Along with the working-age population share, the dependency ratio has received much attention in macroeconomics—especially in the public finance literature involving pension systems. As shown in Figure 6, the dependency ratio is almost a mirror image of the share of the working-age population. Around the turn of the century, the dependency ratio overall was close to 50%; this number for Korea was as low as 40%. The dependency ratio is projected to increase steadily over time—reaching about 100% for the case of Japan and Korea by 2100. The share of the working age population or the elderly dependency ratio indicates that a significant change in the population structure has been occurring since the 2000s which could have important economic implications with regard to the macroeconomy.[4]

As a starting point for understanding the effects of demographic changes on macroeconomic outcomes, we can plot the relationship between demographic variables (elderly share, working-age share, and population growth) and macro variables (per capita real GDP growth, saving/GDP, investment/GDP, current account/GDP, budget balance/GDP, and inflation). If we draw scatter plots for pooled data (both cross-section and time-series)—as shown in Figure A2, A3, and A4—the relationship is not significant, except for government revenue and expenditure. This is not unexpected, as pooled data averages out over countries and over time. It is therefore imperative to conduct a panel analysis based on certain

[4]The EU Aging Report is another source that covers demographic projections —up to the year 2060—where, for example, the dependency ratio in Germany converges to around 85% by then. UN projections suggest a further increase to around 90% by 2100.

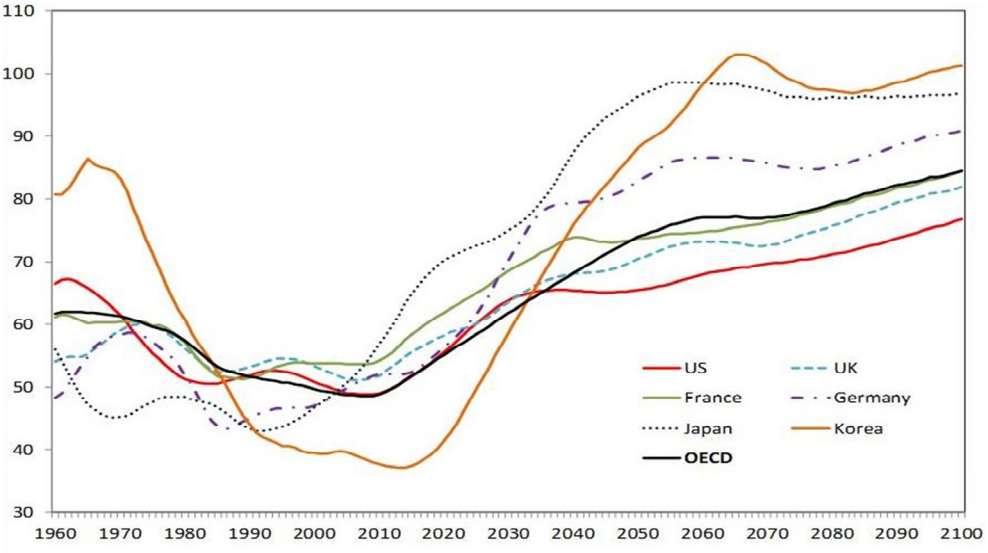

FIGURE 6. DEPENDENCY RATIOS FOR MAJOR ECONOMIES

Source: UN Population Prospects, 2012 revision.

country- or time-specific structures on the macroeconomic effects of demographic changes.

III. Literature Review

A proper analysis of the macroeconomic effects of demographic changes is crucial when exploring appropriate policy responses to minimize the adverse effects or unwanted distortions. Reflecting their grave consequences, there have been extensive studies analyzing various aspects of demographic changes which affect an economy, covering real, external, fiscal, and financial ramifications. There have been broadly two approaches which have been used to analyze the macroeconomic impact of demographic changes. The standard approach assumes constant age-specific behavior with respect to employment, earnings, consumption and savings and assesses the implications of demographic changes. While this approach is useful for capturing what are known as the accounting effects of demographic transitions, the outcomes could be misleading, as economic behaviors can be altered and institutional aspects can be adjusted. The other approach takes into account the behavioral, institutional, and global responses as well. This approach adds a measure of complexity in order to track various channels and their interactions. However, it allows relative richness in its analysis by including reactions to aging-induced price changes, international diversification, and policy changes.

On the macroeconomics side, demographic issues have been most widely addressed in the context of economic growth. In the textbook treatment of growth theories, the growth rate of the population is considered to be exogenous and serves

as a starting point for growth in real activities. Both population growth and population aging are relevant when determining real interest rates and inflation as well. In particular, the dependency of the (equilibrium) real interest rate on population dynamics is contingent on how population dynamics are incorporated into the utility specification. In an infinite-horizon model with a growing household size, the real interest rate may or may not depend on the growth rate of the population.[5] This ambiguity will be a source of difficulty when determining a desirable response by monetary policies in a world of changes in population growth in the medium to short term.

Empirical evidence of the growth effect has been studied extensively.[6] This includes such channels as lower labor inputs, a potential negative impact due to increasing tax and contribution burdens, savings and investment, and productivity. The demographic impact on *aggregate* real GDP is somewhat straightforward when the population is growing, declining or aging given the direct implication on the size of labor inputs, while its impact on *per capita* real GDP is less so, attracting attention for analysis. For example, Chapter 3 of the 2004 World Economic Outlook by Callen et al. (2004) found that per capita GDP growth is positively correlated with changes in the working age population share but is negatively correlated with changes in the elderly share. Based on the decomposition of real GDP growth into productivity and changes in labor input due to both population growth and aging, Choi et al. (2014) also shows that the impending demographic change in Korea has a negative impact on real GDP growth.[7] However, Bloom, Cunning, and Fink (2010) find that population aging will tend to lower labor force participation and savings rates, raising concern about a slowing of economic growth, but behavioral responses (including greater female labor-force participation) and policy reforms (including an increase in the legal age of retirement) can mitigate the adverse economic consequences of an older population.[8]

Population growth affects other real variables as well. The influence of demographic variables has been investigated in the context of the following key economic variables, in addition to growth in real GDP per capita. These include savings- and investment-to-GDP ratios, the current account-to-GDP ratio, and the budget balance-to-GDP ratio. If the life-cycle hypothesis of savings is valid, consumption smoothing through the lifetime would indicate that people move from net borrowers in their youth to net savers in their working years and finally to dis-

[5]In the standard case when agents from different generations are treated equally regardless of the size of each generation to which one belongs, the real interest rate is independent of the population growth rate and increases with the rate of technology change and the rate of time preference; under the alternative assumption that the utility of each generation is weighted equally irrespective of its size (i.e., agents from different generations are treated differently), population growth will bring about a one-to-one increase in the real interest rate. See the textbook treatment in Romer (2012) for a more in-depth discussion of this point.

[6]For a recent reference pertaining to the relationship between demographic changes and economic development, see World Bank Group (2016).

[7]They decomposed real GDP growth into four components (labor productivity, employment rate, changes in the population age structure, and population growth) and found that, from the 2010s, the contribution of the population to Korea's GDP growth has fallen to 0.4%p and the change in the age structure has become a negative component.

[8]Börsch-Supan, Härtl and Ludwig (2014)—based on an overlapping generations model with behavioral reactions—also show that while the negative growth effect from population aging in Europe can be compensated for by reforms and economic adaptation mechanisms, they may be offset by behavioral reactions.

savers in their elderly years. The demographic impact on investment appears to be less clear, but a potential impact exists through savings and labor supply channels. Given the evolution of savings and investment patterns in tandem with demographic changes, current account balances would improve with a larger working age population but worsen with the increase in the elderly share. On the fiscal side, a higher share of the working-age population will induce greater revenue, while an aging population will result in greater spending in such areas as pensions and health and long-term care spending, aggravating the fiscal balance. Existing studies, those by including Callen et al. (2004) and the External Balance Assessment (EBA) methodology by Phillips et al. (2013) at the IMF, broadly confirm these hypotheses, though there are variations in their effects across studies.

