February 2018 Vol.40, No.1

KDI Journal of Economic Policy

KDI Korea Development Institute

KDI Journal of Economic Policy

Statement of Purpose

The KDI Journal of Economic Policy (KDI JEP) is a professional journal published on a quarterly basis. The Journal publishes papers on the academic and policy issues related to the development of Korea's economy. The KDI Journal of Economic Policy welcomes innovative and insightful academic papers on all areas of economics with an emphasis on empirical analysis that contain solid policy implications. KDI JEP is published in English starting in 2015, volume 37 number 1.

The Journal aims to disseminate research outcomes and policy recommendations not only to experts at academia and research institutes but also to policy-makers and the general public. First published in March 1979, the original objective was to circulate ongoing- and past researches conducted in KDI, a leading economic think-tank of South Korea. Starting in August, 2001, the Journal has accepted manuscripts from outside in order to provide the readers more diverse perspectives on Korea's policy initiatives. The Journal now actively seeks and welcomes submissions by researchers at home and from abroad who have genuine interests in the Korean economy.

The contents of papers published in KDI JEP contain personal views of the authors, and thus do not represent the objectives of the Journal or the mission statements of KDI.

Editorial Board

KDI Journal of Economic Policy

February 2018 VOL. 40, NO. 1

Articles

KDI Journal of Economic Policy 2018, 40(1): 1–30
http://dx.doi.org/10.23895/kdijep.2018.40.1.1

Impact of Demographic Changes on Inflation and the Macroeconomy†

By JONG-WON YOON, JINILL KIM AND JUNGJIN LEE*

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

* Yoon: Ambassador of the Republic of Korea to the OECD (e-mail: jyoon999@gmail.com); Kim: (Corresponding Author) Professor, Korea University (e-mail: jinillkim@korea.ac.kr); Lee: Research Officer, International Monetary Fund (e-mail: jlee2@imf.org).
* Received: 2017. 12. 28
* Referee Process Started: 2018. 1. 3
* Referee Reports Completed: 2018. 2. 23
† An initial draft was written while the three authors were working at the International Monetary Fund—as Executive Director, Visiting Scholar, and Research Officer, respectively—and was published as IMF Working Paper WP/14/210. Comments from various IMF Departments and Offices of Executive Directors as well as discussants at conferences are gratefully acknowledged.

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

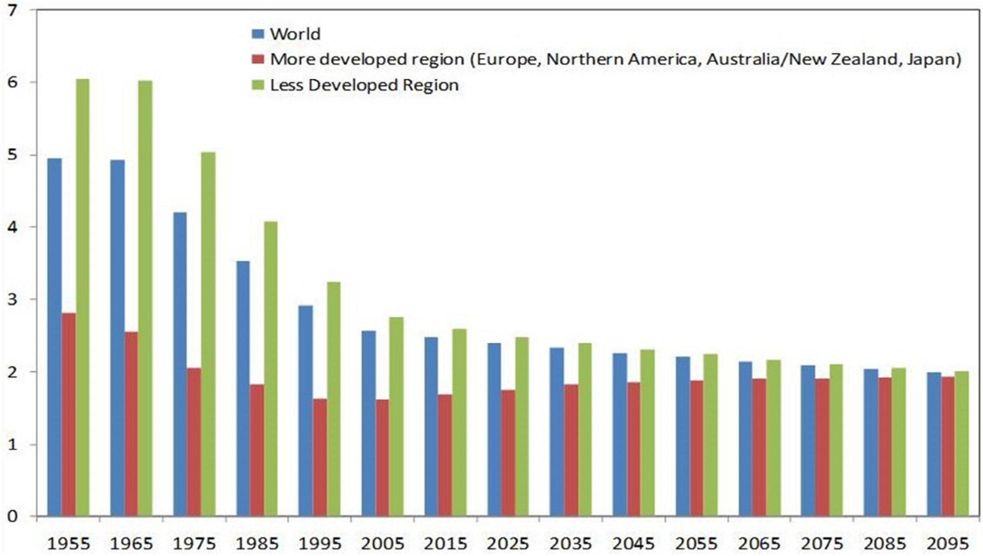


FIGURE 1. TOTAL FERTILITY RATE (CHILDREN PER WOMAN)

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

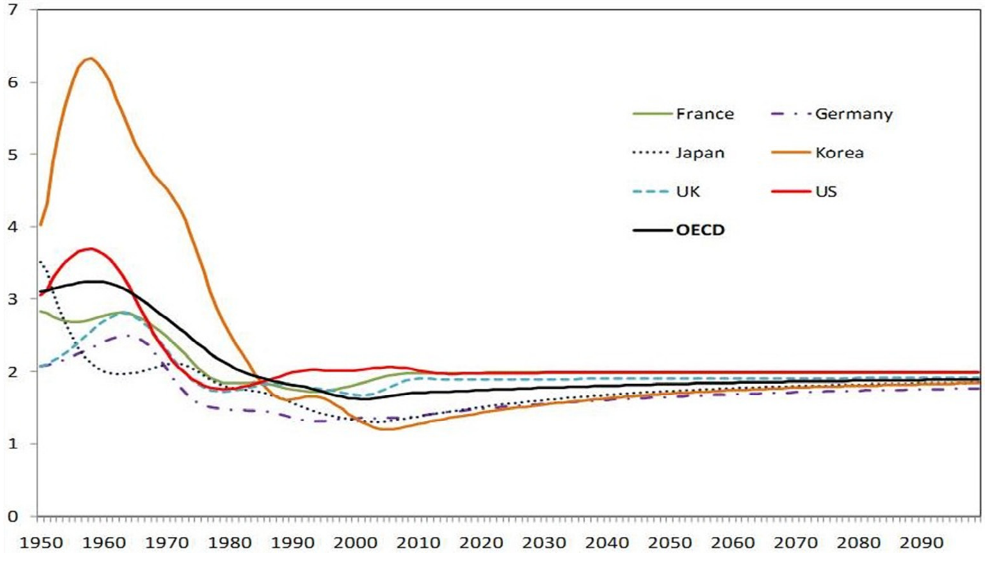


FIGURE 2. TOTAL FERTILITY BY MAJOR ECONOMIES (CHILDREN PER WOMAN)

Source: UN Population Prospects, 2012 revision.

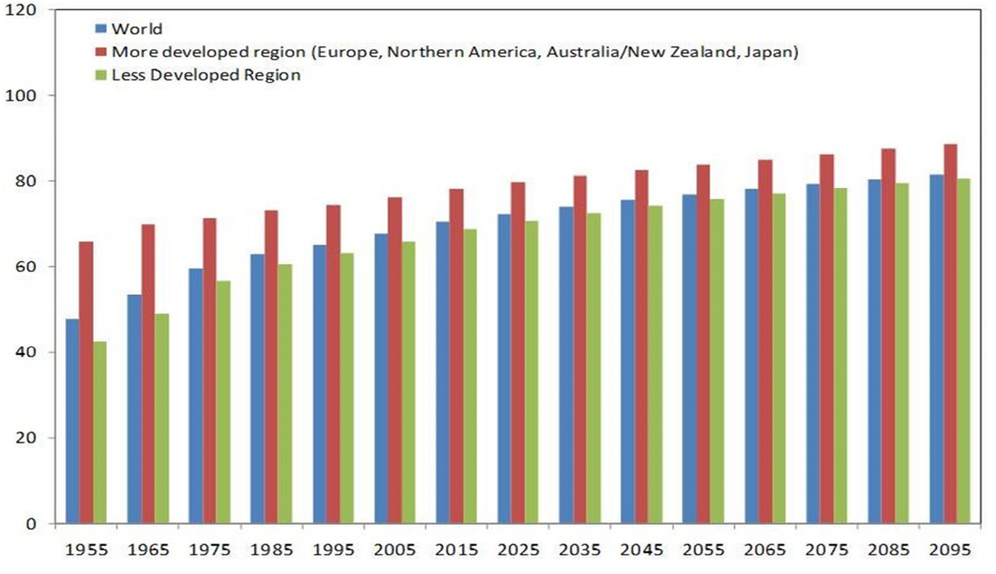


FIGURE 3. LIFE EXPECTANCY (YEARS AT BIRTH)

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

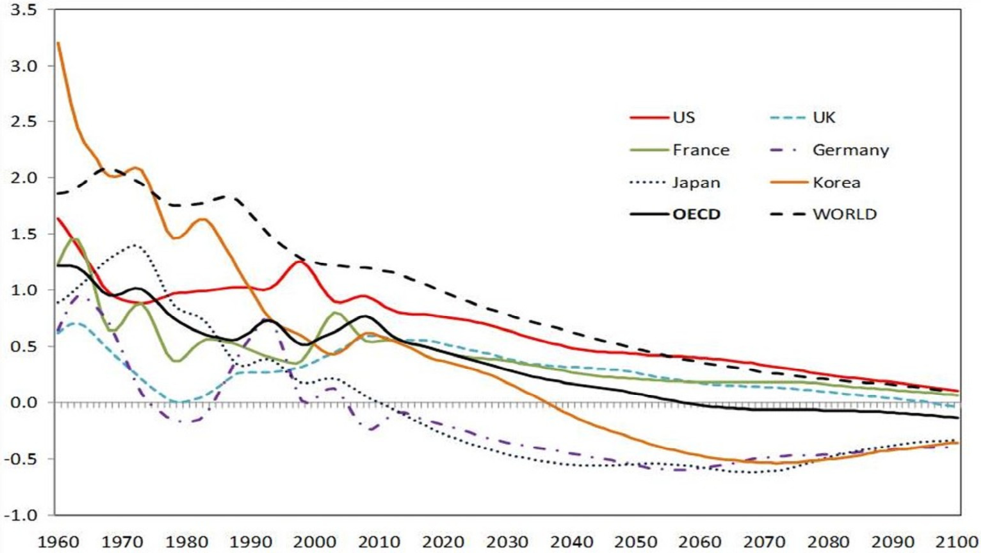


FIGURE 4. TOTAL POPULATION GROWTH (PERCENT)

Source: UN Population Prospects, 2012 revision.

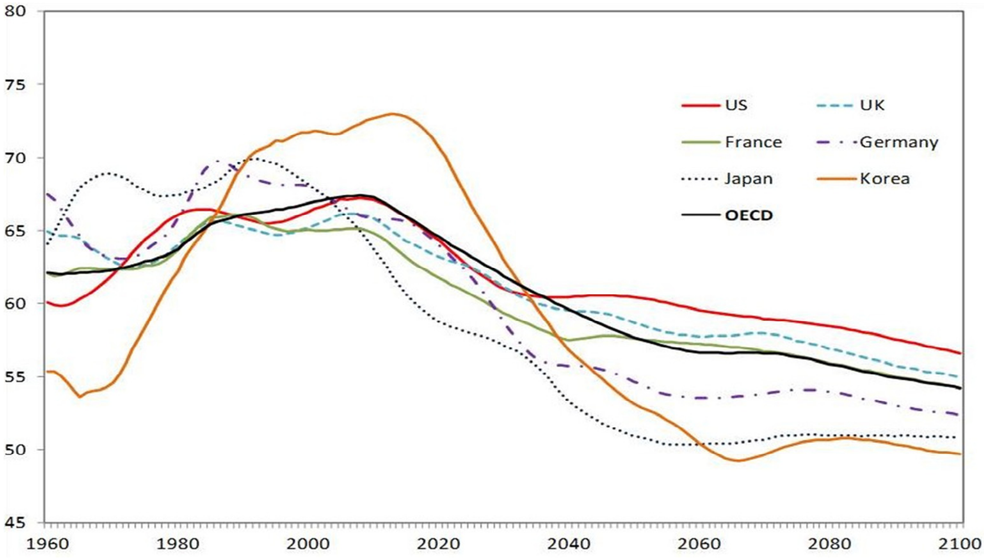


FIGURE 5. WORKING-AGE POPULATION SHARE OF THE TOTAL POPULATION (PERCENT)

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.

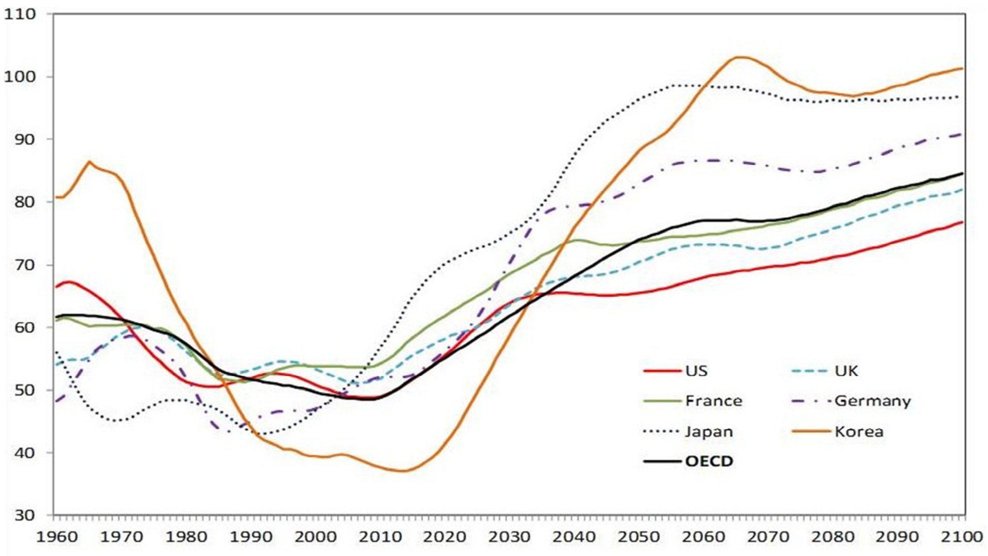


FIGURE 6. DEPENDENCY RATIOS FOR MAJOR ECONOMIES

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%.

	(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.

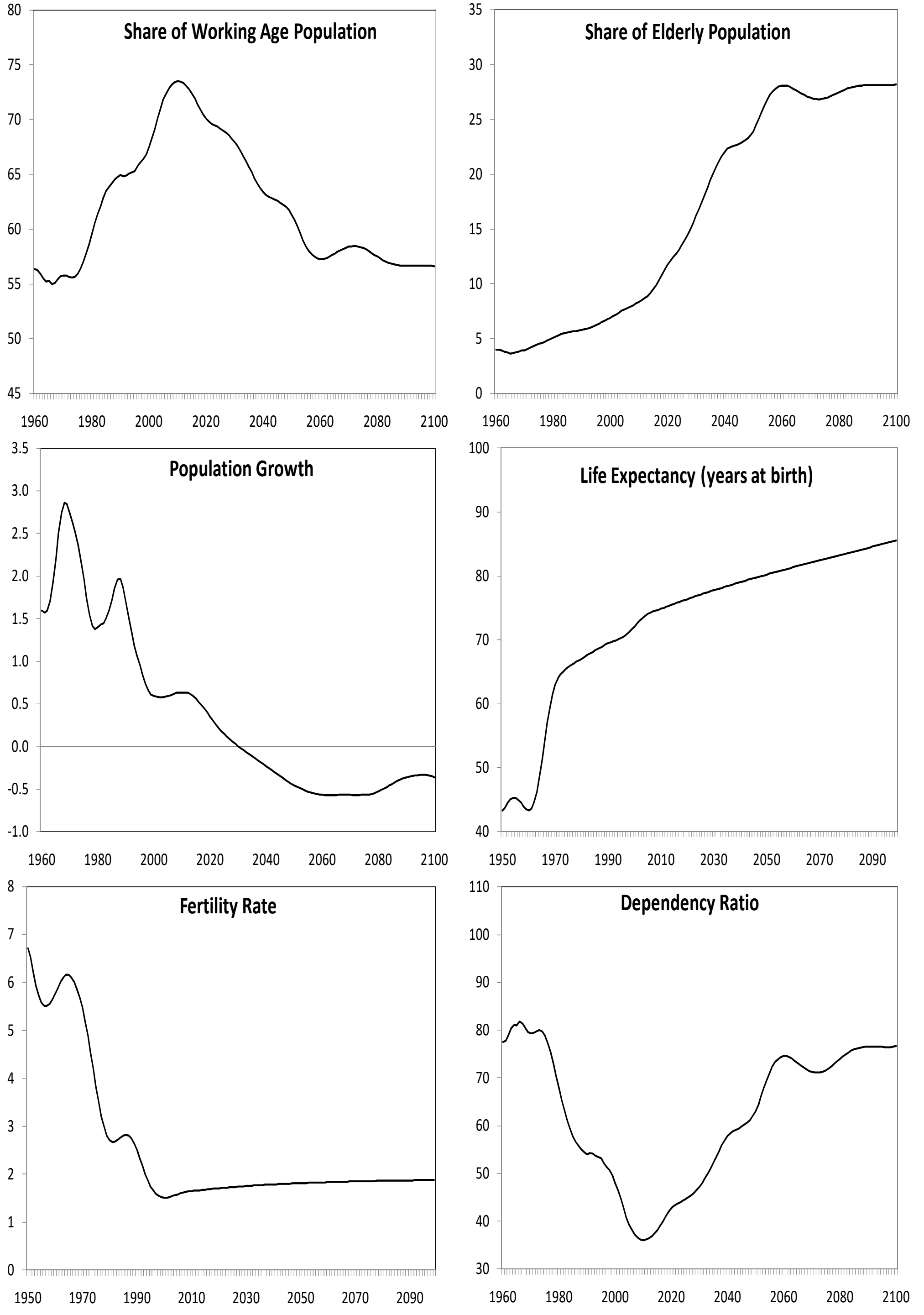


FIGURE A1. DEMOGRAPHIC TRENDS AND PROJECTIONS OF CHINA

Source: UN Population Prospects, 2012 revision.

