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Contributions of human capital investment policy to regional economic growth: an interregional CGE model approach

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Abstract The purpose of this paper is to examine the regional impact of educational investment policies on migration and economic growth utilizing an interregional computable general equilibrium (ICGE) model with a human capital module. The CGE model is developed for three industrial sectors of two regions in South Korea, specifying the behaviors of the following economic agents: six producers, two regional households, two regional governments, a national (central) government, and the rest of the world. The model primarily focuses on structural linkages among migration, university education, labor productivity, and human capital formation in the short run and long run. Our paper demonstrates that the impact of the human capital investment on GRP growth was higher for the 30s age cohort than for any other age cohort, and this holds for both the Seoul Metropolitan Area (SMA) and the rest of Korea (ROK). With the aim of reducing regional disparity and of redistributing concentrated populations, the national government's human capital investment policy should focus on local job training programs with the target population of the 30s age cohort in the ROK.

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1 Introduction

As economic disparities between the Seoul Metropolitan Area (SMA) and the rest of Korea (ROK) have widened with moderate economic growth in South Korea, the national government has implemented regulatory policies to control excessive and unequal regional investment in the SMA. Since the early 1980s, a restrictive zoning system within the SMA has been implemented to prevent its urban sprawl and to reduce regional disparity. Heavy restrictions were imposed on various types of new construction activities, including the expansion of existing manufacturing plants and other large-scale development projects such as office buildings and university facilities. The tax and loan preference system was also introduced to encourage manufacturing relocation from Seoul and its fringe areas within the SMA to industrial parks in the ROK. Furthermore, the relocation policy of public institutions to the ROK was enacted in 2004. This policy was formulated assuming that the SMA is overcrowded, hurting overall economic efficiency in South Korea. However, it is not easy to find supporting empirical evidence. Additionally, only a few questions have been raised about whether such spatial policy tools could have achieved the intended goal of population redistribution from the SMA to ROK, leading to enhanced economic efficiency in the SMA and the opportunity for economic growth in ROK. In particular, because government control on maximum student enrollments and the physical expansion of universities in the SMA could not prevent brain drain from the ROK, some advocate that such regulatory policies should be abolished. During the early 1990s, the SMA's population was 44.1 % of the total South Korean population, but it had increased to 49.4 % in 2013. For the same periods, the total population increased by 14.9 %, while the population of the SMA increased by 28.8 %. This implies that the population growth of the SMA was primarily caused by migration, especially internal migration because of sluggish natural growth and negligible international immigration to the SMA even with the recent increase in foreign population. Moreover, regional economic development is significantly influenced by the accumulation of human capital that generates knowledge and technology in knowledge-based and IT (information technology)-intensive economies.

The purpose of this paper is to examine the regional impact of human capital investments targeting two age cohorts, the 20s and 30s, on regional population and economic growth employing an interregional computable general equilibrium population (ICGEP) model. The ICGEP model is developed for three industrial sectors from each of two regions in South Korea (SMA and ROK), specifying the behaviors of economic agents of six producers from two regions, two regional households, two regional governments, a national (central) government, and the rest of the world. There are eight age cohorts 0–9, 10–19, 20–29, 30–39, 40–49, 50–59, 60–69, and 70+ for each region. Each age cohort has different parameters and values for human capital productivity, mortality rates, and participation rates in the labor market on the supply side and saving rates and consumption behaviors on the demand sides. The developed model focuses on structural linkages among migration, labor productivity, and human capital formation in the short run and long run. We structure this paper as follows. First, we review the existing literature on brain drain through migration in the perspective of regional economic growth. In Sect. 3, we develop an ICGEP model with primary focuses on education and human capital modules. Section 4 synthesizes our simulation results and presents further discussion points.

2 Literature review

Endogenous growth models emphasize the intentional accumulation of knowledge (Romer 1990) and of human capital (Lucas 1988) for regional economic growth in the long run. The intensity can be associated with the policy implementation for sustainable economic growth in the long run (Sterlacchini 2008).

2.1 Regional economic growth in a knowledge-based economy

Knowledge accumulation is vital for regional economic growth in that knowledge can produce innovation locally and absorb innovation from other regions. Entrepreneurial capital plays a critical role to convert public knowledge accumulated by education and R&D activities into applicable economic knowledge in a region (Acs et al. 2004). Sterlacchini (2008) applied the "technology-gap" model of economic growth (Fagerberg 1988) for 197 European NUTS-II regions with the aim of testing the rationale of the Lisbon strategy.[1] He found that the impact of the knowledge base and of human capital on regional economic growth varies depending on the regional level of development. Lack of appropriate local conditions may impede the adoption of diffused technological innovation (Nikamp and Poot 1998). As a consequence, investment of public and private resources in knowledge and education should be carefully designed before its implementation; otherwise, it does not provide equal growth opportunities among EU regions, failing to reduce regional gaps. Additionally, Sterlacchini (2008) suggests that traditional public investment should be a part of the broader policy package, which needs to be tailored to meet regional needs, reflecting the features of a regional innovation system.

