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Skill Choice, Brain Drain, and Variety of Goods: Innovation in the Core-Periphery Model

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Abstract

People judge whether they want to be high-skilled workers by considering the economic returns and the effort required to skill. This study considers two regions: an advanced industrial region, where high-skilled workers increase the variety of goods through innovation, and an underdeveloped region where innovation does not occur. Here, workers become high-skilled, considering regions of origin and potential abilities. Numerical simulations show that the proportion of high-skilled workers reacts in an inverted U-shape, as the variety of goods increases. When the variety of goods is small, the ratio of high-skilled workers in the developed regions is higher than that in the underdeveloped regions; as it increases, the proportion of high-skilled workers born in both regions increase. The proportion of high-skilled workers born in developed regions eventually declines; however, it increases in the underdeveloped regions. As the variety of goods increases, the proportion of high-skilled workers decreases in the underdeveloped regions.

Keywords: *Skill choice; brain drain, innovation, variety of goods; core-periphery model*

JEL classification: O15, O31, R23

1. Introduction

Innovation does not occur uniformly through geographies; it is uneven. In some regions, it occurs frequently, and in others, it does not. Regional differences in innovation may be more consequential than the bias of industrial location (Carlino & Kerr, 2015; Zucker & Darby, 2014). Immigrants play an essential role in innovation (Hunt & Gauthier-Loiselle, 2010; Kerr, 2013). The expected economic rewards can evaluate the benefits of migrants who contribute to innovation. To gain this benefit, migrants acquire skills by educating themselves and working hard (Beine et al., 2001; Djajić et al., 2019; Lumpe, 2019). Alternatively, studies show that urban regions and developed countries to which people migrate are conducive to acquiring skills effortlessly (Glaeser & Mare, 2001; Glaeser & Resseger, 2010; Lucas, 2004).

How do people choose to become highly skilled and migrate (or migrate and become highly skilled)? We are interested in the difference in the ratio of high skills among regions and in educational and regional disparities. A common perception is that higher education will increase the number of skilled workers (e.g., Hanson & Slaughter, 2018). This study too, considers those with higher education (such as a Doctoral or Master's degree awarded) as skilled workers. Figure 1 shows the number of Americans (U.S. Citizens and Permanent

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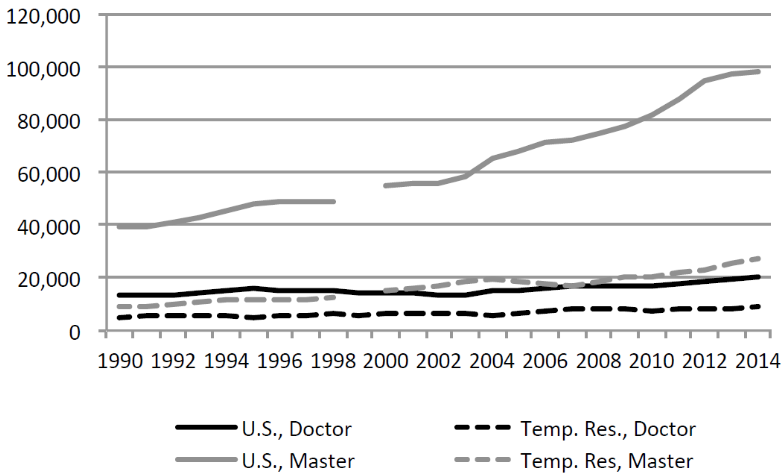
Residents) and Temporal Residents in Doctoral and Master's degree awarded in the field of science. Both numbers are on the rise.

Figure 1. Number of Americans in Doctoral and Master's degree awarded in Science in the U.S.