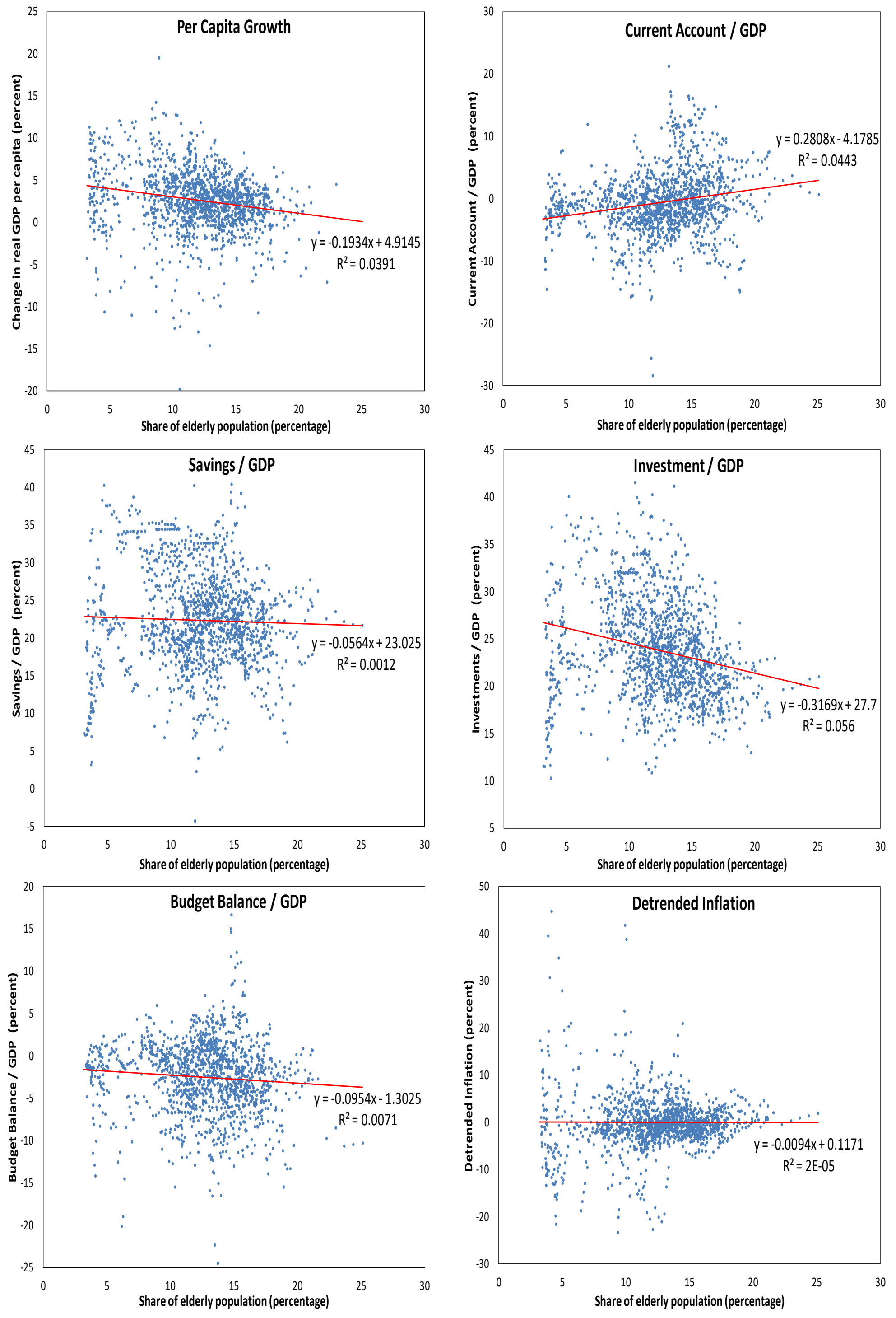


FIGURE A2. RELATIONSHIP BETWEEN MACRO VARIABLES AND THE ELDERLY SHARE

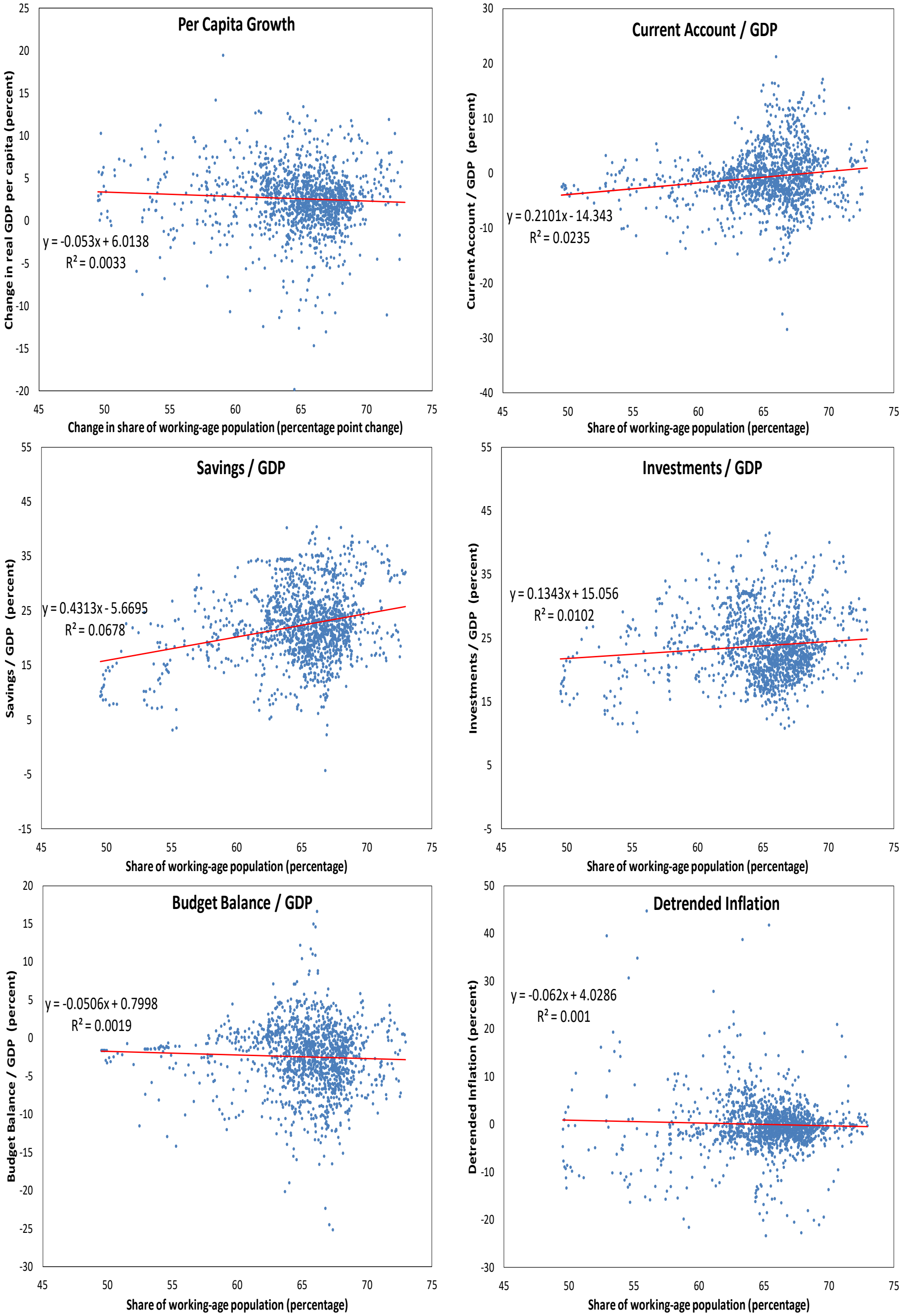


FIGURE A3. RELATIONSHIP BETWEEN MACRO VARIABLES AND THE WORKING-AGE SHARE

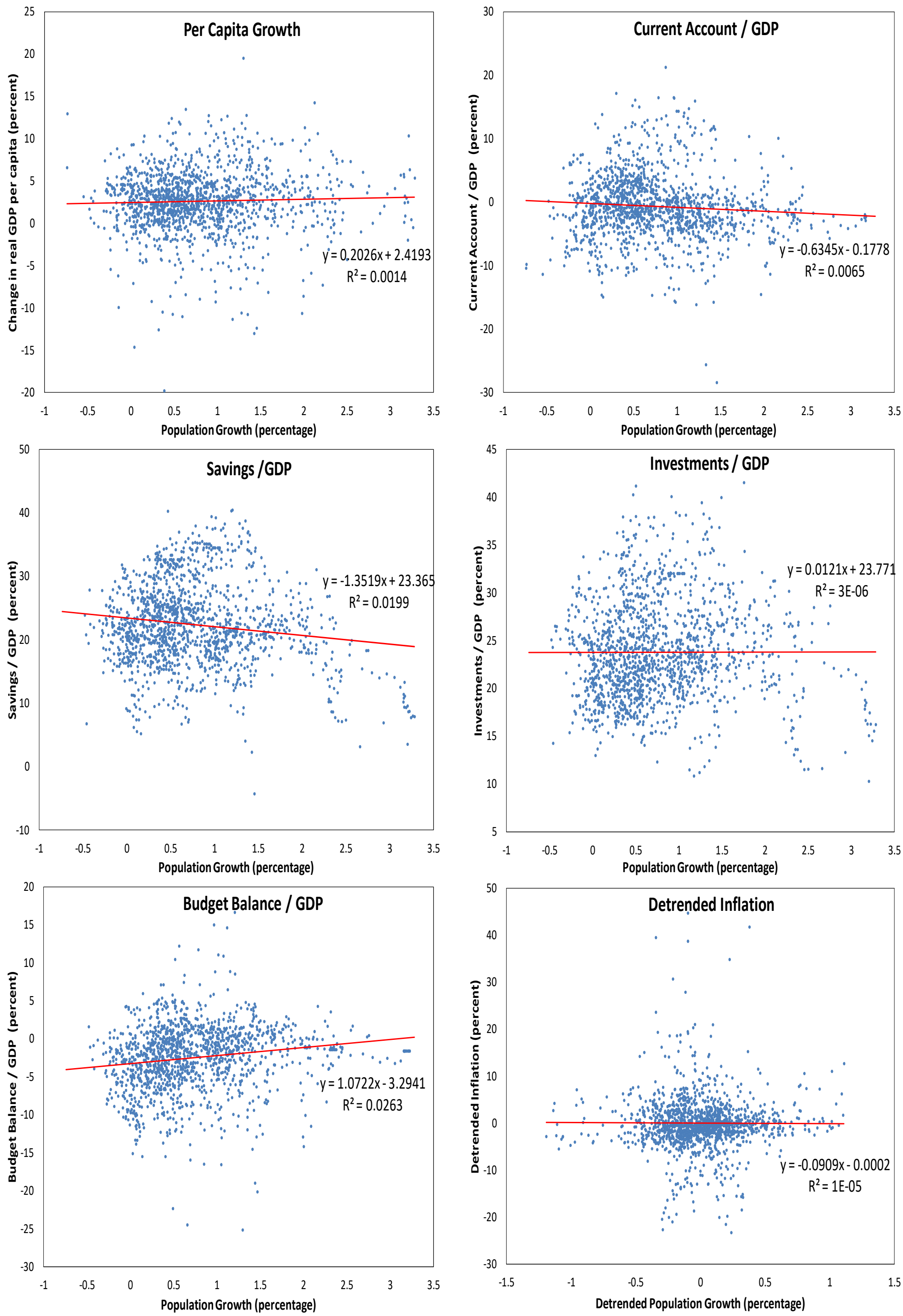


FIGURE A4. RELATIONSHIP BETWEEN MACRO VARIABLES AND POPULATION GROWTH

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%.

REFERENCES

Anderson, D., D. Botman, and B. Hunt. 2014. "Is Japan's Population Aging Deflationary?" *IMF Working paper.* 14/139.

Bloom, D., D. Canning, and G. Fink. 2010. "Implications of population aging for economic growth" *Oxford Review of Economic Policy.* 26(4): 583-612.

Bullard, James, Carlos Garriga, and Christopher J. Waller. 2012. "Demographics, Redistribution, and Optimal Inflation" *Federal Reserve Bank of St. Louis Review.* 419-439.

Börsch-Supan, Axel, Klaus Härtl, and Alexander Ludwig. 2014. "Aging in Europe: Reforms, International Diversification, and Behavioral Reactions" *American Economic Review.* 104(5): 224-29.

Callen, Tim, Nicoletta Batini, and Nicola Spatafora. 2004. "How will demographic change affect the global economy?" *World Economic Outlook.* Chapter 3.

Choi, W., *et al.* 2014. "Demographic waves, growth potential, and policy options" *presented at 2014 Bank of Korea International Conference.* June 2014.

Dent, Harry. 2014. *Demographic Cliff: How to Survive and Prosper During the Great Deflation of 2014-2019*. Penguin. New York.

Fair, Ray, and Kathryn M. Dominguez. 1991. "Effects of the Changing U.S. Age Distribution on Macroeconomic Equations." *American Economic Review*. 81(5): 1276-1294.

Heston, Alan, Robert Summers, and Bettina Aten. 2012. Penn World Table Version 7.1, Center for International Comparisons of Production. Income and Prices at the University of Pennsylvania.

Ikeda, D. and M. Saito. 2012. "The Effects of Demographic Changes on the Real Interest Rate in Japan." *Bank of Japan Working Paper Series.* No. 12-E-3.

International Monetary Fund. 2000. "Implications of aging population will pose crucial policy issues for Japanese authorities." *IMF Survey* Vol.29. October 23. 2000.

Katagiri, M. 2012. "Economic Consequences of Population Aging in Japan: effects through changes in demand structure." *Institute for Monetary and Economic Studies Discussion Paper.* No. 2012-E-3.

Lane, Philip R. and Gian Maria Milesi-Ferretti. 2007. "The external wealth of nations mark II: Revised and extended estimates of foreign assets and liabilities, 1970–2004." *Journal of International Economics 73.* November. 223-250.

Muto, I., Oda, T., Sudo, N. 2012. "Macroeconomic Impact of Population Aging in Japan: A Perspective from an Overlapping Generations Model." *Bank of Japan Working Paper Series.* No. 12-E-9.

Park, Seok Gil. 2012. "Quantifying Impact of Aging Population on Fiscal Space." *IMF Working Paper.* 12/164.

Phillips, S., *et al.* 2013. "External Balance Assessment (EBA) Methodology." *IMF Working Paper.* 13/272.

Rachel, L., and T. Smith. 2015. "Secular Drivers of the Global Real Interest Rate." *Staff Working Paper*. No. 571. Bank of England.

Romer, D. 2012. *Advanced Macroeconomics.* McGraw-Hill.

Terrones, Marco. 2004. "The Global House Price Boom." *World Economic Outlook.* Chapter 2.

United Nations. 2014. *World Population Prospects: The 2012 Revision, Methodology of the United Nations Population Estimates and Projections*. Working Paper No. ESA/P/WP 235.

World Bank Group. 2016. *Global Monitoring Report 2015/2016: Development Goals in an Era of Demographic Change.* Washington DC: World Bank.

KDI Journal of Economic Policy 2018, 40(1): 31–43
http://dx.doi.org/10.23895/kdijep.2018.40.1.31

Can Religion Save Our Health?: Quasi-Experimental Evidence from the U.S.†

By YOON SOO PARK*

There is a large amount of empirical literature reporting that people who regularly attend religious services tend to have better health outcomes. However, it remains an unanswered question as to whether the observed correlation reflects any causality. Exploiting exogenous changes in church attendance driven by law changes in 21 states of the U.S., I find tentative but suggestive evidence that the observed strong correlation between religious participation and health is likely to be driven by endogenous selection.

Key Word: U.S., Religious Participation, Subjective Health, Blue Law, Causal Inference, Instrumental Variable
JEL Code: I18, Z12, K20

I. Introduction

Governments in many countries favor religion in many respects. According to a survey by the Pew Research Center, 83 out of the 199 countries around the world either officially endorse or unofficially favor particular religions (Pew Research Center, 2017). The survey categorizes Korea as one of the 106 countries with no official or preferred religion. However, even in Korea, religion has been enjoying various favors in, for example, taxation and property ownership.

The policy biases for religion are partly based on the belief that religion has beneficial impacts on social outcomes. Given that these policy biases are costly, the evidence for positive externalities needs to be firm. Hence, many social scientists have long been interested in understanding how religious participation affects various social outcomes.[1] However, the evidence for a causal effect of religion is still largely unknown, mainly because it is challenging to isolate exogenous

* Fellow, Korea Development Institute (e-mail: yoonpark@kdi.re.kr)
* Received: 2017. 10. 15
* Referee Process Started: 2017. 10. 31
* Referee Reports Completed: 2018. 1. 30
† This paper is a revised and summarized version of the second chapter of Park (2013).

[1]The scope of the literature has covered a wide range of areas, such as pro-social behavior (Shariff and Norenzayan, 2007; Norenzayan and Shariff, 2008), life satisfaction (Diener and Diener, 2009; Lim and Putnam, 2010), political participation (Brady, Verba, and Schlozman, 1995; Jones-Correa and Leal, 2001; Campbell, 2013), among others.

variations with regard to religious participation. The recent controversy over religious taxation in Korea is also partly due to the lack of firm evidence of any beneficial impacts of religious participation on social outcomes.

This study revisits the well-documented potential benefit of religion on health by exploiting regulation-driven changes in religious attendance in the U.S. There are numerous empirical studies reporting positive correlations between religious participation and various health measures.[2] However, it remains debatable as to whether these observed correlations reflect causal relationships. For example, it may be that people with healthier lifestyles are also more religious or that poor health induces people to adopt a religion (Deaton, 2011).

In order to identify the causal effect of religious participation, this study investigates the repeal of what are known as the blue laws in the U.S. The blue laws, also known as 'day-of-rest' acts, restricted secular activities such as labor and commerce on Sundays in order to encourage people to attend church services. The blue laws were widely implemented in many states of the U.S. until the 1950s but were repealed in many states starting in the early 1960s. Gruber and Hungerman (2008) found that the repeal of the blue laws reduced church attendance significantly. Building on their original work, this study tests whether the observed strong correlation reported in the literature reflects a causal relationship.[3]

II. Data

The data of this study are from the General Social Survey (GSS) over the period between 1973 and 2000. The GSS is a cross-sectional survey on nationally representative sample of non-institutionalized individuals aged 18 or older in the U.S. The GSS is virtually the only data source gathering information on religious attendance and health measure of nationally representative respondents over several decades.

For information on blue law repeals, this study draws on the legal classification by Gruber and Hungerman (2008). According to Gruber and Hungerman (2008), there are 16 states with discrete and significant changes in the regulation on secular activities on Sundays. Table 1 lists the 16 states with significant law changes and 8 states that never had any blue law. The other 26 states are excluded because blue laws were implemented at the city or county level (20 states), laws were repealed gradually over time by adding exceptions to prohibited activities (6 states) (Gruber and Hungerman, 2008: 834-835).

[2] For example, Deaton (2011) found that religiosity is closely associated with better health outcomes using Gallup World Poll data covering 140 countries and 300,000 observations. Hummer *et al*. (1999) analyzed National Health Interview Survey data and found that those who never attend church tend to display higher levels of mortality risk than those who attend church regularly, even after controlling for baseline health status. Koenig, King, and Carson (2012) and Ellison and Levin (1998) summarize hundreds of studies suggesting that more religious people tend to report better health measures.

[3] This study also contributes to the recent literature on understanding the causal effect of religious participation in light of the repeal of blue laws (Cohen-Zada and Sander, 2011; Gerber, Gruber, and Hungerman, 2016).

TABLE 1— TIMING OF THE REPEAL OF BLUE LAW (24 STATES)

Year of repeal	States
1955	Iowa*
1965	Kansas*
1966	Washington*
1969	Florida*
1973	Ohio*, Utah*
1975	Virginia*
1977	Indiana*, South Dakota*
1978	Pennsylvania*
1981	Tennessee*
1982	Vermont*
1985	Minnesota*, South Carolina*, Texas*
1991	North Dakota*
Never had such laws	Arizona*, California*, Colorado*, Idaho, Nevada, New Mexico, Oregon*, Wyoming*

Source: Table 1 of Gruber and Hungerman (2008, p.835). The other 26 states are excluded because blue laws were implemented at the city or county level (20 states), or laws were repealed gradually over time by adding exceptions to the list of prohibited activities (6 states) (Gruber and Hungerman, 2008; p.834-5). The 21 states included in the estimation sample are marked with an asterisk.

Following Gruber and Hungerman (2008), I restrict my sample to those who are Protestant or Catholic because people who follow those religions are most likely to have been affected by the blue laws. I additionally drop observations collected during the exact years the laws were repeal due to the ambiguity arising when attempting to determine whether the blue laws were in place during those years or not. Consequently, my estimation sample consists of 17,329 individuals in the years 1973-2000 in 21 states that either experienced discrete and significant changes in blue laws (16 states) or never had such laws at all (5 states).[4]

Table 2 summarizes the descriptive statistics of the estimation sample. The variable of interest in this study is a subjective health measure. The GSS asks how respondents would describe condition of their own health. There are four possible responses to this question: poor, fair, good, and excellent. Unfortunately, approximately 24% of the respondents refused to report their health conditions. To maximize the sample size, I include these observations in my sample and add an indicator for missing health information as a covariate in regression analyses.[5] I dichotomize the subjective health variable in two different ways (1 if excellent and 0 otherwise; 1 if poor and 0 otherwise) and use the dummies as outcome variables.

[4] The 21 states used for this study are listed in Table 1, marked with an asterisk.

[5] As a robustness check, I also report estimation results when the observations with missing health conditions are dropped in the appendix (Table A1). The main results of this study do not change much when the observations with missing health information are excluded.

TABLE 2—SUMMARY STATISTICS

Variable	N	Mean	Std. Dev.	Min	Max
Religious attendance					
Weekly or more often	17,329	0.31	0.46	0	1
Monthly but less than weekly	17,329	0.23	0.42	0	1
Yearly but less than monthly	17,329	0.26	0.44	0	1
Never or less than yearly	17,329	0.19	0.39	0	1
Linear index (1-4)	17,329	2.67	1.11	1	4
Health condition					
Excellent	17,329	0.24	0.43	0	1
Good	17,329	0.34	0.47	0	1
Fair	17,329	0.14	0.35	0	1
Poor	17,329	0.04	0.20	0	1
Don't know or refuse to answer	17,329	0.24	0.43	0	1
Female	17,329	0.58	0.49	0	1
Age (years, top-coded at 89)	17,329	46.09	17.76	18	89
Age 89 or older	17,329	0.01	0.07	0	1
Age imputed	17,329	0.00	0.05	0	1
Nonwhite	17,329	0.12	0.33	0	1
Education (years)	17,329	12.54	3.03	0	20
Education imputed	17,329	0.00	0.04	0	1
Family income (natural log)	17,329	3.05	0.90	-1.10	5.09
Family income imputed	17,329	0.09	0.28	0	1
Married	17,329	0.58	0.49	0	1
Protestant	17,329	0.74	0.44	0	1
Catholic	17,329	0.26	0.44	0	1
Labor market status					
Employed	17,329	0.60	0.49	0	1
Unemployed	17,329	0.03	0.16	0	1
Out of labor force	17,329	0.37	0.48	0	1
Working hours per week	10,392	41.19	13.82	0	89

Note: All variables are indicators (yes=1, no=0) unless units are specified in parenthesis.

About 24% of the respondents reported that their health conditions are excellent, while 4% answered poor.

The GSS also asks its respondents how often they attend religious services. The nine possible answers to this question are never, less than once a year, once a year, several times a year, once a month, two to three times a month, nearly every week, every week, and more than once a week. Based on this information, I define a linear index on a scale of four: never or less than once a year (=1), at least once a year but less than once a month (=2), at least once a month but less than once a week (=3), and once a week or more (=4). Roughly 31% of the respondents in my sample reported that they attend religious services weekly or more often, while about 19% report that they attend less than once a year. I mainly use the linear index in the analysis, but I also present results when the religious attendance measure is treated as a categorical variable.

Other variables used in this study are gender, age, race (nonwhite=1), education (in years), family income (in 1986 constant dollars), religion (protestant or catholic), labor market status (employed, unemployed, out of the labor force), and working hours (in a week). Women are over-represented (58%) in my sample, mainly because women tend to be more religious than men and because my sample is restricted to those who are either protestant or catholic. Age is top-coded at 89. The proportion of top-coded observations (i.e., aged 89 or older) is around 0.5%. Approximately 9%, 0.3%, and 0.2% of the respondents did not report their income, age, and education, respectively. To secure as many observations as possible, I impute the missing information with the median values and add indicators for the imputation to the list of covariates in regression analyses. The number of observations with regard to working hours is lower (=10,392) because hours of work can only be observed for those who are employed.