There has been rather limited research on inflation in the context of population dynamics. Population aging could affect inflation via both demand and supply channels. On the demand side, a rising share of the elderly with lower incomes and a negative wealth effect from falling asset prices will restrict the aggregate consumption, whereas a greater propensity to consume by the elderly could increase aggregate consumption. Aging could affect inflation in either direction as well from the supply side; this factor could decrease the labor supply and increase average wages, which would push up inflation. Aging could also increase labor participation by the elderly or the female population, who usually work in low-wage areas, hence exerting downward pressure on inflation. The net inflationary impact will depend on the extent of the supply-side adjustment in response to changes in aggregate demand. Therefore, the overall effect on inflation must be discussed in the context of a particular model from a theoretical perspective.[9]

Empirical evidence of inflation has been scant and inconclusive and there are intrinsic difficulties when attempting to identify the empirical impact on asset prices as well. A full-blown DSGE model that is used by the IMF for policy purposes has been modified to incorporate demographic changes—albeit in an hoc manner—by Anderson, Botman, and Hunt (2014) and used to understand whether Japan's population aging is deflationary or not. They found that substantial deflationary pressures arise from population aging—mainly through declining growth and falling land prices—and their findings are based on simulations of a calibrated model rather than being empirically motivated and validated.

Japan is one of a number of countries which have been studied quite extensively in the context of demographic changes. Not only has the country gone through drastic economic changes in terms of growth, but its transition from an aging society to an aged society has been the most rapid in world history. Three European countries—France, Germany, and England—underwent a transformation from an aging society to an aged society in 115, 45, and 45 years, respectively; it took 65 years for the United States to undergo this transformation. In contrast, the change took only 24 years in Japan. Muto *et al.* (2012) investigates how demographic changes affect GNP per capita and other real variables—mainly via changes on the supply side. In contrast, Katagiri (2012) captures the effects via the demand

[9]Focusing on the interaction among different population groups and the desire for a redistribution of resources in the economy, Bullard et al. (2012) asserts that a baby boom can generate temporarily higher inflation and that aging population dynamics will put downward pressure on inflation or even lead to deflation as the elderly—preferring a higher real rate of return from their savings—have more influence over the redistributive policy.

channels by calibrating preference shocks that correspond to the Japanese experience of changes in demand structures and finds using a multi-sector new Keynesian model that population aging—modeled as unexpected shocks to its demand structure—caused deflationary pressure of about 0.3%p. The effect of demographic changes on the real interest rate has been studied in an infinite-horizon setting by Ikeda and Saito (2012).

Considerable difficulty lies in choosing appropriate variables for capturing demographic changes. In a representative-agent model of growth, population growth is a clean exogenous component that is to be used for empirical analysis. However, in a model with heterogeneous agents—typically in the setting of overlapping generations—there are compositional changes in demographics. Callen *et al.* (2004) uses the share of the working-age population and the share of the elderly population as two independent variables; other papers, including Muto *et al.* (2012), capture the growth and composition of the population via the fertility rate and the longevity rate. While changes in fertility or mortality are key drivers of demographic changes, they may not be adequate indicators when analyzing the macroeconomic impact of demographic changes considering the long lag with which these changes affect the population structure and therefore the economy. For this reason, demographic indicators reflecting the age structure, such as the share of the working-age population or dependency ratios, have often been employed to examine their impact on the macroeconomy. In this paper, we follow this approach and use the shares of the working-age population and the elderly population as appropriate variables for capturing population dynamics, while utilizing the dependency ratios in regressions that involve savings, investment, and the current account balance.[10]

IV. Empirical Findings

A. Data and Methodology

A panel dataset covering 30 OECD economies for the period of 1960–2013 is constructed to examine the relationship between demographic variables and macroeconomic variables. Specifically, the analysis focuses on the impact of demographic changes on each of the following measures of macroeconomic performance: the growth of the real GDP per capita, the current account balance/GDP, savings/GDP, investment/GDP, government budget balance/GDP, and the inflation rate. Building on the bivariate relationships as illustrated in Figure A2, A3, and A4, we proceed with a multivariate analysis controlling for other explanatory factors.

In order to examine the impact of demography as a determinant of economic performance, we begin with following specification:

[10]There are alternative ways to split population differently. For example, Fair and Dominguez (1991) classified the entire population into five-year buckets and estimated U.S. consumption as a function of more than one dozen buckets.

$$Y_{it} = \alpha_i + \beta Demo_{it} + \gamma Z_{it} + \varepsilon_{it}$$

where Y is the macroeconomic variable of interest and *Demo* are relevant measures of the demographic structures of individual countries. Z is a set of control variables and the subscripts i and t denote the country and the time period, respectively. Our base estimation scheme is a fixed-effects estimation in the case of cross-country panel data and OLS in the case of a single-country analysis using annual data.

All demography variables, including population growth, the shares of specific age groups, life expectancy, and other derivative measures such as dependency ratios are taken from or calculated based on the population database of the United Nations. An additional benefit of the UN database is that it provides demographic structure projections for most individual countries in the world. In this paper, World Population Prospects: The 2012 Revision, available in United Nations (2014), is used to gain information about the future paths of demographic measures.

Control variables for the growth regression include the secondary school enrollment ratio, investment/GDP, budget balance/GDP, the inflation rate, and degree of openness. For the three regressions of the current account, savings, and investment, the controls are budget balance/GDP, net foreign assets/GDP, growth in the terms of trade, real GDP growth, and openness. Budget balance regression has terms-of-trade growth and openness as control variables. Finally, controls for inflation regression are the terms of trade growth, real GDP growth, M2 growth, and the changes in budget balance/GDP.

Most macro variables of interest, as well as control variables, are constructed using World Economic Outlook and International Financial Statistics databases of the IMF or the World Development Indicator database of the World Bank. Additionally, the PPP-based real GDP per capita variable is from the Penn World Table (PWT) version 7.1 by Heston et al. (2012), and the net foreign asset variable is from the updated version of the Lane and Milesi-Ferretti (2007) dataset. Table A1 and A2 provides summary statistics for the key variables used in the analysis and the list of sample countries. Table A3 presents further details on the variables used to analyze the impacts of demographic variables, including their respective sources.

B. Macroeconomic Impact

1. Growth Impact

We now turn to the effects of the demographic changes on the macroeconomic variables. Because the next subsection will focus on the effects on inflation, the three tables in this subsection focus on the real side of the macroeconomic variables. The first table displays the demographic impact on real GDP growth per capita, and Table 2 will provide information about the impact on the current account, savings, and investment. Table 3 will then focus on the fiscal policy variables of the budget balance, revenue, and expenditures.

TABLE 1—DEMOGRAPHIC IMPACT ON GROWTH OF REAL GDP PER CAPITA (PPP-BASED)

	OECD FE				OECD FE IV 2/				Japan OLS			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Population Growth	-0.686 [0.270]		-1.194 [0.018]**	-1.130 [0.031]**	0.075 [0.807]		-0.621 [0.053]*	-0.504 [0.118]	0.940 [0.791]		-0.259 [0.935]	2.589 [0.717]
Share of 65 and over		-0.211 [0.002]***	-0.261 [0.000]***	-0.122 [0.349]		-0.590 [0.000]***	-0.614 [0.000]***	-0.365 [0.000]***		-0.602 [0.120]	-0.610 [0.088]*	-0.782 [0.118]
Share of 15-64		-0.132 [0.159]	-0.201 [0.037]**	-0.090 [0.372]		-0.159 [0.009]***	-0.192 [0.002]***	0.010 [0.901]		-1.973 [0.027]**	-1.984 [0.037]**	-2.079 [0.032]**
Life Expectancy				-0.198 [0.189]				-0.363 [0.000]***				0.756 [0.672]
Openness	0.008 [0.276]	0.013 [0.188]	0.019 [0.041]**	0.025 [0.006]***	0.007 [0.331]	0.018 [0.011]**	0.022 [0.004]***	0.033 [0.000]***	0.118 [0.326]	-0.083 [0.593]	-0.087 [0.634]	-0.108 [0.595]
Secondary School Enrollment	-0.018 [0.116]	0.005 [0.571]	0.006 [0.485]	0.014 [0.132]	-0.040 [0.000]***	-0.002 [0.862]	-0.002 [0.882]	0.015 [0.185]	-0.297 [0.434]	0.269 [0.427]	0.257 [0.539]	0.200 [0.665]
Budget Balance/GDP	0.091 [0.100]	0.083 [0.135]	0.100 [0.081]*	0.100 [0.070]*	-0.003 [0.956]	0.028 [0.549]	0.044 [0.347]	0.053 [0.258]	0.110 [0.545]	0.450 [0.085]*	0.451 [0.084]*	0.425 [0.132]
Inflation	-0.090 [0.000]***	-0.101 [0.000]***	-0.103 [0.000]***	-0.100 [0.000]***	-0.087 [0.000]***	-0.112 [0.000]***	-0.113 [0.000]***	-0.105 [0.000]***	-0.555 [0.010]***	-0.649 [0.000]***	-0.639 [0.000]***	-0.639 [0.000]***
Investment/GDP	0.272 [0.000]***	0.244 [0.000]***	0.248 [0.000]***	0.244 [0.000]***	-0.105 [0.014]**	-0.179 [0.000]***	-0.178 [0.000]***	-0.188 [0.000]***	0.380 [0.256]	0.623 [0.049]**	0.618 [0.043]**	0.664 [0.030]**
Constant	-1.670 [0.309]	7.407 [0.208]	12.862 [0.035]**	17.557 [0.041]**	8.548 [0.000]***	24.193 [0.000]***	26.897 [0.000]***	35.604 [0.000]***	19.075 [0.692]	106.059 [0.038]**	108.522 [0.124]	60.834 [0.628]
Observations	1,104	1,104	1,104	1,104	1,072	1,072	1,072	1,072	40	40	40	40
Number of ifscode	30	30	30	30	30	30	30	30				
R-squared	0.177	0.185	0.199	0.203					0.444	0.513	0.513	0.516