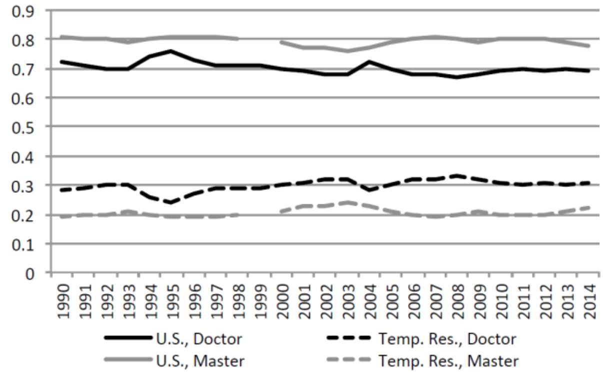
(*Source:* National Science Foundation)

Figure 2 shows the proportions they occupy in each degree awarded, and the transition is stable. Similarly, Figure 3 shows the number of Americans and Temporal Residents in Doctoral and Master's degree awarded in engineering. Influenced by the Great Recession of 2008, Master's degree awarded (especially for temporary residents) decreased several years later. Owing to the difference in the length of study, the Recession may be affecting the number of Doctoral degrees awarded several years later. Ignoring the effects of this economic downturn, more interestingly, it shows an inverted U-shape until 2000 and growth after 2000, showing an overall upward trend. If the information revolution around 2000 has brought about changes in the economic environment and increased demand for higher-educated high-skilled workers, it aligns with the interests of this article.

Figure 4 shows the proportions of Americans and temporary residents in their degree. In Doctoral degree awarded, Americans are on a downward trend and Temporal Residents on an upward trend overall. Observing by period, there were many temporal resident proportions around 1990, with more Americans in the 1990s and more temporal residents in the 2000s. In addition, in the proposal of a Master's degree awarded, the number of Americans is decreasing, and that of temporary residents is increasing. Observing by period, the proportion of Americans decreased (that of temporal residents increased) until the early 2000s, after which the change became smaller. The next example is that of Japan.

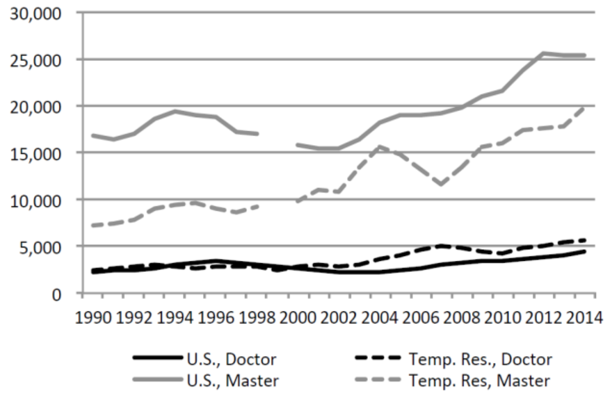
Figure 5 shows the number of Japanese and students from foreign countries enrolled in Japanese graduate schools. The Japanese show an inverted U shape, and the foreigners show an increasing trend. One of the possible factors for this result is that Japan has been slow to adapt to the information revolution, and even after 2000, changes in the economic environment were small. Consequently, there was no significant change in the demand for high-skilled workers.

Figure 2. Proportion of Americans in Doctoral and Master's degree awarded in Science in the U.S.



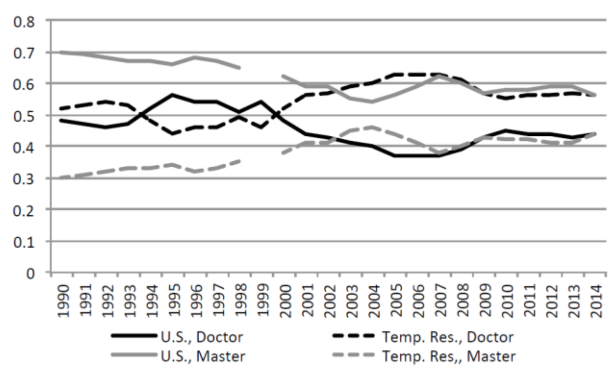
(*Source:* National Science Foundation)

Figure 3. Number of Americans in Doctoral and Master's degree awarded in Engineering in the U.S.



(*Source:* National Science Foundation)

Figure 4. Proportion of Americans in Doctoral and Master's degree awarded in Engineering in the U.S.