III. Data and Estimation Strategy

In order to understand how the repeal of the blue laws affected the level of religious participation, I begin by devising the following equation,

$$\text{(1)} \qquad \text{Attend}_{ist} = \beta_0 + \beta_1 \text{Repeal}_{st} + X_{it}\gamma + \delta_t + \theta_s + \varepsilon_{ist},$$

where Attend_{ist} represents the linear index of religious attendance of individual i in state s during year t, Repeal_{st} denotes an indicator for whether the blue laws were repealed in state s in year t, X_{it} is a vector of covariates such as age, gender, race, education, marital status, income, and a dummy for Catholic; δ_t and θ_s represent year and state dummies, respectively; and ε_{ist} is an error term. The difference-indifferences parameter β_1 captures whether the repeal of a state's blue laws causes a decrease in religious participation relative to that in other states at a given t. I estimate equation (1) using the OLS method, clustering standard errors at the interactions between state and year. In survey years 1982 and 1987, the GSS oversampled blacks. All estimates are weighted in order to ensure a nationally representative sample under the GSS sampling scheme.

The estimation result of equation (1) is presented in column 1 of Table 3. I find that the repeal of blue laws is negatively associated with the religious attendance index. The magnitude of the coefficient (-0.125) is sizable, amounting to roughly half of the coefficient for females (0.268). This suggests that the potential impact of the repeal of the blue laws on religious attendance is comparable to half of the observed gap in religious attendance between men and women. The coefficients of the other covariates are qualitatively similar, as reported in the literature (e.g., Azzi and Ehrenberg, 1975). Older, female, more educated people attend religious services more often than those younger, male, and less educated people.

A key assumption for interpreting the estimate as causal is that states with and without law changes follow a common time trend with regard to the dependent variable. If blue laws were repealed in states where religious participation was in decline anyway, the observed correlation between the law repeals and religious participation would be spurious. In column 2, I add state-specific linear time trends to the list of controls in order to relax this assumption. The addition of the state-specific time trends makes the estimated effect of the repeal of blue laws even stronger (-0.167).

In columns 3 and 4, I also add a placebo dummy indicating a period of 1-2 years prior to the repeal of the laws with and without the state-specific time trends, respectively. If the repeal of the blue laws was driven by some predetermined socioeconomic changes that reduced people's religiosity (i.e., reverse causality), the placebo dummy would have a significant coefficient. However, the estimated coefficients of the placebo dummy are negligible in magnitude and are statistically insignificant. These results suggest that the estimated effects of repealing the blue laws are not likely to be driven by reverse causality.

Overall, the estimation results in Table 3 suggest that repealing blue laws significantly reduced religious participation. However, it is difficult to interpret the magnitude of the estimated effects because the categorical religious attendance measure is treated as a continuous variable. In order to understand the effects more

TABLE 3—EFFECTS OF REPEALING BLUE LAWS ON RELIGIOUS PARTICIPATION

	(1)	(2)	(3)	(4)
Dependent variable	Attendance index (1-4)			
Repeal	-0.125***	-0.167***	-0.117***	-0.175***
	(0.037)	(0.052)	(0.040)	(0.063)
Repeal (placebo)			0.022	-0.012
			(0.049)	(0.056)
Age	0.009***	0.009***	0.009***	0.009***
	(0.001)	(0.001)	(0.001)	(0.001)
Female	0.268***	0.268***	0.268***	0.268***
	(0.017)	(0.017)	(0.017)	(0.017)
Nonwhite	0.349***	0.348***	0.349***	0.348***
	(0.026)	(0.027)	(0.026)	(0.027)
Education	0.051***	0.051***	0.051***	0.051***
	(0.003)	(0.003)	(0.003)	(0.003)
Log income	0.009	0.009	0.009	0.009
	(0.011)	(0.011)	(0.011)	(0.011)
Married	0.187***	0.187***	0.187***	0.187***
	(0.021)	(0.021)	(0.021)	(0.021)
Catholic	0.232***	0.233***	0.232***	0.233***
	(0.025)	(0.025)	(0.025)	(0.025)
State and year FE	Y	Y	Y	Y
State-specific time trend	N	Y	Y	N
Observations	17,329	17,329	17,329	17,329
R-squared	0.086	0.089	0.086	0.089

Note: The dependent variable is a linear index of religious attendance. All regressions control for dummies for median-value imputation (age, education, income) and missing information for health condition. Robust standard errors clustered at the state-by-year level are in parenthesis. Significance *** 1%; ** 5%; * 10%.

clearly, I re-estimate equation (1) by replacing the linear index (Attend) with dummies for each of the four attendance categories separately. These results are summarized in Table 4. Overall, repealing these laws reduced the probabilities for attending weekly or more often (Attend=4) by 3.7%p; the repeals also reduced those for monthly attendance, but at a rate less than the weekly rate (Attend=3) by 2.5%p, while an increase was found for yearly, though it was less than the monthly rate (Attend=2) by 3.6%p and less than the yearly rate or the 'never' reply (Attend=1) by 2.6%p.[6] This suggests that repealing the laws shifted the distribution of the attendance frequency to the left.

The estimation results in Tables 3 and 4 indicate that repealing blue laws decreased religious participation significantly. Hence, if religious participation is indeed causally linked to health, the decreased level of religious participation due to the repealing of these laws would lead to a decreased level of health conditions as well. In order to test this hypothesis, I re-estimate equation (1) by replacing the dependent variable with two dichotomous variables for subjective health condition:

TABLE 4—EFFECTS OF REPEALING BLUE LAWS ON RELIGIOUS PARTICIPATION

	(1)	(2)	(3)	(4)
Dependent variable	Attend=1	Attend=2	Attend=3	Attend=4
Repeal	0.0257**	0.0364**	-0.0248*	-0.0374**
	(0.0119)	(0.0146)	(0.0147)	(0.0166)
Age	-0.0006***	-0.0031***	-0.0007***	0.0044***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Female	-0.0558***	-0.0604***	0.0208***	0.0955***
	(0.0064)	(0.0069)	(0.0065)	(0.0070)
Nonwhite	-0.1214***	-0.0374***	0.0900***	0.0689***
	(0.0086)	(0.0106)	(0.0111)	(0.0118)
Education	-0.0158***	-0.0041***	0.0048***	0.0151***
	(0.0011)	(0.0012)	(0.0012)	(0.0013)
Log income	-0.0083**	0.0032	0.0094**	-0.0043
	(0.0041)	(0.0045)	(0.0042)	(0.0045)
Married	-0.0418***	-0.0284***	-0.0044	0.0747***
	(0.0075)	(0.0078)	(0.0072)	(0.0082)
Catholic	-0.0679***	-0.0108	-0.0070	0.0857***
	(0.0072)	(0.0086)	(0.0079)	(0.0112)
State and year FE	Y	Y	Y	Y
Observations	17,329	17,329	17,329	17,329
R-squared	0.0571	0.0303	0.0183	0.0653

Note: Dependent variables are dummies for each of four categories of religious attendance: never or less than once a year (Attend=1), once a year but less than once a month (Attend=2), once a month but less than once a week (Attend=3), and once a week or more often (Attend=4). All regressions control for dummies for median-value imputation (age, education, income) and missing information for health condition. Robust standard errors clustered at the state-by-year level are in parenthesis. Significance *** 1%; ** 5%; * 10%.

[6] For comparison, the unconditional mean values of the probability of attending weekly or more frequently in my sample are 26% for males and 35% for females. Thus, the estimated effect of repealing the blue laws on the probability of attending weekly or more frequently (-3.7%p) roughly amounts to 40% of the observed gender gap in the probability (9%p).

TABLE 5—EFFECTS OF REPEALING BLUE LAWS ON SUBJECTIVE HEALTH CONDITION

	(1)	(2)	(3)	(4)
Dependent variable	Excellent=1		Poor=1	
Repeal	0.009	0.020	0.008	-0.003
	(0.012)	(0.018)	(0.007)	(0.010)
Age	-0.003***	-0.003***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Female	-0.020***	-0.020***	-0.001	-0.001
	(0.007)	(0.007)	(0.003)	(0.003)
Nonwhite	-0.047***	-0.048***	0.004	0.004
	(0.010)	(0.010)	(0.005)	(0.005)
Education	0.017***	0.017***	-0.005***	-0.005***
	(0.001)	(0.001)	(0.001)	(0.001)
Log income	0.040***	0.040***	-0.024***	-0.024***
	(0.004)	(0.004)	(0.003)	(0.003)
Married	-0.006	-0.006	-0.002	-0.003
	(0.007)	(0.007)	(0.003)	(0.003)
Catholic	-0.007	-0.007	-0.001	-0.001
	(0.007)	(0.007)	(0.003)	(0.003)
State and year FE	Y	Y	Y	Y
State-specific time trend	N	Y	N	Y
Observations	17,329	17,329	17,329	17,329
R-squared	0.155	0.156	0.072	0.073

Note: Dependent variables are dummies for subjective health conditions (1 if excellent/poor and 0 otherwise). All regressions control for dummies for median-value imputation (age, education, income) and missing information on health condition. Robust standard errors clustered at the state-by-year level are in parenthesis. Significance *** 1%; ** 5%; * 10%.

a dummy for excellent health condition and a dummy for a poor health condition. These results are summarized in Table 5, where columns 1 and 2 show the results for the excellent health condition while columns 3 and 4 summarize those for the poor condition. Regardless of the choice of dependent variable, I do not find any evidence that repealing the blue laws affected subjective health conditions. This can be taken as indirect evidence suggesting that there is no causal link between religious participation and health outcomes.

To find more direct evidence of whether religious participation affects health outcomes, I consider the following regression model:

$$\text{(2)} \qquad \text{Health}_{ist} = \beta_0 + \beta_1 \text{Attend}_{ist} + X_{it}\gamma + \delta_t + \theta_s + \varepsilon_{ist}$$

In equation (2), β_1 captures the correlation between religious participation and health conditions. Table 6 summarizes the estimation results for the probabilities of having excellent (columns 1 and 2) and poor health conditions (columns 3 and 4). The odd-numbered columns show naïve OLS estimation results for equation (2). As in the literature, I find that religious participation is strongly correlated with health conditions. People attending religious services more frequently tend to report more often excellent health conditions and less often poor conditions. More

TABLE 6— RELIGIOUS PARTICIPATION AND SUBJECTIVE HEALTH CONDITION

	(1)	(2)	(3)	(4)
Dependent variable	Excellent=1		Poor=1	
Estimation	OLS	2SLS	OLS	2SLS
Attendance index	0.0202***	-0.0732	-0.0079***	-0.0623
	(0.0029)	(0.0991)	(0.0016)	(0.0565)
Age	-0.0028***	-0.0020**	0.0016***	0.0021***
	(0.0002)	(0.0009)	(0.0001)	(0.0005)
Female	-0.0253***	-0.0002	0.0013	0.0159
	(0.0068)	(0.0285)	(0.0027)	(0.0157)
Nonwhite	-0.0543***	-0.0216	0.0069	0.0260
	(0.0097)	(0.0368)	(0.0052)	(0.0202)
Education	0.0159***	0.0206***	-0.0049***	-0.0021
	(0.0012)	(0.0052)	(0.0007)	(0.0029)
Log income	0.0399***	0.0408***	-0.0243***	-0.0237***
	(0.0038)	(0.0041)	(0.0026)	(0.0027)
Married	-0.0097	0.0079	-0.0009	0.0093
	(0.0068)	(0.0190)	(0.0032)	(0.0109)
Catholic	-0.0118*	0.0101	0.0003	0.0131
	(0.0071)	(0.0244)	(0.0034)	(0.0134)
Observations	17,329	17,329	17,329	17,329
R-squared	0.1575	0.0476	0.0732	-0.0220
First-stage F		11.73		11.73
P-value of AR F statistic		0.452		0.261

Note: Dependent variables are dummies for subjective health condition (1 if excellent/poor and 0 otherwise). All regressions control for dummies for median-value imputation (age, education, income) and missing information on health condition as well as state and year dummies. Robust standard errors clustered at the state-by-year level are in parenthesis. Significance *** 1%; ** 5%; * 10%.

precisely, a unit increase in the attendance measure is associated with a greater probability by 2% of reporting excellent health conditions and a lower probability by 0.8% of reporting poor health conditions. For comparison, a one year increase in age is associated with a lower probability by 0.28% of reporting excellent health conditions and a higher probability by 0.16% of reporting poor health conditions. This suggests that on average, a unit increase in the attendance index is correlated similarly with an increase in reported health condition as an increase in age by 5-7 years.

In order to check whether the observed strong correlation between religious participation and health conditions reflects a causal relationship, I subsequently attempt to estimate equation (2) by the two-stage least square (2SLS) method using Repeal_{st} as an instrumental variable for Attend_{ist}. The key identification assumptions with regard to the instrumental variable (IV) strategy are that blue laws should affect religious participation (first-stage condition) and that these laws may affect health conditions, but only through their impacts on religious participation (exclusion restriction). The first-stage assumption appears to be convincing given the estimation results in Tables 3 and 4, whereas it is still possible that repealing the laws affected health outcomes through many other channels apart from religious participation. Presumably, the most important channel would be through an effect on labor supply of individuals. As mentioned in chapter 1, blue laws as implemented prohibited all types of labor and commerce on Sundays. Hence, the repeal of the blue laws was likely to induce people to work more. It has been widely discussed that longer working hours are closely related to lower health conditions.[7] To the extent that the potential increase in the labor supply driven by the repeals of blue laws affects health conditions directly other than by affecting religious participation, the validity of the exclusion restriction would be questionable.

To check this possibility, I examine the effect of blue laws on the labor supply. Specifically, I re-estimate equation (1) replacing the dependent variable with dummies representing a person's labor market status (employed, unemployed, and out of the labor force) and usual weekly hours of work for those who are employed. Table 7 summarizes these estimation results. I do not find evidence that repealing blue laws changed the labor supply of respondents in my sample, indicating that the potential effects of the blue laws on health by affecting the labor supply are not likely to be substantial.

TABLE 7— EFFECTS OF REPEALING BLUE LAWS ON THE LABOR SUPPLY

	(1)	(2)	(3)	(4)
Dependent var.	Employed=1	Unemployed=1	OLF=1	Hours of work
Repeal	-0.0108	0.0055	0.0053	-0.0817
	(0.0131)	(0.0050)	(0.0130)	(0.4586)
Age	-0.0098***	-0.0009***	0.0107***	-0.0428***
	(0.0002)	(0.0001)	(0.0002)	(0.0117)
Female	-0.1652***	-0.0316***	0.1968***	-6.5071***
	(0.0077)	(0.0028)	(0.0077)	(0.2737)
Nonwhite	0.0301***	0.0072	-0.0373***	-0.2312
	(0.0109)	(0.0044)	(0.0113)	(0.3231)
Education	0.0155***	-0.0025***	-0.0130***	0.2881***
	(0.0012)	(0.0004)	(0.0011)	(0.0561)
Log income	0.1166***	-0.0124***	-0.1042***	3.1520***
	(0.0050)	(0.0019)	(0.0048)	(0.2269)
Married	-0.0439***	-0.0134***	0.0573***	-1.3718***
	(0.0085)	(0.0028)	(0.0084)	(0.2946)
Catholic	0.0008	-0.0008	0.0001	0.1910
	(0.0078)	(0.0028)	(0.0073)	(0.3143)
State and year FE	Y	Y	Y	Y
Observations	17,329	17,329	17,329	10,392
R-squared	0.2899	0.0347	0.3175	0.1132

Note: Dependent variables are dummies for labor market status in columns 1-3 and usual hours of work in a week in column 4. "OLF" stands for "out of the labor force." All regressions control for dummies for median-value imputation (age, education, income) and missing information for health condition. Robust standard errors clustered at the state-by-year level are in parenthesis. Significance *** 1%; ** 5%; * 10%.

[7] Sparks *et al*. (1997) reviews the literature on working hours and health conditions extensively.

Even-numbered columns in Table 6 show the two-stage least square (2SLS) estimation results for equation (2) when the law repeal dummy is used as an instrument variable for religious participation. The first-stage F statistic (11.73) is slightly higher than the rule-of-thumb critical value suggested by Stock and Yogo (2005), suggesting that the instrumental variable is likely to meet the first-stage condition. I also present the p-value of the F test of the significance of an endogenous regressor by Anderson and Rubin (1949), which is robust to the weak instrument problem. The 2SLS estimation results in Table 6 are in stark contrast to the parallel OLS estimation result. The OLS estimation results show that religious participation is strongly correlated with health outcomes, while the observed correlations between religious participation and health outcomes disappear when using the 2SLS estimation method. These results suggest that the observed correlations between religious participation and health conditions are likely to be driven by selectivity bias, rather than reflecting a causal relationship.

IV. Conclusion

There is ample empirical literature that reports positive correlations between religious participation and various health outcomes. However, it is still an unanswered question as to whether such correlations reflect a causal relationship between religion and health. In order to address this issue, I exploit a policy-driven increase in the opportunity cost of religious participation as an exogenous source of variation in religious participation.

Using the 1973-2000 GSS data, I find that repealing the blue laws significantly reduced religious participation. In spite of the substantial impact of these laws on religious participation, however, I find no evidence that the health conditions of the respondents here were worsened when they reduced their rate of religious participation in response to the repeal of the blue laws. I also find that the survey respondents' levels of religious participation are strongly correlated with their health conditions, as reported in the literature, whereas this association disappears when the potential unobserved heterogeneity with respect to religious participation is corrected by using the blue laws as an instrumental variable. Based on these results, I conclude that the strong relationships between religious participation and health conditions reported in earlier empirical studies are likely to have been driven by endogenous selection rather than a causal relationship.

I acknowledge that my findings should be taken as suggestive but only tentative evidence against a causal relationship between religious participation and health because there could be other, perhaps very important, dimensions of religious participation that cannot be captured by assessing the frequency of religious attendance. I leave these issues for future research. Presumably, this may be why Deaton (2011) noted in his paper on religion and health that he does not know any credible means of distinguishing causality between the two factors.

APPENDIX

TABLE A1— RELIGIOUS PARTICIPATION AND SUBJECTIVE HEALTH CONDITION: USING A RESTRICTED SAMPLE

	(1)	(2)	(3)	(4)
Dependent variable	Excellent=1		Poor=1	
Estimation	OLS	2SLS	OLS	2SLS
Attendance index	0.0278***	-0.1029	-0.0112***	-0.0958
	(0.0037)	(0.1503)	(0.0020)	(0.0842)
Age	-0.0037***	-0.0025*	0.0022***	0.0029***
	(0.0002)	(0.0014)	(0.0001)	(0.0008)
Female	-0.0335***	0.0015	0.0020	0.0247
	(0.0086)	(0.0428)	(0.0035)	(0.0232)
Nonwhite	-0.0648***	-0.0216	0.0072	0.0352
	(0.0122)	(0.0527)	(0.0065)	(0.0284)
Education	0.0205***	0.0271***	-0.0062***	-0.0020
	(0.0014)	(0.0078)	(0.0008)	(0.0042)
Log income	0.0507***	0.0517***	-0.0310***	-0.0304***
	(0.0048)	(0.0052)	(0.0032)	(0.0034)
Married	-0.0111	0.0122	-0.0020	0.0130
	(0.0088)	(0.0268)	(0.0042)	(0.0152)
Catholic	-0.0138	0.0146	-0.0002	0.0182
	(0.0091)	(0.0343)	(0.0044)	(0.0185)
Observations	13,207	13,207	13,207	13,207
R-squared	0.0843	-0.0105	0.0780	-0.0795
First-stage F		6.763		6.763
P-value of AR F statistic		0.477		0.236

Note: Estimation sample is restricted to those who reported their health conditions. Dependent variables are dummies for subjective health condition (1 if excellent/poor and 0 otherwise). All regressions control for dummies for median-value imputation (age, education, income) and missing information on health condition as well as state and year dummies. Robust standard errors clustered at the state-by-year level are in parenthesis. Significance *** 1%; ** 5%; * 10%.

REFERENCES

Anderson, Theodore W. and Herman Rubin. 1949. “Estimation of the Parameters of a Single Equation in a Complete System of Stochastic Equations.” *The Annals of Mathematical Statistics* 20(1): 46-63.

Azzi, Corry, and Ronald Ehrenberg. 1975. “Household Allocation of Time and Church Attendance.” *Journal of Political Economy* 83(1): 27-56.

Brady, Henry E., Sidney Verba, and Kay Lehman Schlozman. 1995. “Beyond SES: A Resource Model of Political Participation.” *American Political Science Review* 89(2): 271-294.

Campbell, David E. “Social Networks and Political Participation.” 2013. *Annual Review of Political Science* 16: 33-48.

Cohen-Zada, Danny and William Sander. 2011. “Religious Participation versus Shopping: What Makes People Happier?” *Journal of Law and Economics* 54(4): 889-906.

