IMPACTS OF AGING POPULATION ON REGIONAL ECONOMIES USING AN INTERREGIONAL CGE MODEL OF KOREA

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ABSTRACT
The purpose of this paper is to estimate the effects of aging population on regional economies using an Interregional CGE Model of Korea. The CGE model is developed for seven industrial sectors of two regions, namely the SMA and the rest of Korea. This paper showed that aging population has a comparatively negative effect on economic growth in domestic economy, but the regional disparity gets reduced due to serious reductions in the working population groups of the Seoul Metropolitan Area.

KEY WORDS: Aging; CGE model; Regional Economic Growth

1. Background

As the proportion of the elderly population (65+) to those of working age (15–64) in Korea rises from 11% in 2008 to an estimated 23% in 2030, personal spending is expected to rise as savings fall due to the reality of a growing, dependent, elderly class. Dealing with this reality presents a unique challenge for the government, as the welfare programs typically used to alleviate these socio-economic problems—such as public pension payments, medical insurance benefits, and public assistance for the low-income classes—are in need of rapid expansion, and yet tax revenue is on the decline (Chun, 2006). Population transitions have been known to generate negative economy-wide effects, so at the turn of this century most industrialized countries have begun to implement remedial measures in preparation for their aging populations. These measures, however, failed to incorporate the same risk-averse systems for engaging population aging at urban and regional levels as that of national levels. Even though budgetary imbalances and fiscal burdens may be less pertinent to local governments, the economic impacts of such demographic changes should be accounted for at the regional level because there is both causality between structural variations in regional population and economic growth. For example, the migration of retirees and outflows of working age groups result in structural changes in population and industrial sectors, in particular health, finance and insurance, and real estate markets.[1]

As such, we ought to be concerned with how an aging population may have an adverse effect on regional economic performances through a decrease in labor force size and declining saving-investment rates. Awareness of this issue, must lead us to ask the following. How do economic transformations depend on regional industrial structures? How do population aging trends differently impact developed and stagnant regions? What major reforms might compensate for the labor shortfalls brought about by an aging population, how might these reforms work to improve labor productivities? Finally, how much of an increase in labor productivity is required to offset the effect of a shrinking labor force?

Hence, the purpose of this paper is to estimate the effects of an aging population on the regional economies of Korea using an Interregional Computable General Equilibrium Model (ICGE). The ICGE model was developed in order to analyze three industrial sectors of two major Korean regions, the Seoul Metropolitan Area (SMA) and the rest of Korea (ROK). The industrial sectors under consideration have been classified as primary (i.e., agriculture, forestry, fishing, and mining), manufacturing, and service industries. Of the regions, the SMA accounted for roughly 47% of the national population and over 80% of all major enterprise headquarters, while only accounting for 12% of Korea's territory. The model accounts for the behaviors of the economic agents of six producers, two regional households, two regional governments, a central government, and the rest of the world. The policy simulations from the ICGE model can identify how an aging population has effects on regional economic growth and disparity for 25 periods from 2006 to 2030. This article is structured as follows: (1) the economic activities for the regional age groups of the SMA and ROK are discussed in terms of expenditures and incomes; (2) the economic effects of an aging population on regional economies are calibrated with reviewing previous

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[1] Fougère et al. (2007) found that due to population aging trends, the sectoral share of health services in total GDP increased by nearly 50% from 4.8% in 2000 to 7% in 2050. Real wages increased twice as fast in health occupations in comparison to the rest of the economy, so as to prevent shortages in the health services industry. In addition, finance, insurance and real estate activities saw growth during the same period.

works and developing the ICGE model for Korea; and, (3) the article concludes with a summary of the approach and suggestions for future research.

2. Population Structure of Korea

The Korean population is aging. The 60+ age groups have grown in population share by 6.5% over the last two decades, while the younger age cohorts (i.e., 0-9, 10-19, and 20-29) experienced a 5–8% decline during that same time period. As a result, the median population age has shifted from 10–19 in 1985 to the 30–39 age cohort in 2005, thereby increasing the population's average age from 33.3 years old in 1995 to 35.6 years old in 2005. These trends are much more pronounced in the ROK as compared to the SMA. In 2005, the ROK's population by age peaked at the 40–49 age cohort in contrast to the 30–39 age group of the SMA. The difference in peak age group between SMA and ROK is possibly caused by migration of young population into SMA since mid-1970s. SMA experienced a rapid increase in the 20-29, 30-39 and 40-49 age cohorts since mid-1970s while ROK's young age cohorts including the 20-29, 30-39 and 40-49 age cohorts decreased in the same time periods. The ROK's average ages in both 1995 and 2005 (34.1 and 36.6 years old) are also higher than that of the SMA's (32.3 and 34.5 years old). This does not mean that the SMA has avoided the perils of an aging population, however, as it too has seen its 40–49, 50–59 and 60–69 age cohorts' population increase dramatically (by 56.4% , 44.2%, 64.5%, respectively) from 1995 to 2005 while its young age population in between 0 and 29 have decreased since 1990s. Indeed, it is highly likely that the 40–49 age cohort will become the SMA's peak age cohort in the near future.

Nationwide participation in economic activities peaked at the 40–49 age cohort in 2008, with a nearly 80% participation rate; more broadly, the 30–59 age cohorts are the most active age groups in the 2008 labor market (see table 2-1). The slight decrease in economic participation by the 20–29 age cohort since the 1990s may be partially explained by an increased emphasis on higher education. Other age groups evidenced a decreased level of economic participation: from the dramatic 11.9% to 6.5% decline for the 15–19 age group to the more subtle decline of the 60+ age cohort from 2000 to 2008. Interestingly, the SMA showed lower economic participation for the 50–59 and 60+ age cohorts compared to ROK. On the other hand, the SMA's 20–29 age cohort shows higher economic activity participation, and this may suggest more job opportunities are to be found here than the ROK.