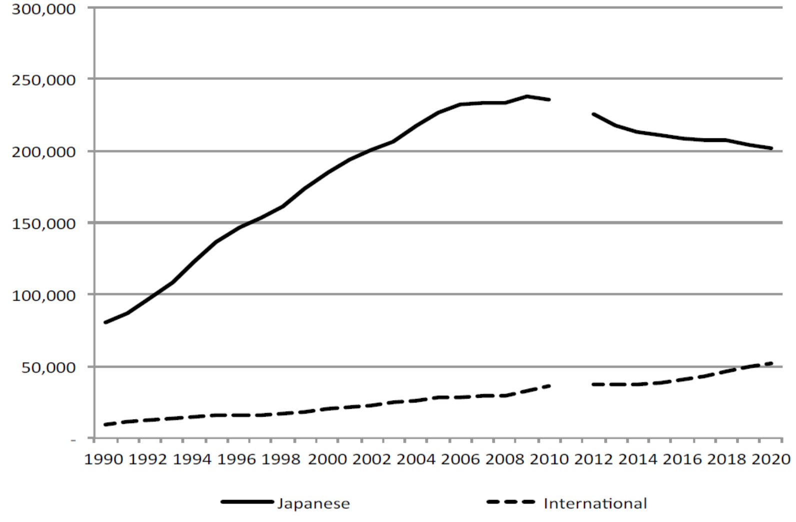


(*Source:* National Science Foundation)

Figure 6 shows the ratio of Japanese and foreign graduate students. In addition, there are various important factors behind the trends in higher education in each country—government research support, policies regarding immigration and acceptance of international students, and economic conditions. For example, there is a policy to increase the number of people trained in science, technology, engineering, and mathematics (commonly known as STEM) (Bloom et al., 2019). Immigration quotas also have a negative impact on the economy (Doran & Yoon, 2020). The Great Recession of 2008 may have caused the degree awarded decline, and the information revolution may have increased the demand for new skilled workers.

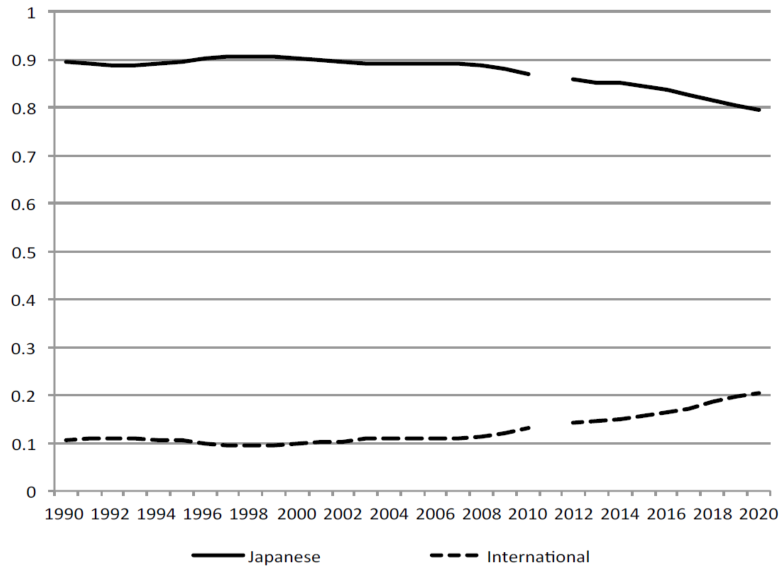
Labor movements between these two types of regions (or nations) are analyzed. While there are various migration patterns in origins and destinations, this study assumes migration from advanced industrial regions to underdeveloped countries (it does not matter if both regions are domestic or foreign). Harris and Todaro (1970) indicated that expected wages are high in urban regions because of the formal and informal sectors, causing labor migration from rural regions. The migration of high-skilled workers from developing countries to developed countries is often discussed as "brain drain" (Docquier & Rapoport, 2011). Notably, migration accelerates the imbalance of human resources. In an analysis that introduced Grossman and Helpman-type innovations that increase the "variety of goods" in endogenous growth theory into the literature of new economic geography, which studies migration between two regions, the "variety of goods" affects the migration of skilled workers (Fujita & Thisse, 2002). An important assumption of New Economic Geography is that only skilled workers move between regions. However, it does not discuss the choices that determine how people become skilled workers.

Figure 5. Number of Japanese and International graduate students.



