Endogenous Growth of the Ageing Economy with Intra-Generational Heterogeneity over Migration Status

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ABSTRACT: This paper seeks to examine the effects of the ageing population in Illinois with the inclusion of the household's ex-ante intra-generational heterogeneity across migration status. The empirical results show that there are significant gaps in returns to education between migration statuses in Illinois; further, there exist significant relationships between a resident's demographics and the probability of in- and out- migration to/from Illinois. Using a two-sector Overlapping Generations (OLG) model incorporated with the intra-generational heterogeneity over migration status, this paper projects the economic growth of Illinois in the future. This paper also shows that the effects of the government's immigration policy, that aims at replacing low-productive international immigrants with native and relatively high-productive unemployed individuals who have been unemployed, are very limited in terms of per-capita income, welfare and aggregate productivity. On the contrary, a tax and transfer policy inducing international immigrants to invest more in their education works relatively better under the demographic transition. Furthermore, under this policy scheme, the native's human capital stock also improves because of positive spillover effects even though the transfer systems direct beneficiary is the international immigrant group.

KEY WORDS: Population Ageing; Human Capital; Intra-Generational Heterogeneity; Educational Transfer

1 Introduction

Overlapping generation (OLG) models have been used extensively to study the impacts of population ageing on the economy. Included in this set are the analyses of Sadahiro and Shimasawa (2002, 2004), Park and Hewings (2009), Ludwig *et al.* (2007) and Kim and Hewings (2010). In these studies, the household agents belonging to the same generation have identical parameter values and asset endowments. That is, the only heterogeneity factor in the model is the agent's age or generation. Therefore, the solutions of household agents' optimization problems are necessarily identical if they belong to same generation.

As a breakthrough in the development of a heterogeneous agent model in a dynamic general equilibrium context, Aiyagari (1994) proposed the model where each agent is of measure zero and lives infinitely. In his model, agents are *ex-ante* homogeneous but *ex-post* heterogeneous, depending on the sequence of realizations of uninsurable idiosyncratic earnings shock. The history of realized earning shocks naturally leads to borrowing constraints on individuals; consequent fluctuations in consumption can be mitigated only by precautionary individual savings. Since agents' histories of earning shocks are different, the equilibrium exhibits cross-sectional distributions of wealth, saving and consumption. Huggett (1996) adopted this ex-post heterogeneity framework within the overlapping generation model to compare the age-wealth distribution to the corresponding distributions in the US economy. However, these papers restrict attention only to the steady state equilibrium since solving this type of model is computationally very intensive.

Alternatively, Kotlikoff *et al.* (2002) adopted *ex-ante* heterogeneity within the perfect foresight overlapping generation framework for analyzing distributional effects of social security alternatives. Their model incorporates intra-generational heterogeneity in the form of twelve lifetime-earnings groups: each group has its own initial skill level and its own longitudinal age-skill profile. They showed that privatizing social security can generate significant long-run economic gains in the US. This model and its methodology was adopted by various studies, that focused primarily on the effects of public pension reforms for the developed countries in which fiscal pressures on the pension system are arising due to population ageing. A typical analysis would be that of Börsch-Supan *et al.* (2002) for Germany. In this paper, members of the same generation are sorted into the categories of employment, unemployment, non-participating in the labor force and retirement to track the evolution of the aggregate labor supply. However, this model assumes each agent's earning ability is an exogenous function of her age and/or type, without paying attention to the role of endogenous growth of human capital stock.

This paper seeks to examine the effects of ageing population with inclusion of a household's ex-ante intra-generational heterogeneity across migration status, extending the analysis presented in Kim and Hewings (2010). Kim and Hewings (2010) showed that the policy measures that encourage an agent to invest more in education is very effective in mitigating the negative effect of population ageing on the regional economy; but the policy that focuses on the direct redistribution of wealth cannot address the challenge of population ageing in terms of per-capita income, welfare and equity of income distribution. In addition, this paper compares the effects of policy alternatives in terms of enhancing the per-capita income and welfare under population ageing. This paper is organized as follows. In the section 2, gaps of return to schooling are estimated across migration status with a stylized Mincer wage regression. An attempt is made to explore the relationship between an individual's demographic profile and the probability of in- and out- migration with a focus on Illinois.[1] Section 3 contains a description of the model, within which the impact of population ageing and effects of policy measures will be analyzed later. Section 4 describes the calibration procedure with the empirical results. The computational results will be presented in the section 5. Section 6 concludes the paper.

2 Empirical evidence

2-1 Heterogeneity of returns to education

Persistent efforts have been made to analyze differentials by race and migration status in the labor market performance in the field of labor economics. In particular, the return to educational investment plays a key role in labor issues such as allocation of resources, determinants of income inequality and explanation of past growth rate and so forth. For example, Altonji and Blank (1999) adopted a Mincerian regression to show that there were ongoing and significant race differences in the labor market, even after controlling for occupational and industry location. They showed that the returns to education for blacks are actually stronger than for whites, but the returns to experience for blacks are substantially lower than those for whites. Altonji and Blank (1999) concluded that this sort of disadvantage for blacks significantly offsets higher returns to education for blacks. Bratsberg and Terrell (2007) examined rates of return to education of immigrant groups by country of origin, revealing the relationship between attributes of a country's educational system and the rate of return to schooling received by US immigrants from that country.

As briefly described above, the Mincer (1958, 1974) model has been extensively adopted in empirical studies to estimate returns to schooling years and to explain the factors that generate wage gaps between interested groups. The Mincerian model can be stylized as:

$$\log[w(s,x)] = \alpha_0 + \rho_s s + \beta_0 x + \beta_1 x^2 + \varepsilon \tag{1}$$

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[1] Illinois is used for illustrative purposes since it is a region with high international in-migration and significant out-migration as well as a region facing the typical challenges of an ageing population. Further, the paper builds on several years of research integrating demographic-economic models that incorporate the characteristics of OLG

where $w(s,x)$ are earnings at schooling level s and working experience x and ρ_s is the marginal effect of schooling or returns to education. In the present paper, a Mincerian regression model is adopted to estimate different returns to education across migration status in Illinois. The sample data for this analysis (see table 1) are obtained from the American Community Survey (ACS, 2007). It should be noted that all household members such as spouse, children and parents are included in the analysis if they are more than 18 years old. However, individuals who reported that they were not employed or not in the labor force were excluded.