Table 2–1 Economic Activity Participation by Age Cohort (Unit: 1000 persons, %)

		Age cohort over 15 years old			Economically Active Population.			Participation Rate (%)		
		1990	2000	2008	1990	2000	2008	1990	2000	2008
Nation	15–19	4,378	3,769	3,238	639	450	210	14.6	11.9	6.5
	20–29	7,153	7,474	6,584	4,673	4,831	4,172	65.3	64.6	63.4
	30–39	6,803	8,467	8,248	5,142	6,355	6,194	75.6	75.1	75.1
	40–49	5,023	6,903	8,353	3,959	5,457	6,681	78.8	79.1	80.0
	50–59	3,931	4,360	6,091	2,846	2,987	4,382	72.4	68.5	71.9
	60–	3,600	5,213	7,084	1,282	1,989	2,665	35.6	38.2	37.6
	Total	30,887	36,186	39,598	18,539	22,069	24,303	60.0	61.0	61.4
SMA	15–19	1,807	1,671	1,574	335	236	124	18.5	14.1	7.9
	20–29	3,589	3,703	3,613	2,464	2,472	2,366	68.7	66.8	65.5
	30–39	3,157	4,239	4,371	2,375	3,185	3,288	75.2	75.1	75.2
	40–49	2,179	3,267	4,198	1,661	2,565	3,356	76.2	78.5	79.9
	50–59	1,363	1,915	2,897	905	1,252	2,064	66.4	65.4	71.2
	60–	1,119	1,910	2,935	295	563	937	26.4	29.5	31.9
	Subtotal	13,215	16,705	19,588	8,035	10,275	12,133	60.8	61.5	61.9
ROK	15–19	2,571	2,098	1,664	304	214	86	11.8	10.2	5.2
	20–29	3,564	3,771	2,971	2,209	2,359	1,806	62.0	62.6	60.8
	30–39	3,646	4,228	3,877	2,767	3,170	2,906	75.9	75.0	75.0
	40–49	2,844	3,636	4,155	2,298	2,892	3,325	80.8	79.5	80.0
	50–59	2,568	2,445	3,194	1,941	1,735	2,318	75.6	71.0	72.6
	60–	2,481	3,303	4,149	987	1,426	1,728	39.8	43.2	41.6
	Subtotal	17,672	19,481	20,010	10,504	11,794	12,170	59.4	60.5	60.8

Source: Retrieved from http://kosis.kr/abroad/abroad_01List.jsp?parentId=B

Regionally, the ROK showed higher levels of economic participation for all age groups over 60 years old in contrast to the SMA. This contrast may be due to differences in the industrial structures of each region; participation in primary industry is the only industrial sector that experiences an increase as people age, and its share in all industries peaks at the 60+ age cohort in both SMA and ROK (see figure 2-1). In addition, the primary industry sector constitutes a relatively large portion (18.8%) of all industries in the ROK as compared to the SMA (2.6%). Thus, the ROK's economic activity participation decreases at a slower rate due to age than that of the SMA.

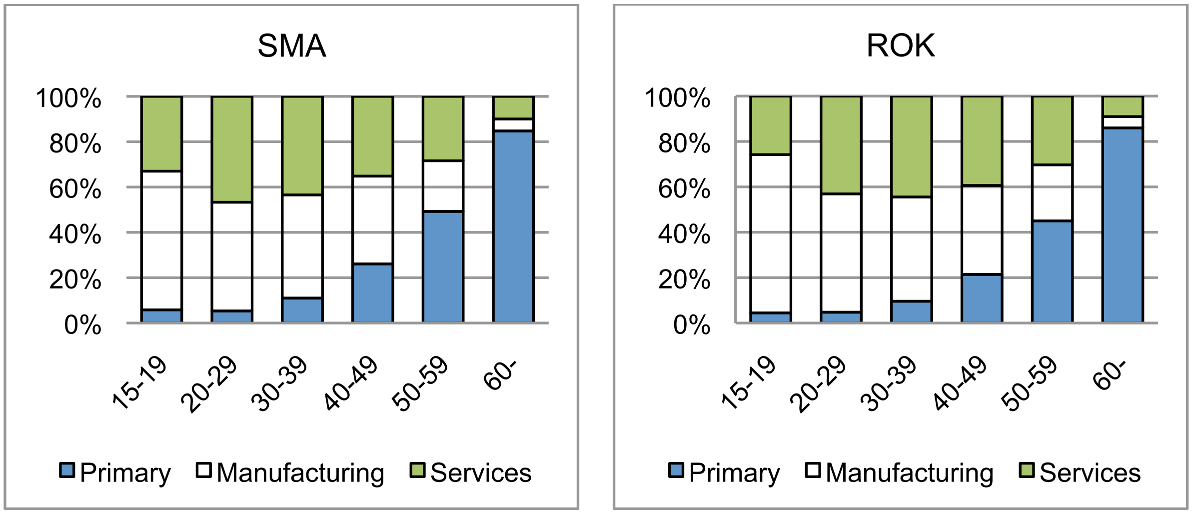

Figure 2-1 Industrial Mix by Age Cohort and by Industry

Source: Retrieved from http://kosis.kr/abroad/abroad_01List.jsp?parentId=A

Among all industrial sectors, the service industry including construction, transportation and telecommunication employs the largest number of people showing slight increase in its share of the total workforce from 59.2% in 2003 to 63.7% in 2008. On the other hand, manufacturing's share decreased from 40.3% to 35.8% in the same time periods. The service industry is the largest employer for the 25–39 age cohorts, but its employment outlook drops sharply for those in the 40–45 age range. The manufacturing industry shows a similar trend in that its employment peaks for the 25–29 age cohort and then declines rapidly for the older age groups; its share of the total workforce, however, has declined from 40.3% in 2003 to 35.8% in 2008. These changes of employment by age cohorts are of concern since aging population are more likely unemployed in every industries. The service industry is the only economic sector that demonstrated continuous growth from 2003 to 2008; its employment, however, sharply declines from the 40-44 age cohort. Manufacturing industry maintained similar level of employment between 2003 and 2008 in term of number of employees; however, its employment also rapidly declines from the 50-54 age group. Primary industry peaks at relatively higher age cohorts, 45-

54 age range; but its share in total employment market is very small and its employment creases from 55-59 age cohorts.