(*Source:* Ministry of Education, Culture, Sports, Science and Technology - Japan)

Figure 6. Proportion of Japanese and International graduate students.



(*Source:* Ministry of Education, Culture, Sports, Science and Technology - Japan)

How are people determined to be skilled workers who help in innovating new products? How should the market determine regional differences in the production of skilled workers? To discuss the factors of interest, we will build an economic model consisting of two regions—an advanced industrial region and an undeveloped region. Innovation occurs in advanced industrial regions, which increases the "variety of goods" traded between regions. Therefore, those born in the advanced industrial region become high-skilled workers and innovate, or become low-skilled workers and engage in other tasks. Those born in the underdeveloped region become high-skilled workers and move to the advanced industrial region to innovate or become low-skilled workers and stay there to engage in other tasks. How would an increase in the variety of goods through innovation affect the proportion of high-skilled workers in both regions? The novel features of this research are that it considers the education level for each region, interregional labor migration, and innovation, determined by the level of a variety of goods. To discuss the issue of factors of interest, we assume that other factors, such as the economic environment and government policy, are constant.

The rest of this paper is organized as follows: Section 2 introduces the model. Section 3 explains the numerical simulation. Finally, section 4 concludes the paper.

2. The model

2.1 Consumers' utility maximization problem

There are two regions in this economy—the advanced industrial region A and the underdeveloped region B—and innovation occurs only in the advanced region A. There are two groups of workers—high-skilled H_r and low-skilled L_r. High-skilled workers in region B migrate to region A, and those $(H=H_A+H_B)$ in advanced region A innovate. As the population of each region is normalized to one, the number of low-skilled workers in region *r* is $L_r=1-H_r$. The economy has three industrial sectors: traditional sector *T*, modern sector *M*, and research sector *R*. The modern sector *M* is sub-divided into the existing old *O* sector and newly invented *N* sector, each of which has *O* kinds and *N* kinds ($M=O+N$) of goods. Consumers purchase them at a given price. The utility function of consumer *j* is

$$U_{jgr} = \frac{Q_{gr}^{\mu} T_{gr}^{1-\mu}}{\mu^{\mu}(1-\mu)^{1-\mu}} - S_{jgr} \qquad (1)$$

where M is a composite of O and N goods,

$$Q_{gr} = \left[\int_0^M m_{gr}(i)^{\rho}\, di\right]^{1/\rho} = \left[\int_0^O o_{gr}(i)^{\rho}\, di + \int_0^N n_{gr}(i)^{\rho}\, di\right]^{1/\rho} \quad (2)$$

where *m* is the consumption of each *M* good, *o* is the consumption of each *O* good, and *n* is the consumption of each *N* good. *T* are numeraire goods, $P_T=1$. As we see in Subsection 2.3, S_{jgr} is the amount of effort required to attain a high skill, depending on individual *j* in region *r*; no effort is required to attain a low skill ($S_{jHr} \geq 0, S_{jLr} = 0$). μ and ρ are parameters. Note that $\sigma = 1/(1-\rho)$ is the elasticity of substitution.

The budget constraint is

$$w_{gr} = p_T T_{gr} + \int_0^M p_{Mr}(i) m_{gr}(i)\, di = p_T T_{gr} + \int_0^O p_{Or}(i) o_{gr}(i)\, di + \int_0^N p_{Nr}(i) n_{gr}(i)\, di, \quad (3)$$

where w_{gr} is labor income. Based on the NEG settings, there is no cost to transport *T* goods, but *M* goods require transportation costs. Therefore, people in region *B* need to pay more money to consume the same amount of goods in department *M* as those in region *A*, $p_{MB}=\Psi_r p_{MA}$, where Ψ_r is transportation cost ($\Psi_A=1$, $\Psi_B \geq 1$). If the goods are symmetric, then

$$w_{gr} = p_T T_{gr} + O\Psi_r p_O o_{gr} + N\Psi_r p_N n_{gr}$$

Solving this consumer utility maximization problem gives the consumer demand function.