Deaton, Angus. 2011. “Aging, Religion, and Health.” 237-268 in *Explorations in the Economics of Aging*, edited by David A. Wise. University of Chicago Press.

Ellison, Christopher G. and Jeffrey S. Levin. 1998. “The Religion-Health Connection: Evidence, Theory, and Future Directions.” *Health Education & Behavior* 25(6): 700-720.

Gerber, Alan S., Jonathan Gruber, and Daniel M. Hungerman. 2016. “Does Church Attendance Cause People to Vote? Using Blue Laws’ Repeal to Estimate the Effect of Religiosity on Voter Turnout.” *British Journal of Political Science* 46(3): 481-500.

Gruber, Jonathan and Daniel M. Hungerman. 2008. “The Church versus the Mall: What Happens When Religion Faces Increased Secular Competition?” *The Quarterly Journal of Economics* 123(2): 831-862.

Hummer, Robert A., Richard G. Rogers, Charles B. Nam, and Christopher G. Ellison. 1999. “Religious Involvement and US Adult Mortality.” *Demography* 36(2): 273-285.

Jones-Correa, Michael A., and David L. Leal. 2001. “Political Participation: Does Religion Matter?” *Political Research Quarterly* 54(4): 751-770.

Koenig, Harold G., Dana E. King, and Verna Benner Carson. 2012. *Handbook of Religion and Health* 2nd edition: Oxford University Press.

Lim, Chaeyoon, and Robert D. Putnam. 2010. “Religion, Social Networks, and Life Satisfaction.” *American Sociological Review* 75(6): 914-933.

Norenzayan, Ara, and Azim F. Shariff. 2008. “The Origin and Evolution of Religious Prosociality.” *Science* 322(58): 58-62.

Park, Yoon Soo. 2013. *Essays in Empirical Microeconomics* (Doctoral Dissertation, Princeton University)Pew Research Center. (Oct. 3rd, 2017). “Many Countries Favor Specific Religions, Officially or Unofficially” Retrieved from http://www.pewforum.org/2017/10/03/many-countries-favor-specific-religions-officially-or-unofficially/ (Access date: Dec. 21st, 2017)

Shariff, Azim F., and Ara Norenzayan. 2007. “God Is Watching You: Priming God Concepts Increases Prosocial Behavior in an Anonymous Economic Game.” *Psychological Science* 18(9): 803-809.

Sparks, Kate, *et al*. 1997. “The effects of hours of work on health: a meta-analytic review.” *Journal of Occupational and Organizational Psychology* 70(4): 391-408.

Stock, James H., and Motohiro Yogo. 2005. “Testing for Weak Instruments in Linear IV Regression.” *Identification and Inference for Econometric Models*. New York. Cambridge University Press: 80-108.

KDI Journal of Economic Policy 2018, 40(1): 45−66
http://dx.doi.org/10.23895/kdijep.2018.40.1.45

What Drives the Stock Market Comovements between Korea and China, Japan and the U.S.?

By Jinsoo Lee and Bok-Keun Yu*

This paper measures the extent of comovements in stock returns between Korea and three major countries (China, Japan and the U.S.) using industry-level data for Korea from 2003 to 2016 in the spirit of the international capital asset pricing model. It also examines what drives the comovements between Korea and the three countries. We find that the comovements of Korean stock returns with those of the U.S. and Japan became smaller after the global financial crisis. In contrast, the comovement in stock returns between Korea and China became larger after the crisis. After an additional analysis, we conclude that trade linkage is the main driver of the comovements between Korea and the three countries.

Key Word: Stock Market Comovement, Trade Linkage, Financial Linkage
JEL Code: F15, F21, G15

I. Introduction

The Korean stock market has shown a high degree of comovement with the stock markets of select major countries, which may reflect the increasing real linkage as well as more financial integration with those countries. It is also intriguing that the extent of this comovement has changed over time and that the degree of change appears to differ for different countries. For example, comparing the period before the global financial crisis with the post-crisis period, the correlations of Korean stock market returns with those of China and the U.S. rose, whereas the stock market comovement between Korea and Japan decreased.[1] In this paper, motivated by these observations, we examine the factors that drive the stock market comovements between Korea and three major countries (China, Japan

* Lee: KDI School of Public Policy and Management (e-mail: jlee@kdischool.ac.kr); Yu: The Bank of Korea (e-mail: bokyu@bok.or.kr).
* Received: 2017. 11. 14
* Referee Process Started: 2017. 11. 16
* Referee Reports Completed: 2018. 2. 22

[1]The correlation coefficients of Korea-China, Korea-Japan and Korea-U.S. stock market returns using weekly data from Datastream are 0.49, 0.59 and 0.47, respectively, for the period of 2003-2007. However, the coefficients are 0.69, 0.49 and 0.60, respectively, for the period of 2010-2016.

and the U.S.).

To undertake this task, we initially measure the comovements in stock returns between 24 Korean manufacturing industries and the three countries using a model in the spirit of the international capital asset pricing model (ICAPM), where the expected return of a country's stock market is influenced by global stock market returns. Specifically, we use the market returns of the three major countries as proxies for global stock market returns, and the stock returns for Korean manufacturing industries are related to the market returns of the three countries. In our model, the degrees of the comovements between Korean manufacturing industries and the three countries are measured using the slope coefficients (betas) of the three countries for these industries.

Next, we examine the driver(s) of the comovements between Korean manufacturing industries and the three countries. According to conventional financial theory, the price of a security can be modelled as the present value of future cash flows from the security, with the future cash flows being discounted at appropriate discount rates. If this is the case, the degree of commonality between securities may come from two sources: (i) comovement in cash flows (real linkage) and (ii) comovement in discount rates (financial linkage). In this paper, as proxies for the two sources of comovement, we use the ratio of trade to sales for the real linkage and the share of foreign stock investment for the financial linkage.

From our analysis, we find that the comovements of the Korean stock market with those of the U.S. and Japan were diminished after the global financial crisis. In contrast, the post-crisis comovement in stock returns between Korea and China is greater than that of the pre-crisis period. With the two proxies for real and financial linkages, we find that the trade-to-sales ratio is positively related to the degree of comovements in stock returns between Korea and the three countries. On the other hand, we find no evidence that financial linkage proxied by foreign stock investment is related to comovements in stock returns between Korea and the three countries.

There are previous studies such as Forbes and Chinn (2004), Elekdag *et al.* (2012) and Arslanalp *et al.* (2016) where a two-stage factor model similar to that used here is employed in order to study linkages in financial markets across countries. These studies use aggregate and macro-level data for their sample countries and thus variations in the linkages and related determinants at the country level. In contrast, our study uses industry-level data for an individual country, in this case Korea. As there are cross-sectional variations as well as time-series variations across industries, we can use such variations in order to examine this issue for an individual country in more depth with industry-level data. In this regard, we expect that our study at the industry level for an individual country will complement previous studies at the country level for groups of countries.

The rest of the paper is organized as follows. In Section II, we explain trade and stock market trends in Korea. We provide a review of the literature in Section III. In Section IV, we describe the data and introduce the methodology used for our analysis. We report the empirical results of our analysis in Section V. We conclude the paper in Section VI.

II. Trade and Stock Market Trends in Korea

Korea's trade (exports plus imports) appears to reflect the overall conditions of the global economy as well as its evolvement. Figure 1 shows the shares of exports, imports and trade in Korea's GDP from 2003 to 2016. The trade share continued to rise until 2008, mainly on the back of the favorable global economy. However, it declined sharply in 2009 in the aftermath of the global financial crisis. From 2010, it increased again, reaching 96%, the highest ratio, in 2011. It has been falling since 2012, possibly due to sluggish investment given the delayed global economic recovery from the crisis. The share of trade in GDP was 65% as of 2016, similar to the level in 2007.

Both exports and imports show similar trends. In 2016, the share of exports and imports in GDP was 37% and 28%, respectively. As shown in Figure 1, the trade surplus (exports – imports) has increased since the crisis, mainly due to decreased commodity prices and strong exports of Korea's flagship products such as semiconductors and automobiles.

Figure 2 shows the shares of exports, imports and trade with the three major trading partners of Korea (the U.S., Japan and China) for the period from 2003 to 2016. In the case of the U.S., the shares of exports and imports continued to decline until 2011. The uptrend in recent years is presumably due to the Korea-U.S. FTA, which came into effect on March 15, 2012. For Japan, both the export and import shares showed declining trends throughout the period. As of 2016, the share of imports was 11.7%, whereas the share of exports was 4.9%. In the case of China, in contrast to the U.S. and Japan, the trends in the shares of exports and imports both increased. The shares of exports and imports were 25.1% and 21.4% in 2016, accounting for the largest portion among Korea's trade partners. Consequently, the share for China in Korea's trade is much higher than those of the U.S. and Japan,

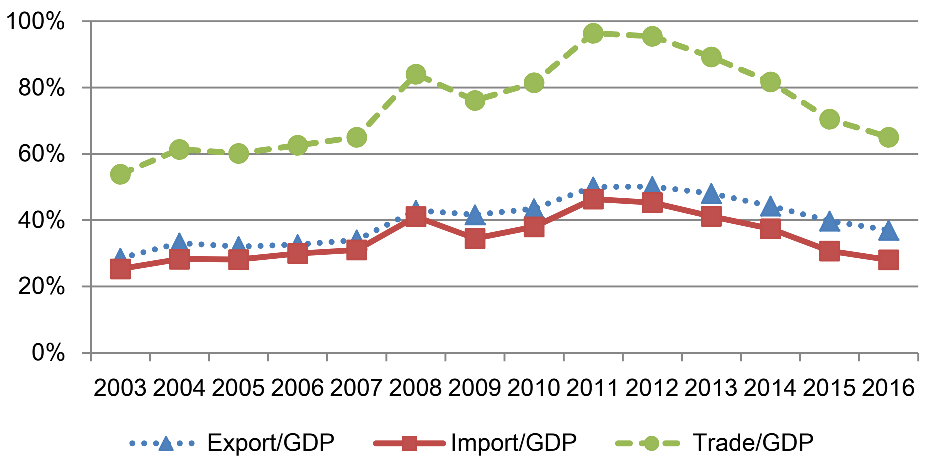


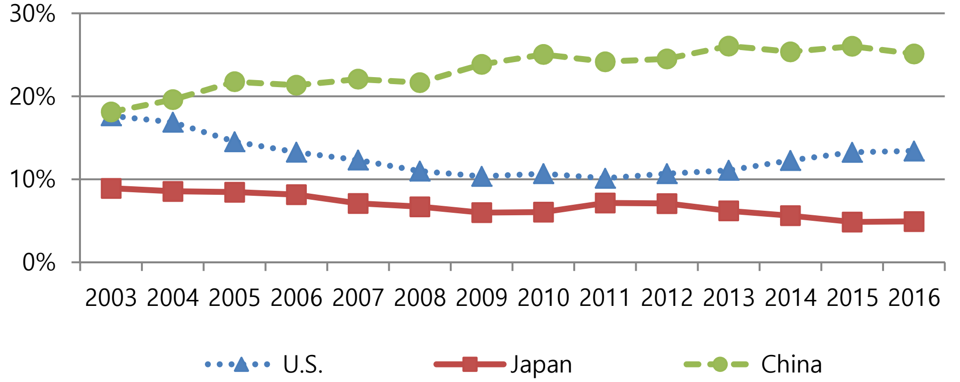
FIGURE 1. SHARES OF EXPORTS, IMPORTS AND TRADE IN KOREA'S GDP

Note: Data are based on nominal amounts, goods and Korean won standards.

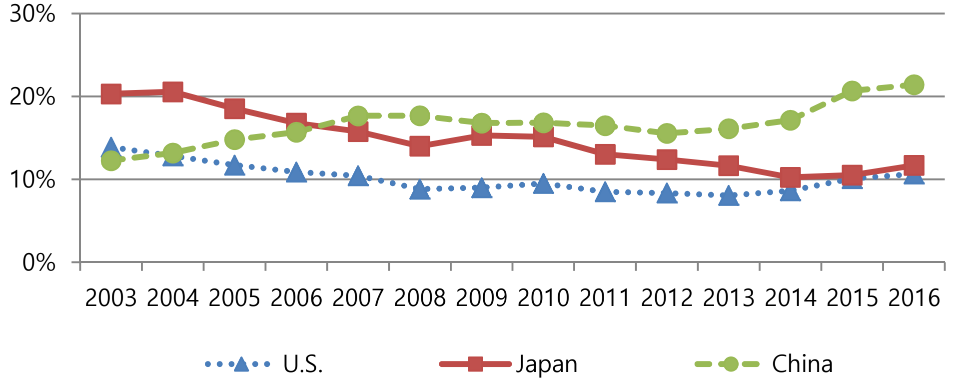
Source: Bank of Korea (ECOS).

reaching 23.4% in 2016. This indicates that China may become a more dominant player in Korea's trade dynamics and thus may have a greater impact on the Korean economy than before, both in real and financial terms.

[Panel A: Exports]



[Panel B: Imports]



[Panel C: Trade]

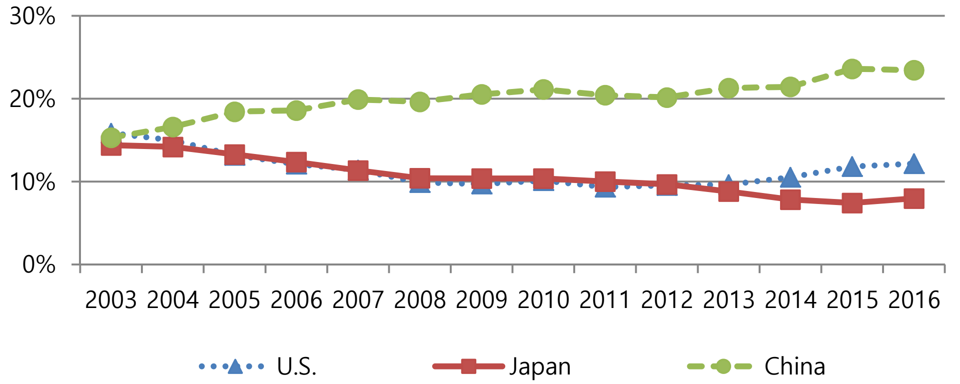


FIGURE 2. SHARES OF KOREA'S EXPORTS, IMPORTS AND TRADE WITH THE U.S., JAPAN AND CHINA

Note: Data are based on nominal amounts, goods and U.S. dollar standards.

Source: Bank of Korea (ECOS).

The Korean stock market has continued to advance together with the growth of the real economy in Korea. Figure 3 presents the ratio of market capitalization[2] to GDP and the share of foreign ownership of the stock market in Korea. The ratio of market capitalization to GDP rose from 48% in 2003 to 101% in 2007. During the crisis, the ratio plunged to 56% in 2008. The ratio then resumed its increase before leveling off at around 90%. On the other hand, the foreign-owned share of stocks in Korea approached 40% in both 2003 and 2004, after which it declined gradually to 27% in 2008. It increased afterwards, reaching 32% in 2016, but it still remains lower than in 2003. Figure 4 reports the shares of foreign investors from the U.S.,

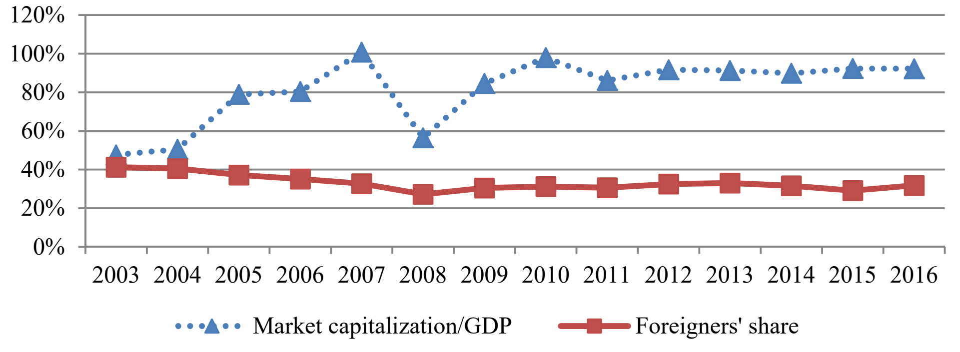


FIGURE 3. MARKET CAPITALIZATION/GDP AND FOREIGN-OWNED SHARE IN THE KOREAN STOCK MARKET

Note: Market capitalization is measured by KOSPI plus KOSDAK.

Source: Bank of Korea (ECOS), Koscom and Financial Supervisory Services.

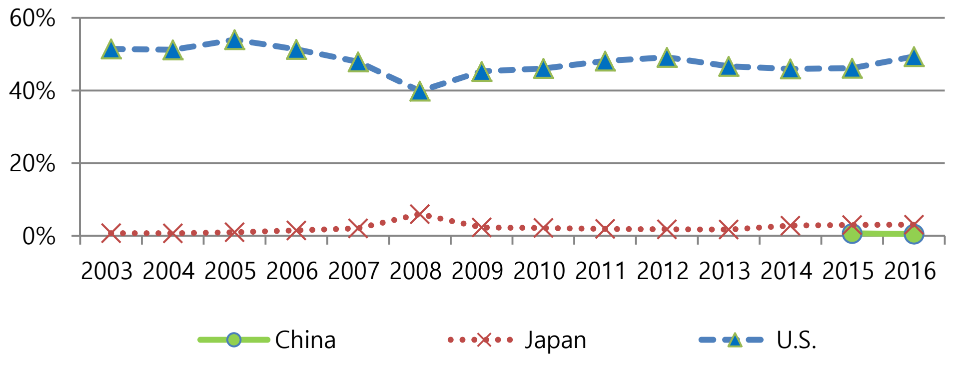


FIGURE 4. SHARES HELD BY THE U.S., JAPAN AND CHINA IN THE KOREAN STOCK MARKET

Note: The equity ratio was determined according to the stock and investment fund shares..

Source: IMF (Coordinated Portfolio Investment Survey).

[2]Market capitalization refers to the total market value of outstanding shares for a company and is computed by multiplying the outstanding shares of the company by the market price of a share. The market capitalization of a country is computed as the sum of the market capitalizations for individual companies.

Japan and China. As of 2016, the U.S. accounted for 49%, whereas the shares of Japan and China were only 3% and less than 1%, respectively. The U.S. portion has been much larger than those of Japan and China throughout the entire period. This implies an outsized influence of U.S. investors on the Korean stock market relative to those of the other two countries.

III. Literature Review

Our paper generally follows the methodology used by Forbes and Chinn (2004), Elekdag *et al*. (2012), and Arslanalp *et al*. (2016). Forbes and Chinn (2004) investigate how trade and financial linkages between five major countries (France, Germany, Japan, the UK and the U.S.) and 38 sample countries affect comovements in stock and bond market returns from 1986 to 2000. First, they estimate the impacts of bilateral, global and sectoral factors on each country's asset returns using a factor model.[3] In the second stage, the bilateral factor loadings, also known as "betas," are regressed on the trade-related and financial variables of trade flows, trade competition in third markets, bank lending and foreign investment. The authors find that trade linkage variables are more significant than financial variables in the explanation of the factor loadings.

Elekdag *et al*. (2012) analyze the evolution of stock market linkages between five major economies (France, Germany, Japan, the UK and the U.S.) and 12 Asian countries[4] during the period of 1992-2011. They document that the degree of financial sensitivity of the Asian countries to the major economies increased, with both trade and financial linkages as the key determinants. They also argue that certain macroeconomic policies the Asian countries, such as reductions in government debt and increases in foreign reserves, made limited contributions to mitigating these levels.

Arslanalp *et al*. (2016) explore comovements in stock markets between Asian countries and four major economic blocks (China, Japan, the euro area, and the U.S.). They build a two-stage model based on Forbes and Chinn (2004) consisting of four major economies and nine Asian countries[5] during the period of 2001-2014 (pre-crisis period: 2001-2007, crisis period: 2008-2009 and post-crisis period: 2010-2014). Their empirical results indicate that the spillover effect from China to the Asian stock markets has increased since the global financial crisis, although the level of its impact is still lower than those by the U.S. and Japan. They also report that the main driver of the spillover from the two major economies in the region (China and Japan) to other Asian stock markets is the trade linkage (the trade linkage for China and trade competition in third markets for Japan) rather than the financial linkage.

[3] The bilateral factors refer to returns for these five countries in the asset markets; the global and sectoral factors include world market returns, global interest rates, oil prices, gold prices and commodity prices, and asset returns for 14 sectoral indexes.

[4] The 12 Asian countries are Australia, China, Hong Kong, India, Indonesia, Korea, Malaysia, New Zealand, Philippines, Singapore, Taiwan and Thailand.

[5] These blocks are China, Japan, the euro area, and the U.S., and the nine sample countries are Australia, India, Indonesia, Korea, Malaysia, New Zealand, Philippines, Taiwan and Thailand.