A key to the endogenous growth model is the role of endogenous technological change through education, training, and R&D, which can be created by both the public and private sectors (Nikamp and Poot 1998). Spatial interactions have direct effects on technological change and on regional economic growth in an open economy through factor mobility, knowledge diffusion, and trade. The neoclassical growth model in an open economy predicts that human capital would flow from abundant regions with lower factor prices to scarce regions with higher factor prices, leading to factor price equalization. However, as described by Lucas (1988), the reverse flow of human capital, known as "brain drain," is more evident in practice. This is largely due to asymmetric information, imperfect labor markets, and an adjustment cost associated with migration (Barro and Sala-i-Martin 1995; Gordon and Bovenberg 1996). Because migrants carry capital (which includes human capital) with their moves, a key question to growth with endogenous migration is the destination choice of highly

[1] The Lisbon strategy is an economic development plan to make the EU "the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion" by 2010.

skilled labor forces. At a regional level with an open economy, reallocation of human capital does not necessarily reduce interregional disparities (Van Dijk et al. 1989). This indicates that neoclassical convergence is not working as described; instead, "cumulative causation" is more likely to happen at the regional level. The central government may implement regional growth policies with the aim of stopping brain drain from less developed regions and eventually reduce interregional gaps. Prior to implementation, the effectiveness of such policies should be carefully reviewed in the perspective of estimated impacts on human capital flow and on regional growth. Recent study by Choi and Cho (2015) analyzes the effect of government's policies for R&D activities in Gyeongbuk Province of South Korea. They could not find empirical evidence supporting strong influence of such policies on innovative and economic performance of regional firms. However, the authors speculate that regional policy to support R&D activities will eventually strengthen innovative system in a region in the long run.

2.2 Flow of highly educated workforce

Mobility of the highly educated may create a concentration of human capital in certain regions attracting more human capital, and this serves as a driving force for regional economic growth (Mathur 1999). Concentrations of highly educated individuals are primarily found in large metropolitan areas with agglomeration economies (Waldorf 2009). Others noted that the abundant managerial and professional jobs worked as pulling factors for the highly educated (Costa and Kahn 2000; Schachter et al. 2003). As a consequence, metropolitan areas that fail to create a highly educated workforce base are more likely to fall behind in a knowledge-based economy (Waldorf 2009). As discussed by Kaldor (1970), cumulative causation in a regional economy strengthens the reinforcing linkages between specialization and competitive advantages on a regional scale.

The uneven distribution of the highly educated population widened the regional disparities in terms of productivity, further aggravating the gaps in regional economic growth in the knowledge-based economy. Education attainment of local residents was found to be the one of the most powerful pulling factors for highly educated in-migrants, and this pattern is much stronger in urban areas but loses its power in rural areas. The empirical evidence found by Waldorf (2009) confirms that the migration pattern of highly educated aggravates disparities among the regions, leading to a "divergence of human capital levels" across space, as defined by Berry and Glaeser (2005).

Faggian et al. (2006, 2007) classified the sequential migration of HEI's (higher education institutions) graduates into five types: repeat migrants, return migrants, late migrants, university stayers, and non-migrants. Based on the sample in their study, the share of repeat migrants was the largest, followed by university stayers and non-migrants. The share of university stayers was relatively high in a core region of the national economy, for instance, London for their study. The share of return migrants, defined as those who leave a region for university education and return to the same region for employment after graduation, was the smallest. These observed patterns are closely related to the large and persistent British regional disparities, which have been widened by the flows of graduate human capital. Faggian and McCann (2009) developed OLS models with a simplified distinction between "leaver" and "stayer" to analyze the migration decision of HEI's graduates. Major findings from their model indicate that university graduates are highly mobile and that most students do not enter employment in the same area and that knowledge spillover effects of universities are very limited and largely determined by the strength of the local economy as a whole, rather than by the quality of the university.

Among various factors influencing migration decision, age of migrants has been extensively studied as a key determinant. A seminal work by Rogers et al. (1978) formulates the regularities of migration rates by age cohorts in Sweden and in the USA. They proposed a set of techniques to model migration schedule, i.e., migration rates by age, and the developed techniques successfully captured the regularities in two contrasting approaches: mortality and fertility approaches. Many subsequent studies to model migration schedule have applied age-specific migration patterns to labor market conditions. Among others, Rogerson (1987) attributed the national mobility decline in the USA during 1970s, to the larger size of young adult (baby boomers) that had experienced increasing competition for jobs. Another study by Plane and Rogerson (1991) focused on the structural change in age composition of population with the growing importance of baby boomers that had experienced increasing competition for jobs. They found delayed migration of baby boomers with much higher mobility beyond usual peak age for migration. Plane (1993) highlighted the importance of age dimension in migration research, especially by combining age cohorts with specific groups of potential migrations. Recently, internal migration research considering age cohorts has been centered on retirement migration with aging of baby boomer generations. For instance, Plane and Jurjevich (2009) described age-specific county-to-county migration pattern along urban hierarchy in the USA with special attention to baby boomer retirees and their echo cohorts. In the context of regional economic growth model, Hewings and Kim (2015) applied a population shock, measured by shifting trend of age composition structures, to measure the effect on Korean economy using ICGE model. Lee and Kim (2014) analyzed production cost change of manufacturing sector among Korean cities with highway investment. Their main goal was to prioritize projects based on the effectiveness measure for enhanced accessibility and population flows. They found that SN highway project further enhanced accessibility among manufacturing cities and caused population concentration in SMA that reduce production cost of selected manufacturing cities located along SN highway.

