ENDOGENOUS GROWTH OF THE AGEING ECONOMY WITH INTRA-GENERATIONAL HETEROGENEITY OVER RACE AND MIGRATION STATUS

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ABSTRACT: This paper seeks to examine the effects of the ageing population in Illinois with inclusion of the household's ex-ante intra-generational heterogeneity across race and migration status. For this, this paper empirically shows that there are significant gaps in returns to education between race and migration status in Illinois; and there exists significant relationships between a resident's demographics and the probability of in- and out- migration around Illinois. Using a two-sector Overlapping Generations (OLG) model incorporated with the intra-generational heterogeneity over race and migration status, this paper projects the economic growth of Illinois in the future. Also, this paper shows that an indirect educational policy, targeting the upgrading of the transmission channel of human capital stock from the old generation to the young generation, is more preferable than the direct employment policy in terms of long-run effects on per-capita income and social welfare under the population ageing phenomenon. This paper also shows that the effects of the government's immigration policy, which aims at replacing low-productive international immigrants with native, 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, 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 significantly because of positive spillover effects even though the transfer system's direct beneficiary is the international immigrant group.

KEY WORDS: Endogenous Growth; Human Capital Transmission; Overlapping Generations; Intra-Generational Heterogeneity; Population Ageing; Tax and 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 (2007), 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 kind 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, which focused primarily on 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 same generation are sorted into the categories of employment, unemployment, non-participating 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 little attention to the role of endogenous growth of human capital stock.

Endogenous growth of human capital stock under population ageing was extensively discussed in Sadahiro and Shimasawa (2002) and Kim and Hewings (2010). The latter showed that the policy measure which encourages 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 redistribution of wealth cannot address the challenge of population ageing in terms of per-capita income, welfare and equity of income distribution.

This paper seeks to examine the effects of ageing population with inclusion of household's ex-ante intra-generational heterogeneity across races and migration status, extending the analysis presented in Kim and Hewings (2010). 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 II, gaps of return to schooling are estimated across races and migration status with a stylized Mincer wage regression. An attempt is made to explore the relationship between an individual's demographic profile and in- and out-migration probability with a focus on Illinois. Section III contains a description of the model, within which the impact of population ageing and effects of policy measures will be analyzed later. Section IV describes the calibration procedure with the empirical results. The computational results will be presented in the section V. Section VI concludes the paper.

2 Empirical evidence

2-1 Heterogeneity of return 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 on. 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 are substantially lower, more than offsetting the advantage in educational returns. 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:

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

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 and race in Illinois. The sample data for this analysis (see table 1) is 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.

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. Also, the residents in Illinois were also divided into three groups according to race (white, black and others).

The first Mincerian regression is as follows:

$$\log(\textit{annual earnings}) = \beta_0 + \beta_1\, age + \beta_2\, age^2 + \beta_3\, schooling\ year + residual. \qquad (2)$$

Here, β_3 measures returns to education.

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 the categories of professional and doctorate degrees.

The estimation results imply that there exist significant gaps in the returns to education over the migration status (1st-3rd column in table 3-1) and races (1st-3rd column in table 3-2). The coefficients of schooling years were 0.190 (domestic immigrants) > 0.129 (natives) > 0.109

(international immigrants) and varied by race as follows: 0.166 (black) > 0.137 (white) > 0.091(others).

However, one should be very cautious in interpreting these estimation results. First of all, there should be recognition of the role of the institutions in the society that encourage employment of particular demographic groups; then the scarcity of labor belonging to those groups tends to increase the return to schooling. Secondly, overall distribution of earnings across schooling years for blacks should be lower than whites even though the return to schooling for blacks is higher than whites. To explore this issue, the following alternative regressions were run with the dummy variables of migration status and races. Therefore, the regression specifications are:

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

$$\log(\text{annual earnings}) = \text{constant} + \beta_1\,\text{age} + \beta_2\,\text{age}^2 + \beta_3\,\text{schooling year} + \beta_4\,\text{d\_black} + \beta_5\,\text{d\_others} \quad (4)$$

Note that there exist notable negative effects from the dummy variables on earnings in Illinois (last columns in tables 3-1 and 3-2). For example, the coefficients for the dummy variables, representing domestic and international immigrants, were -0.121 and -0.485 respectively; the coefficient for the dummy variable representing the black was -0.266. These results, in particular, verify that the overall distribution of earnings over ages of blacks is notably low even though the returns to education for blacks are very high. These findings are largely consistent with Altonji and Blank (1999). Further, one could conjecture from these results that overall earning's distribution over ages of the international immigrant is also quite low compared to the other migration status groups.