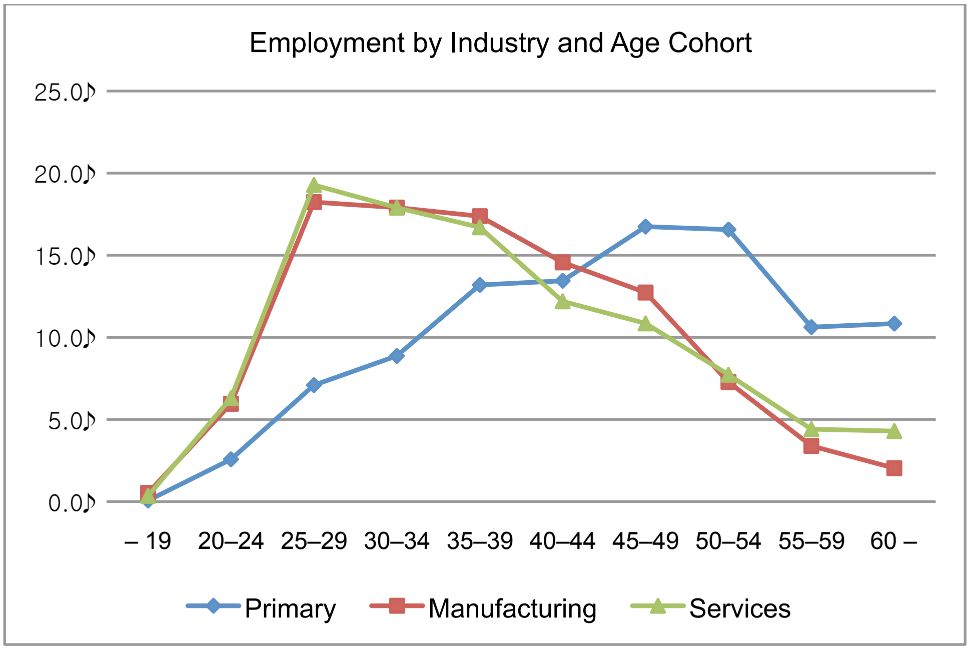

Figure 2-2 Employments by Industry and by Age Cohort (%)

Source: Retrieved from http://kosis.kr/abroad/abroad_01List.jsp?parentId=B

It is known that the relationship between age cohort and earnings shows "an inverted U–shaped pattern" (Luong and Hebert, 2009) or a "hump–shaped" profile (Keese, 2006). As people grow older, their earnings increase initially in the early ages, peak and flatten around middle of age (40–54), and begin to decrease shortly thereafter. For instance, most OECD countries show peak wages at the 45–54 age cohorts and then begin to mildly or sharply decrease (Keese, 2006). The Korean age-earnings profiles show similar trends as the wide range of data in previous studies; average wage peaks for the 40–44 age cohort in 2003, while the 45–49 age cohort records the highest earnings in 2008 (see table 2-5). After the average wage hits its peak, average wages held at a similar level for the 50–54 age cohort, and then declines rapidly for the 55–59 age cohort.

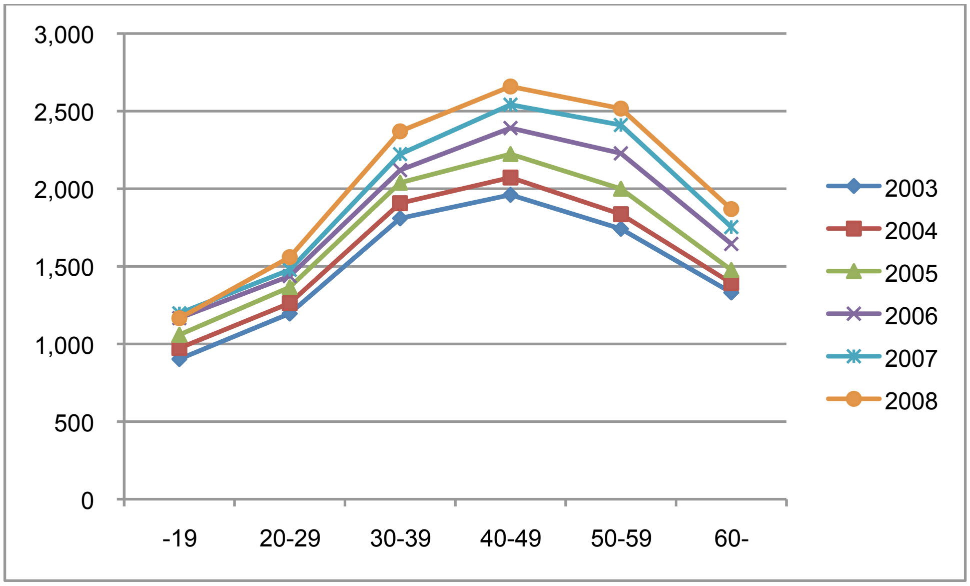

Figure 2-3 Monthly Earnings by Age Cohort (Unit: US$)

Source: Retrieved from http://kosis.kr/abroad/abroad_01List.jsp?parentId=B
Note: 1 US$ = 1000 Korean Won

Among industrial sectors, both the service and manufacturing industries' wages have increased continuously over the period of 2003 to 2008, whereas the primary industry's earnings decline slightly during the year 2008. The service industry, on average, pays the highest wage to its employees peaking at the 50-54 age cohort; it, however, evidences significantly larger pay differences between the various age cohorts. For instance, the service industry's 20–24 age cohort makes only about 46% of what the 50–54 age cohort earns, whereas the same age cohort in the manufacturing industry earns about 57% of its peak age cohort's wage. The service industry's the 60+ age cohort also earns the least wages, about 76%, of peak employment wage; in contrast both primary and manufacturing industries' the same age cohorts make nearly 83% of their peak employment wages. The primary industry's age-earning profiles resonate with the more general Korean age-earning profile; in that salaries tend to grow consistently until the 45-49 age cohort and then declines sharply from the 60+ age cohort. Unlike other industries, the manufacturing industry workers' see their wages peak at the 40–44 age cohort—the earliest among all industrial sectors. Notably, the primary industry workers earn more than manufacturing industry from 45-49 age cohort.