3 Analysis

The diffusion of endogenous technological changes induced by proper investment policy in a multi-regional system plays a vital role for regional economic growth. A successful regional development policy designed to attract highly skilled workers can lead to increases in steady-state effective capital intensity, which will increase the long-run growth rate in a region (Nikamp and Poot 1998). However, regional development policies with human capital investment through HEIs (higher education institutions) cannot succeed without proper local employment opportunities to retain highly educated human capital in the region. In turn, a lack of adequate human capital in a region is likely to restrain employment growth. In a lagging region, attracting highly skilled workers through migration is not a viable solution; rather, a locally developed workforce would be an alternative. In this perspective, workforce development through job training and employment readiness programs can serve as a sustainable solution to supply adequate human resources for regional economic growth. The beneficiaries of workforce development programs are usually local residents who are less mobile than the students in local HEIs, who are younger and highly mobile. With this approach, the target for human capital retention would not be the fresh graduate from local HEIs.

Many peripheral countries in the EU pursue regional economic growth by increasing investment in R&D and education because neoclassical growth theory (Solow 1956; Swan 1956) assumes growing productivity due to increased human capital per worker. In addition, because of diminishing returns to scale of investment in core regions and potential congestion, reallocating limited R&D and education investment from the core region to those on the periphery is believed to serve as a more efficient regional growth policy from the central government's perspective. Among others, Romer (1990) and Lucas (1988) focus on the role of technology in endogenous growth models for regional economic development in the long run. Under an endogenous growth model, advances in technology as a result of increased investment in R&D and education lead to increasing returns to scale. However, investment in R&D and education is not an efficient policy to promote regional economic growth in a periphery and lagging region because it may be too costly to a region lacking critical mass (Bilbao-Osorio and Rodriguez-Pose 2004). Rodriguez-Pose (1999) introduces the concept of "social filters" in various regions that determines the capacity of a region to accommodate R&D investment and successfully translate it into a factor for regional economic growth. Two distinctive types of societies with different levels of capacity are "innovation prone" and "innovation averse" societies (Rodriguez-Pose 1999). While the former is equipped with the capacity to transform R&D activities and associated investment eventually into economic growth, the latter fails to transform the R&D activities and associated investment into economic growth. The goal of the central government's policy is to restructure an innovation averse region into an innovation prone region with increased investment in R&D and education. However, such policy cannot be successful, unless it is effectively combined with other types of industrial investment and policy instruments to build a solid base to accommodate the restructuring process.

3.1 Method

There have been numerous efforts to apply general equilibrium models for new growth theory since 1970s. Among others, Adelman and Robinson (1978) developed a general equilibrium model for South Korean economy to study dynamic processes under discrete sequential structure. However, their approach easily misleads growth process due to the presence of inconsistency between intra- and intertemporal optimization. Later models for dynamic general equilibrium resolved the inconsistency issue (see Mercenier 1995; Jorgenson and Wilcoxen 1991; McKibbin 1993; Devarajan and Go 1998). Their approaches are without limitation due to the use of exogenous specification of technological change and other factors that determines the growth path. As pointed out by Diao et al. (1996), earlier approaches failed to build a link between given economic structure and effects of policy on growth. Diao et al. (1996) applied general equilibrium structure to an R&D-driven endogenous growth. They derived transitional dynamics under CGE model structure by combining Romer's capital variety with Grossman and Helpman's multi-sector open economy model.

We developed an interregional CGE population (ICGEP) model of South Korea to estimate the effects of educational investments on the regional economies. The model accounts for the economic behavior of producers and consumers on the real side economy, following the neoclassical elasticity approach of Robinson (1989), which includes market-clearing prices, the maximization of a firm's profit, and a household's utility. We adopt a conventional CGE framework to model economic agents' behavior, in which both producers and households optimize utility or profit levels selecting an optimal set of commodity demand sets and factor inputs under the set of given constraints, and thus, an economy-wide general equilibrium is attained. The three major economic regions in our ICGEP model are the Seoul Metropolitan Area (SMA), the rest of Korea (ROK), and one representing the rest of the world (ROW). The ICGEP model accounts for the behaviors of the economic agents of three industrial sectors (primary, manufacturing, and service) of two regions, two regional households,[2] two regional governments, the central government, and the rest of the world. The structure of this ICGEP model could be regarded as a simple one in terms of industrial and spatial classifications due to the lack of information for industry by commodity matrix and time series data of regional consumption goods, but the population groups have been disaggregated into eight age cohorts; 0–9, 10–19, 20–29, 30–39, 40–49, 50–59, 60–69, and 70+ age groups. Population groups between 0 and 19 years are assumed not to participate in the labor markets. Each age cohort is specified in terms of demand and supply sides and has different parameters and values for human capital productivity, mortality rates, and labor force participation rates on the supply side and savings rates and consumption behaviors on the demand side.[3]