Note: 1) Fixed-effect estimation for OECD and OLS for individual country regressions using annual data. 2) Secondary school enrollment, Budget balance/GDP, Inflation, and Investment/GDP are instrumented using their lagged values. 3) P-values based on robust t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 1 shows the results of how demographic variables—together with other key explanatory variables—affect the growth in real GDP per capita (PPP-based) in OECD countries. The first column includes only the growth rate of the population as a demographic variable. Population growth affects real growth negatively, though insignificantly. Among the other variables, the coefficient of inflation is negative and significant at the 1 percent level, and the impact of investment to the GDP ratio on real GDP growth per capita is significantly positive. The next column is based on a regression that uses the share of the elderly (65 and above) and the share of those aged 15-64 instead of population growth. Between the two variables, the share of the elderly affects output growth negatively and significantly, while the influence of the share of those aged 15-64 is insignificantly negative. Inflation and the investment-to-GDP ratio affect GDP growth in ways similar to those shown in Column (1). Column (3) includes the three population variables together; it is interesting that all three variables—population growth, the share of the elderly, and the share of those aged 15-64—turn out to be significant while openness becomes significant at the 5 percent confidence level. The fourth column has life expectancy as well as the three population variables, as life expectancy affects the population dynamics differently; in this case, only the impact of population growth is significant at the 5 percent level. The message of the four specifications is that the size of the population affects real GDP per capita growth negatively and that aging, as captured by the share of those aged 65 and above, influences real GDP growth in a negative way. The next four columns—Columns (5) to (8)—are based on the instrumental variables method to address a potential endogeneity problem, and the message is similar. Life expectancy affects real GDP growth significantly and negatively in this case.

Table 1 also includes the results for Japan. Though it is generally regarded that changes in population dynamics have been most dramatic in this country, the results of the demographic impact on growth are not as strong.[11] For example, the share of those aged 15-64 affects GDP growth per capita negatively, most likely due to endogeneity, which is not fully captured in this specification. It is interesting that the coefficient for inflation is significantly negative in all four specifications.

2. Impact on Current Account, Savings, and Investment

We now turn to the demographic impact on three key macroeconomic variables: current account, savings, and investment—all relative to GDP. It is interesting to note with regard to their bivariate relationships, as presented in Appendices 4 and 5, that a rising elderly share improves the current account mainly through a reduction in investment, while a greater working-age share improves the current account, but due to a greater increase in savings than in investment. Turning to the results of the multivariate analysis, the top part of Table 2 is based on the population variables that were used in Table 1, while the bottom part is based on

[11]The impact on *aggregate* real GDP growth could be sizable, considering the effect of the declining and aging population on labor inputs. The demographic impact on *per capita* growth would be less so, as it will depend on how demographic changes affect the combination of factor inputs and the level of productivity.

two newly defined variables regarding the composition of the population. The results based on the regressions for the OECD countries using the share of those aged 65 and above and the share of those aged 15-64, as well as population growth and life expectancy, are displayed in Columns (1) to (3). Population growth influences current account, savings, and investment negatively, though insignificantly. The negative impact of the elderly share is significant for savings and investment. Life expectancy affects savings positively and significantly, which reflects the growing need for the elderly to spread their consumption over their longer living years.[12]

The columns on the right are based on the data of Japan. Columns (5) and (6) show that population growth and life expectancy influence savings and investment negatively and that the negative impacts are significant at the 1 percent confidence level.

The lower half of Table 2 is based on the old dependency and young dependency ratios, which are a transformation of the population shares, as noted below the table. As in the other case displayed in the upper half, the old dependency ratio influences savings and investment negatively for OECD countries, as in Columns (8) and (9); population growth and life expectancy affect savings and investment negatively for Japan, as in Columns (11) and (12).

3. Fiscal Impact

Table 3 focuses on the variables that are closely related to fiscal policy: budget balance, government revenue, and government expenditure—all relative to GDP. For OECD countries, population growth affects the budget balance positively. The elderly share is shown to affect the budget balance negatively, as its effect on expenditure appears to be greater than that on revenue. Other variables do not affect the budget balance significantly. Revenue is negatively affected by population growth, while the impact by the population shares, on the other hand, is positive. Expenditure variables are affected similarly, with openness affecting them negatively.

In the case of Japan, the bottom panel, which shows the influence of population growth on the budget balance, is mixed. The share variables are quite significant in their impact on these fiscal policy variables, particularly when including the positive and significant coefficient of the elderly share on expenditure.

[12]This demographic impact on the current account needs to be considered when assessing the desirable level of the current account positions, including those in the IMF's External Balance Assessment exercise.

TABLE 2—DEMOGRAPHIC IMPACT ON CURRENT ACCOUNT, SAVINGS, AND INVESTMENT

	OECD			Japan		
	CA/GDP (1)	S/GDP (2)	I/GDP (3)	CA/GDP (4)	S/GDP (5)	I/GDP (6)
Population Growth	-0.397 [0.603]	-0.776 [0.277]	-0.185 [0.836]	2.050 [0.305]	-7.740 [0.000]***	-10.113 [0.002]***
Share of 65 and over	-0.372 [0.141]	-0.942 [0.001]***	-0.486 [0.043]**	-0.464 [0.199]	0.270 [0.217]	0.604 [0.239]
Share of 15-64	-0.246 [0.163]	0.012 [0.951]	0.249 [0.219]	0.358 [0.339]	0.582 [0.085]*	0.122 [0.836]
Life Expectancy	0.379 [0.180]	0.428 [0.019]**	-0.210 [0.327]	0.826 [0.085]*	-2.222 [0.000]***	-2.942 [0.000]***
Budget Balance/GDP	0.109 [0.215]	0.399 [0.000]***	0.313 [0.000]***	0.089 [0.311]	0.516 [0.000]***	0.445 [0.013]**
NFA/GDP	0.026 [0.009]***	0.028 [0.000]***	0.002 [0.652]	0.111 [0.059]*	0.018 [0.681]	-0.088 [0.296]
TOT change	0.110 [0.001]***	0.063 [0.001]***	-0.049 [0.043]**	0.079 [0.000]***	0.010 [0.564]	-0.072 [0.017]**
GDP Growth	-0.106 [0.195]	0.180 [0.027]**	0.255 [0.000]***	0.109 [0.043]**	0.066 [0.294]	-0.047 [0.564]
Openness	0.033 [0.105]	0.005 [0.754]	-0.024 [0.209]	0.078 [0.317]	0.004 [0.948]	-0.084 [0.462]
Constant	-9.447 [0.484]	2.229 [0.824]	31.270 [0.006]***	-85.597 [0.022]**	167.525 [0.000]***	254.051 [0.000]***
Observations	1,163	1,121	1,163	43	43	43
Number of ifscode	30	29	30			
R-squared	0.184	0.439	0.383	0.770	0.973	0.953
RMSE	3.157	2.889	2.834	0.763	0.741	1.170
	OECD			Japan		
	CA/GDP (7)	S/GDP (8)	I/GDP (9)	CA/GDP (10)	S/GDP (11)	I/GDP (12)
Population Growth	-0.654 [0.380]	-0.876 [0.258]	-0.021 [0.981]	1.681 [0.376]	-8.125 [0.000]***	-10.213 [0.001]***
Old Dependency	-0.162 [0.215]	-0.560 [0.000]***	-0.332 [0.006]***	-0.423 [0.026]**	-0.036 [0.813]	0.372 [0.172]
Young Dependency	0.143 [0.080]*	0.019 [0.829]	-0.121 [0.173]	-0.110 [0.547]	-0.291 [0.064]*	-0.117 [0.680]
Life Expectancy	0.448 [0.133]	0.368 [0.038]**	-0.339 [0.148]	0.755 [0.087]*	-2.341 [0.000]***	-3.013 [0.000]***
Budget Balance/GDP	0.115 [0.184]	0.398 [0.000]***	0.306 [0.000]***	0.088 [0.302]	0.525 [0.000]***	0.459 [0.008]***
NFA/GDP	0.026 [0.009]***	0.029 [0.000]***	0.002 [0.566]	0.117 [0.032]**	-0.002 [0.967]	-0.117 [0.141]
TOT change	0.108 [0.001]***	0.063 [0.001]***	-0.048 [0.044]**	0.079 [0.000]***	0.012 [0.466]	-0.070 [0.015]**
GDP Growth	-0.109 [0.185]	0.180 [0.025]**	0.259 [0.000]***	0.112 [0.037]**	0.068 [0.274]	-0.048 [0.544]
Openness	0.033 [0.109]	0.004 [0.811]	-0.025 [0.208]	0.079 [0.302]	0.000 [0.993]	-0.090 [0.417]
Constant	-36.980 [0.097]*	5.890 [0.672]	61.560 [0.002]***	-50.522 [0.170]	229.472 [0.000]***	272.624 [0.000]***
Observations	1,163	1,121	1,163	43	43	43
Number of ifscode	30	29	30			
R-squared	0.188	0.431	0.379	0.780	0.973	0.955
RMSE	3.149	2.909	2.844	0.745	0.739	1.141