The average household consumption according to age cohort saw a similar inverted U-shaped pattern as that of the average household income in that consumption and income both peak for the 40–49 age cohort and then decreases sharply for the 60+ age group (see Table 2-2). On average, a household spends about 80 percent of its income, but the 40–49 age cohort and 60+ age cohort evidence relatively higher expenditure/income ratios. For instance, cohorts under the age of 40 earn 90% of the 40–49 age group's salary, yet they consume only about 85% of the 40–49 age cohort's expenditure. The 60+ age cohort's expenditure/income ratio is similar to the 40–49 age group.

Expenditures for the 50–59 age cohort consisted of 75% for goods and services and the remaining 25% spent on taxes, pension, social security and public insurances; other age groups, however, spent 80% and 20%, respectively. Both the under 40 and 40–49 age cohorts allocated more money towards service related expenditures, such as cultural activities, entertainment, dining, education, and personal insurance, while spending a relatively lower portion of their total expenses towards health and primary industry related products. On the other hand, the 60+ age cohort allocated significantly more money towards primary industry, housing (including water and energy), and health related expenditures (see table 2-2).

Table 2–2 Monthly Consumption by Sector (Unit: US$, %)

	39 or less	40–49	50–59	60+	Average
Total Consumption	2,794	3,233	2,920	1,779	2,782
Consumption of Goods and Services	78.0	78.2	75.1	78.5	77.5
– Primary Industry Produces	9.9	10.0	10.2	15.9	10.7
– Manufacturing Products	6.1	5.6	5.7	5.0	5.7
– Housing, water, energy	10.8	9.3	9.7	13.9	10.3
– Health	4.9	4.0	4.9	9.5	5.1
– Transportation	10.0	8.7	10.5	9.5	9.6
– Telecommunication	4.7	4.7	5.3	4.3	4.8
– Services	31.6	35.8	28.8	20.4	31.3
Other Consumption (Tax, Pension)	22.0	21.8	24.9	21.5	22.5

Koreans receive their income from a variety of sources: wage, self–employed income, capital income, transfers and irregular incomes (see table 2-3). Income from employee salaries constitutes the largest monetary source for all age groups; however, its percentage for overall household income decreases as average household age increases. For instance, the 39 or less age cohort receives 71% of its income from employee wages, whereas the 60+ age cohort receives only 41% from employment. That the 40–49 age cohort receives their largest percentage of income from self-employment suggests that people begin to leave prior work at this age in favor of establishing their own personal businesses, and then frequently retire from the labor market altogether as they enter into the 60+ age cohort. As such, the 60+ age cohort depends on income transfers from pensions, unemployment benefits, social security, and government compensation for 28% of their income.

Table 2–3 Monthly Income by Source (Unit: US$, %)

	39 or less	40–49	50–59	60+	Average
Total Income	3,034	3,371	3,342	1,973	3,042
Regular Income	95.8	97.1	94.2	92.7	95.6
− Wage	71.2	63.4	62.5	40.5	63.1
− Income from Self–employed family member	18.0	27.6	25.5	22.1	23.7
− Property Income	0.2	0.4	0.6	1.7	0.5
− Transfer Received	6.5	5.7	5.5	28.4	8.2
Irregular Income	4.2	2.9	5.8	7.3	4.4

In summary, the structural changes in population composition, age-earning profile and income sources are expected to have significant negative effects on both national and regional economies. In particular, as the growing aging population becomes less economically active, they are likely to become increasingly economically dependent. This potential outcome is supported by the fact that the 60+ age cohort depends significantly more on outside income (e.g., social security) than other age groups, while simultaneously possessing considerably lower overall income levels. Non-wage income sources such as grown-up children, subsidies from state or local governments, and social security benefits accounts for over 50% of the total income of the 60+ population. Hence, it is important to understand how elderly populations function before the combined effects of their dependency and increased longevity (due to higher life expectancy rates) acts as a damper on contemporary economic growth.

3. Simulation

3.1 Literature Review

In the past three decades, there has been much work done regarding the impact of changing demographics and aging populations have on national economies. These have included various impact studies focusing on macroeconomic and public finance sectors using partial or general equilibrium models (Fougère *et al,* 2007). Yet, little attention has been given to the regional impact analysis; that is until recently. Park (2006) was among the first to combine a schematic structure of regional CGE models with an Overlapping Generation framework (OLG). This integrated model was capable of quantifying the effects of an aging population, and subsequent retirement migration, on both regional and national economies: including changes in factor input markets, spatial disparities, savings behavior, and retirement income. The key factor for this model was in specifying household behavior by age cohort over time. The model assumed that each household maximized a time separable inter-temporal utility function in each period under inter-temporal budget constraints; hence, the optimal solution for the model could be found in the marginal rate of substitution between two periods equal to their relative prices.

In 2007, Park and Hewings (2007a) elaborated upon the original study by analyzing the behavior of aging populations with respect to regional economies: specifically, the dynamic effects changing demographics had on the regional economies of Chicago and the rest of the United States. Similarly, Park and Hewings (2007b) were interested in understanding the impact of increased immigration upon periods of population aging. They found that, while wages were expected to fall due to the increased immigration, these same immigrants could provide the tax base necessary to continue to fund social security systems as well as increase the after-tax income of native workers. This effect on social security funding would continue to be positive until 2050, when it was believed these immigrants would began to retire in significant numbers. Park and Hewings (2007c), thus, sought out the optimal policy combinations necessary to account for changes in retirement age, reduced pension benefits, and increased levels of immigration. They found that an influx of larger number of immigrants into the Chicago region combined with more generous pension benefits did not necessarily result in more desirable outcomes, whereas an increase in the retirement age produced monotonically average welfare improvements.