<<insert table 1 here>>

The sample was segregated into four comparison groups according to its migration status, comparing current location with residence in the prior year: individuals were grouped into (i) those who remained in Illinois, (ii) migrated into Illinois from the other states, (iii) migrated into Illinois from other nations and (iv) moved out of Illinois.

The Mincerian regression is as follows:

$$\log(\text{annual earnings}) = \beta 0 + \beta 1 \text{ age} + \beta 2 \text{ age2} + \beta 3 \text{ schooling year} + \text{residual}. \quad (2)$$

Here, β_3 measures returns to education.

<<insert table 2 here>>

There is a technical but important problem that needs to be addressed: measurement of schooling years. Since the Census Bureau does not provide the schooling year data but respondent's degree or diploma based information, this has to be transformed into schooling years. One option would be to use the following tabulation between Census Bureau' educational attainment data and schooling years (see table 2). In this tabulation, schooling year is assigned as a mean value of each category in table 5 of Jaeger (2003) except for the categories of professional and doctorate degrees.

<<insert table 3 here>>

The estimation results imply that there exist significant gaps in the returns to education over the migration status (1st-3rd column in table 3). The coefficients of schooling years were 0.190 (domestic immigrants) > 0.129 (natives) > 0.109 (international immigrants). However, one should be very cautious in interpreting these estimation results. The overall distribution of earnings across schooling years for domestic immigrants should be lower than natives even though the returns to schooling for domestic immigrant is higher than natives. To explore this issue, the following alternative regressions were run with the dummy variables of migration status:

$$\log(\text{annual earnings}) = \text{constant} + \beta_1 \text{ age} + \beta_2 \text{ age}^2 + \beta_3 \text{ schooling year} + \beta_4 \text{ d\_int'l} + \beta_5 \text{ d\_domestic} \quad (3)$$

Note that there exist notable negative effects from the dummy variables on earnings in Illinois (last columns in tables 3). For example, the coefficients for the dummy variables, representing domestic and international immigrants, were -0.121 and -0.485 respectively. These results, in particular, verify that the overall distribution of earnings over ages of domestic immigrants is notably lower than natives even though the returns to education for domestic immigrants are very high. The most important result from the estimation above is that the earnings distribution over ages and returns to schooling of the international immigrants are the lowest among three migration status groups in IL.

2-2 Migration and demographics

Immigration: From ROUS to Illinois

Within the literature that has evaluated the migration associated with demographic issues, Frey (1995) analyzed in- and out-migration patterns of California from 1990 Census data. In his paper, he discovered that California's out-migration consists of two different systems: first, the exporting of lower income and less-educated residents to near-by states and secondly, the redistribution of better-educated and higher income migrants across the rest of the US. Meyer and Speare (1985) showed that mobility behavior is associated with socio-demographic characteristics, using a longitudinal data set of Rhode Island from the Census. For example, younger, married, and more affluent elderly are more likely to select out-of-state migration. In case of recent analysis on Illinois, Yu (2009) describes the migration patterns of Illinois such as the average household income of in- and out- migrants of Illinois, using the Internal Revenue Service data for 1992 through 2006. She revealed that there is a notable discrepancy in the income levels of domestic and international in- and out- migrants of Illinois; further, she noted that, on average, $1.682 billion of personal income drains out of Illinois per year. The literature reveals that migration is deeply affected by residents demographic and skill factors including age, schooling years and household income.

To explore the issue further, a binary logit regression model, whose dependent variable is whether the individual selected Illinois or not, was estimated, where move-in (=1) and no move-in (=0). The analyzed sample is composed of individuals who did not live in Illinois one year ago and have the experience of moving *between states* for the previous one-year. Individuals younger than 18 years old were excluded. Attention was directed to estimating the probability of mobility with demographic and skill factors, which are related with age, income and schooling years. In the next section, the empirical results of this section will be used in the calibration of the dynamic OLG model.

The regression specification is as follows:

logit (prob. of move into Illinois) = constant + γ_1 age + γ_2 log(household income) + γ_3 schooling years + γ_4 d_int'l + residual (4)

where d_int'l represents an individual who lived outside the US in previous year.

The estimation results imply that the probability of moving into Illinois from ROUS is inversely related to age and household income, but positively related to years of schooling. Further, international immigrants have a higher probability of choosing Illinois as their destination than US domestic residents (table 4).

<<insert table 4 and figure 1 here>>

Now, to check the expected probability of moving into Illinois, the other explanatory variables are set equal to their mean values except the age and dummy variables. Figure 1 plots the expected probability of moving into Illinois according to an individual's age. The results reveal that a domestic resident who is 40 years old, who is going to move between states, chooses Illinois as a destination with the probability around 3%. However, the expected probability declines gradually as the individual ages.

Out-migration: From Illinois to ROUS

A similar binary logit regression model was created to explore out-migration, whose dependent variable is whether the individual moves out of Illinois: move-out (=1) and no move-out (=0). The sample is restricted to individuals who lived in Illinois the previous year and has moved *within and between states* for the previous year. The binary logit regression is specified as follows:

logit (prob. of move out from Illinois) = constant + γ_1 age + γ_2 age^2 + γ_3 log(household income) + γ_4 schooling years + residual. (5)

<<insert table 5 here>>

The estimation result reveals that there exist a slight quadratic relationship between age and probability of emigrating from Illinois (table 5).[2] Note that the sign of the coefficient of logged household income is positive. This positive sign should be compared with the result of in-migration analysis (case of ROUS → IL) in the previous section, where the coefficient of logged household income was negative. This result implies that there is a reverse effect of household income level on in- and out- migration to Illinois. Lower income residents outside Illinois have a higher probability of migrating into Illinois than higher income residents. On the contrary, higher income residents in Illinois are more likely to migrate out of Illinois than lower income residents. These results confirm the findings of Yu (2009).