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 lower income and less-educated residents to near-by states and secondly, the redistribution of better-educated and higher income migrants with 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 migration data for 1992 through 2006. She revealed that there is a notable discrepancy of income level of domestic and international in- and out- migrants of Illinois; further, she noted that, on average, $1,682 million dollars 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) or no move-in (=0). The analyzed sample is composed of individuals who did not live in Illinois one year ago and have ever moved *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 (5)

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 domestic residents (table 4).

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, choose 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. (6)

The estimation result reveals that there exist a slight quadratic relationship between age and probability of emigrating out of Illinois (table 5).[1] 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 Frey (1995) and Yu (2009) even though Frey (1995) analyzed case of California.

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[2] (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 at the age-cohort over than 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+ ; and this inflated magnitude of covariate age^2 and its positive coefficient dominates the effects from the other explanatory variables. Note that the data including the individual who is

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

80+ is relatively small in the sample; thus the regression result itself was not affected significantly by the data whose individual's age is 80+. Thus the alternative binary response model was adopted to deal with this problem in the expected probability as follows:

logit (prob. of move out from Illinois) = constant + $d\_age\_cohort'\beta + \gamma_1$ log(household income) + γ_2 schooling years + residual. (7)

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 logged household income and schooling years are largely consistent with the former binary regression. Figure 3 shows the expected probability along the age-cohort group 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.

The empirical result presented in this section reveals that there are statistically significant gaps in the returns to education between the agents belonging to different races and migration status 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 in the second model.

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 pension 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 when the ageing phenomenon is projected to assume greater importance in Illinois as well as the US. There are no uncertain factors in the economy. There exist J generations in every single year: the generations are overlapped every sample period.[3]

3.1 Households

We suppose that households are heterogeneous in their returns to education. This intra-generational heterogeneity depends on their race (in the 1st model) or migration status (in the 2nd model) 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

[3] Thus, we could call this paper's model as perfect foresight overlapping generation model.
[4] Note that age 1 in the model corresponds to age 20 in reality.

decision on allocating resources between consumption and savings as well as splitting the endowment time into 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]

$$u(c_{t,j}, e_{t,j}) = \frac{c_{t,j}^{1-\gamma} + \theta e_{t,j}^{1-\gamma}}{1-\gamma} \quad \gamma > 1,\ 0 < \theta < 1 \tag{8}$$

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 involves a decision about expenditures now as opposed to saving to facilitate consumption later.

The individual's life-time utility function as following:

$$U_t^1 = \sum_{j=1}^{J} \beta^{j-1} u(c_{t+j-1,j}, e_{t+j-1,j}) = \sum_{j=1}^{J} \beta^{j-1} \left(\frac{c_{t+j-1,j}^{1-\gamma} + \theta e_{t+j-1,j}^{1-\gamma}}{1-\gamma} \right) \tag{9}$$

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:

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

$$+ \sum_{j=j^*+1}^{J} \left(\left(\prod_{k=t}^{t+j-2} \frac{1}{1+r_k} \right) pen_{t+j-1,j} \right) \tag{10}$$

[5] If a formula or equation does not denote the race or migration group, the formula or equation is applied to all races or 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 $j = 1, ..., j^*$.

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.