Our production structure model is composed of three stages. In the first stage, the gross output by region and by sector is determined through a two-level Leontief production function of value added and composite intermediate inputs. The intermediate inputs are derived from interregional input–output coefficients, whereas the value added is determined by physical capital stock and human capital stock by age cohort. The human capital stock is defined as the number of workers multiplied by the quality of human capital possessed by workers. Lucas's endogenous growth model assumes that the quality of labor input depends on the number of years of schooling. Our study employs the average wage by age cohort as a proxy variable to measure the quality of labor input. The average wage level is determined by gender, education level, and total years of working experience and type of industrial sector in a Mincerian earning

[2] We assume there are two regions, representing a single representative agent for each region (SMA and ROK). Therefore, there are two households to avoid a computational difficulty in finding an optimal solution. If the ICGEP model would be composed of 16 households (eight age cohorts by two regions), it could not identify optimal solution due to a computational issue.

[3] This is quite distinct from other CGE models.

Table 1 The elasticity of schooling years with respect to labor productivity (wage)

Age cohort	20–29	30–39	40–49	50–59	60–69
SMA	1.062***	1.007***	0.639***	0.630***	0.194***
ROK	0.819***	0.641***	0.733***	0.781***	0.265***

*** $p < 0.01$

function. Table 1 presents the elasticity of education level for the labor productivity by region. Those in their 20s and 30s are higher in the SMA than in the ROK. The marginal product of human capital is determined not only by the quantity of labor inputs but also by their qualities, so it might not be diminishing in this paper.

We assume that labor input is homogeneous across regions and mobile across sectors. Regional labor demand by industrial sectors is derived from the first-order condition of producers' profit maximization. Labor supply relies on participation rates in economic activities and the total size of the regional population, so changes in the size of the labor pool available for each region are estimated as the sum of the natural growth of the native population and the social growth driven by interregional migration for each region.

As formulated by Sjaastad (1962), migration is a type of investment to attain higher net present value with increased income streams discounted by cost factors. Human capital approach utilizing job search model by Yezer and Thurston (1976) found a higher lifetime earnings at destination with migration due to learning process. Using National Longitudinal Surveys of Youth 1979 (NLSY79) data, Yankow (2003) estimated migration rates and wage growth conditioned on job change with various control variables, including race, education attainment, work experience, industrial mobility, and reasons for job change. He found the contemporaneous returns to migration for workers with high school graduate or less, while much bigger pecuniary returns to migration were found for highly educated workers but with a time lag of almost two years. This indicates that higher initial investment costs for highly skilled/educated workers but that can be yielded higher return in the long run. Another empirical study by Blackburn (2009) focused on the earning growth for "tied-movers," married couples migrants within the USA during 1990s. His finding indicates the loss of earnings of wives for "tied-movers" that is consistent both for 1970s and for 1990s. Ham et al. (2011) found the two contrasting effects of migration on the wage growth for two young migrants groups varied by education attainment. While the effect was significant and positive for college graduates, they found a negative effect for high school dropouts on wage growth with migration. Following the Harris–Todaro model structure (Harris and Todaro 1970), interregional migrants by regional age cohort are estimated by expected wage differentials considering comparative employment opportunities between origin and destination, discounted by the physical distance between the two regions. The expected wage income is defined as the GRP multiplied by the ratio of workers to the population, and the models are estimated with data from the National Statistical Office of South Korea. Table 2 describes the elasticity of expected income being higher in the case of gross migrants from the ROK to the SMA in all age cohorts, and moreover,

Table 2 The elasticity of expected income with respect to gross migrants

Age cohort	Total	10–19	20–29	30–39	40–49	Over 50
Gross migrants from SMA to ROK						
Origin (SMA)	0.244***	0.272***	0.171***	0.204***	0.335***	0.356***
Destination (ROK)	0.582***	0.445***	0.720***	0.599***	0.482***	0.559***
Gross migrants from ROK to SMA						
Origin (ROK)	0.096	0.080	0.006	0.105*	0.153***	0.201***
Destination (SMA)	0.754***	0.774***	0.931***	0.658***	0.662***	0.693***

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

it is highest for those in the 20s age cohort. Under this structure, we can identify the effects of educational policies on regional incomes and population changes through their linkage with the human capital accumulation and flow stock of population by region.

In the second stage, intermediate demand is decomposed into demand for domestic products and demand for foreign imports. Under the Armington assumption, cost minimization leads to an optimal ratio between foreign imports and domestic products. The demand for foreign imports relies on the price of domestic products relative to foreign imports, a share parameter, and the level of elasticity of substitution. In the final stage, demand for an intraregional product is determined by its price and total demand under the Cobb–Douglas function.

The total demand for goods and services is the sum of intermediate demand, household consumption, investment, and government expenditure. Total household incomes consist of wage, capital income, and subsidies from the government. The functional types for consumption and savings of regional households are derived from Mankiw and Weil (1989) to identify how housing demand was affected by changes in the size of different age cohorts. Private consumption for three industrial goods by region is modeled with the gender of households, the number of family members, and income[4] by age cohort as an additive function of the demand of its members. The private savings amount by region is also estimated with not only these consumption determinants but also the household debt. The primary dataset for estimating these equations in Table 3 is the Korean Labor and Income Panel Study (KLIPS) of the Korea Labor Institute.