In addition to these studies, other studies have examined interdependence in stock market returns between countries. Tavares (2009) examines 40 developed and emerging markets from the 1970s to 1990s, finding that the intensity of bilateral trade increases the correlations in stock market returns between countries, while real exchange rate volatility, asymmetry in output growth and dissimilarity in exports all decrease this correlation. Eiling and Gerard (2015) find that there are significant time trends in cross-country correlations in 32 emerging markets for the period from 1991 to 2009. They argue that official market liberalization, equity market openness, equity market development and trade openness drive these trends. Paramati *et al*. (2015; 2016) find that the degree of trade intensity drives stock market interdependence between Australia and its trading partners.

The above-mentioned papers use aggregate and macro-level data. In contrast to these studies, our study uses industry-level data for an individual country. As there are cross-sectional variations as well as time-series variations in real and financial linkages across industries for an individual country, we can use such variations in order to examine comovements in stock returns between the individual country and foreign countries in more depth.

The literature on stock return comovements and variations across countries using industry and/or firm level data can be traced back to Roll (1992), Heston and Rouwenhorst (1994), and Griffin and Karolyi (1998).

Roll (1992) documents that industry factors such as differences or similarities in industrial compositions are the main factors explaining stock return correlations across countries. In his analysis, he uses daily stock indexes for 24 countries from April of 1988 to March of 1991. However, Heston and Rouwenhorst (1994) argue that variations in the stock returns of countries are mainly due to country-specific factors rather than industry factors. Their sample includes 829 firms in 12 European countries for the period of 1978 to 1992. Griffin and Karolyi (1998) find that the industry effect is greater for traded-goods industries than for nontraded-goods industries in explaining stock return variations for 25 countries for the period of 1992 to 1995.

More recently, Brooks and Del Negro (2006) and Faias and Ferreira (2016) explore international stock market commonality using firm-level data. Brooks and Del Negro (2006) analyze the relationship between international stock market return comovement and the degree of internationalization of firms such as firm's international sales, assets and income as well as sector affiliation (traded versus non-traded). They use firm-level data composed of 1,239 firms in 20 developed and emerging countries for the period from 1985 to 2002. They find that the higher the degree of globalization of a firm, the higher the sensitivity of stock returns to global shocks, indicating that firms that operate internationally have stronger linkages with the global stock market. Faias and Ferreira (2016) find using monthly stock return data from 45 countries for the period from 2001 to 2010 that the degree of stock return variation is better explained by industry and global factors rather than country factors.

There have also been several studies of the stock return comovements of Korean companies using firm-level data. Park (2007) examines the impacts of analysts and foreign investors on the synchronicity of stock returns between Korean individual firms and the market from 2000 to 2003, finding that the degree of synchronicity becomes greater as the number of financial analysts following a firm increases, whereas the impact of foreign investors as measured by the foreign-owned equity share of the firm is not significant. The author argues that foreign investors rely on firm-specific financial information based on the firm's intrinsic value rather than on market-wide information, whereas analysts provide investors with more market-related information. Kim *et al*. (2015) and Cho and Mooney (2015) investigate the comovement of stock returns for firms belonging to business groups (known as *chaebol*) and its key determinants during the periods of 1980-2009 and 2002-2011, respectively. Both papers report that companies affiliated with business groups exhibit more salient comovements in stock returns with other companies in the same business group than with companies not affiliated with the business group.

IV. Data and Methodology

In the first stage of this paper, we measure comovements in stock returns between Korea and three countries—the U.S., Japan, and China—using stock returns at the industry level, and in the second stage, we examine what drives the comovements between Korea and the three countries. The three countries are chosen based on the fact that they are major trading partners of Korea. From 2003 to 2016, Korea's average proportion of trade with China (20.5%) was the highest, with the U.S. (11.0%), Japan (10.0%), Saudi Arabia (3.7%), Hong Kong (3.2%), and Taiwan (3.0%) following.[6] We choose these three countries as major trading partners of Korea because each of their portions of trade with Korea exceeded 5% for the period.

In the first stage, in order to measure the comovements in stock returns between Korea and the three countries at the industry level, we use two alternative specifications, denoted here as (1) and (2).

$$R_{i,t} = \alpha_i + \beta_{us,i} R_{us,t} + \beta_{Japan,i} R_{Japan,t} + \beta_{China,i} R_{China,t} + \varepsilon_{i,t} \tag{1}$$

$$\begin{aligned} R_{i,t} = {} & \alpha_i + \beta_{us,i} R_{us,t} + \beta_{Japan,i} R_{Japan,t} + \beta_{China,i} R_{China,t} + \beta_{CRB,i} R_{CRB,t} \\ & + \beta_{USTN,i} \Delta Y_{USTN,t} + \beta_{VIX,i} \Delta VIX_t + \beta_{CDS,i} \Delta CDS_t + \varepsilon_{i,t} \end{aligned} \tag{2}$$

In (1), $R_{i,t}$ represents the return of industry i during the week of t for Korea. $R_{us,t}$, $R_{Japan,t}$ and $R_{China,t}$ denote the market returns during week t for U.S., Japan and China, respectively. In the first specification, we follow the spirit of the ICAPM, where the expected return of a country's stock market is influenced by global stock market returns. We use the three market returns of major countries as proxies for global stock market returns. In (2), following Arslanalp *et al*. (2016), we add four control variables to the market returns of the U.S., Japan and China.

[6]We compute the proportions of trade with foreign countries for Korea using data from the Bank of Korea (ECOS).

The four control variables are the returns computed by the CRB (Commodity Research Bureau) index ($R_{CRB,t}$),[7] changes in the yield of U.S. two-year Treasury notes ($\Delta Y_{USTN,t}$), changes in the VIX (ΔVIX_t), and changes in the CDS premium on Korea's five-year bonds from week t-1 to week t. We collect the CRB index and VIX data from Bloomberg, the yield of U.S. two-year Treasury notes from the Federal Reserve Economic Data and the CDS premium on Korea's five-year bonds from the Korea Center for International Finance. As the CDS premium is regularly available from 2003, we begin our sample period at that point.

In our sample, we include Korean manufacturing companies for which stocks were traded for the period from 2003 to 2016. We compute weekly stock returns (Wednesday to Wednesday) for each of the stocks using their stock prices adjusted for any distribution to stockholders, such as stock splits and dividend payments.

TABLE 1—KOREAN STANDARD INDUSTRIAL CLASSIFICATION (REVISION 9) FOR MANUFACTURING

Division Code	Name of Division
10	Food products
11	Beverages
12	Tobacco products
13	Textiles, except apparel
14	Wearing apparel, clothing accessories and fur articles
15	Tanning and dressing of leather, manufacture of luggage and footwear
16	Wood and products of wood and cork, except furniture
17	Pulp, paper and paper products
18	Printing and reproduction of recorded media
19	Coke, hard-coal and lignite fuel briquettes and refined petroleum products
20	Chemicals and chemical products, except pharmaceuticals and medicinal chemicals
21	Pharmaceuticals, medical chemicals and botanical products
22	Rubber and plastic products
23	Other non-metallic mineral products
24	Basic metal products
25	Fabricated metal products, except machinery and equipment
26	Electronic components, computer, radio, television and communication equipment and apparatuses
27	Medical, precision and optical instruments, watches and clocks
28	Electrical equipment
29	Other machinery and equipment
30	Motor vehicles, trailers and semi-trailers
31	Other transport equipment
32	Furniture
33	Other manufacturing

Source: Korea National Statistical Office (Korean Standard Industrial Classification, 2008).

[7] The CRB index is based on exchange-traded futures for 19 commodities and reflects price changes in commodity markets. (https://financial.thomsonreuters.com/content/dam/openweb/documents/pdf/financial/cc-crb-total-return-index.pdf).

The adjusted stock prices are provided by DataGuide. We compute weekly value-weighted stock returns for each industry using all stock returns of individual companies included in the industry. We use the market capitalization of each stock in order to compute the value-weighted stock returns for the industry. The data on the industry to which each company belongs and the market capitalization of the company are also provided by DataGuide. For the classification of industries for Korea, we use the Korean Standard Industrial Classification (KSIC, revision 9) provided by the Korea National Statistical Office.[8] There are 24 divisions (industries) for manufacturing in the KSIC (revision 9). Table 1 reports the codes and names for the 24 divisions (industries). For the U.S., Japan and China, we compute stock market returns using the stock market return index provided by Datastream. The stock market returns are also computed weekly (Wednesday to Wednesday) for the period from 2003 to 2016. All returns are computed in terms of local currencies.[9]

In both (1) and (2), we run a regression for each year in our sample period and estimate the coefficients yearly in order to measure the comovements of stock returns for industry i with respect to the U.S., Japan and China for the year.

In the second stage, in order to examine what determines the comovements in stock returns between Korea and the three countries at the industry level, we use three main explanatory variables: (i) the ratio of trade to sales as a proxy for the trade linkage (ii) the proportion of foreign stock investment as a proxy for the financial linkage and (iii) export competition in third markets. In addition, we add a dummy variable for the period of the global financial crisis (2008-2009) following Arslanalp *et al*. (2016), as the stock returns between Korea and the three countries may comove more or less during the crisis. We also consider industry effects for Korea using 23 industry dummies. The ratios of trade to sales and export competition in third markets are computed yearly for each Korean manufacturing division (industry) for each of the three countries (the U.S., Japan and China). The proportion of foreign stock investment is computed for each such division (industry) for a given year. In the regression, we use the natural log of ($1+$ trade-to-sales ratio $\times 100$) and the natural log of ($1+$ proportion of foreign stock investment $\times 100$). The specifications without the dummy variables for the second stage are expressed as follows:

$$(3\text{-}1)\qquad \begin{aligned}\beta_{us,i} = \delta_{us,i} + {}& \delta_{us,trade}\mathrm{Trade}_{us,i} + \delta_{us,finance}\mathrm{Finance}_{i} \\ & + \delta_{us,xc}\mathrm{ExportCompetition}_{us,i} + \varepsilon_{us,i}\end{aligned}$$

[8]The KSIC, introduced in 1963, is based on the UN's International Standard Industrial Classification (ISIC). There have been ten revisions since its introduction. The tenth revision went into effect in July of 2017. The ninth revision, which became effective in 2008, was the latest revision in our sample period. The KSIC has a hierarchical five-digit system. The KSIC (revision 9) was divided into 21 sections, and each section is broken down into divisions (denoted by two digits). The divisions are further broken down into groups (three digits), into classes (four digits) and then into subclasses (five digits). There were 76 divisions, 228 groups, 487 classes and 1,145 subclasses for the KSIC (revision 9) (Source: https://unstats.un.org/unsd/cr/ctryreg).

[9]We also used the estimates of betas with the returns denominated in U.S dollars and obtained results qualitatively similar to the current results. .

$$\beta_{\text{Japan,i}} = \delta_{\text{Japan,i}} + \delta_{\text{Japan,trade}}\text{Trade}_{\text{Japan,i}} + \delta_{\text{Japan,finance}}\text{Finance}_{\text{i}} + \delta_{\text{Japan,xc}}\text{ExportCompetition}_{\text{Japan,i}} + \varepsilon_{\text{Japan,i}} \tag{3-2}$$

$$\beta_{\text{China,i}} = \delta_{\text{China,i}} + \delta_{\text{China,trade}}\text{Trade}_{\text{China,i}} + \delta_{\text{China,finance}}\text{Finance}_{\text{i}} + \delta_{\text{China,xc}}\text{ExportCompetition}_{\text{China,i}} + \varepsilon_{\text{China,i}} \tag{3-3}$$

Specifically, the ratio of trade to sales for industry i for a certain year for each of the three countries ($\text{Trade}_{\text{us,i}}$, $\text{Trade}_{\text{Japan,i}}$, and $\text{Trade}_{\text{China,i}}$) is computed as follows. We collect the annual exports and imports between Korea and each of the three countries in U.S. dollars from the UN Comtrade database at the level of HS 6-digit codes under HS 1996. Next, we convert HS 6-digit codes under HS 1996 to HS 6-digit codes under HS 2002 using a correspondence table provided by the UN Statistics Division.[10] Subsequently, we use two correspondence tables for the 2010 Input-Output Statistics of Korea.[11] The first is a correspondence table between the HS 6-digit codes under HS 2002 and I-O commodity codes for the 2010 Input-Output Statistics of Korea. The second is a correspondence table between the I-O commodity codes and the KSIC (revision 9) codes. By combining the two correspondence tables, we convert HS 6-digit codes under HS 2002 to KSIC (revision 9) codes. Next, we sum up the annual trade for all of the HS 6-digit codes in each industry so that we can compute the annual trade for the industry. For the sales of each industry, we collect the annual sales in Korean won for each company within the industry from DataGuide and then compute the annual sales in Korean won for the industry by adding up the annual sales for all of the companies in the industry.[12] We then divide the annual sales for the industry in Korean won by the average exchange rate between the Korean won and U.S. dollar for the year[13] and thus compute the annual sales for the industry in U.S. dollars. Lastly, we compute the ratio of trade to sales using the annual trade and sales in U.S. dollars for the industry.

For the proportion of foreign stock investment each year in a Korean industry, we determine the proportion of foreign stock investment for each company in the industry at the end of each month during the sample period using data from DataGuide and compute the value-weighted mean of the proportions for all of the companies in the industry at the end of the month. Next, we calculate the annual average of the monthly proportions for the industry. Following Arslanalp *et al.* (2016), we compute export competition in third markets for industry i each year for each of the three countries ($\text{ExportCompetition}_{\text{us,i}}$, $\text{ExportCompetition}_{\text{Japan,i}}$, and $\text{ExportCompetition}_{\text{China,i}}$) as the minimum between the share of industry i out of all exports for Korea and that for each of the three countries.

[10] https://unstats.un.org/unsd/trade/classifications/correspondence-tables.asp

[11] Bank of Korea (2014)

[12] It is possible that sales data underestimate the actual amount of each industry to some degree because DataGuide does not include non-listed companies.

[13] We collect the annual average exchange rates between the Korean won and U.S. dollar from the Bank of Korea (ECOS).

TABLE 2—TRADE-TO-SALES RATIO, PROPORTION OF FOREIGN STOCK INVESTMENT AND EXPORT COMPETITION FOR KOREA (AVERAGE FOR 24 MANUFACTURING DIVISIONS)

Category	Country	2003-2007 (A, %)	2008-2009 (B, %)	2010-2016 (C, %)	(C-A, %p)
Trade to Sales	U.S.	39.7	28.2	26.4	-13.3
	Japan	45.7	34.7	27.9	-17.9
	China	53.4	68.0	72.1	18.7
Foreign Stock Investment	All countries	20.3	17.7	19.8	-0.5
Export Competition	U.S.	2.8	2.7	2.7	-0.1
	Japan	2.9	2.9	2.9	0.0
	China	2.8	2.8	2.8	0.0

Table 2 reports the averages of the trade-to-sales ratio, the proportion of foreign stock investment and export competition for the 24 Korean manufacturing divisions before the global financial crisis (2003-2007), during the global financial crisis (2008-2009), and after the global financial crisis (2010-2016). The average of the trade-to-sales ratio for the U.S. decreased from 39.7% before the crisis to 26.4% after the crisis. The average of the trade-to-sales ratio for Japan also decreased from 45.7% before the crisis to 27.9% after the crisis. On the other hand, the average of the trade-to-sales ratio for China increased from 53.4% before the crisis to 72.1% after the crisis. For the average proportion of foreign stock investment, it was 20.3% before the crisis and changed to 19.8% after the crisis. For export competition, the three countries have similar levels of competition with Korea and show little change over time.

V. Empirical Results

Table 3 reports the estimates of the betas from specification (1), in this case the regression without control variables, in Section IV. Panel A in Table 3 provides the estimates of betas for the 24 Korean manufacturing divisions (industries) with respect to the U.S. and their averages for three sub-periods: before the global financial crisis (2003-2007), during the global financial crisis (2008-2009), and after the global financial crisis (2010-2016). For the U.S., the average betas before and after the global financial crisis are estimated to be 0.270 and 0.218, respectively. Moreover, the beta after the crisis is smaller than that before the crisis for 18 out of 24 divisions. Thus, we conclude that the comovement between the Korean and U.S. stock markets decreases over time. Interestingly, the average beta during the crisis was -0.163, and the beta was negative for 22 out of 24 divisions. This suggests that the Korean and U.S. stock markets moved in opposite directions during the crisis when controlling for the effects of the other two major markets, Japan and China.

Panel B in Table 3 provides the estimates of the betas for the 24 Korean manufacturing divisions (industries) with respect to Japan and their averages for the three sub-periods. For Japan, the average betas before and after the global financial crisis are estimated to be 0.365 and 0.114, respectively. In addition, the beta after the crisis is smaller than that before the crisis for 23 out of 24 divisions. Thus, the comovement between the Korean and Japanese stock markets also declines over time. The average beta during the crisis was 0.494, which suggests that the Korean and Japanese stock markets moved further in the same direction during the crisis.

Panel C in Table 3 provides the estimates of the betas for the 24 Korean manufacturing divisions (industries) with respect to China and their averages for the three sub-periods. For China, the average betas before and after the global financial crisis are estimated to be 0.129 and 0.229, respectively. Furthermore, the beta after the crisis is larger than that before the crisis for 20 out of 24 divisions.

TABLE 3—ESTIMATES OF BETAS FOR THE KOREAN MANUFACTURING INDUSTRY WITH RESPECT TO U.S., JAPANESE AND CHINESE STOCK MARKET RETURNS (WITHOUT CONTROL VARIABLES)

[Panel A: U.S.]

Industry	2003-2007 (A)	2008-2009 (B)	2010-2016 (C)	(C-A)
10	0.228	-0.143	0.025	-0.203
11	0.192	-0.168	0.100	-0.092
12	0.294	-0.081	0.153	-0.140
13	0.061	-0.151	0.278	0.217
14	0.310	-0.114	0.119	-0.191
15	-0.006	-0.316	0.543	0.549
16	0.397	-0.030	0.225	-0.171
17	0.259	-0.233	0.194	-0.065
18	0.666	0.040	0.232	-0.434
19	0.273	-0.029	0.257	-0.016
20	0.402	-0.087	0.259	-0.143
21	0.226	-0.220	-0.061	-0.288
22	0.217	-0.155	0.286	0.070
23	0.213	-0.287	0.214	0.002
24	0.334	0.265	0.289	-0.046
25	0.164	-0.440	0.412	0.248
26	0.265	-0.011	0.202	-0.063
27	0.462	-0.336	0.230	-0.231
28	0.400	-0.135	0.231	-0.169
29	0.375	-0.350	0.337	-0.038
30	0.166	-0.173	0.104	-0.062
31	0.147	-0.225	0.381	0.234
32	0.326	-0.080	0.122	-0.204
33	0.110	-0.446	0.089	-0.021
Average	0.270	-0.163	0.218	-0.052

TABLE 3—ESTIMATES OF BETAS FOR THE KOREAN MANUFACTURING INDUSTRY WITH RESPECT TO U.S., JAPANESE AND CHINESE STOCK MARKET RETURNS (WITHOUT CONTROL VARIABLES) *(CONTINUED)*

[Panel B: Japan]

Industry	2003-2007 (A)	2008-2009 (B)	2010-2016 (C)	(C-A)
10	0.322	0.306	0.133	-0.189
11	0.329	0.116	0.116	-0.213
12	0.039	0.168	0.012	-0.026
13	0.323	0.403	0.158	-0.165
14	0.303	0.284	0.226	-0.077
15	0.278	0.199	0.059	-0.218
16	0.271	1.037	0.153	-0.118
17	0.134	0.483	0.058	-0.075
18	0.172	0.556	0.073	-0.099
19	0.170	0.296	-0.080	-0.249
20	0.388	0.517	0.053	-0.335
21	0.269	0.440	0.272	0.003
22	0.405	0.580	0.118	-0.287
23	0.426	0.636	0.115	-0.311
24	0.711	0.454	0.030	-0.681
25	0.414	0.744	0.126	-0.288
26	0.614	0.487	0.277	-0.338
27	0.391	0.655	0.104	-0.287
28	0.354	0.604	0.103	-0.251
29	0.569	0.788	0.184	-0.385
30	0.715	0.437	-0.015	-0.729
31	0.545	0.722	0.195	-0.350
32	0.198	0.201	0.061	-0.136
33	0.424	0.754	0.197	-0.227
Average	0.365	0.494	0.114	-0.251

TABLE 3—ESTIMATES OF BETAS FOR THE KOREAN MANUFACTURING INDUSTRY WITH RESPECT TO U.S., JAPANESE AND CHINESE STOCK MARKET RETURNS (WITHOUT CONTROL VARIABLES) *(CONTINUED)*

[Panel C: China]

Industry	2003-2007 (A)	2008-2009 (B)	2010-2016 (C)	(C-A)
10	0.102	0.205	0.053	-0.049
11	0.138	0.207	0.060	-0.078
12	-0.042	0.021	-0.003	0.039
13	0.162	0.215	0.130	-0.032
14	0.061	0.280	0.060	-0.001
15	0.043	0.512	0.120	0.077
16	0.030	0.286	0.201	0.171
17	0.038	0.224	0.179	0.141
18	0.105	-0.129	0.210	0.105
19	0.239	0.251	0.578	0.339
20	0.255	0.222	0.392	0.138
21	0.113	0.244	0.117	0.004
22	0.129	0.181	0.170	0.041
23	0.145	0.312	0.213	0.069
24	0.226	0.421	0.440	0.214
25	0.130	0.387	0.240	0.110
26	0.191	0.066	0.330	0.138
27	0.111	0.363	0.264	0.154
28	0.137	0.067	0.278	0.141
29	0.166	0.466	0.304	0.138
30	0.183	0.224	0.348	0.165
31	0.267	0.556	0.419	0.152
32	0.109	0.154	0.139	0.029
33	0.062	0.232	0.247	0.185
Average	0.129	0.249	0.229	0.100

Thus, we conclude that the comovement between Korean and Chinese stock markets increases over time. The average beta during the crisis was 0.249. This suggests that the Korean and Chinese stock markets moved further in the same direction during the crisis.