<<insert figure 2 here>>

Again, to check the expected probability of moving out of Illinois, the other explanatory variables are set equal to their mean values except age. The expected probability declines until the individual is about 50 years old and then increases afterwards[3] (see figure 2). However, the overall shape of this expected probability seems to be partially counter-intuitive: the probability of migrating out of Illinois peaks for the cohort aged 80 years and more. This odd shape of expected probability comes from the fact that the magnitude of the explanatory variable age^2 in the binary logit model accelerates rapidly as the age approaches to 80+ ; this inflated magnitude of covariate age^2 and its positive coefficient dominates the effects from the other explanatory variables. Note that the size of the sample of those 80+ is relatively small; thus, the regression result itself was not affected significantly by the data whose individual's age is 80+. An alternative binary response model was adopted to deal with this problem in the expected probability as follows:

$$\text{logit (prob. of move out from Illinois)} = \text{constant} + d\_age\_cohort'\beta + \gamma_1 \log(\text{household income}) + \gamma_2 \text{ schooling years} + \text{residual}. \quad (6)$$

where *d_age_cohort* is composed of dummy variables representing the age-cohort group such as below 30, 30-40, 40-50, 50-60, 60-70, 70-80 and 80+. The results imply that there still exits the quadratic relationship between age and out-migration probability until age 70; but the probability of out-migration drops substantially after age 70 (table 6). Note that the sign and magnitude of

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[2] If we insert the squared age as an explanatory variable in case of the regression of ROUS → IL, as analyzed above, the coefficient estimate is not statistically significant.

[3] Further studies could be focused on analyzing quantitatively what forces drive this quadratic relationship between age and mobility. For example, individuals' participation in searching jobs during early years and amenity accessibility after retirement age would affect age and out-migration pattern.

logged household income and schooling years are largely consistent with the former binary regression. Figure 3 shows the expected probability over the age-cohort groups by using this binary regression results. The high expected out-migration probability between 60 and 80 could be interpreted as the high frequency of retirement migration to the other states from Illinois.

<<insert table 6 and figure 3 here>>

The empirical results presented in this section reveal that there are statistically significant gaps in the returns to education between the agents belonging to different migration groups in Illinois. This empirical evidence will be incorporated into the intra-generational heterogeneous OLG model, whose specification will be described in the next section. Also, the results indicated that there are linear and quadratic relationships between age and probability of in- and out- migration in Illinois. These results will be used for projecting the composition of residents of Illinois in terms of migration status.

3 Model Descriptions

There are three types of agents in the baseline model: households, firms and government. The households maximize utility, subject to the usual budget constraint. Household agents participating in the labor market at age 1 (that is, age category 1) would continue to participate in the market until retirement age and non-participating agents would continue to remain outside the market. Hence, it is assumed that there is no change in labor market status over a lifetime. We assume that there are no unemployed individuals if they participate in the labor market. Firms hire labor and rent physical capital to produce physical goods in a competitive market. The Government levies a social security tax on the workers and operates the social pension system of a "pay-as-you-go" type with the tax revenue. There are two sectors in the economy: physical goods and human capital sectors. The target period is 2001 through 2050, a period during which the ageing phenomenon is expected to assume greater importance in Illinois as well as the US. There exist J generations in every single year: the generations are overlapped every sample period.

3.1 Households

We suppose that households are heterogeneous in their returns to education. This intra-generational heterogeneity depends on their migration status even though they belong to same age-cohort. It is assumed that the individual enters into labor market at age 1 and retires at age j^*. Every agent is supposed to live until age J.[4] At the beginning of age 1, each agent, who will continue to participate in labor market, makes a decision on allocating resources between consumption and savings as well as splitting the endowment time between schooling and work for a whole life-time to maximize his/her life-time welfare. The instantaneous utility function has two arguments, consumption and investment in human capital:[5]

$$u(c_{t,j}, e_{t,j}) = \frac{c_{t,j}^{1-\gamma} + \theta e_{t,j}^{1-\gamma}}{1-\gamma} \quad \gamma > 1,\ 0 < \theta < 1 \tag{7}$$

where $c_{t,j}$ is consumption and $e_{t,j}$ is time fraction of investment in human capital[6] at time t and age j while θ is the parameter of the degree of educational investment motive and γ is the parameter of inverse of the inter-temporal elasticity of substitution. Hence, consumption also has two component, involving a decision about expenditures now as opposed to saving to facilitate consumption later. The individual's life-time utility function is as follows:

$$U_t^1 = \sum_{j=1}^{J} \beta^{j-1} u(c_{t+j-1,j}, e_{t+j-1,j}) = \sum_{j=1}^{J} \beta^{j-1} \left(\frac{c_{t+j-1,j}^{1-\gamma} + \theta e_{t+j-1,j}^{1-\gamma}}{1-\gamma} \right) \tag{8}$$

where U_t^1 denotes the lifetime utility of the individual who is born in the year t and the parameter β denotes the subjective discount rate. The individual who was born in time t has a following inter-temporal budget constraint:

$$\sum_{j=1}^{J} \left(\left(\prod_{k=t}^{t+j-2} \frac{1}{1+r_k} \right) c_{t+j-1,j} \right) = \sum_{j=1}^{j^*} \left(\left(\prod_{k=t}^{t+j-2} \frac{1}{1+r_k} \right) (1-\tau_{t+j-1}^p) h_{t+j-1,j} w_{t+j-1} (1-e_{t+j-1,j}) \right)$$
$$+ \sum_{j=j^*+1}^{J} \left(\left(\prod_{k=t}^{t+j-2} \frac{1}{1+r_k} \right) pen_{t+j-1,j} \right) \tag{9}$$

where r_t is the real interest rate , w_t is the wage rate and τ_t^p is the social security tax rate at time t while $h_{t,j}$ is the human capital stock and $pen_{t,j}$ is the level of pension benefit at time t and age j.

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[4] Note that age 1 in the model corresponds to age 20 in reality.
[5] If a formula or equation does not denote the migration group, the formula or equation is applied to all migration groups in an identical way.
[6] In the model, the individual whose age is between 1 and j^* allocates his/her endowment time (=1) into labor and education investment. Therefore, $0 \le e_{t,j} \le 1$ for $j = 1, ..., j^*$.

Every new generation in each year maximizes the lifetime utility function (8) under the budget constraint (9). The Euler equations (10) and (11) could be derived by computing the first order conditions with regard to consumption, saving and education investment time:

$$c_{t+1,j+1} = \left(\beta(1+r_{t+1})\right)^{1/\gamma} c_{t,j} \tag{10}$$

$$e_{t,j} = \left(\frac{\theta}{(1-\tau_t^p)w_t h_{t,j}}\right)^{1/\gamma} c_{t,j} \text{ if } j \le j^*. \tag{11}$$ [7]

An individual's wealth, which, in this model, means accumulated personal saving, at time t and age j ($=a_{t,j}$) comprises the following components:

$$a_{t+1,j+1} = (1-\tau_t^p)h_{t,j}w_t(1-e_{t,j}) + (1+r_t)a_{t,j} - c_{t,j} \text{ if } 1 \le j \le j^*$$

(12)

$$a_{t+1,j+1} = pen_{t,j} + (1+r_t)a_{t,j} - c_{t,j} \text{ if } j > j^*.$$

The aggregate supply of physical capital stock at time t is:

$$K_t^s = \sum_q \sum_j a_{t,j}^q \left(v^q N_{t,j}^q\right) \tag{13}$$

where q denotes migration status, $N_{t,j}^q$ denotes population size of age-cohort j in time t belonging to group q and $a_{t,j}^q$ denotes savings of agents of age-cohort j in time t belonging to group q and v^q denotes labor-market participating rate of group q.