$$T_{gr} = \frac{(1-\mu) w_{gr}}{p_T} \qquad (4)$$

$$m_{gr}(i) = \mu w_{gr} \left(\Psi_r p_{Mr}(i)\right)^{-\sigma} P_r^{\sigma-1}, \qquad (5)$$

where P_r is a composite price index for *M* goods, which varies by region because it includes transportation costs.

$$P_r \equiv \left[\int_0^M p_r(i)^{1-\sigma}\, di\right]^{\frac{1}{1-\sigma}} \qquad (6)$$

Substitute the demand function into the utility function to obtain the indirect utility function.

$$v_{jgr} = w_{gr} P_r^{-\mu} - S_{jgr} \qquad (7)$$

Here, the total demand for O goods and N goods in each market is calculated.

$$Do(i) = \mu p_{OA}(i)^{-\sigma} P_A^{\sigma-1}\left(E_A + E_B\, \Psi_B^{-1}\right) \qquad (8)$$

$$D_N(i) = \mu p_{NA}(i)^{-\sigma} P_A^{\sigma-1}\left(E_A + E_B\, \Psi_B^{-1}\right), \qquad (9)$$

where E_A is the total expenditure of region *A* (i.e., the sum of the spending of low-skilled workers in *A*, high-skilled workers in region *A*, and high-skilled workers who moved from region *B* to region *A*),

$$E_A = w_L L_A + w_H(H_A + H_B) = w_L L_A + w_H H \qquad (10)$$

E_B is the total expenditure of low-skilled workers in region *B*.

$$E_B = w_L L_B \qquad (11)$$

2.2 Producers' profit maximization problem

There are three industrial sectors: traditional sector *T*, modern sector *M*, and research sector *R*. The traditional sector *T* and the modern sector *M* (both *O* and *N* sectors) produce goods. The research sector *R* develops a new product *N* (*N* goods themselves are not produced). The *T* and *M* sectors hire low-skilled workers, and the *R* sector hires high-skilled workers. Production technology of the *T* and *M* sectors has a constant return to scale. There is one type of product in the *T* sector and *M* types in the *M* sector (total of *O* types in the *O* sector and *N* types in the *N* sector). The *M* and *R* sectors exist only in region *A*. As a result of product development in the *R* sector, *N* goods are invented, and the number of *M* goods increases. *N* goods invented during that period are sold in the monopolistic competition market and are sold in one of the *M* sectors. However, previously invented *O* goods are sold in the competitive market.

(i) T sector

In the competitive market, the *T* sector is operated by constant-return-to-scale technology, and one unit of *T* goods is produced from one unit of the low-skilled worker, $T_r = L_{Tr}$, where L_{Tr} is the number of low-skilled workers working in the *T* sector in region *r*. As it is assumed that the trade of *T* goods does not involve transportation costs, the wages of low-skilled workers are p_T in the *T* and *M* sectors of both regions. If there is excess demand for *T* goods, which have no transportation costs, they are traded outside the economy.

$$w_{LA} = w_{LB} = p_T = 1 \qquad (12)$$

(ii) M sector

The *M* sector is located in the *A* region, and one unit of low-skilled labor *L* produces one unit of *M* goods by the constant-return-to-scale technology; $M = L_{AM}$. Therefore, the wage is $w_L = p_T = 1$. One type of *M* goods requires one innovation (blueprint) developed in the *R* sector to date. In the *M* sector, *N* goods invented in this period and already existing goods *O* are distinguished. The market of *O* goods is competitive, and the price is equal to the cost. Therefore, the price in the production region is $p_{or}(i) = 1$. As the trade of *M* goods (both *O* and *N* goods) involves transportation costs, the price of *O* goods for consumers is

$p_{or}(i)\Psi_r = \Psi_r,$ (13)

where $L_{MA} = L_{OA} + L_{NA}$ is the number of low-skilled workers working in the *M* sector, and *M* goods have balanced supply and demand within the economy. The analysis is performed to the extent that there are sufficient workers in region *A* ($L_A > L_{MA} = OD_O + ND_N$). Other low-skilled workers in region *A* work in L_{AT} in region *A*. The market for *N* goods is a monopolistic competitive market. Firms set a price p_N that maximizes profit, $\pi_N(i) = (p_N(i) - p_T)D_N(i)$. An equilibrium price common to *N* goods is obtained, assuming the symmetry of goods.