Note: 1) Fixed-effect estimation for OECD and OLS for individual country regressions using annual data. 2) Young Dependency= (Ages 0-14) / (Ages 15-64); Old Dependency= (Ages 65 and over) / (Ages 15-64). 3) P-values based on robust t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.

TABLE 3—DEMOGRAPHIC IMPACT ON BUDGET BALANCE, REVENUE, AND EXPENDITURE PER GDP

OECD	Balance				Revenue				Expenditure			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Population Growth	1.771 [0.009]***		1.472 [0.034]**	1.489 [0.030]**	-3.533 [0.001]***		-1.489 [0.126]	-1.703 [0.052]*	-5.151 [0.000]***		-3.017 [0.023]**	-3.282 [0.008]***
Share of 65 and over		-0.288 [0.024]**	-0.214 [0.126]	-0.051 [0.779]		0.900 [0.000]***	0.825 [0.000]***	0.204 [0.469]		1.102 [0.000]***	0.952 [0.000]***	0.182 [0.571]
Share of 15-64		-0.046 [0.722]	0.035 [0.792]	0.158 [0.340]		0.373 [0.005]***	0.310 [0.039]**	-0.108 [0.642]		0.366 [0.060]*	0.239 [0.277]	-0.279 [0.362]
Life Expectancy				-0.184 [0.319]				0.685 [0.015]**				0.849 [0.010]**
TOT Change	0.011 [0.604]	0.015 [0.474]	0.012 [0.550]	0.012 [0.560]	0.039 [0.015]**	0.029 [0.066]*	0.032 [0.051]*	0.024 [0.139]	0.001 [0.961]	-0.012 [0.552]	-0.005 [0.795]	-0.015 [0.483]
Openness	-0.021 [0.028]**	-0.006 [0.508]	-0.012 [0.257]	-0.006 [0.603]	-0.007 [0.806]	-0.075 [0.008]***	-0.068 [0.011]**	-0.089 [0.001]***	0.001 [0.981]	-0.077 [0.008]***	-0.063 [0.024]**	-0.089 [0.002]***
Constant	-2.417 [0.001]***	4.487 [0.568]	-2.385 [0.772]	0.929 [0.920]	33.001 [0.000]***	-0.789 [0.923]	4.821 [0.641]	-9.84 [0.292]	36.304 [0.000]***	-0.105 [0.993]	11.259 [0.432]	-6.917 [0.610]
Observations	1,338	1,338	1,338	1,338	1,193	1,193	1,193	1,193	1,193	1,193	1,193	1,193
Number of ifscode	30	30	30	30	30	30	30	30	30	30	30	30
R-squared	0.057	0.051	0.071	0.076	0.113	0.299	0.315	0.362	0.130	0.230	0.267	0.308
RMSE	3.202	3.214	3.182	3.173	3.399	3.021	2.988	2.885	4.489	4.226	4.124	4.011

Note: 1) Fixed-effect estimation for OECD and OLS for individual country regressions using annual data. 2) P-values based on robust t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.

TABLE 3—DEMOGRAPHIC IMPACT ON BUDGET BALANCE, REVENUE, AND EXPENDITURE PER GDP *(CONTINUED)*

Japan	Balance				Revenue				Expenditure			
	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
Population Growth	1.979 [0.001]***		1.857 [0.128]	-5.381 [0.050]**	-8.902 [0.000]***		-1.072 [0.358]	-3.558 [0.057]*	-10.881 [0.000]***		-2.929 [0.042]**	1.822 [0.307]
Share of 65 and over		-0.165 [0.012]**	-0.006 [0.965]	0.892 [0.000]***		0.939 [0.000]***	0.847 [0.000]***	1.156 [0.000]***		1.104 [0.000]***	0.853 [0.000]***	0.264 [0.192]
Share of 15-64		0.235 [0.208]	0.276 [0.201]	2.117 [0.000]***		0.809 [0.000]***	0.785 [0.000]***	1.418 [0.000]***		0.574 [0.000]***	0.510 [0.000]***	-0.699 [0.037]**
Life Expectancy				-1.931 [0.000]***				-0.663 [0.029]**				1.267 [0.000]***
TOT Change	-0.058 [0.203]	-0.056 [0.220]	-0.054 [0.219]	0.016 [0.616]	-0.039 [0.482]	-0.048 [0.043]**	-0.049 [0.056]*	-0.025 [0.293]	0.019 [0.734]	0.008 [0.849]	0.005 [0.898]	-0.041 [0.295]
Openness	-0.250 [0.004]***	-0.163 [0.095]*	-0.192 [0.060]*	0.289 [0.075]*	-0.033 [0.638]	-0.167 [0.004]***	-0.151 [0.004]***	0.015 [0.879]	0.216 [0.012]**	-0.004 [0.956]	0.042 [0.594]	-0.275 [0.016]**
Constant	0.514 [0.774]	-14.021 [0.310]	-19.244 [0.239]	-12.109 [0.309]	21.026 [0.000]***	-47.738 [0.001]***	-44.724 [0.001]***	-42.273 [0.001]***	20.511 [0.000]***	-33.717 [0.000]***	-25.48 [0.002]***	-30.164 [0.000]***
Observations	54	54	54	54	54	54	54	54	54	54	54	54
R-squared	0.412	0.419	0.431	0.649	0.740	0.886	0.888	0.898	0.839	0.904	0.912	0.934
RMSE	2.400	2.410	2.408	1.913	2.486	1.665	1.669	1.606	2.576	2.004	1.944	1.699

Note: 1) Fixed-effect estimation for OECD and OLS for individual country regressions using annual data. 2) P-values based on robust t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.

C. Inflation Impact

As mentioned above, the demographic impact on real variables—summarized in Tables 1 to 3—has also been analyzed in previous studies. What has received much less attention is the demographic impact on inflation, which is ambiguous in theory given various conflicting channels. For example, population aging or shrinking will have multifarious demand-side effects due to changing consumption preferences, possibly leading to a reduction in aggregate demand in the economy and lower inflation. On the other hand, it would reduce the effective supply of labor in the economy, adding inflation pressures. As noted earlier, the demographic impact would depend on how changes in the population size and structure affect aggregate demand and supply, agents' inflation expectations, and asset prices, which in turn depend on the extent of nominal and real friction, institutional aspects, and behavioral responses.