Total investment is determined by aggregate savings with regard to the macroeconomic closure rule for capital market. A regional capital market consists of household savings, corporate savings of regional production sectors, private borrowings from abroad, and government savings. Total domestic investment amounts should be equal to the sum of net national savings and net capital inflows, and their sectoral allocation by destination is endogenously determined by capital price for each sector and the allocation coefficient of investment. This is transformed into sectoral investment by origin through a capital coefficient matrix. Two tiers of government structure are spec-

[4] The wage variable has to be used as a proxy one for the consumption power instead of total income because of statistical significance and data limitations by age cohort.

Table 3 Major equations in ICGEP model

Output	Output = Leontief (value added, intermediate demand)
Value added	Value added = CD (physical capital stock, human capital stock)
Human capital stock	Human capital stock = quality of labor input * quantity of labor input
Quality of labor input	Wage by age cohort = WA (education, type of employment, job experience, gender)
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 = CD (regional imports, intraregional supply)
Labor demand	Labor demand = LD (wage by age cohort, value added, net price)
Labor supply	Labor supply = LS (labor market participation rate, population)
Population[a]	Population = natural growth of previous year's population + net migration
Regional incomes	Regional incomes = wage + capital returns + government subsidies
Migration[a]	Migration = Harris – Todaro (incomes and employment opportunities of origin and destination, distance between origin and destination)
Consumption by commodity	Consumption by commodity = CC (price, population size and incomes by age cohort)
Private savings	Household savings = PS (population size and incomes by age cohort, debt)
Government revenues	Government revenues = indirect tax + direct tax + tariff
Government expenditures	Government use of funds = government current expenditure + government savings + government investment expenditure + government subsidies
Labor market equilibrium	Labor demand = Labor supply
Capital market equilibrium	Private savings + government savings + foreign savings = total private investments
Commodity market equilibrium	Supply of commodities = demand for commodities
Government	Government use of fund = government revenues
Capital stock	Capital stock = depreciated lagged capital stock + new investments

[a] Demographic change is estimated by two equations, population and migration, within the proposed ICGEP model

ified in the ICGEP model: two regional governments and one national government. Government expenditures consist of consumption and investment expenditures, subsidies to producers and households, and savings. Revenue sources include taxation of household incomes, value added, and foreign imports. The government investments and savings are exogenous, but the government consumption is derived from a balance condition between the government revenue and the government use of funds.

In the recursive pattern, the ICGEP has two subsystems: within-period and between-period modules. The within-period module computed equilibrium quantity and price levels under objectives and constraints for each economic agent, and the equilibrium from this module represents a market clearance level in a perfectly competitive market. There are three different sources of model parameters. The first one could be calibrated from SAM (social accounting matrix) such as tax and saving rates or balancing conditions such as shift and share parameters of production, export and import functions. The second is to borrow parameters from previous studies of Korean economies such as elasticity values of substitution and transformation for import and export goods. The final one is to estimate them with econometric methods such as migration and labor productivity by age cohort, and consumption. Some parameters, such as world market prices or government expenditures, are given exogenously, and the numeraire of the module is indexed to the consumer price index. We calibrate the ICGEP model by utilizing the existing SAM data as a benchmark equilibrium level. Once the simulation of the within-period module is completed, we run the between-period module to find a sequential equilibrium path over the time periods of our analysis by using the within-period simulation results. Therefore, the ICGEP model is a recursive dynamic model. In its optimization process, the between-period module updates the values of key exogenous variables such as government expenditures, labor supply, and capital stock by sector for future time periods. For example, the capital stock is a sum of the previous period's stock and new investment flow of the current period. The within-period module takes 2005 as the base year and adjusts key parameters by replicating the equilibrium conditions for the base year.

3.2 Policy simulation

We construct the baseline scenario, representing a reference case under the existing policy framework, in such a way that there is no change in the national government policies for the educational and R&D investments in the regions. Four scenarios reflect counterfactual conditions that can be attained under different policy options from the existing ones, and each of them is set to increase the regional educational investments by 5 % in period 1.

- *Scenario 1*: Increasing educational investment in the 20s age cohort (university tuition subsidy) of the SMA by 5 %
- *Scenario 2*: Increasing educational investment in the 30s age cohort (workforce development program) of the SMA by 5 %
- *Scenario 3*: Increasing educational investment in the 20s age cohort (university tuition subsidy) of the ROK by 5 %
- *Scenario 4*: Increasing educational investment in the 30s age cohort (workforce development program) of the ROK by 5 %

After simulations are completed for all the scenarios from year 2005 (baseline year) to year 2011, we compare the simulation results of counterfactual scenarios with those of the baseline scenario (Table 4). The regional education investment is assumed to be a part of its total expenditures, which expresses that an increase in education investment would affect the amount of other regional government expenditures or consumption. Each scenario is expected to generate a dissimilar equilibrium because the ICGEP determines total factor productivity for a particular sector in each region based on the human capital accumulation. However, the magnitude of regional educational

Table 4 Impacts of human capital investment by 5 % point (unit: %)