$$p_{Nr} = \frac{1}{\rho} p_T \Psi_r \quad (14)$$

If the goods are symmetric, then substituting (14) into (2), the regional price index becomes

$$P_r = \left(O + N p_N^{-(\sigma-1)}\right)^{\frac{-1}{\sigma-1}} \Psi_r, \quad (15)$$

and profit is

$$\pi_r(i) = (p_{Nr} - 1)D_N \quad (16)$$

(iii) R sector

The *R* sector employs high-skilled workers to invent *N* goods. The high-skilled worker in region *A* is $H = H_A + H_B$ because the high-skilled worker born in region *B* moves to region *A*. One high skill produces *d* new goods.

$$N = dH \quad (17)$$

Profit is positive because the market for *N* goods is a monopolistic competitive market. This profit is given as wages to high-skilled workers who invented *N* goods.

$$wH = d\pi \quad (18)$$

As it takes effort to become a high-skilled worker, $w_H > w_L$ needs to be satisfied for high skills from the advanced region *A*.

2.3 Consumer's choice to be skilled or unskilled

Consumers live for a specific period. At the beginning of the period, consumer *j* compares the indirect utility of becoming a high-skilled worker to that of becoming a low-skilled worker. Subsequently, consumer *j* chooses whether to make an effort S_{jgr} to become a high-skilled worker or make no effort and remain a low-skilled worker. First, we define the effort S_{jHr} required to become a high-skilled worker.

$$S_{jHr} = c\eta_r H_{jr} \quad (19)$$

No effort is required to become a low-skilled worker, $S_{jLr} = 0$. H_{jr} indicates the ability of consumer *j* and is normally distributed at $[0, 1]$ (a smaller H_{jr} means higher ability, as this person can become a high-skilled worker with less effort). $c > 0$ is a parameter.

$\eta_r \geq 1$ (η_A=1, $\eta_B \geq 1$) is a parameter that indicates the difficulty of access to education, which differs by region. People born in region *A* with an *R* sector find it easier to learn than do those born in region *B*.

The indirect utility function when a person from region *r* becomes a high-skilled worker is

$$v_{jHr} = (d\pi_r\ )^{\mu}\ P_A^{-\mu} - c\eta_r\ H_{jr} \quad (23)$$

and the indirect utility function for becoming a low-skilled worker is

$$v_{jLr} = P_A^{-\mu}\Psi_{jr}^{-\mu} \quad (24)$$

The conditions for people from region *r* to become high-skilled workers are

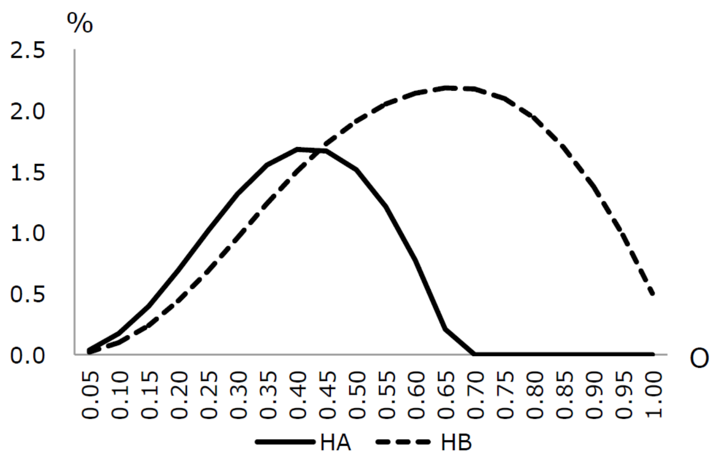
$$H_{jr} \leq \frac{((d\pi_r\ )^{\mu} - \Psi_r^{-\mu})P_A^{-\mu}}{c\eta_r} \qquad (25)$$

A person for whom equation (25) is equal is indifferent between choosing to become a high-skilled worker or a low-skilled worker. Such H_{jr} is the ratio of high-skilled workers born in each region (H_{jr} also represents the number of these workers because the population is normalized to one). Those who become high-skilled workers in the underdeveloped region *B* move to the advanced region *A* and work in the *R* sector to develop new products. Low-skilled workers in the underdeveloped region *B* stay in *B* and work in the *T* sector. During the period, people work and consume all their income.