Hence, it is difficult to determine from a theoretical perspective how various changes in demographics affect inflation, and it would ultimately be an empirical issue, to which Table 4 is devoted.[13] This table is based on regressing inflation on demographic variables, as well as other relevant conditioning variables; the columns on the left display results for the OECD data and those on the right correspond to the Japanese case. To capture the deviation from the anticipated change in inflation and population changes, the two variables are detrended using a quadratic trend given that there is a slow-moving component in these series.[14]

As displayed in Column (1), population growth affects inflation positively, as a greater population implies more aggregate demand. This may be due to the fact that the aggregate supply adjustment could be slower than the aggregate demand adjustment in response to demographic shocks in the short or medium term.[15] When the share of the elderly is added as an independent variable (Column 2), population growth continues to affect inflation positively and the influence of the elderly share is significantly negative. Conditional on population growth, the aging process will suppress inflation significantly. This is true when the share of those aged 15-64 is coupled with the elderly share (Columns 3 and 4) and when life expectancy is added as well (Column 5). Other conditioning variables used are the changes in terms of trade, GDP growth, M2 growth, and the change in the budget balance, all of which show very significant coefficients with the expected signs.[16]

[13]We attempted to estimate the impact of population growth and aging on housing prices, but were not produce to draw meaningful empirical evidence. This may be partly due to the intrinsic difficulties in estimating asset prices. See Terrones (2004), however, for an empirical analysis regarding this issue. Dent (2014) focuses on the influence of demographic changes on asset prices as well as aggregate consumption based on the size of the population cohort with the highest consumption capacity.

[14]Detrending would also avoid the possibility of a spurious regression due to non-stationary trend elements. The detrended time series can be interpreted as an unanticipated shock from the trend.

[15]If supply responses are as flexible as demand responses, there could be little impact on inflation. However, there may be other channels through which demographic shocks could impart deflationary pressures on the economy, including its impact through the wealth effect, due to changing asset prices and/or real exchange rate appreciation arising from changes in asset allocations.

[16]It would be desirable if the coefficients for the share of those aged 15-64 to be positive, which is not true in Table 4. However, if the share of the elderly and the share of those aged 15-64 could be replaced with the population sizes of the two groups, the two coefficients are estimated to have the desirable signs, though the outcomes would not be statistically significant. See the Table A4.

TABLE 4—DEMOGRAPHIC IMPACT ON INFLATION

	OECD					Japan				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Population Growth	0.339 [0.715]	0.524 [0.577]		0.549 [0.570]	0.317 [0.764]	6.689 [0.005]***	6.363 [0.003]***		6.708 [0.001]***	6.725 [0.001]***
Share of 65 and over		-0.176 [0.009]***	-0.125 [0.013]**	-0.137 [0.006]***	-0.416 [0.008]***		-0.101 [0.394]	-0.321 [0.082]*	-0.300 [0.060]*	-0.242 [0.227]
Share of 15-64			-0.101 [0.226]	-0.103 [0.233]	-0.330 [0.037]**			-0.476 [0.030]**	-0.544 [0.008]***	-0.499 [0.026]**
Life Expectancy					0.304 [0.043]**					-0.092 [0.748]
TOT Change	-0.145 [0.005]***	-0.144 [0.005]***	-0.145 [0.005]***	-0.144 [0.005]***	-0.143 [0.005]***	-0.169 [0.016]**	-0.174 [0.014]**	-0.178 [0.013]**	-0.148 [0.016]**	-0.147 [0.016]**
GDP Growth	-0.750 [0.000]***	-0.795 [0.000]***	-0.799 [0.000]***	-0.802 [0.000]***	-0.784 [0.000]***	-0.246 [0.015]**	-0.319 [0.033]**	-0.517 [0.008]***	-0.431 [0.008]***	-0.452 [0.022]**
M2 Growth	0.192 [0.000]***	0.183. [0.000]***	0.180 [0.001]***	0.180 [0.001]***	0.176 [0.000]***	0.059 [0.118]	0.034 [0.379]	0.007 [0.869]	-0.009 [0.826]	-0.015 [0.751]
Budget Balance Chg.	0.129 [0.051]*	0.153 [0.022]**	0.153 [0.033]**	0.158 [0.018]**	0.150 [0.022]**	-0.105 [0.540]	-0.086 [0.563]	0.006 [0.971]	0.040 [0.776]	0.059 [0.690]
Constant	-0.053 [0.910]	2.418 [0.060]*	8.443 [0.149]	8.739 [0.151]	4.132 [0.255]	0.074 [0.821]	1.870 [0.399]	37.962 [0.031]**	42.051 [0.010]**	45.446 [0.038]**
Observations	1,167	1,167	1,167	1,167	1,167	53	53	53	53	53
Number of ifscode	30	30	30	30	30					
R-squared	0.212	0.216	0.217	0.217	0.222	0.530	0.545	0.462	0.602	0.603
RMSE	5.235	5.227	5.223	5.223	5.209	2.077	2.066	2.246	1.954	1.973

Note: 1) Inflation and population growth are detrended using quadratic filter. 2) Fixed-effect estimation for OECD and OLS for individual country regressions using annual data. 3) P-values based on robust t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.

The columns on the right hand side of Table 4 are generated from the data on Japan. Population growth influences the inflation rate significantly positively in all regressions. The effect from population shares is not as strong as it is in the OECD data.[17] Terms of trade and GDP growth are significant in the Japanese data as well, while the insignificant result for the money growth variable is puzzling.[18]

These results suggest that the ongoing demographic changes could have a significant deflationary impact in the years ahead, particularly on an economy experiencing a rapid decline and a significant aging of its population. Under such circumstances, the macroeconomic policy framework—including monetary and fiscal policies—must be revisited. This will be discussed in the concluding section.

V. Conclusion: Policy Implications

Demographic changes are among the most crucial long-term challenges that have a grave influence on the economy. Given the current fertility and mortality trends, the recent and coming decades will represent a watershed in demographic structures, in that we will observe a significant drop in population growth and the working-age population share and a rapid rise in the dependency ratio. Such demographic shifts have already accelerated in some countries, including Japan and Korea, and their impact on the economy may already be widespread, traversing economic growth, inflation, savings and investment, asset prices, and fiscal positions.

Despite the expected grave consequences on the economy, in many macroeconomic policy discussions or debates, demographic changes do not usually take center stage. For example, most growth models assume that a population grows at a constant rate—sometimes zero for simplicity—and many business cycle models fix the size of the population when analyzing aggregate demand. We have analyzed how demographic variables move over time and how these variables influence inflation as well as real macroeconomic variables.

By using a regression analysis, this paper found that population growth affects real economic variables in a negative manner, though the outcomes were insignificant in many instances. The influence of population dynamics on fiscal policy variables is rather mixed. On the inflation side, population growth affects the inflation rate positively, most likely through its influence on lower aggregate demand and the slow supply responses for which specific channels have yet to be examined. In this vein, the ongoing demographic changes—both shrinking and aging—could have a sizable deflationary impact in the coming years. These dynamics involving demographic changes would change the framework of

[17]The significance of population growth with regard to inflation regression on Japan, which is in stark contrast to that in the other OECD countries, may be due to the rapidly declining population. In addition to reducing aggregate demand, the declining population may have led to falling housing prices, which lowers aggregate demand even further.

[18]Money growth with a lag could be included in the regression to alleviate the endogeneity problem. However, the inclusion of lagged variables did not change the result significantly. It is possible to use short-term nominal interest rates instead of money growth, but is also well known that short-term rates respond to various macroeconomic variables, notably inflation and the output gap.

macroeconomic policies.

Taking the discussion of monetary policy as an example, one of the most popular ways to conduct and/or analyze monetary policy is via a reaction function that relates the policy short-term rate to a few variables that capture the state of the economy. The most well known is the rule set forth by John Taylor, under which the setting of short-term interest rates responds to inflation and the output gap as well as the equilibrium real interest rate. Population dynamics could affect the independent variables in this reaction function.

First, the equilibrium real interest rate can depend on both the growth rate of the population and the age composition of the population. It is, furthermore, challenging to nail down this relationship. The dependence on population growth is related to how the society treats different generations when there is population growth. Regarding the population composition, different assumptions with reference to the demand structure in an aging society would yield different implications pertaining to the real interest rate.

Second, the concept of the output gap depends on how the potential output is measured, which clearly depends on the population dynamics. Especially when the age structure changes over time, the potential output will depend critically on the assumptions regarding the labor participation rate and retirement age.[19] Any disagreement on the potential output would cause different policy prescriptions with regard to the short-term policy rate.

Last but not least, the direction of the policy rate depends on whether the actual inflation rate is above or below its target rate. In principle, the target rate can be set independently of any other variables in the economy if we follow the monetarist doctrine.[20] However, when population dynamics affect other target variables—such as the equilibrium real rate and the level of potential output—any misspecification in other parts of the economy would amount to unwanted inflation dynamics, and the inflation rate may not converge to its target as policymakers intend.[21] If demographic changes bring significant deflationary pressures, an original inflation target will become unrealistic, and sticking to the target will require the central bank to continue inflating its balance sheet, which will soon become unsustainable. For this reason, the potential demographic impact on inflation must be taken into account properly in monetary policy decisions.[22]

We have just taken monetary policy as an example of how understanding the impact of population dynamics could inform policymakers, but there are many other examples as well. The issue of how to implement fiscal policy is especially important when investigating the interaction with population dynamics. Fiscal policy tools are sometimes geared to specific groups and population dynamics

[19]Measuring the potential output could become complicated since, as implied by the term 'demographic dividend', productivity may depend on demographic changes instead of moving exogenously.