	2005	2006	2007	2008	2009	2010	2011	Avg.
Education investments in the 20s age cohort of SMA								
GDP	0.1392	0.1474	0.1558	0.1636	0.1710	0.1779	0.1842	0.1627
GRP of SMA	0.3429	0.3681	0.3941	0.4201	0.4463	0.4728	0.4997	0.4206
GRP of ROK	−0.0531	−0.0636	−0.0749	−0.0875	−0.1018	−0.1179	−0.1363	−0.0907
Population of SMA	0.0226	0.0465	0.0711	0.0968	0.1233	0.1513	0.1810	0.0989
Population of ROK	−0.0212	−0.0442	−0.0687	−0.0951	−0.1233	−0.1542	−0.1881	−0.0993
Population of 20s age cohort of SMA	0.0731	0.1511	0.2333	0.3202	0.4111	0.5067	0.6067	0.3289
Population of 30s age cohort of SMA	0.0184	0.0385	0.0598	0.0826	0.1069	0.1329	0.1606	0.0857
Population of 20s age cohort of ROK	−0.0743	−0.1583	−0.2535	−0.3628	−0.4889	−0.6371	−0.8129	−0.3983
Population of 30s age cohort of ROK	−0.0201	−0.0427	−0.0672	−0.0941	−0.1235	−0.1558	−0.1911	−0.0992
Education investments in the 30s age cohort of SMA								
GDP	0.3118	0.3280	0.3441	0.3594	0.3737	0.3871	0.3993	0.3576
GRP of SMA	0.7278	0.7724	0.8175	0.8622	0.9066	0.9510	0.9955	0.8619
GRP of ROK	−0.0809	−0.0967	−0.1139	−0.1331	−0.1545	−0.1788	−0.2063	−0.1377
Population of SMA	0.0327	0.0672	0.1029	0.1402	0.1786	0.2192	0.2617	0.1432
Population of ROK	−0.0307	−0.0640	−0.0995	−0.1378	−0.1786	−0.2233	−0.2720	−0.1437
Population of 20s age cohort of SMA	0.1055	0.2184	0.3378	0.4637	0.5953	0.7337	0.8770	0.4759
Population of 30s age cohort of SMA	0.0265	0.0557	0.0867	0.1197	0.1548	0.1925	0.2323	0.1240
Population of 20s age cohort of ROK	−0.1071	−0.2289	−0.3670	−0.5254	−0.7079	−0.9225	−1.1752	−0.5763
Population of 30s age cohort of ROK	−0.0290	−0.0618	−0.0974	−0.1363	−0.1789	−0.2257	−0.2765	−0.1437
Education investments in the 20s age cohort of ROK								
GDP	0.0738	0.0751	0.0766	0.0778	0.0788	0.0794	0.0800	0.0774
GRP of SMA	−0.0352	−0.0394	−0.0432	−0.0475	−0.0521	−0.0570	−0.0622	−0.0481

Table 4 continued

	2005	2006	2007	2008	2009	2010	2011	Avg.
GRP of ROK	0.1766	0.1845	0.1926	0.2006	0.2085	0.2163	0.2243	0.2005
Population of SMA	−0.0082	−0.0166	−0.0250	−0.0336	−0.0421	−0.0508	−0.0597	−0.0337
Population of ROK	0.0077	0.0158	0.0242	0.0330	0.0421	0.0518	0.0620	0.0338
Population of 20s age cohort of SMA	−0.0208	−0.0424	−0.0646	−0.0873	−0.1104	−0.1338	−0.1574	−0.0881
Population of 30s age cohort of SMA	−0.0095	−0.0197	−0.0301	−0.0409	−0.0520	−0.0635	−0.0752	−0.0416
Population of 20s age cohort of ROK	0.0211	0.0444	0.0702	0.0990	0.1313	0.1683	0.2109	0.1065
Population of 30s age cohort of ROK	0.0104	0.0218	0.0338	0.0466	0.0601	0.0744	0.0895	0.0481
Education investments in the 30s age cohort of ROK								
GDP	0.1766	0.1797	0.1829	0.1854	0.1874	0.1887	0.1897	0.1843
GRP of SMA	−0.0542	−0.0599	−0.0654	−0.0717	−0.0787	−0.0864	−0.0948	−0.0730
GRP of ROK	0.3945	0.4087	0.4232	0.4372	0.4511	0.4648	0.4787	0.4369
Population of SMA	−0.0118	−0.0241	−0.0366	−0.0495	−0.0627	−0.0765	−0.0908	−0.0503
Population of ROK	0.0111	0.0229	0.0354	0.0487	0.0627	0.0780	0.0944	0.0505
Population of 20s age cohort of SMA	−0.0299	−0.0615	−0.0945	−0.1289	−0.1645	−0.2016	−0.2398	−0.1315
Population of 30s age cohort of SMA	−0.0136	−0.0285	−0.0440	−0.0603	−0.0774	−0.0956	−0.1146	−0.0620
Population of 20s age cohort of ROK	0.0304	0.0645	0.1027	0.1461	0.1957	0.2535	0.3213	0.1592
Population of 30s age cohort of ROK	0.0149	0.0316	0.0494	0.0686	0.0894	0.1121	0.1363	0.0718

investments on the economic growth is uncertain due to multiplicative linkages of the educational investment expenditure, the human capital, production, and population change and migration.