In another study, Kim and Hewings (2010a) compared the effectiveness of government policy on aging populations from an endogenous growth perspective. They found that an endogenously determined investment in human capital significantly offset the negative effects of an aging population on regional economies. Moreover, educational transfer systems were superior to money transfer systems in long-term growth of per-capita income, aggregate welfare, and the stabilization of factor prices; however, implementing an educational transfer system created a trade-off between economic growth and equity of income and wealth. In another study, Kim and Hewings (2010b) modified their previous model by incorporating the household's intra-generational heterogeneity across race and migration status. Each agent was assumed to allocate his or her resources between consumption and savings, while also dividing available time between schooling and work for the duration of his or her life, so as to maximize total life-time welfare. Their study revealed that upgrading the transmission channel of human capital stock from the older generation to the younger generation was more preferable than direct employment policies for long-term effects on income and social welfare. This would improve the native's human capital stock, as well, due to the result of spillover effects.[2]

Studies such as Kim and Hewings (2010a, 2010b, 2010c) contribute to a better understanding of the policy impacts of an aging population, such as changes in retirement, shifts in immigration, demands for government subsidies, and continued education programming, have on regional economic growth and fluctuations. Their model succeeded in integrating a perfect foresight assumption for households with an optimization behavior for consumers and producers. However, more work is needed regarding the specification of interregional economic interactions and the roles of financial sectors in the market.

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[2] Aside from the application of this CGE-OLG model, Yoon and Hewings (2006) attempted to explore the effects of an ageing population and changes in income distribution on consumption behaviors in the Chicago region using an extended Chicago Region Econometric Input-Output Model. They confirmed that disaggregation of households' demands by age group or by income quintiles could capture some of the inherent variability in consumption patterns as compared to a case of a single representative household. Because of gradual increases of consumption multipliers by age groups and by income quintiles over the period, even small changes in the consumption behavior could generate significant impacts on the regional economies.

With regard to the CGE model structure, there is no substantial difference between the ICGE model of this paper and that of Kim and Hewings' (2010a, 2010b), as they each are rooted in an elasticity structuralist CGE model of the neoclassical type. Both models are dynamic, but the ICGE model follows an adaptive expectation for price inflation, whereas Kim and Hewings' (2010a, 2010b) employs Auerbach and Kotlikoff's OLG model to accommodate uncertainty and idiosyncratic risk. This means that household consumption in Kim and Hewings (2010a, 2010b) is accounted for in terms of a mathematical optimization process, whereas in this paper, based upon an ICGE model, household consumption is determined by the saving rate.

3.2 Basic Structure of Interregional CGE Model

We developed an ICGE model to assess the economic impacts of an ageing population on regional income disparity and national growth. The ICGE model accounts for the economic behavior of producers and consumers on the real side economy, following the neoclassical elasticity approach of Robinson (1989), such as that of market-clearing prices, the maximization of a firm's profit, and a household's utility. Three major economic regions constitute our ICGE model: the Seoul Metropolitan Area (SMA) and the rest of Korea (ROK) and one representing the rest of the world (ROW). As explained in the previous section, production activity is divided among three industrial sectors. This industrial sectors were not, unfortunately, classified in detail due to a lack of information for industry by commodity matrix and time series data of regional consumption goods by population cohort.

It is assumed that economic agents, including both producers and households, select an optimal set of factor inputs and commodity demand sets under the maximization principles of constrained profit and private utility, thereby responding to various sets of commodity and factor prices. However, we impose no optimizing behavior on the government. For international and interregional trade, the commodities for economic agents are composed of intraregional supplies, regional imports, and foreign imports in terms of the product origin, whereas the regional products are spatially distributed among intraregional supplies, regional exports, and foreign exports in terms of the product destination. Commodity price is assumed to adjust towards a balance between supply and demand in terms of factor inputs and commodity markets.

To measure the effects of aging on regional economies, population demographics are disaggregated into nine age cohorts: 0–9, 10–19, 20–29, 30–39, 40–49, 50–59, 60–69, 70–79, and an 80+ age group. Among the age cohorts, those individuals between 0–19 years of age are assumed not to participate in the labor markets, and instead believed to be supported by their parents. More generally, each age cohort carries different parameters and values for labor productivity, mortality rates, and participation rates in the labor market (i.e., share of labor supply relative to total population size) on the supply side, and saving rates and consumption behaviors on the demand side.

Our production structure model is composed of three-stages. At the top of the structure, the gross output by region and sector is determined via a two-level production function of value-added and composite intermediate inputs; that is, in accordance with the Leontief production function, the producer coordinates the level of intermediate demands and value-adding elements against a fixed proportion of gross output. The intermediate inputs are derived from interregional input-output coefficients, whereas the value-added element is determined by a Cobb-Douglas production function of labor and capital inputs with the total factor productivity. The labor inputs consist of five working age groups--20–29, 30–39, 40–49, 50–59 and 60+ years--each with their own contribution to the marginal productivity of labor. Each regional labor input by age cohort is assumed to be homogeneous and possess intersectoral mobility, whereas it is assumed that capital stock cannot move from one region to another. The labor demand by various regions and industry is derived from the producers' value-added maximization of the first order conditions, whereas labor supply relies on the participation rates of the various age cohorts and the total population size of the region overall. Average wage rate by region and working age group is estimated according to a Mincerian earning regression, in which the determinants of the wage are gender, education level, job experience, type of occupation and industrial sector, and possession (or lack thereof) of a professional license.

Under the neoclassical closure rule for the labor market, the labor participation rate is derived by balancing out total labor demand against total labor supply. If the population flows among the regions are not exogenous to the model, then in–migration is assumed to be in response to interregional differences between origin and destination regions in terms of wage per capita and unemployment rate, as well as the physical distance between the regions. Hence, the population of a given region is the sum of the natural growth of the native population combined with the net gain (or loss) of migrant populations.

For the second stage, intermediate demands are transformed into demands for domestic products and foreign imports. We use the Armington approach to distinguish among commodities by place of origin, so as to emphasize the imperfect substitutability between various commodities. Moreover, cost minimization with the Armington approach accounts for an optimal ratio of foreign imports to domestic sales. The demand for foreign imports relies on three variables of domestic sales: the price of the domestic product relative to the domestic price of the foreign import, and the two key parameters of share and elasticity of substitution.