Also aggregate consumption at time t is:

$$C_t = \sum_q \sum_j c_{t,j}^q \left(v^q N_{t,j}^q\right) \tag{14}$$

where $c_{t,j}^q$ denotes consumption of agents of age-cohort j in time t belonging to group q.

3.2 Human capital

We follow the human capital production function of Sadahiro and Shimasawa (2002):

$$h_{j+1,t+1}^q = (1-\delta_h)h_{j,t}^q + B^q(mk_t)^\phi (h_{j,t}^q e_{j,t}^q)^{1-\phi} \tag{15}$$

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[7] Note that we have a boundary condition $e_{t,j} \le 1$.

where k_t is the physical capital/labor ratio while B^q is the parameter for accumulation efficiency of human capital applied to group q, m is the portion of physical capital stock that is allocated for producing the human capital stock, δ_h is the parameter for the depreciation rate of human capital stock and ϕ is the parameter of the elasticity of the human capital formation function. Therefore, we assume that some portion of physical capital is needed for accumulating the human capital, in addition to the schooling investment. The next step involves developing a rule of assigning a human capital stock for age 1 generation of each year. Following Sadahiro and Shimasawa (2002), it is assumed that the new generation is born with a portion of human capital stock of previous generations according to the following scheme:

$$h_{t,1}^q = \pi^{hc,q}\left(\left(\sum_{j=1}^{j^*} h_{t-1,j}^q \left(v^q N_{t-1,j}^q\right)\right) / \sum_{j=1}^{j^*}\left(v^q N_{t-1,j}^q\right)\right)$$

(16)

where $\pi^{hc,q}$ is the parameter of efficiency of human capital transmission applied to group q. Now, define aggregate human capital stock at time t as:

$$H_t = \sum_q \sum_{j=1}^{j^*} h_{t,j}^q \left(v^q N_{t,j}^q\right). \quad (17)$$

Then, the aggregate supply of effective labor can be computed as:

$$L_t^{e\ s} = \sum_q \sum_{j=1}^{j^*} (1-e_{t,j}^q) h_{t,j}^q \left(v^q N_{t,j}^q\right). \quad (18)$$

3.3 Firms

Each firm produces a composite good by renting physical capital and effective labor in order to maximize its profit each year. A Cobb-Douglas production function is adopted that has the following specification:

$$Y_t = A(K_t^d)^{\alpha}(L_t^{e\ d})^{1-\alpha} \quad (19)$$

where K_t^d the demand of physical capital and $L_t^{e\ d}$ is the demand of effective labor at time t while A is the parameter of total factor productivity and α is the parameter of the physical capital income share. Factor prices are determined in the competitive market:

$$r_t = \alpha A(K_t^d)^{\alpha-1}(L_t^{e\ d})^{1-\alpha} - \delta \quad (20)$$

and

$$w_t = (1-\alpha)A(K_t^d)^{\alpha}(L_t^{e\ d})^{-\alpha} \tag{21}$$

where δ is physical capital depreciation rate.

3.4 Government

The government operates the social security system: government levies a social security tax on labor income and transfers the pension benefit to retirees. The government's budget is assumed to be balanced every period:

$$\tau_t^p \left(\sum_q \sum_{j=1}^{j^*} \left(v^q N_{t,j}^q \right) \left((1-e_{t,j}^q) w_t h_{t,j}^q \right) \right) = \sum_q \sum_{j=j^*+1}^{J} \left(v^q N_{t,j}^q \right) pen_{t,j}^q \, . \tag{22}$$

The magnitude of the annual pension benefit of each retiree is dependent on his/her average yearly (gross) labor income before retirement. The Government transfers a pension benefit to a retiree which amounts to his/her yearly average labor income multiplied by replacement ratio (ξ).

4 Calibration

This paper uses the same parameter values as Kim and Hewings (2010) except for the parameters of return to education (B) and degree of efficiency in transmitting human capital stock from generation to generation (π^{hc}) as well as the initial human capital stock distributions.

Given the age-cohort population structure and death rate of each age for the initial year of the model, the size of the population belonging to each age-cohort in the future could be estimated simply using a modified cohort survival model. That is, for example, the number of population of age-1 cohort in 2010 multiplied by (1-death rate) is same as the number of population in age-2 cohort in 2011. This projection result provides the basic population structure of Illinois. However, the population structure will be affected by migration so that the actual age-population structure might be significantly different from the basic population structure. The following procedure is used to forecast the age-population structure:

# of population belonging to age *j* in time *t* in Illinois
= (1- death rate of age *j-1*) × # of population belonging to age *j-1* in time *t*-1 in Illinois
+ # of domestic immigrants of age *j* in time *t* to Illinois
+ # of international immigrants of age *j* in time *t* to Illinois
- # of out-migrants of age *j* in time *t* from Illinois

The expected number of domestic and international in-migrants to Illinois and out-migrants from Illinois can be estimated by using the empirical result of section 2. For example, the following projection strategy could be adopted for estimating the number of domestic in-migrants in the future. First, the projections of the *national* age-cohort population structure in the future are available from the US Census Bureau. By using ACS (2007) data, it is possible to compute the nation's yearly ratio of individuals per age-cohort who move between states from among the total individuals in each state. Now, the number of *potential* in-migrants into Illinois and their distribution across ages are known. Next, the estimation results summarized in table 4 and figure 1 are used to compute the expected number of domestic in-migrants into Illinois per age-cohort in the future. Similar methods are used to estimate the number of international in-migrants and out-migrants[8] per age-cohort for every year in the future. Table 7 shows the example of calibration of the population structure related to migration status. The calibration procedure regarding the population of migrants is largely consistent with the actual population structure of ACS (2007).