If education and human capital investment in the 20s age cohort in the SMA increase by 5 % (Scenario 1), the GRP in the SMA would expand by 0.34 % in the short run and 0.50 % in the long run. The impact on GRP in the SMA with a 5 % investment increase in the 30s age cohort (Scenario 2) is more than two times higher, with 0.73 % in the short run and 1.00 % in the long run. This finding indicates that a more effective education and human capital investment policy within SMA would be the expansion of investment in the 30s, age cohort, rather than in the 20s age cohort. The education and human capital investment targeting the 30s age cohort can focus on job readiness initiatives through various training/retraining programs for the current labor force. Though the comparable effects in the ROK are smaller than those in the SMA, we still found a similar pattern with higher effects from the 5 % increase in education and human capital investment in the 30s age cohort than that in the 20s age cohort. The 5 % increase in the investment in the 20s age cohort in the ROK (Scenario 3) yielded 0.18 % GRP growth in the short run and 0.22 % GRP growth in the long run, while the expanded investment in the 30s age cohort in the ROK by 5 % (Scenario 4) yielded 0.39 % growth in the short run and 0.48 % growth in the long run. Simulation results indicated that impact on national GDP growth was the highest, with a 5 % investment increase in the 30s age cohort in the SMA (Scenario 2); the second highest was Scenario 4, with a 5 % investment increase in the 30s age cohort in the ROK; the third highest was Scenario 1, with a 5 % investment increase in the 20s age cohort in the SMA; and the lowest was Scenario 3, with a 5 % investment increase in the 20s age cohort in the ROK. The impact of human capital investment on regional growth (measured by GRP growth) was higher for investment in the 30s age cohort than for investment in the 20s age cohort. The investment expansion policies in the SMA yielded a higher impact on regional growth than matching investment policies in the ROK. However, it is noticeable that the impact on regional growth was higher with a 5 % increase in investment in the 30s age cohort in the ROK (Scenario 4) compared to a 5 % increase in investment in the 20s age cohort in the SMA (Scenario 1). The same pattern holds for the impact on national GDP growth. The intended goal of the Korean national government's educational investment policy is to reduce the interregional gap between the SMA and the ROK by expanding investment mainly in HEIs in the ROK. This policy has focused on providing higher-quality education for university students (mainly in their 20s) in the ROK to stop the brain drain to the SMA. However, our simulation results reveal that an expanded human capital investment in the 20s age cohort in the ROK is found to be the least effective policy in terms of regional economic growth; rather, human capital investment policy targeting those in the 30s age cohort is found to be more effective in promoting regional economic growth. The latter approach might include job training and employment readiness programs for the 30s age cohort, similar to various workforce development programs implemented by state and local governments in the USA under the Workforce Investment Act (WIA). Currently, Ministry of Employment and Labor in South Korea provides funding for various training/retraining programs through employment insurance system. In 1995, national employment insurance system started with the aim to provide unemployment benefit and to enhance employment stability by providing training/retraining programs. However, local governments' roles are very limited. With the increasing roles of local governments as in the case for WIA in the USA, various workforce development and training/retraining programs could be developed through continuing education programs and vocational training programs in partnership between local governments and regional and/or local HEIs, mainly focusing community colleges in ROK. The national government would still remain as a funding source for such programs; however, its role would be confined to identifying the most effective programs among competitors in the ROK. Additional funding required for the increases in such human capital investment in our scenarios will be available by reallocating certain portion of R&D investment for HEIs to vocational training programs in community college type of HEIs. This policy approach would be more effective in producing higher regional growth in the ROK and eventually contribute to reduce the interregional disparity in Korea.

In the perspective of population growth, expanded investment in the 30s age cohort in the both SMA and the ROK would have a greater impact. When human capital investment increased by 5 % in the SMA, population growth in the SMA was higher, at 0.03 % with a 5 % investment increase in the 30s age cohort, than the matching growth rate of 0.02 % in the 20s age cohort in the short run. In the long run, population growth rate with expanded investment in the 30s age cohort was also higher at 0.26 % compared to the growth rate of 0.18 % with expanded investment in the 20s age cohort. Generally, population growth impacts were much higher with expanded investment in the SMA than with those in the ROK. Our simulation also estimated the population growths for two age cohorts, the 20s and 30s age cohorts, both in the SMA and in the ROK. For all age cohorts and regions, population growth effects were much higher with expanded educational investment in the 30s age cohort than was the case with expanded investment in the 20s age cohort. For instance, long-run population growth in the 20s age cohort in the ROK and the 30s age cohort in the ROK was 0.21 and 0.09 %, respectively, under Scenario 3 (a 5 % investment increase in the 20s age cohort), whereas the matching long-run growth rates were 0.32 and 0.14 %, respectively, under Scenario 4 (a 5 % increase in the 30s age cohort). Another finding indicates that population growths of the 20s age cohort in either the SMA or ROK under all four scenarios were much higher, confirming the higher mobility of younger generations. Comparison of the population growth impacts among the counterfactual scenarios demonstrated the interesting finding that expanded human capital investment in the 30s age cohort induced not only higher population growth in the 30s age cohort but also higher population growth in the 20s age cohort. This pattern holds for the both SMA and the ROK. The Korean government's intended goal of population redistribution through expanded human capital investment in the ROK is somewhat limited because the investment mainly supports HEIs in the ROK to attract more students (mainly in their 20s) by expanding tuition subsidy programs. Rather, more effective policy to induce faster population growth in the ROK is an investment expansion specifically targeting the 30s age cohort, which might include various local workforce development programs. With this policy approach, the population of both age groups, the 20s and 30s age cohorts, was found to grow faster, and the population growth rate of the 20s age cohort was even faster than that of the 30s age cohort. These simulation results reveal that not only direct beneficiaries from a human capital investment expansion for the 30s age cohort but also the future beneficiaries, the 20s age cohort, could be attracted to the ROK with increased investment.