At the final stage, demand for the intraregional product is determined by the price and total demand for domestic products under the Cobb-Douglas function. However, profit maximization according to the two-level Constant Elasticity of Transformation (CET) function determines the optimal allocation of the gross output via two competing commodities: the domestic supplies and the foreign exports. These domestic supplies include both intraregional supplies and regional exports. The ratio of foreign exports to gross output depends on the relative ratio of domestic product price to the foreign export price, the share parameter, and the elasticity of transformation under revenue maximization.

The total demand for goods and services consists of intermediate demands, total consumption expenditures for households, government consumption expenditures, and investment practices. Total household income consists of wage, capital income, and any exogenous subsidies from the government. The total consumption expenditures are linear functions of the total household income, the direct tax rates of the regional and national governments, and the marginal propensity to save. After paying income taxes and allocating for savings, the household assigns total consumption expenditures to each commodity. The consumption amount is determined endogenously by income, size of household, and the composition of population by age cohort. Household savings are linearly dependent on household disposable income with a fixed marginal propensity to save.

Two tiers of government structure are specified in the model: two regional governments and one national government. Government expenditures consist of consumption expenditures, subsidies to producers and households, and savings. Revenue sources include taxation of household incomes, value-added, and foreign imports. With regard to the macroeconomic closure rule for the capital market, aggregate savings determines investments. There is one consolidated capital market, consisting of household savings, corporate savings of regional production sectors, private borrowings from abroad, and government savings. There are no financial assets in the model, so overall consistency requires equating total domestic investment to net national savings plus net capital inflows. The sectoral allocation of total investment by destination is endogenously determined by the capital price from each sector and the allocation coefficient of investment. This is transformed into the sectoral investment by origin through a capital coefficient matrix. This price adjustment is required for the Walrasian equilibrium condition, and every price is measured in a relative scale.

The ICGE model is a recursive and adaptive dynamic model, and is composed of a within-period model and a between-period model. The within-period model determines equilibrium quantities and prices under objectives and constraints for each economic agent, in which the balance between supply and demand is achieved in a perfectly competitive market. The between-period model finds a sequential equilibrium path for the within-period model over the multiple periods by updating the values of all exogenous variables, such as government expenditures, from one period to another. For example, the current capital stock is expanded with new investment but also reduced with a constant depreciation rate. The within-period model is a square system of equations with 196 equations and 231 variables; a unique solution can be found because the number of endogenous variables is the same as the number of the equations under convexity. The exogenous variables include world market prices and government expenditures. The numeraire of the model is set as the consumer price index. In addition, we calibrated a Social Accounting Matrix (SAM) as a benchmark for the development of the ICGE model.

The SAM consists of six accounts—factors, households, production activities, government, capital, and the rest of the world—and is treated as an initial equilibrium for the ICGE model. Values of some parameters are adjusted to replicate the equilibrium conditions for the base year, 2005.

Table 3–1 Major Equations in ICGE Model

Output	Output = Leontief (Value added, Intermediate demand)
Value added	Value added = Total Factor Productivity*CD (Capital stock, Labor by age cohort)
Supply	Output = CET (Foreign exports, Domestic supply)
Domestic supply	Domestic supply = CET (Regional exports, Intraregional supply)
Demand	Demand = Armington (Foreign imports, Domestic demand)
Domestic demand	Domestic demand = Armington (Regional imports, Intraregional supply)
Labor demand	Labor demand = LD (Wage by age cohort, Value added, Net price)
Wage by age cohort	Wage by age cohort = WA (Education, Type of employment, Experience)
Labor supply	Labor supply = LS (Labor market participation rate, Population)
Population	Population = Natural growth of previous year's population + Net population
Regional incomes	Regional incomes = Wage + Capital returns + Government subsidies
Migration	Migration = TODARO (Incomes and Employment opportunities of origin and destination, Distance between origin and destination)
Consumption by commodity	Consumption by commodity = CC (Price, Population size by age cohort, Incomes)
Private savings	Private savings = PS (Saving rate by age cohort, Population size by age cohort)
Government revenues	Government revenues = Indirect tax + Direct tax + Tariff
Government expenditures	Government expenditures = Government current expenditure + Government
Labor market equilibrium	Labor demand = Labor supply
Capital market equilibrium	Private savings = Total investments
Commodity market	Supply of commodities = Demand of commodities
Government	Government expenditures = Government revenues
Capital stock	Capital stock = Depreciated lagged capital stock + New investments

It is hard to estimate the economic effects with confidence, due to the deterministic feature of the ICGE model, but model reliability could be examined by analyzing the stability of the results over time (De Maio *et al*., 1999). As such, a sensitivity analysis was carried out to determine the robustness of the results, with respect to key parameter values. In this paper, the GDP and the consumer price index could only be reduced by 4.1–4.9% and 1.1–3.1%, respectively, if the elasticities of substitution and transformation for Armington and CET functions increased by 10%. This shows that the model is comparatively reliable for counterfactual analysis.

3.3 Simulation

In general, an aging population carries with it both positive and negative effects for economic development. Negatively, it results in an intergenerational imbalance between benefits, costs of pensions, and overall healthiness, thereby reducing the total labor supply and lowering saving and investment rates (Canning, 2007; Horioka, 2007; Bloom *et al.*, 2009). Positively, however, it induces higher levels of labor market from older workers, thereby leading to longer working lives. Moreover, the declining fertility rate, associated with an aging population, may lead to a more general increase in female labor force participation, which may help to offset the foregoing negative effects from lower male labor force participation and savings rates.

The impacts an aging population has on changes in the consumption expenditures, however, can be rather ambiguous in that the effect depends on life expectancy rates and expected retirement age. For example, an individual may consume less and work more in order to finance additional consumption expenditures after retirement (Park and Hewings, 2007c). Yet, if one's expected retirement age were to be deferred in accordance with prolonged life expectancy rates, future welfare needs may be deemed to distant, and hence consumption patterns might decline drastically as one nears or enters retirement age.