<<insert table 7 and figure 4 here>>

Figure 4 presents the growth rate of the retirees. From this figure, it is possible to conjecture that the ageing phenomenon of Illinois will accelerate until the mid 2020s and then decelerate substantially. In addition, it is assumed that a domestic in-migrant's status lasts only one year: that is, the heterogeneity across domestic in-migrants and native residents will disappear in one year as the in-migrant takes on the characteristics of the existing residents. However, the characteristics as an international in-migrant are not assumed to disappear permanently; for

[8] For computing the number of out-migrants, we used the results of the binary response model, which included the dummy variables representing the age-cohort groups as its covariates.

example, prior experience with migration may make a household less risk adverse to migrating again in contrast with a household that has only remained in the same state.

The returns to education parameter value should be given to natives, domestic in-migrants and international in-migrants consistently with the result of section 2. For this, it is assumed that the labor earnings per a unit of working time reflect labor productivity of the corresponding worker perfectly. The value of the parameter *B* of each migration group should be consistent with the exponentials of coefficients of schooling year from table 3 (1st to 3rd column). Therefore, the values were assigned from table 8. The value of *B* in Kim and Hewings (2010) was 0.28; thus, the assignment of the parameter values is made so that the average of parameter value weighted by each migration group's composition ratio is 0.28.

<<insert tables 8 and 9 here>>

In section 2, it was noted that the migration effect of being an international immigrant on earnings is the lowest among the three migration categories. This could be a consequence of notable gaps in the average human capital stocks belonging to *young* generations of each race. To calibrate this interpretation into the model, different values for the parameter π^{hc} are assigned across races (table 9). Note that this parameter determines the level of transmission of human capital stock from proceeding generation to the new generation. Again, the weighted average of this parameter value is set equal to the values in Kim and Hewings (2010) (=1.0). Also, the initial human capital stock distribution over ages was assumed to be heterogeneous between migration status; but their average values should be same as that in Kim and Hewings (2010).[9]

5 Computational results

The computational results show that per-capita output will increase by 46.4% from 2001 to 2050. Growth of per-capita output will decrease until the mid 2020s and then will recover thereafter (figure 5). The computational results imply that the gaps of human capital levels between continuing residents ("native") and international immigrants will be maintained in the future.[10] International immigrants' human capital level is 58.0% smaller in 2001 and will be still 46.4% smaller than natives in 2050 (figure 6).

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[9] See the appendix for the assumptions and estimation procedure of the initial human capital distribution of each group.

[10] Due to restrictive assumption of this model, that is domestic immigrants will turn to natives in one year after he/she immigrated into Illinois, comparison between domestic immigrants and native residents is meaningless.

<<*insert figures 5 and 6 here*>>

Policy makers could consider two alternative policies because there are significant productivity gaps between migration statuses. Those policies are called "international immigration restriction" and "educational transfer" policy in this paper. First, international immigration restriction policy strengthens the criteria for employment of international immigrants; therefore, natives' unemployment rate will decrease. This policy stems from the belief in the crowding out notion, that immigrants displace native residents in the job market; alternatively, immigration policy could target specific occupational needs to maximize matching immigrants with unmet job demands thus minimizing the competition with native residents. In the simulation, *newly* immigrated international individuals' labor market participation rate is set to be zero. Instead, these international individuals are replaced with native individuals who have been unemployed but have higher productivity than international immigrants. Secondly, we experiment with the educational transfer policy regime, which was explored in Kim and Hewings (2010). When the government operates the educational transfer system, it levies an educational tax on household's income that is reimbursed proportionally to his/her opportunity cost stemming from time spent on educational investment. In this experiment, the government's educational transfer policy targets the individuals with relatively low productivity, namely international immigrants. For illustration, the reimbursement rate is set to .20 but it is assumed that the government reimburses part of opportunity cost of schooling investment of *only international immigrant workers*.

This educational transfer policy for international immigrants could be supported by the following information. According to Capps *et al.* (2003), 18% of all foreign-born workers attained less than 9^{th} grade; on the contrary, only 1% of native workers attained less than 9^{th} grade. Even in a same group of low-wage workers, defined as workers earning less than 200 percent of the state minimum wage, the gaps of formal schooling between the international immigrant and native workers are obvious: 28% of foreign-born workers finished less than 9^{th} grade while only 2% of native workers attained less than 9^{th} grade. Also, 46% of all foreign-born workers have limited English proficiency. Without fiscal incentives, the lack of formal schooling and English proficiency would continue to play as a barrier to international immigrant workers' participation in schooling and thus accumulation of human capital with the result that it would have a deleterious impact on their current income and their capacity to accumulate assets for retirement.

For simulation, we assume that government's social security system and educational transfer system are operated independently from each other. Also we continue to assume that the government's budget is balanced every period. Therefore, the budget constraint corresponding to the educational transfer system is like following while the constraint of social security system is same as (22):

$$\tau_t^e\left(\left(\sum_q\sum_{j=1}^{j*}v^q N_{t,j}^q\left((1-e_{t,j}^q)w_t h_{t,j}^q\right)\right)+\left(\sum_q\sum_{j=1}^{J}v^q N_{t,j}^q\left(r_t a_{t,j}^q\right)\right)\right)=\mu\sum_{j=1}^{j*}v^{\text{int}}N_{t,j}^{\text{int}}\left(e_{t,j}^{\text{int}}w_t h_{t,j}^{\text{int}}\right) \qquad (23)$$

where the superscript *int* denotes international immigrants.

Computational results show that educational policy focused on improving human capital of low-productive workers is preferable in terms of improving aggregate productivity in contrast to the immigration restriction policy that restricts the international immigrants' employment. When governments restricts newly arrived international immigrants' employment even completely and replaces those workers with relatively high productive native residents, the positive effects on per-capita output is close to constant in term of deviation from the baseline economy. However, if the government tries to improve international immigrant worker's productivity in a way that the policy encourages immigrant people to spend more time in education, the effect on per-capita output will accumulate and grow gradually (figure 7).