4 Conclusions

The purpose of this paper is to examine the regional impacts of educational policies on migration and economic growth by employing the ICGEP model with a human capital module. The simulation results show that the impact of expanded human capital investment in the rest of Korea (ROK) was lower than that in the Seoul Metropolitan Area (SMA). When differentiated by types of investment, human capital investment in the 30s age cohort had a larger impact in inducing the growth of GRP than investment in the 20s age cohort, and this pattern was found for the both SMA and ROK. While the former can be viewed as the central government's effort to promote various local programs for workforce development, the latter can be regarded as a direct investment from the national government to enhance the quality of education offered at local HEIs in the ROK and to make it more accessible at a cheaper cost. In practice, investments made in local HEIs to promote human capital creation in the ROK had failed because brain drain from the ROK to the SMA had continued to aggravate the regional disparity and population concentration. For the last three decades, most of the central government's regional development policies were driven by two policy goals: reducing the regional gap between the SMA and ROK and redistributing population from the SMA to the ROK. Education policy to promote human capital in South Korea has been utilized to meet these goals for regional economic development. As our simulation results indicate, increased investment in the 20s age cohort in local HEIs in the ROK is less effective compared to the national investment to promote local workforce development efforts, mainly concentrated for the 30s age cohort. In addition, human capital investment in the 30s age cohort induces much faster population growth of both age cohorts, the 20s age cohort and the 30s age cohort, in the ROK. More importantly, the national GDP in South Korea was found to grow faster with expanded human capital investment in the 30s age cohort in the ROK even when compared to the alternative of expanding investment in the 20s age cohort in the SMA. With the aim of reducing regional disparity and resolving population concentration in the SMA, the national government should expand human capital investment in the ROK, as has been implemented. However, the Korean national government should carefully review and revise its current investment formula into one more accessible for local governments in the ROK to fund local efforts for workforce development.

With the aim of accumulating human capital in a lagging region, three widely adopted policy tools can be utilized, separately and/or combined. These include human capital attraction, creation, and retention. Current policy approaches of the Korean national government primarily focus on attraction and creation, by expanding education investment in local HEIs in the ROK, to reduce regional disparity between the SMA and the ROK and to redistribute the overcrowded population from the SMA to the ROK. However, these approaches cannot be successful if a lagging region fails to retain the attracted and locally developed human capital in the region. Our empirical findings confirm the higher mobility of the younger age group, the 20s, age cohort, compared with the 30s age cohort, chasing better opportunities in the SMAs where they can successfully build their early career. If the ROK fails to retain the young highly educated workforce in the ROK, those attracted and locally developed by the expanded education investment from the national government, regional disparity between the SMA and the ROK and population concentration in the SMA will continue to increase. Due to lower mobility, the mid-career workforce in their 30s and 40s in the ROK can be a good target audience for enhancing the overall human capital accumulation in the ROK by expanding training/retraining programs specifically designed to meet the demands from major local industries/employers. This will contribute to partly balance the unequal spatial distribution of human capital between the SMA and the ROK and slow population concentration in the SMA by restraining massive migration from the ROK to the SMA. An enhanced human capital level in the ROK would induce more investment, resulting in reduced regional disparity. In addition, South Korea has the fastest aging population among OECD countries. After hitting a peak in the working age population in 2016, South Korea is expected to suffer from a continuous loss in the workforce. Potential policy tools to prepare for the expected labor shortage problem in South Korea could be combined with the education investment policies discussed in our paper. Through expanded job training opportunities for the mid-career workforce, the enhancement of their human capital will increase their labor productivity. Combined with their experience, improved human capital will equip them with the skill levels required by future labor demand. This may delay retirement age and even recall some of the retired workforce (workforce reserve) back to employment. As a consequence, the national government's expanded investment in training/retraining programs targeting mid-career labor is expected to partly resolve the labor shortage and elderly poverty issues in a rapidly aging country such as South Korea.

There have been few attempts to empirically quantify the effects of educational policies at the regional level utilizing a general equilibrium structure. As such, a few points need mentioning regarding the prospect of further research on the issues. First of all, our paper focused only on pecuniary economies, such as labor wages and employment opportunities. However, decisions regarding migration and the relocation of economic production could be more dependent on consumption externalities and location-specific amenities, such as the quality of commercial and medical services, education, neighborhood, and natural amenities. Another extension of the present work would be to modify the human capital functions by developing a channel of technical changes and innovation in a dynamic framework.

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