In this section, the ICGE model was applied to estimate the effects of an aging population on the regional economies of residents for the Seoul Metropolitan Area and the rest of Korea. The baseline assumed that population aging had not yet gone into effect. The population share by cohort in this baseline is projected using the trend from 1990–2005 (see table 3-2); likewise, all parameters are kept at their 2005 levels, so as to emulate a scenario in which all population related policies remain unchanged from that same year. The base year and the snapshot year for this analysis are 2006 and 2030 respectively; that is, the baseline accounts for what would happen without any significant changes for a 25-year period. In this paper, the aging population and the composition of population by age cohort are key variables, and their changes based on the scenario are considered 'shocks' to the ICGE model.

Table 3–2 Share of Population by Cohort from 2006 to 2030 without Population Aging (unit: %)

	2006	2010	2015	2020	2025	2030	average
Seoul Metropolitan Area							
0–9	11.8	10.5	9.0	7.6	6.4	5.2	8.4
10–19	13.2	12.0	10.5	9.0	7.7	6.4	9.8
20–29	16.4	15.0	13.2	11.4	9.8	8.2	12.3
30–39	19.2	19.0	18.4	17.7	16.8	15.7	17.8
40–49	18.0	19.9	22.3	24.7	27.0	29.1	23.5
50–59	10.4	11.1	11.9	12.6	13.2	13.7	12.1
60+	11.1	12.6	14.7	17.0	19.3	21.6	16.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Rest of Korea							
0–9	11.6	10.5	9.2	8.0	6.8	5.7	8.6
10–19	13.5	11.9	10.0	8.4	6.9	5.6	9.4
20–29	14.5	13.3	11.8	10.4	9.0	7.7	11.1
30–39	16.4	16.3	16.0	15.5	14.9	14.1	15.5
40–49	17.1	18.8	21.0	23.2	25.2	27.2	22.1
50–59	11.2	11.5	11.8	12.0	11.9	11.8	11.7
60+	15.8	17.7	20.2	22.8	25.4	27.9	21.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Regarding simulations, there are at least three shocks including (1) population effects, such as changes in population growth rate, number of households, working age population, and labor supply available, all effect levels of private consumption; (2) technological innovations, which enhance productivity; and, (3) public policies, such as reforms in pension benefits, education and training programs, and insurance systems, which may have a variety of welfare related effects. However, only the first one has to be considered in this paper due to the model structure designed for the real-side economy. The two other shocks can be taken into account in the model simulation if the ICGE model is expanded to the financial side economies. The shock from the population variables is modeled and injected into the ICGE, and then a new set of equilibrium values can be generated for regional production and prices for a 25-year span, thereby satisfying the price normalization rule subject to the exogenous consumer price inflation rate without operation of the interregional migration module. Long-term effects come into action during the second period in the form of the stock-accumulation effects of changes in capital stock and population demographics. In the counterfactual scenario, population aging continues (see table 3-3). Here, composition of the population by age cohort continues along the projections provided by the National Statistical Office of Korea so as to reflect the demographic effect of population aging for future generations.

Table 3–3 Share of Population by Cohort from 2006 to 2030 with Population Aging (unit: %)

	2006	2010	2015	2020	2025	2030	average
Seoul Metropolitan Area							
0–9	11.6	10.0	9.2	8.7	8.2	7.9	9.1
10–19	13.5	13.2	11.1	9.3	8.8	8.4	10.6
20–29	16.6	14.9	13.6	13.5	11.5	9.7	13.2
30–39	19.0	18.2	17.0	15.0	13.9	13.9	16.0
40–49	17.5	17.5	17.5	17.0	16.1	14.4	16.8
50–59	10.7	13.2	15.7	16.2	16.5	16.2	15.1
60+	11.1	13.0	15.9	20.4	25.1	29.5	19.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Rest of Korea							
0–9	11.3	9.3	8.0	7.3	7.1	7.0	8.1
10–19	13.9	13.8	11.7	9.3	8.0	7.4	10.6
20–29	14.4	13.1	12.7	12.8	11.0	8.8	12.1
30–39	16.1	14.9	13.5	12.4	12.1	12.4	13.4
40–49	16.8	16.7	16.4	15.2	13.9	12.8	15.3
50–59	11.7	14.3	16.7	17.0	16.8	15.8	15.8
60+	15.7	17.9	21.1	26.1	31.2	35.8	24.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: National Statistical Office of Korea

The baseline and counterfactual simulations each produce a sequential path of economic behavior following an inter-temporal consistency under its own population scenario. The results are compared with the baseline case for periods under existing circumstances, with the differences of major economic variables between the baseline without shocks and the counterfactual cases with the shocks assessed in terms of efficiency and distribution, and duration (i.e., short- or long-term). However, these differences should be interpreted with care since they are dependent upon underlying assumptions and changes in the values and types of exogenous or policy variables. Moreover, they are not forecasting values, but derived from the sensitivity analysis and projections.

If the shares of the age cohort 20-59 decrease by 4.6% points for the SMA and 3.8% points for the ROK according to the population aging for 25 years[3], there will be a sharp downturn in the economy, an outcome that is similar to previous work. Total labor supply would decline by 4.55% in the 25-year average compared with the baseline as shown in table 3-4. Also the government revenues and the private savings are expected to drop by 4.97% and 5.25% respectively. In addition, the population aging has a negative effect on the GDP by -5.93% on the average; -0.59% in the period of 2006-2010, -3.82% in the period of 2011-2015, -8.35% in the period of 2016-2020, -8.58% in the period of 2021-2025, and -8.29% in the period of 2026-2030. In 2022, the difference of the GDP growth rate between cases without and with the population aging reached 8.66%, the biggest decline of the simulation periods.

The population aging could generate negative impacts on the economic growth of both the SMA and ROK regions, but it seems to threaten more the SMA economy. The growth rate gap between the baseline and the Experiment for this region is -5.93% on the average higher than the ROK by 1.31% points, and continues to expand over the periods from -0.66% (2006-2010) to -9.79% (2026-2030). On the other hand, the difference of the economic growth rate for the ROK increases until year of 2020, then decreases down to the snapshot year. The manufacturing sectors of both regions are most deeply shocked by the population aging, dropping their growth rates by -6.84% for the SMA and -6.05% for the ROK. Similar tendencies are shown in the services sectors, which the growth rates of the SMA and the ROK are reduced by -6.63% and -4.99% respectively. In a sense that the demographic change has more

[3] The proportions of the population aged 60 + increase by 3.2% point for the SMA and 3.1% point for ROK during the same period.

negative effects on the SMA economies, it is possible to figure out that the regional income disparity would not widen any more.