<<insert figure 7 and table 10 here>>

This is mainly because aggregate human capital stock is more positively affected by educational policy (table 10). In 2050, aggregate human capital stock under the educational transfer policy regime is 4.27% higher than the baseline economy where no government policy is involved. On the contrary, human capital under the restrictive immigration policy is barely (0.66%) higher than the baseline economy. It should be noted that the educational transfer policy, that is focused on improving international immigrants' human capital stock, also improves the human capital stock of native workers by 4.16% while the restrictive immigration policy has no such impact. This could be interpreted to imply that there exist the positive spillover effects between native and international immigrant's human capital stock. Further, as Park and Hewings (2009) have documented, under an ageing economy with no immigration, welfare effects are likely to deteriorate as the shrinking of the labor force raises not only the dependency ratio but also bids up wages that may reduce the region's competitiveness as well as reducing gross product and gross product per capita. However, the findings in this paper suggest that absent a proactive program to enhance immigrants' human capital, continued immigration may result in deterioration in income inequality.[11]

6 Conclusion

In this paper, we have developed a two-sector OLG model with intra-generational heterogeneity over individual's migration status. Also we examined the impact of population ageing on the regional economy and examined the effect of two alternative government policy measures on the economy. To accomplish this, we set up an empirical model to investigate the implication of heterogeneity over migration status. We found out that there are significant gaps of return to education between migration status in Illinois: there are overall noteworthy negative effects for international immigrants on their earnings. Also, we revealed with empirical data that young and low-income residents outside Illinois have a higher probability of in-migrating to Illinois while older and high-income residents inside Illinois have a higher probability of out-migrating from Illinois.

Using a two-sector OLG model, we demonstrated that the growth of the Illinois economy will decelerate substantially until mid 2020's due to population ageing and then partially recover. We drew some implications for policy makers. The positive effects of a policy that restricts employment of the international immigrants turn out to be limited in terms of per-capita income, welfare and aggregate productivity. On the contrary, a tax and transfer policy that induces international in-migrants to invest more in their education works much better. Even though the regime's direct beneficiary is an international immigrant, the natives' human capital stock also improves significantly because of positive spillover effects. Overall, with the limited fiscal budget constraint, government policies should be focused on facilitating the growth of the human capital of the disadvantaged groups (such as international immigrants in this paper) to maintain the sustainable growth in the future, taking the fact into considerations that today's skilled workforce are rapidly approaching to retirement age.

Finally, two comments on further research topics will be presented. First, the subject this paper explored could be examined further by adopting the approaches of Aiyagari (1994) and Huggett (1996). In our paper, even though we incorporated the heterogeneity between migration status,

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[11] The unrest in the Paris suburbs with large North African ethnic populations in 2005 reflected the problems of lack of opportunity for youth with limited human capital endowments. Many US cities with significant Hispanic populations may face similar challenges in the decades ahead.

the heterogeneity inside the same migration status group was not captured in our model. Therefore, further study could assume that the individuals are exposed to the uninsured idiosyncratic productivity shock over their lifetime. The transition specification of risks including a Markov chain of the shocks could be calibrated from the empirics including the results in section II. This kind of paper would present a more detailed and robust picture of transition path of economic variables such as income distribution and welfare.

Secondly, as Yoon (2006) revealed, the heterogeneity of consumption bundles among different age-cohort groups as an empirical fact, our one-composite-commodity general equilibrium model could be extended to trace the interactions between the change of demographics and development of consumption structure and growth of the economy. As a starting point, Foellmi (2005)'s growth model could be adopted into our OLG framework. Foellmi (2005) accepted the non-homotheticity but proposed an hierarchical preference structure, whose property eventually enables individual's consumption composition to exhibit different patterns according to the development of an individual's income level. Hence, heterogeneity in consumption presents an important challenge since it will have important impacts on what goods and services are produced and consumed potentially changing income generation with important welfare impacts over time.

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Table 1: Data description: ACS 2007

	U. S				Illinois			
	Average	Std. Dev	Min	Max	Average	Std. Dev	Min	Max
Age	39.0	23.2	0	95	38.6	23.1	0	93
Log of household income	11.1	1.2	0	16.1	11.1	1.2	1.4	16.1
Obs.	2,994,662				127,458			
Sex	Male 48.6%, Female 51.4%				Male 48.4%, Female 51.6%			
Race/Ethnicity	-White 77.9%, Black 9.9%, Asian 4.3% -Hispanic 12.4%				-White 78.3%, Black 10.7%, Asian 3.7% -Hispanic 10.5%			
Student	- Student 25.4% - No student 71.1% - NA 3.5%				- Student 26.5% - No student 70.0% - NA 3.5%			
Employment	- Employed 46.7% - Unemployed 2.9% - Not in labor force 29.8% - NA 20.5%				- Employed 47.6% - Unemployed 3.4% - Not in labor force 28.0% - NA 21.0%			

Source: Integrated Public Use Micro-data Series, Minnesota Population Center, University of Minnesota

Table 2: Tabulation between Census' educational attainment and schooling years

Census' educational attainment categories	Schooling years
No school completed	1.30
Nursery school-4th grade	3.92
5th-6th grade	6.22
7th-8th grade	7.84
9th grade	9.08
10th grade	9.90
11th grade	10.81
12th grade, no diploma	11.38
High school graduate, or GED	12.00
Some college, less than 1 year	13.35
One or more years of college but no degree	13.87
Associate degree	14.29
Bachelor's degree	16.04
Master's degree	17.57
Professional degree	18.57
Doctorate degree	20.57

Note: School years of professional degree = school years of master's degree + 1
School years of doctorate degree = school years of master's degree + 3
Source: Jaeger (2003) except for the cases of professional degree and doctorate degree

Table 3: Mincerian regression results: different migration status

	I. Natives in IL	II. Domestic immigrants to IL	III. Inter'l immigrants to IL	Current residents in IL (I+II+III)	Emigrants from IL
constant	4.196 (0.039)	2.195 (0.324)	4.270 (0.751)	4.172 (0.039)	2.875 (0.255)
age	0.191 (0.002)	0.250 (0.016)	0.168 (0.041)	0.192 (0.002)	0.233 (0.013)
age^2	-0.002 (0.000)	-0.003 (0.000)	-0.002 (0.001)	-0.002 (0.000)	-0.002 (0.000)
schooling year	0.129 (0.002)	0.190 (0.014)	0.109 (0.030)	0.130 (0.002)	0.159 (0.012)
d _int'l				-0.485 (0.065)	
d_dom				-0.121 (0.031)	
obs.	66,104	1,262	280	67,646	1,626
R^2	0.2587	0.3296	0.1990	0.2611	0.3484

Note: standard errors are denoted inside the parenthesis.

Table 4: Result of binary logit regression: ROUS → Illinois

	Coefficient (Standard error)
Constant	-3.2992 (0.2016)
Age	-0.0083 (0.0015)
Log of household income	-0.0604 (0.0125)
Schooling year	0.0612 (0.0084)
d_int'l	0.1186 (0.0567)
Obs.	61,463
R^2	0.0064

Note: standard errors are denoted inside the parenthesis.