Table 4 reports the estimates of the betas from specification (2), in this case regression with control variables, in Section IV. Panel A in Table 4 provides the estimates of the betas for the 24 Korean manufacturing divisions (industries) with respect to the U.S. and their averages for the three sub-periods. For the U.S., the average betas before and after the global financial crisis are estimated to be 0.479 and 0.006, respectively. In addition, the beta after the crisis is smaller than that before the crisis for 21 out of 24 divisions. Panel B in Table 4 provides the estimates of the betas for the 24 Korean manufacturing divisions (industries) with respect to Japan and their averages for the three sub-periods. For Japan, the average betas before and after the global financial crisis are estimated to be 0.304 and 0.124, respectively. The beta after the crisis is smaller than that before the crisis for 20 out of 24 divisions. Panel C in Table 4 provides the estimates of the betas for the 24 Korean manufacturing divisions (industries) with respect to China and their averages for the three sub-periods. For China, the average betas before and after the global financial crisis are estimated to be 0.112 and 0.192, respectively. In addition, the beta after the crisis is larger than that before the crisis for 19 out of 24 divisions. By industry, the increase in the value of beta was especially significant in divisions 19 (0.270), 24 (0.231) and 30 (0.182).

When we look at the post-crisis period (2010-2016) in terms of specific Korean industries, the estimated beta with regard to China was the highest in division 19 (0.533), followed by divisions 24 (0.396), 30 (0.344), 20 (0.338), 31 (0.331) and 26 (0.320). The betas in divisions 19 (0.410), 31 (0.406), 22 (0.255) and 30 (0.254) were

TABLE 4—ESTIMATES OF BETAS FOR THE KOREAN MANUFACTURING INDUSTRY WITH RESPECT TO U.S., JAPANESE AND CHINESE STOCK MARKET RETURNS (WITH CONTROL VARIABLES)

[Panel A: U.S.]

Industry	2003-2007 (A)	2008-2009 (B)	2010-2016 (C)	(C-A)
10	0.300	-0.301	-0.204	-0.504
11	0.087	-0.401	-0.161	-0.248
12	0.300	-0.217	0.071	-0.229
13	0.378	-0.084	-0.144	-0.522
14	0.460	0.004	-0.136	-0.596
15	0.272	0.177	0.201	-0.071
16	0.711	-0.056	-0.352	-1.063
17	0.429	-0.086	0.044	-0.474
18	1.662	0.310	-0.112	-1.774
19	0.265	-0.141	0.410	0.145
20	0.581	0.108	0.169	-0.412
21	0.389	-0.085	-0.249	-0.638
22	0.283	0.110	0.255	-0.029
23	0.167	-0.274	0.031	-0.136
24	0.775	0.453	-0.040	-0.815
25	0.466	-0.310	0.030	-0.436
26	0.584	0.349	0.134	-0.450
27	1.036	-0.104	-0.214	-1.250
28	0.620	0.179	0.026	-0.594
29	0.743	0.110	0.179	-0.564
30	0.078	0.762	0.254	0.176
31	0.091	0.260	0.406	0.315
32	0.410	-0.151	-0.160	-0.570
33	0.407	-0.539	-0.197	-0.604
Average	0.479	0.003	0.006	-0.473

TABLE 4—ESTIMATES OF BETAS FOR THE KOREAN MANUFACTURING INDUSTRY WITH RESPECT TO U.S., JAPANESE AND CHINESE STOCK MARKET RETURNS (WITH CONTROL VARIABLES) *(CONTINUED)*

[Panel B: Japan]

Industry	2003-2007 (A)	2008-2009 (B)	2010-2016 (C)	(C-A)
10	0.265	0.169	0.140	-0.125
11	0.247	0.051	0.171	-0.076
12	0.057	0.184	0.060	0.003
13	0.295	0.227	0.150	-0.145
14	0.163	0.088	0.192	0.029
15	0.299	-0.087	0.036	-0.263
16	0.223	0.689	0.198	-0.025
17	0.059	0.361	0.082	0.023
18	0.130	0.519	0.060	-0.070
19	0.116	0.134	-0.051	-0.167
20	0.276	0.313	0.081	-0.195
21	0.202	0.457	0.327	0.125
22	0.367	0.312	0.121	-0.246
23	0.379	0.476	0.123	-0.256
24	0.578	0.149	0.080	-0.499
25	0.321	0.398	0.145	-0.176
26	0.587	0.317	0.255	-0.332
27	0.362	0.491	0.070	-0.291
28	0.282	0.434	0.100	-0.183
29	0.500	0.512	0.183	-0.317
30	0.656	0.040	-0.028	-0.684
31	0.420	0.309	0.232	-0.188
32	0.182	0.185	0.058	-0.124
33	0.336	0.545	0.189	-0.148
Average	0.304	0.303	0.124	-0.180

TABLE 4—ESTIMATES OF BETAS FOR THE KOREAN MANUFACTURING INDUSTRY WITH RESPECT TO U.S., JAPANESE AND CHINESE STOCK MARKET RETURNS (WITH CONTROL VARIABLES) *(CONTINUED)*

[Panel C: China]

Industry	2003-2007 (A)	2008-2009 (B)	2010-2016 (C)	(C-A)
10	0.083	0.096	0.041	-0.043
11	0.130	0.163	0.016	-0.114
12	-0.033	-0.032	-0.001	0.032
13	0.169	0.065	0.107	-0.061
14	0.033	0.125	-0.023	-0.055
15	0.042	0.396	0.058	0.016
16	-0.017	0.101	0.147	0.164
17	0.008	0.150	0.141	0.133
18	0.097	-0.155	0.140	0.043
19	0.263	0.149	0.533	0.270
20	0.209	0.142	0.338	0.129
21	0.126	0.174	0.110	-0.016
22	0.112	0.035	0.157	0.045
23	0.106	0.191	0.166	0.060
24	0.165	0.348	0.396	0.231
25	0.112	0.235	0.188	0.076
26	0.186	-0.007	0.320	0.135
27	0.081	0.228	0.231	0.150
28	0.107	0.000	0.278	0.171
29	0.131	0.380	0.270	0.139
30	0.162	0.173	0.344	0.182
31	0.272	0.411	0.331	0.059
32	0.086	0.142	0.114	0.029
33	0.048	0.055	0.212	0.163
Average	0.112	0.149	0.192	0.081

the highest with respect to the U.S.. In the case of Japan, the betas in divisions 21 (0.327), 26 (0.255) and 31 (0.232) were the highest.

Thus, together with the results from Table 3 and Table 4, we conclude that the comovements in stock returns between Korea and the U.S. and between Korea and Japan decline over time. In contrast, the comovement in stock returns between Korea and China increases over time.

Table 5 reports the results of a regression analysis where we examine the drivers of comovements in stock returns between Korea and the three countries. In Panel A of Table 5, we use the betas for the 24 Korean manufacturing divisions (industries) with respect to the U.S. from specifications (1) and (2) in Section IV, i.e., regression without and with control variables, as dependent variables. When we use the beta from specification (1), i.e., without control variables, as a dependent variable, and the variables of trade flows, foreign stock investment and export competition in third markets as independent variables, the variable of trade is positive and significant at the 5% level, but the variables of foreign stock investment and export competition are not significant at any conventional level. When we add a dummy variable for the global financial crisis, none of the three variables is significant. When we use the beta from specification (2), i.e., with control variables, as a dependent variable, the variable of trade is positive and significant at the 5% level, whereas the variables of foreign stock investment and export competition are not statistically significant. When we add a dummy variable for the global financial crisis, the variable of trade is still positive and significant at the 5% level. However, the variables of foreign stock investment and export competition are not significant. Thus, for the U.S., we conclude that the variable of trade has a positive relationship with beta, but the variables of foreign stock investment and export competition show no relationship with beta.

In Panel B of Table 5, we use the betas for the 24 Korean manufacturing divisions (industries) with respect to Japan from specifications (1) and (2) as dependent variables. When we use the beta from specification (1) as a dependent variable, the variable of trade is positive and significant at the 1% level, but the variables of foreign stock investment and export competition are not significant. When we add a dummy variable for the global financial crisis, the variable of trade is still positive and significant at the 1% level, but the variables of foreign stock investment and export competition are not significant. When we use the beta from specification (2) as a dependent variable and variables of trade and foreign stock investment as independent variables, the variable of trade is still positive and significant at the 5% level, but the variables of foreign stock investment and export competition are not significant. When we add a dummy variable for the global financial crisis, the variable of trade is still positive and significant at the 5% level. However, the variables of foreign stock investment and export competition are not significant. Thus, in the case of Japan, we conclude that the variable of trade has a positive relationship with beta, whereas the variables of foreign stock investment and export competition are unrelated to beta.

In Panel C of Table 5, we use the betas for the 24 Korean manufacturing divisions (industries) with respect to China from specifications (1) and (2) as dependent variables. When we use the beta from specification (1) as a dependent variable, the variable of trade is positive and significant at the 1% level, but the variables of foreign stock investment and export competition are not statistically significant. When we add a dummy variable to represent the global financial crisis, the variable of trade is still positive and significant at the 1% level, but the variables of foreign stock investment and export competition are not significant. When we use the beta from specification (2) as a dependent variable, the variable of trade remains positive and significant at the 10% level, but the variables of foreign stock investment and export competition are not significant. When we add a dummy variable for the global financial crisis, the variable of trade is still positive and significant at the 10% level. However, the variables of foreign stock investment and export competition are not significant. Therefore, for China, we conclude that the variable of trade is positively related to beta but that the variables of foreign stock investment and export competition are not.

TABLE 5—REGRESSION OF BETA ON TRADE, FOREIGN STOCK INVESTMENT AND EXPORT COMPETITION FOR THE KOREAN MANUFACTURING INDUSTRY

[Panel A: U.S.]

Independent Variables	Dependent Variable: Beta of the Korean Manufacturing Industry			
	Without Control Variables		With Control Variables	
Trade	0.161** (2.11)	0.082 (1.12)	0.335** (2.44)	0.301** (2.20)
Finance	0.007 (0.09)	-0.031 (-0.45)	-0.068 (-0.63)	-0.084 (-0.78)
Export Competition	-0.009 (-0.34)	-0.006 (-0.24)	-0.008 (-0.18)	-0.006 (-0.15)
Crisis Dummy		-0.395*** (-7.55)		-0.169** (-2.17)
Industry Effect	Yes	Yes	Yes	Yes
N	336	336	336	336
R^2	0.054	0.166	0.079	0.087

[Panel B: Japan]

Independent Variables	Dependent Variable: Beta of the Korean Manufacturing Industry			
	Without Control Variables		With Control Variables	
Trade	0.225*** (3.70)	0.230*** (4.02)	0.123** (2.10)	0.128** (2.17)
Finance	0.057 (0.95)	0.074 (1.35)	0.022 (0.41)	0.029 (0.55)
Export Competition	-0.012 (-0.72)	-0.010 (-0.63)	0.005 (0.28)	0.006 (0.33)
Crisis Dummy		0.279*** (7.10)		0.105*** (2.73)
Industry Effect	Yes	Yes	Yes	Yes
N	336	336	336	336
R^2	0.143	0.240	0.102	0.118

Note: 1) Numbers in parentheses are heteroscedasticity-robust t-statistics. 2) ***, **, and * denote statistical significance at the levels of 1%, 5% and 10%, respectively.

TABLE 5—REGRESSION OF BETA ON TRADE, FOREIGN STOCK INVESTMENT AND EXPORT COMPETITION FOR THE KOREAN MANUFACTURING INDUSTRY *(CONTINUED)*

[Panel C: China]

Independent Variables	Dependent Variable: Beta of the Korean Manufacturing Industry			
	Without Control Variables		With Control Variables	
Trade	0.134*** (3.11)	0.132*** (2.98)	0.087* (1.95)	0.087* (1.96)
Finance	0.019 (0.70)	0.022 (0.83)	0.023 (0.77)	0.022 (0.75)
Export Competition	-0.014 (-1.06)	-0.013 (-1.03)	-0.004 (-0.32)	-0.005 (-0.33)
Crisis Dummy		0.060 (1.69)		-0.011 (-0.33)
Industry Effect	Yes	Yes	Yes	Yes
N	336	336	336	336
R^2	0.239	0.248	0.212	0.212

Note: 1) Numbers in parentheses are heteroscedasticity-robust t-statistics. 2) ***, **, and * denote statistical significance at the levels of 1%, 5% and 10%, respectively.

Together with the results for the U.S., Japan and China, we conclude that the trade linkage is the main driver of comovements in stock returns between Korea and the three major countries. We find no evidence that either the financial linkage proxied by foreign stock investment or export competition is related to comovements in stock returns between Korea and the three countries. However, we admit that the proxy used for measuring the bilateral financial linkage between Korea and the three countries in our paper may have some limitations if used to explain the interconnection.

VI. Conclusion

This paper measures the extent of comovements in stock returns between Korea and three major countries (China, Japan and the U.S.) using industry-level data for Korea from 2003 to 2016, in the spirit of the ICAPM. It also examines what drives the comovements between Korea and the three countries.

From our analysis, we find that the comovements of the Korean stock market with those of the U.S. and Japan decline after the global financial crisis. In contrast, the post-crisis comovement in stock returns between Korea and China is greater than that during the pre-crisis period.

Next, we examine the drivers of comovements in stock returns between Korea and the three countries. Specifically, we use betas for 24 Korean manufacturing divisions (industries) with respect to the U.S., Japan and China as dependent variables and variables of trade and foreign stock investment as independent variables in an effort to examine whether either the trade or financial linkage between Korea and the three countries can explain the degrees of comovements in stock returns between Korea and the three countries. From our analysis, we find that the trade linkage is the main driver of comovements in stock returns between Korea and the three countries. On the other hand, we find no evidence that the financial linkage proxied by foreign stock investment is related to comovements in stock returns between Korea and the three countries.

REFERENCES

Arslanalp, S., W. Liao, S. Piao and D. Seneviratne. 2016. “China’s Growing Influence on Asian Financial Markets,” *IMF Working Paper* WP/16/173.

Brooks, R. and M. Del Negro. 2006. “Firm-Level Evidence on International Stock Market Comovement,” *Review of Finance* 10: 69-98.

Cho, C. and T. Mooney. 2015. “Stock Return Comovement and Korean Business Groups,” *Review of Development Finance* 5: 71-81.

Eiling, E. and B. Gerard. 2015. “Emerging Equity Market Comovements: Trends and Macroeconomic Fundamentals,” *Review of Finance* 19: 1543-1585.

Elekdag, S., P. Rungcharoenkitkul and Y. Wu. 2012. “The Evolution of Asian Financial Linkages: Key Determinants and the Role of Policy,” *IMF Working Paper* WP/12/262.

Faias, J. and M. Ferreira. 2016. “Does Institutional Ownership Matter for International Stock Return Comovement?” *ECGI Working Paper* No. 465.

Forbes, K. and M. Chinn. 2004. “A Decomposition of Global Linkages in financial Markets over Time,” *Review of Economics and Statistics* 86(3): 705-722.

Griffin, J. and A. Karolyi. 1998. “Another Look at the Role of Industrial Structure of Markets for International Strategies,” *Journal of Financial Economics* 50: 351-373.

Heston, S. and K. Rouwenhorst. 1994. “Does Industrial Structure Explain the Benefits of International Diversification?” *Journal of Financial Economics* 36: 3-27.

Kim, M., W. Kim and D. Lee. 2015. “Stock Return Commonality within Business Groups: Fundamentals or Sentiment?” *Pacific-Basin Finance Journal* 35: 198-224.

Paramati, S., R. Gupta and E. Roca. 2015. “Stock Market Interdependence between Australia and its Trading Partners: Does Trade Intensity Matter?” *Applied Economics* 47(49): 5303-5319.

Paramati, S., R. Gupta and E. Roca. 2016. “Economic Integration and Stock Market Dynamic Linkages: Evidence in the Context of Australia and Asia,” *Applied Economics* 48(44): 4210-4226.

Park, K. 2007. “Stock Price Synchronicity and Analyst & Foreign Investor Activity,” *Korean Journal of Business Administration* 20(6): 2753-2775.

Roll, R. 1992. “Industrial Structure and the Comparative Behavior of International Stock Market Indices,” *Journal of Finance* 47(1): 3-41.

Tavares, J. 2009. “Economic Integration and the Comovement of Stock Returns,” *Economics Letters* 103: 65-67.

KDI Journal of Economic Policy 2018, 40(1): 67–83
http://dx.doi.org/10.23895/kdijep.2018.40.1.67

Measuring Nuclear Power Plant Negative Externalities through the Life Satisfaction Approach: The Case of Ulsan City†

By KYEWOO LEE AND SE JONG YOO*

We have hypothesized that nuclear risk is significantly inversely related to the distance from residences to nuclear power plants and that the level of life satisfaction of residents therefore increases with the distance. We empirically explore the relationship between Ulsan citizens' life satisfaction levels and the distance between their residences and the Kori and Wolsong nuclear power plants (NPP) based on the life satisfaction approach (LSA). The dataset we used covers only Ulsan citizens from the biennial Ulsan Statistics on Citizen's Living Condition and Consciousness of 2014 and 2016. Controlling for micro-variables such as education, work satisfaction, gender, marital status, and expenditures, we found a statistically significant relationship between life satisfaction and the distance between the residences and the nuclear power plants. Nuclear negative externalities including (i) health and environmental impact, (ii) radioactive waste disposal, and (iii) the effect of severe accidents can be quantified in terms of LS units and monetary units. We were able to calculate the monetary value of NPP externalities at $277 per kilometer of distance for Kori and $280 per kilometer of distance for Wolsong at constant 2015 prices. These estimates are quite different from the traditional estimates made with the contingent valuation method, whereas they are similar to the findings of LSA studies abroad. Hence, the need to adopt the LSA in South Korea and policy implications are demonstrated.

Key Word: Negative Nuclear Externalities, Nuclear Risk, Life Satisfaction Approach, Non-market valuation, Nuclear Power Plants, South Korea
JEL Code: D61, H43, L94, Q41

* Lee: (corresponding author) Professor, KDI School of Public Policy and Management (e-mail: kwlee@kdischool.ac.kr); Yoo: Senior Analyst, Samjung KPMG (e-mail: imccom@naver.com)
* Received: 2018. 1. 9
* Referee Process Started: 2018. 1. 17
* Referee Reports Completed: 2018. 4. 1
† Authors gratefully acknowledge the insightful comments and constructive suggestions made by the two anonymous referees; however, only authors are responsible for any remaining errors and shortcomings.

I. Introduction

The purpose of this paper is to analyze negative externalities related to Kori and Wolsong nuclear power plants (NPPs) using life satisfaction data as a proxy for the utilities. While nuclear energy generation offers the advantages of energy security, an absence of air pollution, marginal greenhouse gas emissions and low operating costs, there are also negative externalities for our health, the environment, and for property values. Such NPP negative externalities are geographically concentrated near nuclear power plants, while the benefits accrue for the population in general. In the past, NPP analyses took into consideration mainly positive externalities while neglecting to factor negative externalities into the analyses for a proper comparison with other sources of energy.

There Likewise, although shallow analyses have often mistakenly concluded that coal energy is the most economic energy source, these analyses have not considered a variety of hidden costs related to coal-powered plants borne by society as a whole (Amerasinghe, 2011). Failure to internalize the externalities of coal energy means that energy investment analyses have instead used distorted market prices. If this inadequate reflection of external costs continues in energy investment analyses, it will have detrimental effects on the global climate, environment, and efficient optimization of social wellbeing. To date, most governments have considered explicit internal costs but have not taken into account external costs in their energy sector investment decisions.

To correct market price distortions, appropriate analyses should capture the external costs associated with generating electricity from a given source as much as possible. Therefore, this study applies the life satisfaction quantitative approach to an economic analysis of the external costs and benefits associated with investment in nuclear energy sources in South Korea. This study, as far as we know, is the first in South Korea to use the life satisfaction approach to measure NPP negative externalities.

In an economy with resource constraints in general, all governments, both developed and developing, have adopted a public investment appraisal system to assess the rate of return of competing investment operations and maximize the net benefits of chosen investment opportunities. Traditionally, they consider only explicit internal costs and benefits while using market prices. However, distortions in market prices have become even clearer due to market imperfections, leading to increased government interventions in the market to correct market distortions or to achieve various policy objectives, such as redressing inequities and protecting the poor and/or the environment.