[20]That is, whether or not aging exerts downward pressure on prices may be irrelevant as a central bank committed to do whatever it takes should remain capable of anchoring inflation expectations at the target. Anderson, Botman, and Hunt (2014) attributed this monetarist doctrine to the lack of theoretical and empirical research on the relationship between demographics and inflation.

[21]Rachel and Smith (2015) argued that global real interest rates have fallen by nearly 450 basis points over the past 30 years, referring to demographic forces as among the most important.

[22]One possible approach is to consider the impact of demographic variables indirectly via a Taylor rule through other variables, such as the real interest rate, output gap or inflation expectations.

would affect fiscal policy directly, while monetary policy more or less affects economic agents without particular regard to individual population groups.[23]

In this paper, we have examined how population dynamics influence various macroeconomic variables—including the inflation rate—from an empirical perspective. Our empirical results would help researchers form their ideas on how demographic changes could affect inflation or deflation and the macroeconomy. However, population dynamics and their interactions with macroeconomic variables are multifarious, with the macroeconomic impact being different depending on the particular stage of the demographic transition. For this reason, underlying theories about the relationships between demographics and macroeconomic variables and their link with the empirical results, including specific channels through which demographic changes affect inflation and the macroeconomy, were not suggested in this paper.

To recap, it would be desirable, therefore, for further research, if the relationship could be analyzed from a theoretical perspective using a macroeconomic model. As alluded to in the preceding paragraphs, the interaction between population dynamics and variables involving macroeconomic policy need be incorporated into such a model based on a certain microeconomic foundation. Additional empirical study would also bring a better understanding of the channels through which demographic changes affect inflation and the macroeconomy and of the macroeconomic consequences. From a policy perspective, it remains crucial to implement appropriate policies without delay through a combination of sound monetary policy, fiscal consolidation, and bold structural reforms to mitigate the perverse effects of the ongoing drastic demographic changes. In addition to advanced countries which are already in the demographic watershed, developing countries facing the opposite demographic challenges with high fertility and younger populations should consider the potential impact when the demographic trends ultimately reverse and make intertemporally consistent policy choices.

[23]See Park (2012) for an example.

APPENDIX

TABLE A1—SUMMARY OF KEY VARIABLES

Variable	Obs	Mean	Std. Dev.	Min	Max
Population Growth	1,354	0.735	0.631	-0.482	3.172
Population Growth (detrended)	1,354	-0.017	0.300	-1.194	1.103
Share of 15-64	1,354	65.299	3.589	49.549	72.942
Share of 65 and over	1,354	12.672	3.769	3.316	25.078
Life Expectancy	1,354	74.992	4.804	47.575	83.580
Old Dependency Ratio	1,354	19.285	5.511	5.956	40.532
Young Dependency Ration	1,354	34.368	12.756	19.904	94.425
Per Capita Growth	1,255	2.343	3.425	-14.613	12.748
CA/GDP	1,329	-0.532	5.004	-28.383	21.266
Savings/GDP	1,295	21.990	5.855	-4.245	40.445
Investment/GDP	1,335	23.561	4.817	10.864	41.170
Budget Balance/GDP	1,354	-2.485	4.222	-25.130	16.652
Revenue/GDP	1,209	30.166	9.534	9.461	55.731
Expenditure/GDP	1,209	32.835	10.112	9.714	58.459
Inflation	1,342	7.323	11.369	-4.480	188.005
Inflation (detrended)	1,342	0.179	7.569	-23.281	150.243

TABLE A2—LIST OF SAMPLE OECD COUNTRIES

United States	Norway	Spain
United Kingdom	Sweden	Turkey
Austria	Switzerland	Australia
Belgium	Canada	New Zealand
Denmark	Japan	Mexico
France	Finland	Korea
Germany	Greece	Czech Republic
Italy	Iceland	Slovak Republic
Luxembourg	Ireland	Hungary
Netherlands	Portugal	Poland

TABLE A3—VARIABLE DEFINITIONS AND SOURCES

Demography variables from UN population prospects (future projections based on the 2012 revision)
Population Growth, detrended: Population growth after quadratic detrending, where population growth is subtracted by a fitted value determined by regressing it on constant, trend, and trend squared.
Share of the Working Age Population: Share of those aged between 15 and 64 years out of the total population.
Share of the Elderly Population: Share of those aged over 64 out of the total population.
Total Dependency Ratio: Number of persons in the population that are not of working age as a percentage of the working age population.
Old Dependency Ratio: Number of persons in the population above the age of 64 as a percentage of the working age population.
Young Dependency: Number of persons in the population below the age of 15 as a percentage of the working age population.
Fertility Rate: Average number of child births per woman.
Life Expectancy at Birth: Average number of years a person born can expect to live given the prevailing mortality rates in that area and period.
Variables from World Economic Outlook (WEO) and/or World Development Indicator (WDI) databases
Current Account/GDP, Savings/GDP, and Investment/GDP are from WEO and extended by WDI.
Inflation rate is based on the CPI and is constructed from WDI and supplemented by WEO.
Inflation rate, detrended: Inflation rate after quadratic detrending, where inflation rate is subtracted by a fitted value determined by regressing it on constant, trend, and trend squared.
Openness: Sum of exports and imports of goods and services divided by the nominal GDP. It is based on WDI and extended using WEO.
Budget Balance/GDP: Central government budget balance divided by the nominal GDP. Government Revenue, Expenditure, and Balance divided by GDP are based on the WDI database and extended using WEO.
Budget Balance Change: Change in the budget balance per GDP over the previous period.
Secondary School Enrollment: Total is the total enrollment in secondary education, regardless of age, expressed as a percentage of the population of official secondary education age. This variable is from the WDI database.
TOT Change: Log difference of goods-and-services terms of trade index from the previous period. Data are based on WEO values.
GDP growth: Growth rate of the real GDP from the WDI database.
Variables from Other Sources
Per Capita GDP growth: Growth of real GDP per capita in PPP terms. The underlying PPP GDP variable is from the PENN World Table version 7.1.
NFA/GDP: Net foreign assets divided by GDP is from the updated and extended version of the External Wealth of Nations dataset constructed by Lane and Milesi-Ferretti (2007).
M2 Growth: Growth rate of money and quasi money. M2 data are from WDI and are extended using values from the International Financial Statistics (IFS) database.