Table 5: Result of binary logit regression: IL → ROUS

	Coefficient (Standard error)
Constant	-3.7680
	(0.2492)
Age	-0.0164
	(0.0069)
Age^2	0.0002
	(0.0001)
log(household income)	0.0841
	(0.0115)
schooling year	0.1189
	(0.0099)
Obs.	11,562
R^2	0.0185

Table 6: Result of binary logit regression with the dummy variables: IL → ROUS

	Coefficient (Standard error)
Constant	-4.1589
	(0.2034)
d_age3040	-0.1327
	(0.0653)
d_age4050	-0.2071
	(0.0799)
d_age5060	-0.1124
	(0.0874)
d_age6070	0.6488
	(0.0997)
d_age7080	0.3392
	(0.1292)
d_age80	-0.4997
	(0.1612)
log(household income)	0.0954
	(0.0114)
schooling year	0.1169
	(0.0098)
Obs.	11,562
R^2	0.0251

Note: *d_age3040* represents the group of people who are ≥ 30 and < 40; and *d_age80 represents the people who are* ≥ 80.

Table 7: Ratio of migrants: Calibration vs. Survey data

	Ratio of residents who migrated *domestically* into IL for one year	Ratio of residents who migrated *internationally* into IL for one year	Ratio of residents who migrated out of IL for one year
Calibration in case of 2007	1.66%	0.47%	2.24%
ACS 2007	1.58%	0.43%	2.01%

Note: Based on the people who age >= 20.

Table 8: Parameter value of *B*: efficiency of human capital accumulation

	Coefficient of schooling year	Exp (Coef.)	Value assignment to *B*
Continual residents	0.129	1.1377	0.2796
Domestic immigrants	0.190	1.2092	0.2972
International immigrants	0.109	1.1152	0.2741

Table 9: Parameter value of π^{hc} : efficiency of human capital transmission

	Coefficient multiplied by dummy variable	Value assignment to π^{hc}
Continual residents	0	1.0087
Domestic immigrants	-0.121	0.8867
International immigrants	-0.485	0.5195

Table 10: Comparison of human capital stock of each group in 2050

	Baseline economy (A)	Under restrictive immigration policy (B)	Under educational transfer policy (C)	(B-A)/A	(C-A)/A
Whole workers	2.7599	2.7782	2.8778	0.66%	4.27%
Native workers	2.7842	2.7827	2.9000	-0.05%	4.16%

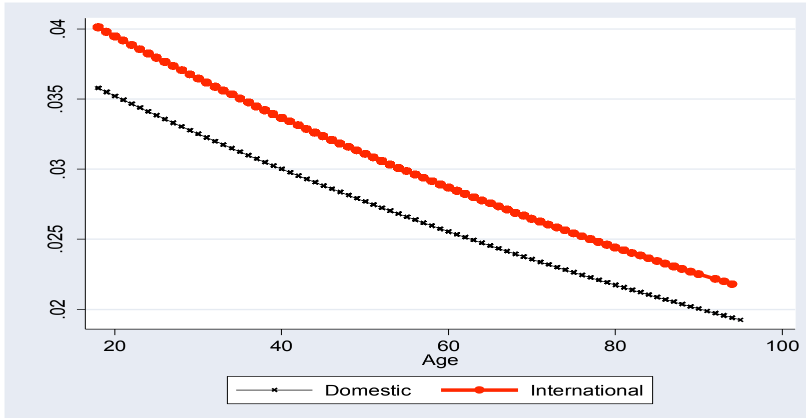

Figure 1: Expected probability of selecting move into IL from ROUS

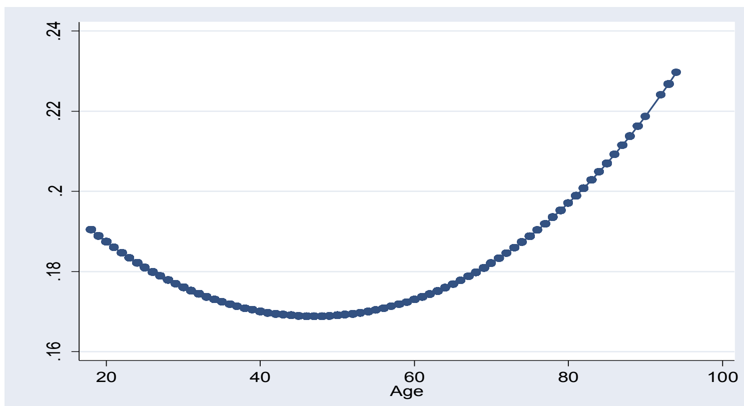

Figure 2: Expected probability of selecting moving out of IL to ROUS

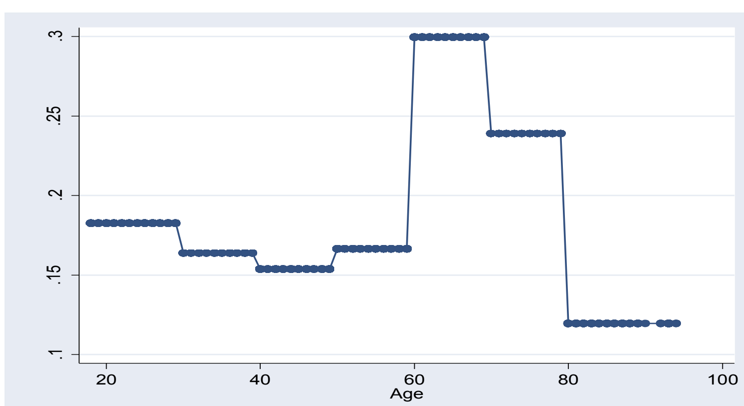

Figure 3: Expected probability of selecting moving out of IL to ROUS (alternative)