Table 3-4 Impacts of Population Aging on Value Added, Government Revenues, Private Savings, and Labor Supply for 25 Years (unit: %)

	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	average
VA of SMA + ROK (a)	-0.59	-3.82	-8.35	-8.58	-8.29	-5.93
VA of SMA (b)	-0.66	-3.83	-9.10	-9.77	-9.79	-6.63
VA of ROK	-0.54	-3.82	-7.72	-7.55	-6.98	-5.32
Govt. Revenue	-0.47	-3.20	-6.68	-7.16	-7.32	-4.97
Saving	-0.47	-4.19	-9.26	-7.29	-5.05	-5.25
Labor supply	-0.39	-1.04	-3.27	-7.00	-11.05	-4.55
Share of SMA (b/a)	-0.03	0.00	-0.38	-0.60	-0.76	-0.35
VA of SMA AG	-0.14	3.42	-9.80	-7.18	-3.25	-3.39
VA of SMA MN	-0.70	-4.09	-9.35	-9.87	-10.19	-6.84
VA of SMA SER	-0.65	-3.86	-9.01	-9.80	-9.81	-6.63
VA of ROK AG	-0.03	-1.47	-5.70	-4.33	-2.56	-2.82
VA of ROK MN	-0.58	-4.00	-8.98	-8.87	-7.81	-6.05
VA of ROK SER	-0.55	-3.85	-7.01	-6.86	-6.69	-4.99

* VA: Value added, SMA: Seoul Metropolitan Area, ROK: Rest of Korea, AG: agricultural sector, MN: manufacturing sector, SER: service sector

The direct impact of the population aging on the economies is a reduction in the labor supply. The largest decline among the age groups is recorded in the age cohort 40-49 (-27.00% for the SMA and -28.83% for the ROK), and the next one is the age cohort 30-39 (-10.39% for the SMA and -14.18% for the ROK). On the contrary, there are substantial increases in the labor supplies in the age group of 50-59 by 23.46% for the SMA and 33.96% for the ROK. The shares of the population group with 60 + increase by 16.52% for the SMA and 11.99% for the ROK, too. To cope with this shortage problem of the labor supplies, the government needs to find out the solutions from the immigration policy. In particular, it is necessary to provide incentives and benefits to give to female workers. To improve the technological skills, further nationwide deregulation should be implemented to develop a variety of education and training program.

Table 3-5 Impacts of Population Aging on Labor Supply by Age Cohort for 25 Years (unit: %)

	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030	average
SMA 10-19	6.37	9.04	3.73	8.51	23.79	10.29
SMA 20-29	0.43	-0.02	12.13	19.30	16.74	9.72
SMA 30-39	-2.38	-5.91	-12.10	-17.85	-13.73	-10.39
SMA 40-49	-7.09	-17.57	-27.53	-36.54	-46.27	-27.00
SMA 50-59	10.93	29.01	29.87	26.32	21.17	23.46
SMA 60 +	1.64	4.82	15.14	27.10	33.88	16.52
ROK 10-19	9.74	18.20	13.30	13.22	25.81	16.05
ROK 20-29	-1.03	2.25	17.11	24.46	17.19	12.00
ROK 30-39	-4.89	-12.71	-18.46	-20.42	-14.39	-14.18
ROK 40-49	-6.26	-17.75	-29.53	-40.83	-49.75	-28.83
ROK 50-59	13.65	35.76	42.21	41.48	36.68	33.96
ROK 60 +	0.47	2.82	10.50	20.21	25.97	11.99

* SMA: Seoul Metropolitan Area, ROK: Rest of Korea

4. Limitations and Further Research Agenda

This paper shows that aging populations have a comparatively negative effect on economic growth for domestic economies, but these effects are not amplified at the regional level due to reduction in the working population groups of SMA. As Borsch-Supan (2004) have discussed elsewhere, regional policies for coping with the challenges of shifting demographic structures can be practically formulated if the responses of economic agents are specified according to economic incentives and motivations for labor participation by recognizing age-specific productivities. For example, which populations are willing to migrate from labor-abundant to labor-scarce regions? What policy measures lead to more participation in training and education programs? What are the levels of labor productivity and labor market participation for various age and gender cohorts? What barriers exist that discourage women from participating in the labor market? What are the positive and negative effects of raising the mandatory retirement age? Should national or local governments encourage increased immigration flows for dealing with labor shortage issues? Are less restrictive capital flows more capable of overcoming the various political barriers regarding cross-border labor flows?

A few points need mentioning regarding the prospect of further research on issues of aging. First, more focus is needed on calibrating the interaction of labor productivities with that of a worker's socio-economic background, such as schooling, job training, work experiences, and the holding of technical certificates. This would enable the possibility for grasping which policies minimize the economic losses of an aging population with the labor productivity function for each age cohort. Secondly, it seems possible to extend the current real-side ICGE model to the real-financial side ICGE model, so as to measure the effects of allocating financial assets on the economies. The agent could choose a set of financial assets including not only simple savings with commercial banks but also bonds and equities depending on their own capital costs and returns. Thirdly, another possible extension of the present work is to implement a migration model by cohort so as to uncover sources of regional growth in terms of supply and demand. It is also worth noting that this paper assumes an identical productivity level in the same age group regardless of migrant's various skill or education level. Yet, we know that if there were to be a massive inflow of rich retirees from the SMA to the ROK, their presence could function to increase the consumption expenditures of the ROK, thereby reducing regional consumption differences. Higher education levels for migrants can be expected to affect the region positively. Hence, the different levels of contribution by migrant could be quantified through integrating the migration models of micro perspectives into the structure of the ICGE model. Finally, it would be meaningful to compare the results from the recursive and adaptive versions of the current model with those from a perfect foresight ICGE model, such as that of Kim and Hewings (2010a, 2010b).

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