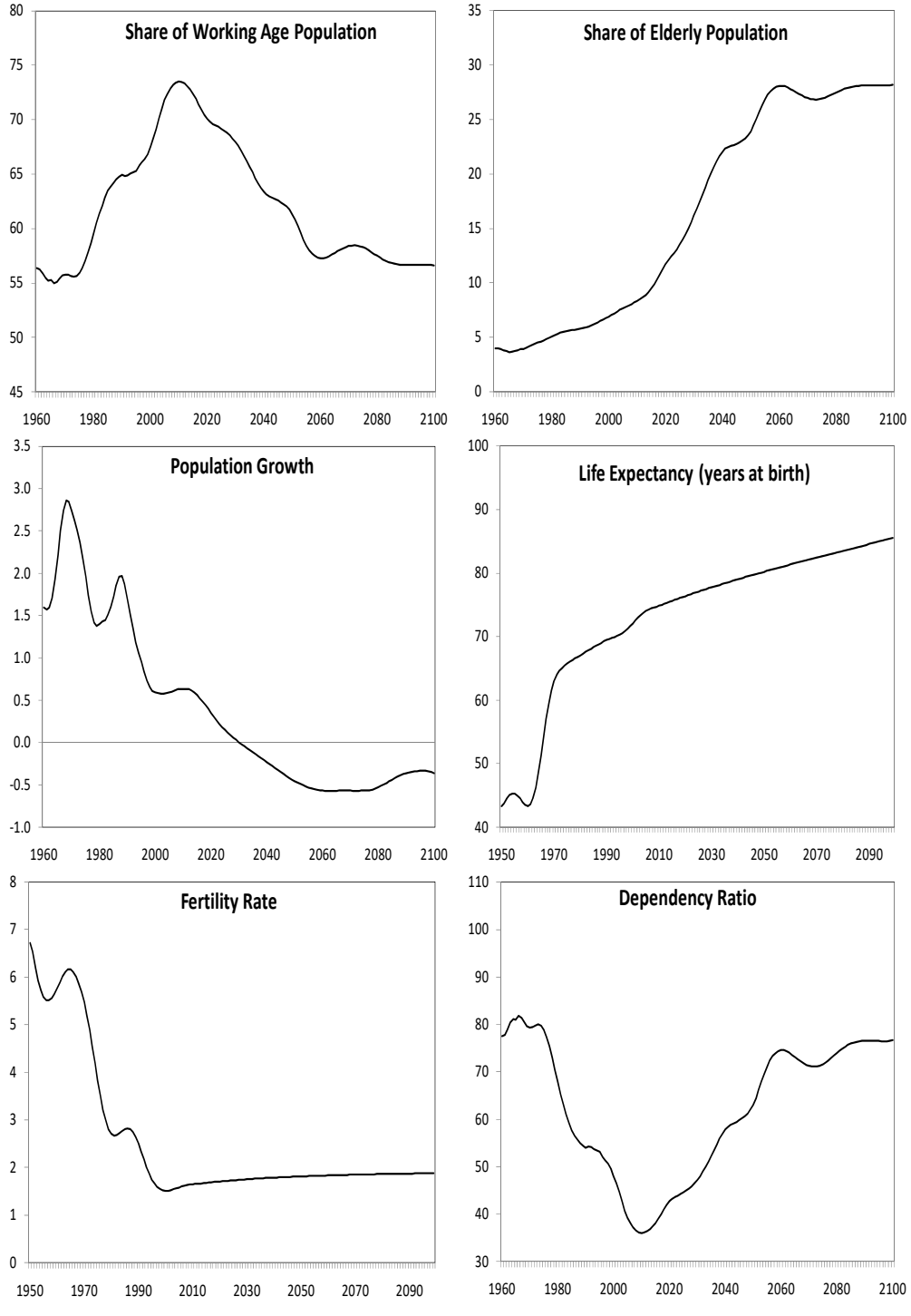

FIGURE A1. DEMOGRAPHIC TRENDS AND PROJECTIONS OF CHINA

Source: UN Population Prospects, 2012 revision.