Therefore, both academics and public policy makers have realized the need to make, in parallel with financial assessments, economic analyses of proposed investment operations, using shadow prices. Currently it is standard practice for both governments in advanced countries and international development organizations to carry out financial and economic analyses of proposed investment operations and make the results available to policy makers. Such analyses have long covered mainly explicit internal costs and benefits and have included only qualitative assessments of externalities.

As concerns over environmental protection and adjustments to global climate change have become serious, both academics and policy practitioners have made creative efforts to internalize externalities, especially negative externalities, in their economic analysis framework in general (National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 1993).

More specifically, in conjunction with the 2016 agreements on the Sustainable Development Goals (SDGs) for 2030 at the UN and on sustainable environmental protection measures against global climate changes at Paris, both developed and developing countries have made adjustments to their future energy policies, enacting favorable trade-offs between different sources of energy. South Korea was no exception. Earlier conservative governments and the new liberal government that started in 2017 established or revised their long-term energy supply plans. However, greater government investment in a specific source of power relative to other sources of energy has had a significant impact on growth of the economy overall and on the wellbeing of society. Therefore, greater government investment in a specific source of energy should be determined in consideration of not only explicit internal costs and benefits but also the implicit external costs and benefits of different sources of energy. This approach will enable the government to choose a better investment opportunity that creates more net benefits and greater wellbeing for the economy than other options.

This study assumes that people's disutility from nuclear risk decreases (i.e., the level of life satisfaction increases) with the distance between one's residence and an NPP, as people in general prefer to be distant from NPP risks assuming all other factors are equal. Therefore, the greater the income is, the greater the distance between the residence and NPP risks becomes. By measuring the marginal utility of income and the marginal disutility of the Kori and Wolsong NPPs, the trade-off ratio between income and distance between the residence and NPP externalities, while maintaining the same level of life satisfaction, can be calculated in monetary terms (Frey *et al*., 2009), enabling us to estimate the negative externalities of NPPs.

The rest of this paper is structured as follows: this study initially defines the meaning and scope of the externalities of NPPs for this study. Secondly, it reviews previous studies through a literature review. Thirdly, it applies the life satisfaction approach to the Ulsan Metropolitan City with the introduction of the conceptual and empirical backgrounds to clarify the life satisfaction approach and to describe the Wolsong and Kori NPPs and the neighboring Ulsan districts. The study then elaborates on the method and strategy of the empirical analysis and discusses the empirical analysis results. Finally, the study summarizes the main findings of the analysis and discusses the policy implications of its findings.

II. Definition of Nuclear Externalities in this Paper

Ea Energy Analyses (2008) identifies, as the major elements of external costs, possible nuclear accidents and radioactive waste disposal and storage. Moreover, the Nuclear Energy Agency (NEA) also defines external costs as future financial liabilities due to (1) the decommissioning and dismantling of nuclear facilities, (2) the health impact and general impact of the radioactivity diffused during the operation of plants, and (3) spent fuel and effects of severe accidents (NEA, 2003). On the other hand, positive nuclear externalities also exist. They are, for example, security of the energy supply, cost stability, and declines in other pollutant gases due to the replacement of other sources of electricity by NPPs. However, these positive externalities have been studied, and the results indicate that positive externalities are not a major cause of price distortions (OECD/NEA, 2003).

Thus, this study not only disregards the positive externalities of NPPs but also does not take into account factors such as policy costs borne by the society that finances nuclear energy R&D, NPP neighboring community support, public acceptance, and government-funded nuclear related institutions. In sum, in this paper, nuclear externalities refer to (i) health and environmental impacts, (ii) radioactive waste disposal, and (iii) the effects of severe accidents that can be quantified in terms of LS units and monetary units, as we assume that these negative externalities are generally recognized by the citizens in Ulsan as factors affecting their life satisfaction levels.

III. Data and Estimation Strategy

In this section we review previous studies related to the measurement of nuclear externalities. In particular, this review focuses on not only the limitation of previous studies but also on the relative merits of the Life Satisfaction Approach.

In economics, literature on methods pertaining to how people value the environment can be categorized largely into three groups: (1) revealed preference methods such as the Hedonic Method (HM), (2) stated preference methods such as the Contingent Valuation Method (CVM), and (3) the Life Satisfaction Approach (LSA).

A. *Revealed Preference Methods (the HM)*

The Hedonic Method (HM), a typical example of a revealed preference method, has been widely used in research on environment evaluations. Since externalities have an impact on the differentiated market goods of housing and jobs, the housing and labor markets, as a result, reflect externalities. Wage and rent differentials serve as implicit prices and correspond in equilibrium to individuals' marginal willingness to pay for a public good (Rosen 1974). Yamane *et al*. (2013) studied property values around the Fukushima-Daiichi plant, which decreased with an increase in the level of local nuclear contamination, but not with proximity to the plant. Fink and Stratmann (2013) found no change in property prices relative to proximity to NPPs in the US, whereas Bauer *et al*. (2017) found that house prices near NPPs in Germany dropped by up to 11%.

The inconsistent results of HM studies stem from the assumption of hedonic locational equilibrium, i.e., that the housing and labor markets are perfectly in equilibrium. This assumption is justified only (a) when households have a high degree of information, (b) when there is a sufficiently wide variety of houses and jobs available, (c) when prices adjust rapidly, (d) when transaction and moving costs are low, and (e) when there are no market restrictions (Freeman 2003, p. 366), all of which cannot be readily satisfied in the real economy. In short, the HM yields biased results if housing and labor markets are not in equilibrium (Frey, 2009).

B. *Stated Preference Methods (the CVM)*

Many studies have attempted to measure the risk of nuclear power plants based on Contingent Valuation Methods (CVM), a typical type of stated preference method. Respondents are asked to value a specific public good under well-specified conditions of contingent markets (Carson *et al*. 2003). Lee and Kang (2016) assessed the statistical value of life based on the CVM in consideration of risk aversion to calculate the externalities of NPPs in South Korea. Approximately 1,550 participants answered hypothetical choice decision questions. The researchers argued that the estimated external cost of an NPP accident represents about 0.13% of the unit electricity generation cost of a NPP (or $0.00439/MWh) in South Korea.

In 2013, the Korea Environment Institute (KEI) measured NPP externalities by asking 1,000 respondents questions based on two survey designs. The first survey design asked about people's willingness to pay (WTP) for mitigating nuclear accident risk in general. Based on the results of this survey, KEI argued that NPP externalities for general nuclear risk range from $4.18 to $6.93/MWh. In the second survey design, people were asked about their WTP for avoiding the construction of NPPs in their neighborhood. Interestingly, the WTP for avoiding the construction of NPPs in close proximity is much higher than the nuclear risk in general ($57.31 to $104.39/MWh).

The CVM has an advantage that it does not require the goods or labor markets to be in hedonic locational equilibrium. However, the hypothetical nature of CVM survey questions and unfamiliarity with the task often lead to superficial answers and symbolic valuations (Kahneman *et al*. 1999) because most people are unfamiliar with assigning monetary value to nuclear risk, which is characterized as extremely high risk at an extremely low frequency. As a result, the CVM may not adequately represent the true value of nuclear risk due to information bias that arises when respondents are forced to value attributes with which they have little or no experience. Symbolic valuation in the form of attitudes, expressions, and superficial answers is likely to bias results (Frey 2004). Further, strategic behavior in the case of NPPs is more likely to bias the results of the CVM than it is with other projects, as the benefits of NPPs are diffused among many people, whereas the costs of NPPs are concentrated among a few people. Moreover, the majority of survey respondents are not residents in proximity to NPPs. Accordingly, bipolarized attitudes towards NPPs change the results of surveys depending on the structure of the survey questionnaires.

C. *Life Satisfaction Approach*

The Life Satisfaction Approach (LSA) is a complementary evaluation method that obviates the inherent problems with the CVM and HM (Frey *et al*. 2009). Because the LSA does not rely on the hedonic equilibrium assumption, it can avoid the biased results of the HM. Further, in the LSA, respondents are required not to value hypothetical NPP risk directly but to assess their life satisfaction levels with some degree of precision. In fact, people may not consciously notice that there is a relationship between an environmental condition such as NPP risk and their subjective well-being. The connection between life satisfaction and an environmental condition such as NPP risk is made ex-post by the researcher. Because the LSA requires fewer cognitive tasks and does not elicit strategic behavior, it negates the biased hypothetical nature of the CVM (Frey, 2009).

Although LSA has been applied to environmental programs and projects extensively abroad, it is not often applied to NPP externalities intensively. However, when Welsch and Biermann (2016) studied measuring nuclear power plant externalities in Switzerland, they found a significantly positive relationship between life satisfaction levels and greater distances from NPPs. In their research, they argued that living 1 km farther away from the nearest NPP is worth 0.5% of equalized disposable income, corresponding to $305 as of 2015. Because both the HM and the CVM have corresponding limitations, the LSA complements conventional methods of evaluating NPP externalities. This paper contributes to measuring NPP externalities by applying LSA for the first time in South Korea.

IV. Empirical Study of the Case of Ulsan City

A. *Conceptual Model and Assumptions*

In economics, a consumer's indirect utility function $u = v(p, w)$ shows that the consumer's utility u is a function of vector p of goods prices and the amount of income w. Given a person's income, as a consumer he/she chooses an affordable bundle of housing and a numeraire that maximizes his/her utility. The total expenditure cannot exceed income. Based on the utility maximization function, people realize their highest utility by optimizing their income to buy marketable goods at a given rent with regard to housing and perceived nuclear risk. Thus, the utility maximization function of an individual with personal characteristics denoted by θ takes the following form:

$$(1) \qquad u = v(I, NR, \theta)$$

In this formulation, u denotes life satisfaction (utility), I denotes income, and NR represents nuclear risk. This study expects that the sign of the coefficients for I is positive, whereas NR is negative. Percieved nuclear risk is divided into two factors. NR takes the following form:

$$(2) \qquad NR = D * \pi$$

In this formulation, D denotes expected damages associated with a nuclear accident, whereas π denotes the probability of being affected by an accident (Welsch *et al.*, 2009; 2016). This study assumes that expected damages decrease in proportion to the distance from the nearest NPP. Therefore, this specification indicates that risk-averse people and those who are pessimistic about nuclear energy are more likely to choose residences further away from NPPs. Therefore, on the basis of the assumptions for equation (2), equation (1) can be expressed as follows:

$$(1') \qquad u = V\left(I, \text{distance}, \theta\right)$$

In this formulation, individual life satisfaction depends on income I, the distance to NPPs, and a set θ of micro-level determinants of the LS. Ferrer-i-Carbonell and Frijters (2004) and many others argue that treating life satisfaction as ordinal or cardinal and applying the corresponding estimation methods have little effect on qualitative results.

B. *Empirical Background*

In 2016, a total gross capacity of 21.6 GWe is installed in the 24 operating NPPs in South Korea, consisting of 20 pressurized water reactors (PWRs) and four CANDU pressurized heavy water reactors (PHWRs). Table 1 shows the status of the NPPs in South Korea.

Out of 24 operating NPPs, 12 NPPs are located in the areas around Ulsan districts. Moreover, six additional NPPs in Kori are expected to enter operation in the near future. According to the research (SEDAC, 2015), Kori and Wolsong are

TABLE 1—NUCLEAR POWER REACTORS OPERATING IN SOUTH KOREA

S/N	Name	Reactor	Capacity (MWe)	Commercial Start	Planned Close
1	Kori 1	PWR	576	29.04.1978	2017
2	Wolsong 1	CANDU	645	22.04.1983	2022 or 2023
3	Kori 2	PWR	639	25.07.1983	2023
4	Kori 3	PWR	1,003	30.09.1985	2025
5	Kori 4	PWR	1,001	29.04.1986	
6	Hanbit 1 (YG)	PWR	958	25.08.1986	
7	Hanbit 2 (YG)	PWR	953	10.06.1987	
8	Hanul 1 (UC)	PWR	960	10.09.1988	
9	Hanul 2 (UC)	PWR	962	30.09.1989	
10	Hanbit 3 (YG)	System 80	998	31.03.1995	
11	Hanbit 4 (YG)	System 80	997	01.01.1996	
12	Wolsong 2	CANDU	653	01.07.1997	
13	Wolsong 3	CANDU	675	01.07.1998	
14	Hanul 3 (UC)	KSNP	994	11.08.1998	
15	Wolsong 4	CANDU	679	01.10.1999	
16	Hanul 4 (UC)	KSNP	998	31.12.1999	
17	Hanbit 5 (YG)	KSNP	988	21.05.2002	
18	Hanbit 6 (YG)	KSNP	995	24.12.2002	
19	Hanul 5 (UC)	KSNP	996	29.07.2004	
20	Hanul 6 (UC)	KSNP	996	22.04.2005	
21	Shin Kori 1	OPR-1000	996	28.02.2011	
22	Shin Kori 2	OPR-1000	993	20.07.2012	
23	Shin Wolsong 1	OPR-1000	991	31.07.2012	
24	Shin Wolsong 2	OPR-1000	1,050	24.07.2015	

Source: Korea Hydro Nuclear Power Website (2017).

ranked the first and third in terms of population exposure at 30km to the NPPs among mega-NPPs globally (a mega-NPP is defined as a site containing more than six NPPs). Kori has 3.4 million and Wolsong has 1.3 million citizens within 30km to the NPPs. In fact, it is safe to say that the citizens of Ulsan are completely besieged by mega-NPPs, as illustrated in Figure 1. Moreover, the citizens of Ulsan are exposed to nuclear waste because spent fuel is stored at the NPPs, as South Korea has yet to allocate funding for fuel storage sites. As a result, any disutility from the presence of NPPs includes the disutility from nuclear waste disposal.

In South Korea, issues related to NPPs are seriously discussed and broadcast by media, meaning that people are well aware of the exact locations of NPPs and any possible health and property risks associated with the NPPs. According to a future population trend survey taken in 2017, Ulsan's population in 1973 was 469,631, whereas Ulsan's population in 2017 was 1,165,646. Therefore, most survey respondents are assumed to have chosen their residences after the construction and commissioning of the NPPs, as the Kori and Wolsong NPPs have been operating since 1978 and 1983, respectively.

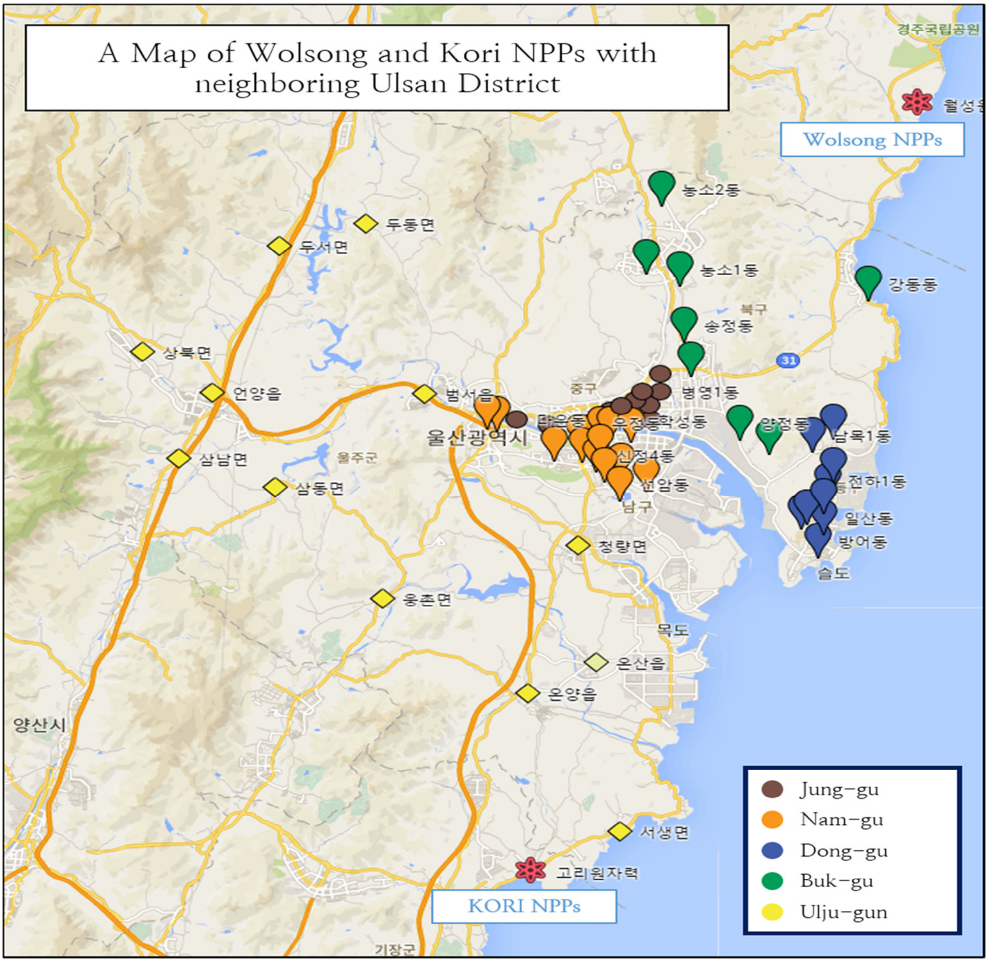


FIGURE 1. A MAP OF WOLSONG AND KORI NPPS WITH NEIGHBORING ULSAN DISTRICTS

C. *Estimation Method and Strategy*

NPP externalities can be measured using the first derivative of V with respect to distance (Equation 1'). The coefficient of distance from utility is assumed to be positive when income and individual characteristics are controlled. A change in the nonmarket good of $\Delta\text{distance}$ is valued by ΔI (corresponding to an implicit WTP) if the LS is constant. For a marginal change of distance, the marginal WTP can be derived when the derivative of LS = 0 (Mankiw, 2014)

$$\text{MWTP}=\frac{-\partial\text{income}}{\partial\text{distance}} \tag{3}$$

To calculate the cost of externalities of nuclear power plants, this study utilizes the Life Satisfaction Approach (LSA), especially in relation to equation (1'), as follows:

$$\begin{aligned}\text{LS}_i &= \alpha + \beta_1 \ln\text{income}_i + \beta_2\text{distanceWolsong}_i \\ &\quad + \beta_3\text{distanceKori}_i + \delta\theta i + \varepsilon_i\end{aligned} \tag{4}$$

Here, LS is the life satisfaction index, θ denotes the socio-demographic characteristics (age, religion, work satisfaction, sex, marriage, and education), and ε_i is an error term. This study assumes that the self-reported life satisfaction of individual i depends on one's income; distance to NPPs; and micro-variables such as work satisfaction, monthly expenditures, education level, marital status, gender, and other related factors.

Based on Roy's identity, the marginal WTP for nuclear risk can be calculated as shown below.

<u>Stage 1: Partial derivative of life satisfaction with respect to distance</u>

$$\begin{aligned}&\frac{\partial LS}{\partial\text{distanceNPP1}} \\ &= \frac{\partial}{\partial\text{distanceNPP1}}\left(\alpha + \beta_1 \ln\text{income}_i + \beta_2\text{distanceNPP1}_i + \beta_3\text{distanceNPP2}_i + \delta\theta_i + \varepsilon_i\right) \\ &= \beta_2\end{aligned} \tag{5}$$

By estimating β_2, the impact of the nuclear distance on life satisfaction can be measured.

Stage 2: Partial derivative of life satisfaction with respect to income

$$\frac{\partial LS}{\partial \text{income}} \tag{6}$$
$$= \frac{\partial}{\partial \text{income}}\left(\alpha + \beta_1 \ln \text{income}_i + \beta_2 \text{distanceNPP1}_i + \beta_3 \text{distanceNPP2}_i + \delta\theta_i + \varepsilon_i\right)$$
$$= \frac{\beta_1}{\text{income}}$$

By estimating β_1, the impact of income on life satisfaction can be measured.

Stage 3: Calculating marginal willingness to pay for distance

$$\text{MWTP} = \frac{-\partial \text{income}}{\partial \text{distance}} = \frac{\beta_2}{\frac{\beta_1}{\text{income}}} = \frac{\beta_2}{\beta_1} * \text{income} \tag{7}$$

In stage 3, the marginal WTP can be calculated when the derivative of life satisfaction is equal to zero.

Stage 4: Calculating the average marginal willingness to pay for distance

$$\text{Average marginal willingness to pay for distance} = \frac{\beta_2}{\beta_1} * \text{Mean Monthly Income} \tag{8}$$

D. *Data*

The dataset is derived from the biennial Ulsan Statistics on Citizens' Living Conditions and Consciousness in 2014 and 2016. This dataset contains 7,767 observations (0.7% of Ulsan's population) and information about the respondents' levels of life satisfaction. (The index of life satisfaction ranges from 0 = 'totally dissatisfied to 10 = 'totally satisfied' on an 11-point ordinal scale.). It also contains each respondent's address, household income, gender, age, education level, marital status, religion, work satisfaction, and occupation. The dataset does not have information about the distance between the residence and the NPPs, but it does contain detailed addresses of residences, allowing this study to estimate the distance between the residence and Wolsong and Kori NPPs, with corresponding total installed capacities of 4,693MW and 5,208MW, for each respondent. This study also uses the mean income of households from the Ulsan citizen survey, and the average number of persons in households in Ulsan from the South Korea Census in 2015 (Korea Census, 2015).