3. Numerical simulation

Using numerical simulation, we solve for equations (9), (15), and (25) (for *r=A, B*) for H_A, H_B, and D_N, while equations (10), (11), (12), (14), (17), and (18) are applied. The parameters are c=1, d=2, η_B =2, Ψ_B =1.5, μ=0.3, and ρ=0.1. Figure 7 shows the derived H_A and H_B.

Figure 7. High-skilled worker rate in Region A and Region B



When the variety of goods is small, the high-skilled worker ratio (H_A) in the advanced region *A* is higher than that (H_B) in the underdeveloped region *B*. As the variety of goods increases, the ratio of high-skilled workers increases in both regions.

Eventually, the ratio of high-skilled workers in developed region *A* will begin to decline, as that in region *B* will continue to increase. If the variety of goods further increases, the ratio of the high-skilled labor force in region *B* will become higher than in advanced region *A*. As it continues to increase, the high-skilled labor force in Region *B* will also decline.

The profits obtained by inventing new products are high, while the variety of goods is small. Nevertheless, the profits obtained from new products are small when the variety of goods is large—however, the greater the variety of goods, the higher the marginal utility of income. The rate of attaining a high skill becomes an inverted U-shape due to these trade-offs.

People from region *B* have less access to education and are less likely to be high-skilled workers. They are motivated to become high-skilled workers because they can avoid the transportation costs for *M* goods when they move to region *A*. The utility levels increase as the variety of goods increases. The variety of goods at the peak of the ratio of high-skilled workers in region *B* is higher than that in region *A*.

As additional simulations, the parameters are moved in a direction that is likely to change over time. For example, when η_B (difficulty of learning in region *B*) decreases, *d* (several inventions by one high-skilled worker) increases, Ψ_B (transportation cost) decreases, and μ (ratio of consumer spend on *M* goods of the total) increases. The decline in Ψ_B reduces incentives for those from region *B* to become high-skilled workers, and the number of high-skilled workers decreases even at the peak.

4. Conclusion

The proportion of high-skilled human resources that produce innovation changes with time and varies by region. This study considers a model in which innovation has regional bias and high-skilled workers move to innovative regions. Therefore, many high-skilled workers are born in developed regions when innovation is not well accumulated, and the variety of goods is small. With the accumulation of innovation and a greater variety of goods, the number of high-skilled workers in the developed regions begins to decrease and that in the underdeveloped regions increases. When innovation occurs sufficiently and the variety of goods increases, the number of high-skilled workers also decreases in the underdeveloped regions. Owing to the availability of data and the conventions of previous studies, the high-skilled workers in this study were defined as those with higher education.

Considering the current situation in the United States corresponding to the simulation results, the degree awarded to Americans and Temporal Residents in higher education (Doctoral and Master's) is increasing (Figures 1 and 3), that is, there are few "variety of goods" in the simulation results. Therefore, the results of this simulation suggest that the number of high-skilled workers will increase for a while and then begin to decrease, and economic progress will stagnate after sufficient innovation has progressed. However, it is possible to accomplish continuous innovation by changing exogenous factors (the difficulty of access to learning by region and benefit of inventors), factors not covered (the variety of goods deteriorates and decreases), as well as economic and educational policies. For example, higher education in the field of engineering in the United States tended to stagnate in the early 2000s (Figure 3).

However, the information revolution may have renewed the economic environment, created room for new product development, and increased demand for high-skilled workers.

Contrarily, the number of graduate students enrolled in Japan is decreasing for Japanese and increasing for foreigners (Figure 5). The information revolution is slow in Japan, and it may not be shifting to a new economic environment. In the future, as the information revolution progresses in Japan, the economic environment will change, and there will be room for new product development, which may increase the number of graduate students and high-skilled workers.

Future research should consider the geographical agglomeration of star innovators (Zucker & Darby, 2014). Additionally, analysis using the multi-regional model would reveal the factors that cause developed regions to lose status and underdeveloped regions to develop further.

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