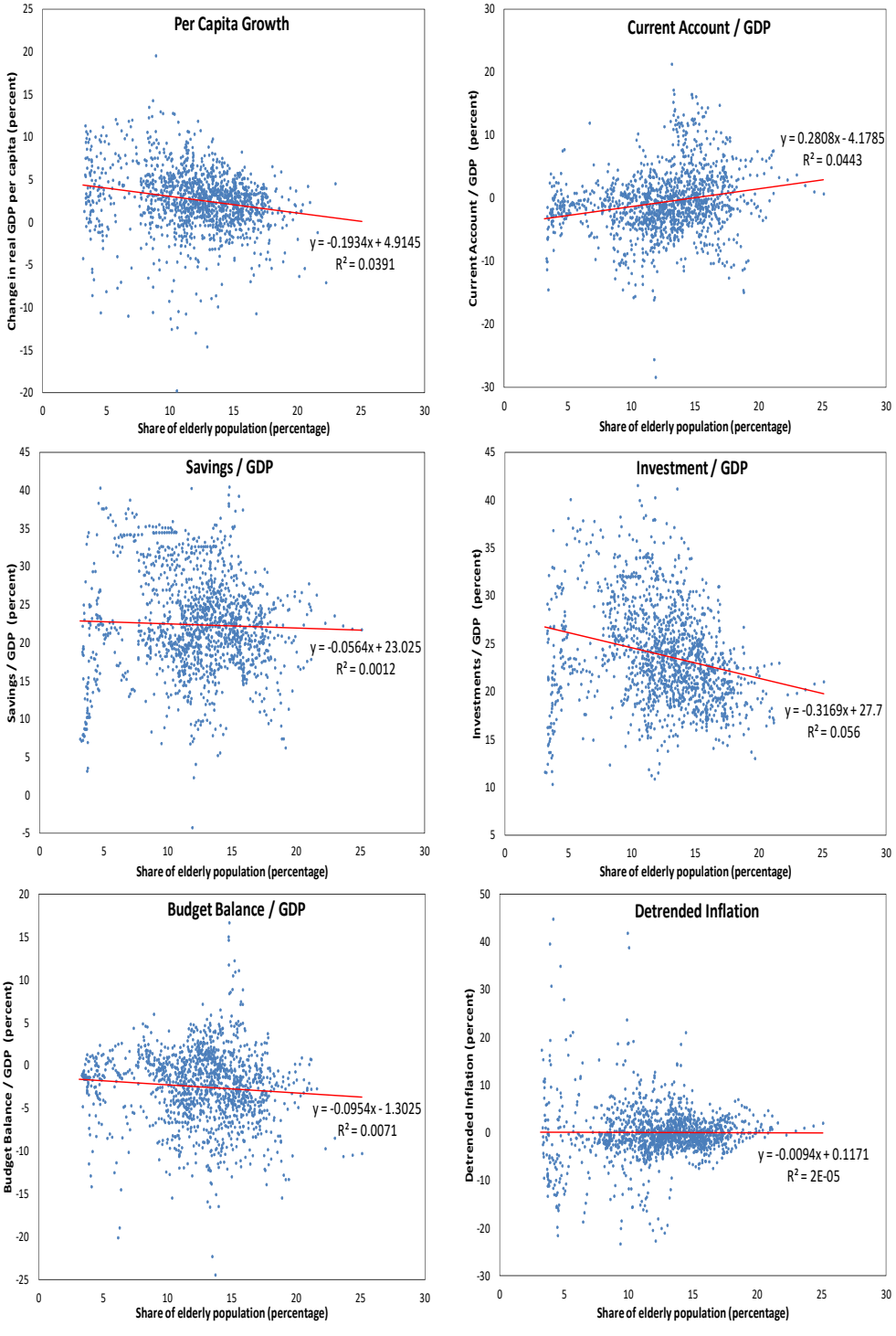

FIGURE A2. RELATIONSHIP BETWEEN MACRO VARIABLES AND THE ELDERLY SHARE

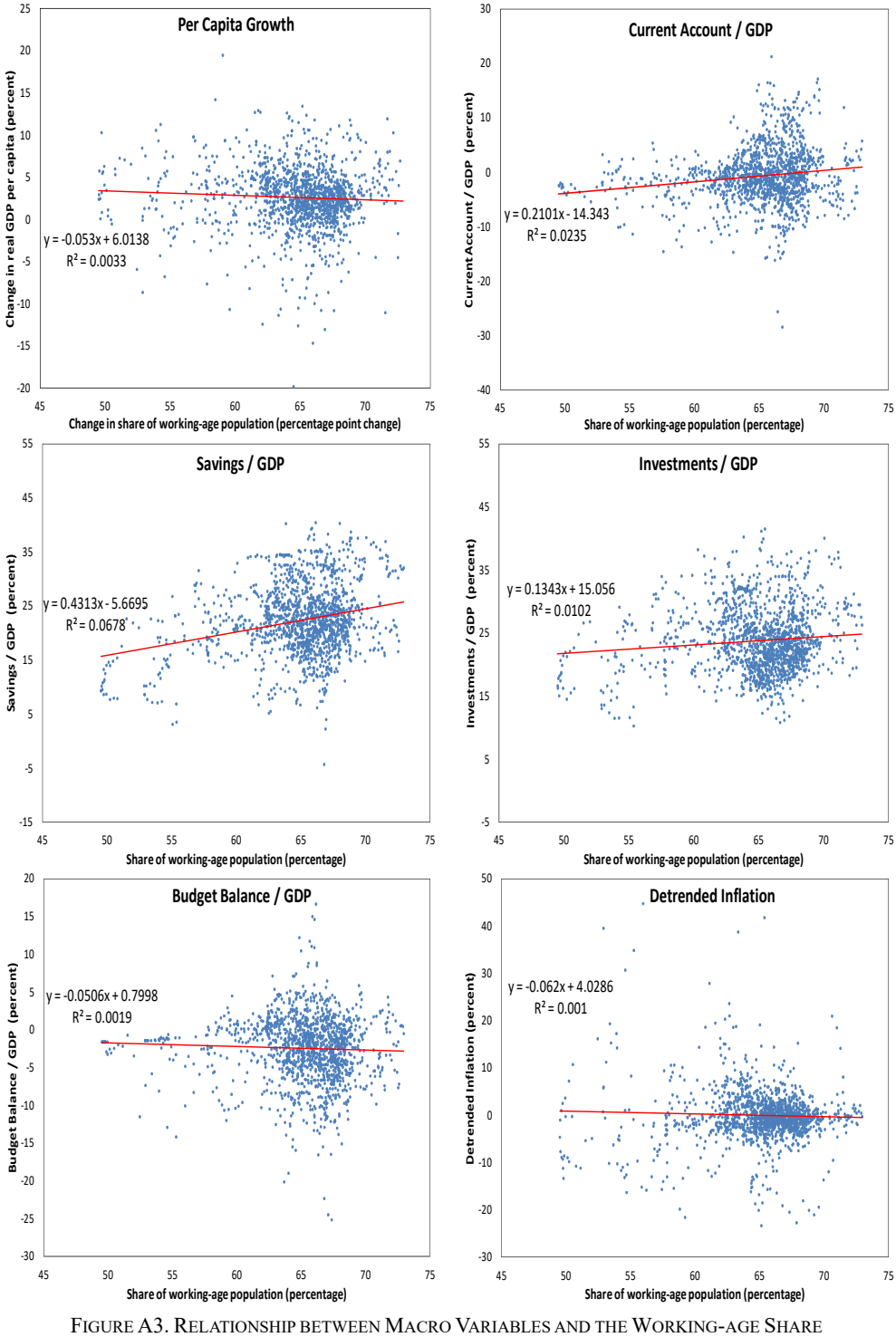

FIGURE A3. RELATIONSHIP BETWEEN MACRO VARIABLES AND THE WORKING-AGE SHARE

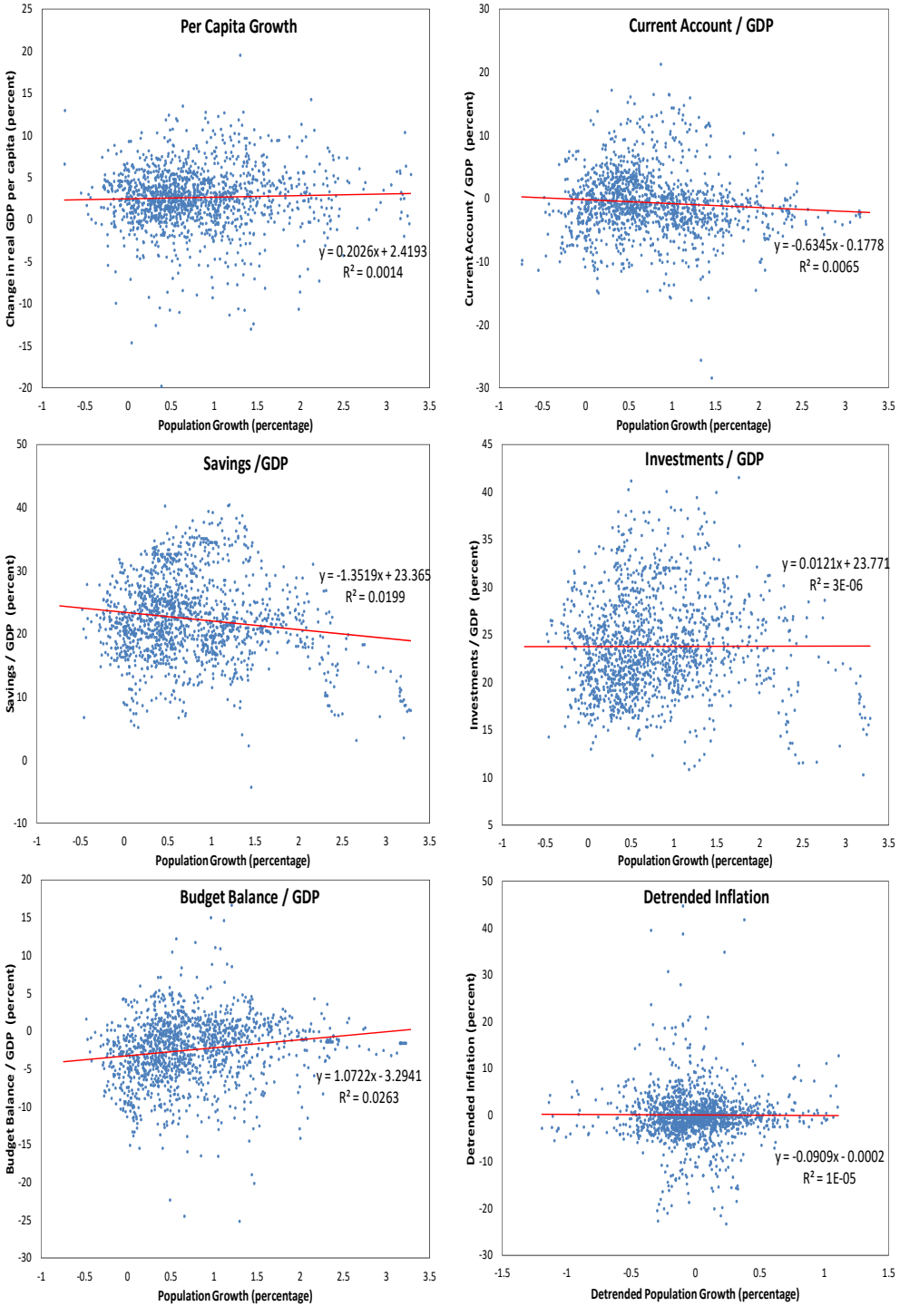

FIGURE A4. RELATIONSHIP BETWEEN MACRO VARIABLES AND POPULATION GROWTH

TABLE A4—DEMOGRAPHIC IMPACT ON INFLATION (WITH THE SIZE OF THE POPULATION)

	OECD					Japan				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Population Growth	0.339 [0.715]	0.369 [0.693]		0.378 [0.683]	0.523 [0.594]	6.689 [0.005]***	6.338 [0.003]***		6.467 [0.001]***	6.272 [0.003]***
Population 65 and over		-0.062 [0.130]	-0.103 [0.036]**	-0.107 [0.033]**	-0.087 [0.122]		-0.079 [0.378]	-0.113 [0.252]	-0.079 [0.335]	-0.281 [0.224]
Population 15 to 64			0.019 [0.146]	0.019 [0.145]	0.032 [0.071]*			-0.136 [0.113]	-0.147 [0.076]*	-0.320 [0.084]*
Life Expectancy					-0.074 [0.224]					0.595 [0.341]
TOT Change	-0.145 [0.005]***	-0.145 [0.005]***	-0.145 [0.005]***	-0.145 [0.005]***	-0.145 [0.005]***	-0.169 [0.016]**	-0.173 [0.013]**	-0.181 [0.009]***	-0.154 [0.012]**	-0.153 [0.014]**
GDP Growth	-0.750 [0.000]***	-0.765 [0.000]***	-0.764 [0.000]***	-0.765 [0.000]***	-0.784 [0.000]***	-0.246 [0.015]**	-0.326 [0.034]**	-0.564 [0.015]**	-0.476 [0.019]**	-0.470 [0.020]**
M2 Growth	0.192 [0.000]***	0.189 [0.000]***	0.189 [0.000]***	0.189 [0.000]***	0.186 [0.000]***	0.059 [0.118]	0.032 [0.419]	-0.003 [0.952]	-0.016 [0.766]	-0.014 [0.781]
Budget Balance Chg.	0.129 [0.051]*	0.136 [0.041]**	0.133 [0.055]*	0.136 [0.041]**	0.147 [0.025]**	-0.105 [0.540]	-0.082 [0.577]	0.035 [0.825]	0.062 [0.690]	0.050 [0.748]
Constant	-0.053 [0.910]	0.323 [0.639]	0.018 [0.980]	0.027 [0.970]	5.277 [0.267]	0.074 [0.821]	1.848 [0.384]	14.497 [0.104]	14.485 [0.081]*	-14.843 [0.652]
Observations	1,167	1,167	1,167	1,167	1,167	53	53	53	53	53
Number of ifscode	30	30	30	30	30					
R-squared	0.212	0.213	0.213	0.213	0.215	0.530	0.546	0.451	0.582	0.589
RMSE	5.235	5.236	5.236	5.237	5.235	2.077	2.063	2.268	2.002	2.008

Note: 1) Inflation and population growth are detrended using quadratic filter. 2) Fixed-effect estimation for OECD and OLS for individual country regressions using annual data. 3) P-values based on robust t-statistics in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%.

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