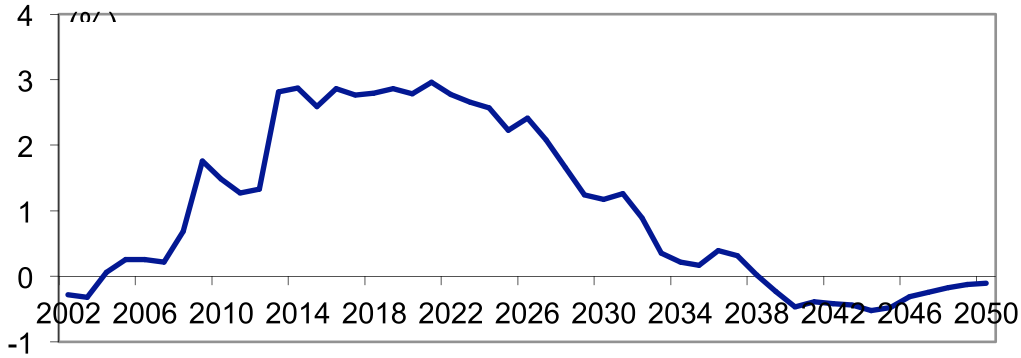

Figure 4: Growth rate of the retirees

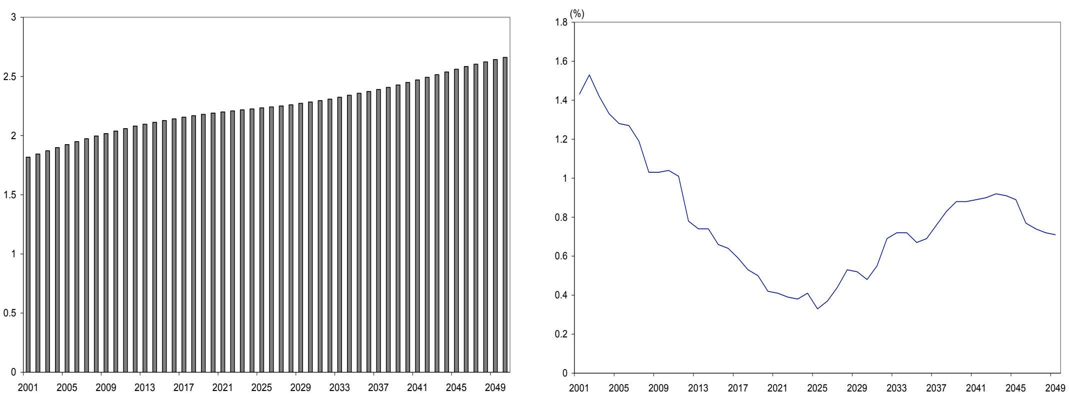

Figure 5: Per-capita output and its growth rate

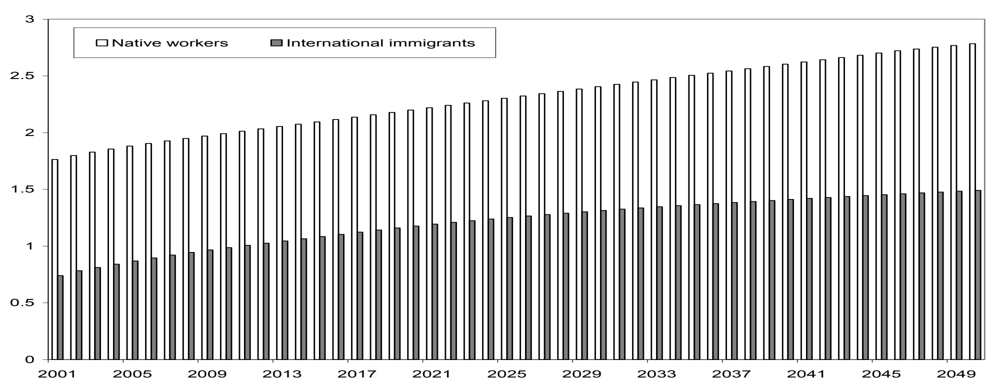

Figure 6: Average human capital stock per worker

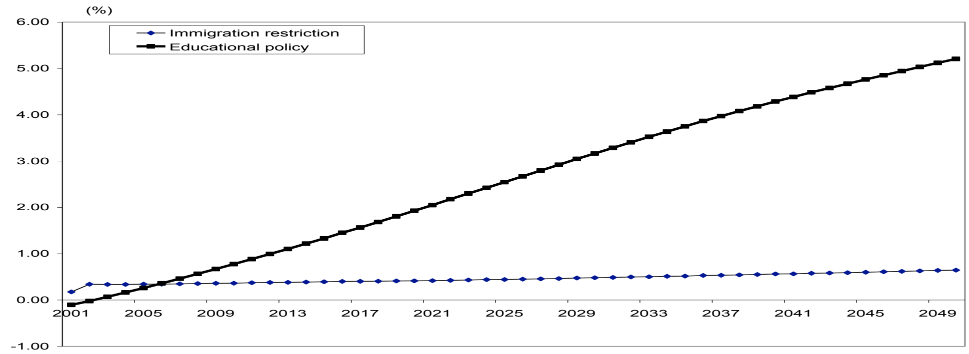

Figure 7: Deviation of per-capita output from baseline economy (%)

Appendix: Estimation of the initial human capital stock distribution over age-cohorts

In order to obtain the initial age-profile of human capital stock, we set up the following regression model:

log(annual earnings) = const.+ β_1 age+ β_2 d_domestic+ β_3 d_int'l+ β_4 age·d_domestic+ β_5 age·d_int'l+ ε

where d_domestic and d_int'l denotes the dummy variables representing domestic in-migrants and international immigrants respectivly. The right-hand side variables include the interaction of dummy and age variables to capture the heterogeneity of growth and levels of earnings from belonging to a certain migration status. Data set is same as the one for the former estimations in section 2. The following table demonstrates the estimation results.

Table: Estimation results for estimating age-earning profile

	Coefficients
constant	9.3224 (0.0153)
age	0.0187 (0.0003)
d_domestic	-0.7452 (0.1055)
d_int'l	-1.3222 (0.2143)
age · d_domestic	0.0196 (0.0030)
age · d_int'l	0.0234 (0.0060)
obs.	67,646
R^2	0.0472

Note: standard errors are denoted inside the parenthesis.

From these results, we get the following estimation of age-earning relationship for each groups such as:

- log(annual earnings)=9.3224+0.0187*age for natives,
- log(annual earnings)=8.0002+0.0421*age for international immigrants and
- log(annual earnings)=8.5772+0.0383*age for domestic in-migrants.

Now we can get the estimates of logged annual earnings of each age-cohort for each group. The differences of estimated logged annual earnings of a certain age-cohort between the groups mean the ratio of annual earnings of that age-cohort between the groups. Now we assume two things: (i) the annual earnings perfectly reflect the human capital stock (or productivity) shown by the laborer for one year and (ii) the average of estimates of human capital stock distribution across the migration status are exactly same as the initial human capital stock distribution adopted in Kim and Hewings (2010).