The dependent variable used to represent utility is the life satisfaction index. As the independent variable of interest, this study uses (a) the distance of each residence from Wolsong, and (b) distance of each residence from Kori. As independent variables, this study also uses (c) household income and (d) the sociodemographic characteristics included in regression (age, work satisfaction, gender, marriage, and education level). In this study, we control for factors that may be correlated with life satisfaction, such as work satisfaction, expenditures, marriage, and education, to avoid endogeneity issues. A set of descriptive statistics pertaining to the data is provided in the Appendix.

E. *Analysis Results*

The results of the estimation of the regression equation (8) are summarized in Table 2. As shown in Table 2, the signs of coefficients are identical and the ratios of the coefficients are similar regardless of whether life satisfaction is treated as ordinal or cardinal.

TABLE 2—RESULTS OF LIFE SATISFACTION REGRESSION – OLS AND ORDERED LOGIT ESTIMATION: WOLSONG AND KORI NPPs

Dependent Variable	OLS				Ordered Logit
	Model 1	Model 2	Model 3	Model 4	
Control Variables	**All included**	Excluding All Distances	Excluding Distance to Kori	Excluding Distance to Wolsong	Adj. Model 1
Log income	**0.212*** (0.041)**	0.202*** (0.041)	0.209*** (0.041)	0.201*** (0.041)	0.258*** (0.04)
Distance from Wolsong NPPs (DW)	**0.028*** (0.003)**	-	0.009*** (0.002)	-	0.038*** (0.005)
Distance from Kori NPPs (DK)	**0.028*** (0.004)**	-	-	0.005 (0.003)	0.036*** (0.006)
Expenditure	**-0.044** (0.022)**	0.043** (0.022)	-0.043* (0.022)	-0.044** (0.022)	-0.048 (0.030)
Work Satisfaction	**0.592*** (0.008)**	0.597*** (0.008)	0.596*** (0.008)	0.597*** (0.008)	0.956*** (0.016)
Male	**-0.099*** (0.031)**	-0.101*** (0.031)	-0.103** (0.031)	-0.100** (0.032)	-0.155*** (0.043)
Marriage	**-0.074* (0.037)**	-0.062* (0.037)	-0.065* (0.037)	-0.063* (0.037)	-0.108* (0.051)
Education	**0.008 (0.033)**	0.011 (0.034)	0.012 (0.034)	0.009 (0.034)	-0.009 (0.047)
Constant	**-0.127 (0.263)**	1.251 (0.183)	0.988 (0.197)	1.128 (0.195)	-
Sample Size	**7,767**	7,767	7,767	7,767	7,767
R-squared	**0.4288**	0.4249	0.4258	0.4251	-
Adj. R-squared	**0.4282**	0.4244	0.4253	0.4246	-

Note: Standard errors in parenthesis. The dependent variable is measured on an 11-point life satisfaction scale. ***p<0.01, **p<0.05, *p<0.1

The results of the pooled-OLS estimation of model 1 show that life satisfaction is statistically positively related to income at the 1% significance level, and an increase in income by 1% is likely to increase life satisfaction by 0.21 points. Furthermore, a 1km increase in the distance from Kori or Wolsong is associated with an increase in life satisfaction by 0.028 points on the aforementioned 11-point scale.

For a robustness test of estimation model 1, the impact of income on life satisfaction is tested without considering the distances from the Wolsong and the Kori NPPs in model 2. As compared with Model 1, the coefficient of log income diminishes merely by 0.008, indicating that the impact of income on life satisfaction has a similar value with and without considering the distance from the NPPs in the estimation models, and income and distance independently affect the level of life satisfaction. Likewise, it was whether the distances from the Wolsong NPPs and the Kori NPPs independently affect the life satisfaction level (Models 3 and 4). When only the distance from the Wolsong NPPs is included in the estimation model without controlling for the distance from the Kori NPPs, the coefficient of the distance from the Wolsong decreases sharply compared to Model 1 (Model 3). The same is true when the distance from Kori alone is included in the model as an independent variable without controlling for the distance from the Wolsong NPPs (Model 4). Thus, these distances are inter-related in terms of how they affect the life satisfaction level. Therefore, the two distances should both be included in the estimation model, as in Model 1. Otherwise, the coefficient of the included distance variable will be biased due to the missing variable.

For a robustness test of the multicollinearity issue, this study conducted the Farrar-Glauber test for overall and individual multicollinearity diagnostics. The multicollinearity issue may be suspected in this study because Ulsan is located between the Kori NPPs and the Wolsong NPPs. As a result, it is expected that the correlation between the distance from the Kori NPPs (DK) and the distance from the Wolsong NPPs (DW) is negative. To conduct the test of multicollinearity, this

TABLE 3—IMPLICIT MONETARY VALUE OF NUCLEAR RISK IN RELATION TO INCOME AND DISTANCE

Life Satisfaction with Respect to Income and Distance	Value for Kori	Value for Wolsong	Note
Coefficient of ln income for LS	0.212	0.212	β_1
Coefficient of ln distance (1km) for LS	0.028	0.028	β_2 & β_3
Coefficient of ln distance / Coefficient of ln income for LS	0.1309	0.1323	
Mean Monthly Household Income	5,490*	5,490*	Constant 2015 US Dollar Price
The Average Number of Persons in a Household in Ulsan	2.59	2.59	Population Census in 2015
Individual Income = Household Income Divided by the Number of Family Members	2,116	2,116	Constant 2015 US Dollar Price
MRS from Equation (8) Externalities for a 1km Change in Distance	277.1	280.0	Constant 2015 US Dollar Price

Source: * Household Finance and Welfare Survey in 2017.

study used the variance inflation factor (VIF). If the VIF for an independent variable is more than 10, multicollinearity is likely. The values of VIF for all independent variables excluding factor variables is less than 2.1, indicating that the independent variables are not strongly correlated.

The monetary value of the distance from the NPPs is calculated by dividing the marginal life satisfaction level from the distance by the marginal utility of income, creating the marginal rate of the utility-constant substitution of income (MRS) for distance. Based on equations (3) through (8), this study calculates the monetary value of NPP externalities for a 1 km change in the distance using the values of Model 1 in Table 2.

For Ulsan residents, the linear specification of the distance produces $MRS = 0.1309 * \text{Mean Monthly Household Income}$. As a result, living 1km farther away from the Kori NPPs is worth $277.1. The estimated NPP external costs cannot be directly compared because every study estimates nuclear externalities for different amounts of electricity generated. Therefore, the levelized cost of electricity (LCOE) is a convenient way to compare the externalities for the different amounts of electricity generated on a consistent basis. In this study, nuclear externalities estimated by different studies are directly compared by the LCOE.

Table 4 shows a summary of the estimated externalities in this study and in previous studies. Note that the identification of nuclear externalities varies depending on the methodology used in the study. For example, the Korea Environment Institute measured people's willingness to pay (WTP) for mitigating the nuclear

TABLE 4—SUMMARY OF NPP EXTERNALITIES ESTIMATED IN THIS STUDY AND IN PREVIOUS STUDIES

Research Conducted by	LCOE Calculation	Estimated Externalities (USD/MWh)	Study Method
This Study	Kori Externalities / Electricity Generation by Kori NPPs	33.86	Life Satisfaction
	Wolsong Externalities / Electricity Generation by Wolsong NPPs	15.89	
KEI (2013)	Total Externalities / Electricity Generation by All NPPs in South Korea in 2012	4.18~6.93	Contingent Valuation Method
	1 NPP / Electricity Generation by 1 NPP (APR-1400) in South Korea in 2012	57.31~104.39	
Lee and Kang (2016)	Total Externalities / Electricity Generation by All NPPs in South Korea in 2013	0.00439	
Cho and Park (2015)	Externalities for Transmission Policy, and Risk Response Cost	9.75	Mutual Aid Method for Damage Compensation

accident risk in general, finding that it ranges from 4.18 to 6.93 USD / MWh. Moreover, the KEI measured people's WTP to avoid the construction of a NPP in their neighborhood, finding that this ranges from 57.31 to 104.39 USD / MWh. Furthermore, Lee and Kang estimated the external costs of NPP accidents, measuring the value of statistical life and the relative risk aversion coefficient. The comparison of all externalities of NPPs based on the LCOE shows that the previous estimates with the CVM were in general serious underestimations, while using the LSA leads to significant differences in the estimates.

V. Conclusion and Implications

Using the life satisfaction approach, this study measures the monetary value of nuclear power plant externalities. This paper used data on the officially reported subjective well-being of Ulsan citizens to test the hypothesis that the negative externalities from nuclear power plants are significantly related to Ulsan residents' income levels and distances from NPPs.

Our empirical results show a statistically significant positive relationship between the life satisfaction level and the distance between the residences and the nearest NPP. The ordinary least square regression estimation indicates that a 1km increase in the distance is valued at $277 for Kori and at $280 for Wolsong. The monetary value of nuclear negative externalities estimated by this study is roughly comparable to those found by previous studies which took place abroad, such as that by Farber in 1998 (range of $200~$300 per mile) concerning property values for residents of Boston in the U.S. and that by Welsch *et al.* in 2016 (305 USD per km), which used the life satisfaction approach for Swiss residents. However, the estimates in this study and previous domestic studies show significant differences. Previous studies which used the CVM method (e.g., Lee and Kang, 2016; KEI, 2013; Cho and Park, 2015) contained serious underestimations, demonstrating the practical utility of the LSA in South Korea. Unlike in advanced countries, where NPPs are generally located in remote areas and/or on uninhabited seashores, most NPPs in South Korea are located not far from populated towns and cities. Therefore, the LSA approach is more appropriate in the South Korean context.

This study provides several insights for energy policy decision-makers within the framework of economic analyses of NPPs in comparison with other energy sources by estimating the monetary value of NPP externalities using shadow prices (life satisfaction level) for NPP risks. When making investment decisions not only in the energy sector but also in many other sectors, policy makers should adopt an appropriate measure to internalize the cost of externalities as much as possible so as to correct market price distortions due to externalities. In this way, we can achieve the highest possible rate of economic growth and maximize national welfare.

APPENDIX

TABLE A1—NUMBER OF VARIABLES

Variable	ln income (Monthly)	Distance from Wolsong	Distance from DK	Monthly Expenditure	LS
Unit	ln (10USD)	1km	1km	7 Point Scale	11 Point Scale
Sample Size	7,767	7,767	7,767	7,767	7,767
Min	3.91	11.30	4.53	1.00	0
Max	6.48	42.80	37.47	7.00	10.00
Range	2.56	31.49	32.94	6.00	10.00
Median	5.40	24.35	24.88	2.78	5.00
Mean	5.42	24.01	24.95	2.76	5.76

TABLE A2—FACTOR VARIABLES

Sex	
Female	3,927
Male	3,840
Education	
Below University Graduate	5,311
Over University Graduate	2,456
Religion	
No Religion	3,367
Have Religion	4,400
Marriage	
Not in a State of Marriage	1,717
In a State of Marriage	6,050
Ages	
Under 20 Years Old	430
Over 20 Years Old	806
Over 30 Years Old	1,405
Over 40 Years Old	1,735
Over 50 Years Old	1,811
Over 60 Years Old	932
Over 70 Years Old	648

REFERENCES

Amerasinghe, N. and S. Porter. 2011. *Fossilized thinking: The World Bank, Eskom, and the real cost of coal*. Center for International Environmental Law (CIEL), Washington DC.

Bauer, T. K., S. T. Braun, and M. Kvasnicka. 2017. "Nuclear power plant closures and local housing values: Evidence from Fukushima and the German housing market," *Journal of Urban Economics*, 99: 94-106.

Carson, R. T., R. C. Mitchell, M. Hanemann, R. J. Kopp, S. Presser, and P. A. Ruud. 2003. "Contingent valuation and lost passive use: Damages from the Exxon Valdez oil spill," *Environmental and Resource Economics*, 25(3): 257-286.

Cho, Seongjin and Changuk Park. 2015. *Optimal energy mix in consideration with economic and social costs for nuclear power plants*, Korea Energy Economics Institute (KEEI), Ulsan.

Ea Energy Analyses. 2008. *Renewable Energy Costs and Benefits for Society* (RECABS), prepared for the IEA's Implementing Agreement on Renewable Energy Technology Deployment, Ea Energy Analyses, Copenhagen.

Farber, S. 1998. "Undesirable Facilities and Property Values: A Summary of Empirical Studies," *Ecological Economics,* 24: 1-14.

Freeman, A. Myrick. III. 2003. *The Measurement of Environmental and Resource Values: Theory and Methods*, Resources for the Future, Washington D.C.

Ferrer-i-Carbonell, A. and P. Frijters. 2004. "How Important Is Methodology for the Estimates of the Determinants of Happiness?" *Economic Journal* 114: 641-659. .

Frey, B. S., S. Luechinger, and A. Stutzer. 2009. "The Life Satisfaction Approach to Environmental Valuation," CESifo Working Paper Series No. 2836.

Frey, B. S., S. Luechinger, and A. Stutzer. 2004. *Valuing public goods: The life satisfaction approach*. CREMA Working Paper 2004(11).

Future population trend. 2017. [Data file]. Retrieved from http://kostat.go.kr/

Fink, A. and T. Stratmann. 2013. "U.S. housing prices and the Fukushima nuclear accident: To update, or not to update, that is the question," Working Paper 2013(4), International Center for Economic Research.

Household Finance and Welfare Survey. 2017. Retrieved from http://kostat.go.kr/

Kahneman D, I. Ritov, and D.A. Schkade. 1999. "Economic Preferences or Attitude Expressions?: An Analysis of Dollar Responses to Public Issues," *Journal of Risk and Uncertainty,* 19: 203-235.

Korea Census. 2015. [Data file] Retrieved from http://kostat.go.kr/

Korea Hydro Nuclear Power. 2017. Retrieved from http://www.khnp.co.kr/eng/content/529/main.do?mnCd=EN03020101

Korea Environment Institute (KEI). 2013. *Externalities of Nuclear Power*, Sejong.

Lee, S. H. and H. G. Kang. 2016. "Integrated framework for the external cost assessment of nuclear power plant accident considering risk aversion: The Korean case," *Energy Policy,* 92: 111-123.

Mankiw, N. G. 2014. *Principles of macroeconomics*, Cengage Learning. South-Western College Pub; 7th edition.

National Oceanic and Atmospheric Administration, U.S. Department of Commerce. 1993. "Natural Resource Damage Assessments under the Oil Pollution Act of 1990," *Federal Register*, 58 (10): 4601-4614.

Nuclear Energy Agency. 2003. *Nuclear Electricity Generation - What Are the External Costs?* Paris: OECD.

Rosen, Sherwin. 1974. "Hedonic prices and implicit markets: product differentiation in pure competition," *Journal of political economy,* 82(1): 34-55.

Socioeconomic Data and Applications Center (SEDAC). 2015. *Gridded population of the world (GPW)*, [Online].

Ulsan City. 2014 and 2016. Statistics on Citizen's Living Condition and Consciousness, Ulsan. Retrieved from: http://kosis.kr/statHtml/statHtml.do?orgId=207&tblId=DT_20704_084_2014&vw_cd=MT_OTITLE&list_id=207_A001_2014_002_003&seqNo=&lang_mode=ko&language=kor&obj_var_id=&itm_id=&conn_path=E1

Welsch, H. and J. Kühling. 2009. "Using happiness data for environmental valuation: issues and applications," *Journal of Economic Surveys*, 23: 473–494.

Welsch, H. and P. Biermann. 2016. "Measuring power plant externalities using life satisfaction data: A spatial analysis for Switzerland," *Ecological Economics,* 126: 98–111.

Yamane, F., H. Ohgaki, and K. Asano. 2013. "The immediate impact of the Fukushima Daiichi accident on local property values," *Risk Analysis*, 33(11), 2023-2040.

Guidelines for Manuscript Submission

1. The manuscripts published in the KDI Journal of Economic Policy are creative academic papers on all areas of economics that contain implications on Korea's economic policies.

2. Manuscripts that have been published in other journals, translations of such manuscripts, or summaries will not be accepted.

3. Manuscripts with one theme will be published in one volume.

4. No particular qualifications are required for the author(s) shown in the title page.

5. Manuscripts should be in English.

6. Manuscripts must be prepared in MS Word, LaTeX, or Hancom Office formats.

7. Manuscripts should have abstracts with 100-150 words. Five key words representing the manuscript should be suggested.

8. The first page should display title, the key words, JEL code, name and position of the author(s), and full postal address and e-mail address in English.

9. Manuscripts with more than one author should display names in order of their contribution.

10. Decision for publication will be sent out after due review process by the KDI Journal of Economic Policy Board of Editors.

11. Authors of papers that contain empirical work or simulations must provide KDI full data sets, programs, or any other computational details in electronic formats that are sufficient to enable replication by the reviewers. In case of econometric or simulation papers, it is recommended that authors include in their submissions a description of how intermediate data sets have been employed to produce the final data sets.

12. For submission or further information, please contact:

Address : Korea Development Institute, 263 Namsejong-ro, Sejong-si, 30149, Korea

Phone : +82-44-550-4354

Email : kdijournal@kdi.re.kr

Instructions for Accepted Manuscript Preparation

1. Manuscripts must be prepared in English on A4-sized paper using the "Times New Roman" or similar font, size 12p, and space between lines of 11.3 points. If in Hancom Office format, font size should be 10.5p, and between-paragraph spacing should be 17.3p.

2. When Romanization or other foreign languages are needed, the first word of proper nouns, such as names of people and geographical locations, must begin with a capital letter. And, abbreviation of names of groups and organizations must be written in all capital letters.

3. Terms, units, names of people, and technology must maintain consistency throughout the whole manuscript.

4. The main body should be divided into the following order: I, A, 1, a, II, A... etc. Please refer to the KDI-JEP webpage (www.kdijep.com) for detailed instruction.

5. Tables and figures must be numbered with Arabic numerals. A detailed instruction on creating tables and figures can also be found on the KDI-JEP webpage (www.kdijep.com).

6. Please comply with the American Economic Association (AEA) style in formatting references. If a manuscript has a Korean reference that has been translated into English, both titles must be displayed. Foreign references written in Chinese characters must follow the same rule. In addition, foreign references must be displayed in alphabetical order (last name, organization name). See below for examples:

> Bhagwati, J. N. 1958. "Immiserizing Growth: A Geometrical Note." *Review of Economic Studies* (3): 201–205.
>
> Lee, Jong Kyu. 2014. "Evaluation on DPRK's External Trade of the First Half of 2014." *Review of North Korean Economy 16*(7): 46-53, Korea Development Institute (in Korean).
>
> 이종규. 2014.「2014년 상반기 북한의 대외무역 평가」.『KDI 북한경제리뷰』7월호: 46-53.

7. Submit manuscripts at: kdijournal@kdi.re.kr.

KDI Book Membership Information

Exclusive Offer (Members-Only)

- All KDI publications, with the exception of those classified as confidential or limited, are to be mailed to members
- Preferential invitations to special events hosted by KDI including seminars, policy discussion forums, public hearings, etc., are to be mailed.
- A 10% discount on the online purchases of additional copies of the published research monographs (printed-only) from the KDI homepage.

KDI Publications

- Publications include books, research monographs, policy studies, KDI policy forums, KDI FOCUS, research papers and policy-information materials.
- Three types of periodicals are available:
  - Monthly: KDI Monthly Economic Trends, KDI Review of the North Korean Economy, Economic Bulletin, Narakyungje, click-Economic Education
  - Quarterly: KDI Journal of Economic Policy
  - Biannual: KDI Economic Outlook

Annual Fees

- Individual Purchase: 100,000 KRW
- Institutional Purchase: 300,000 KRW

Sign-Up

- You may sign up for membership via KDI homepage. Please register on the homepage by completing and submitting the registration form. Possible payment methods are as follows:
  - Bank-Transfer: Woori Bank, 254-012362-13-145 (account holder name: Korea Development Institute)
  - GIRO System: No. 6961017 (Credit Card and Mobile Payments available)
  - Direct Payment to the Research Outcome Dissemination Unit of KDI Division of External Affairs.

Contact

- Publication personnel in charge: Research Outcome Dissemination Unit, Division of External Affairs, KDI.
  -Tel: 82-44-550-4346 / Fax: 82-44-550-4950 / E-mail: book@kdi.re.kr
- Sales Distributors
  - Kyobo Bookstore (Gwanghwamun Branch: Government Publications Section)
    Tel: 82-2-397-3628
  - Yongpoong Bookstore (Jongno Branch: Policy & Economy Section)
    Tel: 82-2-399-5632

KDI Journal of Economic Policy
韓國開發研究

Registration Number 세종 바00002호
Printed on February, 24, 2018
Published on February, 28, 2018

Price : 3,000 KRW

Registered on March, 13, 1979

Korea Development Institute
263, Namsejongro, Sejong-Si, Korea | TEL 044-550-4114
FAX 044-550-4310 | www.kdi.re.kr

ISSN 2586-2995