Every new generation in each year maximizes the lifetime utility function (9) under the budget constraint (10). The Euler equations (11) and (12) could be derived by computing the first order conditions with regard to consumption, saving and education investment time:

$$c_{t+1,j+1} = \left(\beta\left(1+r_{t+1}\right)\right)^{1/\gamma} c_{t,j} \tag{11}$$

$$e_{t,j} = \left(\frac{\theta}{(1-\tau_t^p)w_t h_{t,j}}\right)^{1/\gamma} c_{t,j} \text{ if } j \le j^*. \quad (12)^7$$

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:

$$a_{t+1,j+1} = (1-\tau_t^p)h_{t,j}w_t(1-e_{t,j}) + (1+r_t)a_{t,j} - c_{t,j} \text{ if } 1 \le j \le j^* \tag{13}$$

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

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

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

where q denotes races or 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:

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

$$C_t = \sum_q \sum_j c^q_{t,j} \left(v^q N^q_{t,j} \right) \tag{15}$$

where $c^q_{t,j}$ 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):

$$h^q_{j+1,t+1} = (1-\delta_h)h^q_{j,t} + B^q (mk_t)^\phi (h^q_{j,t} e^q_{j,t})^{1-\phi} \tag{16}$$

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 for producing the human capital stock, δ_h is the parameter of 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:

$$h^q_{t,1} = \pi^{hc,q} \left(\left(\sum_{j=1}^{j^*} h^q_{t-1,j} \left(v^q N^q_{t-1,j} \right) \right) / \sum_{j=1}^{j^*} \left(v^q N^q_{t-1,j} \right) \right) \tag{17}$$

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:

$$H_t = \sum_q \sum_{j=1}^{j^*} h^q_{t,j} \left(v^q N^q_{t,j} \right). \tag{18}$$

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

$$L_t^{e\ s} = \sum_q \sum_{j=1}^{j*} (1-e_{t,j}^q) h_{t,j}^q \left(v^q N_{t,j}^q\right). \tag{19}$$

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:

$$Y_t = A(K_t^d)^{\alpha} (L_t^{e\ d})^{1-\alpha} \tag{20}$$

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:

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

and

$$w_t = (1-\alpha) A(K_t^d)^{\alpha} (L_t^{e\ d})^{-\alpha} \tag{22}$$

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:

$$\tau_t^p \left(\sum_q \sum_{j=1}^{j*} \left(v^q N_{t,j}^q\right)\left((1-e_{t,j}^q) w_t h_{t,j}^q\right)\right) = \sum_q \sum_{j=j*+1}^{J} \left(v^q N_{t,j}^q\right) pen_{t,j}^q \ . \tag{23}$$

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*), degree of efficiency in transmitting human capital stock from generation to generation (π^{hc}) and labor-market participation rate (*v*) as well as the initial human capital stock distributions.

Now we suppose there are two different OLG frameworks where the transition path of the Illinois economy will be presented in both cases. In the first model, there are three categories of race: white, black and others so that it is possible to incorporate the heterogeneity of agents over race. In the second model, heterogeneity of households across migration status is incorporated.

4-1 First model: heterogeneity over race

The age-cohort population structure from 2001 to 2050 is identical to the one used in Kim and Hewings (2010). Thus, in this model, the ageing phenomenon will be accelerated until the mid 2020s and it will be subdued substantially in the mid 2040s.[8] The Census Bureau's population composition ratio by race in the state of Illinois (table 7) provides the benchmark for the racial composition of the population.

[8] See Kim and Hewings (2010).

In the model, the percentage of Others increases by 0.30%p every year from 2000, as a result of a rapid increase of immigration of Others (especially Latinos) into Illinois in recent decades. For example, in 2001, the percentages of White, Black and Others were 73.24%, 15.06% and 11.70% (=11.40% in year 2000 + 0.30%p) respectively. The composition ratio of races incorporated into the model is presented in figure 4.

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 race should be consistent with the exponentials of coefficients of $schooling\ year$ from table 3-2 (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 race's composition ratio is 0.28.

In section 2, it was noted that Black's marginal return to schooling is the highest. Nevertheless, the race effect (that is, the coefficient of the racial dummy) of Blacks on earnings is the lowest among the three racial categories. This could be a consequence of notable gaps in the average human capital stocks belonging to *young* generations of each race. In other words, although Black's marginal return to investment in schooling is very high, young black people's human capital stock is relatively low. 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.[9] The dependent variable of the Mincer regression in the section II was the logarithms of earnings. Thus, the difference of estimation results between races, denoted by dummy variable and its coefficient, could be interpreted as the overall percentage gap of

[9] This paper assumes that *current* young generation's initial human capital stock is transmitted from the *old* generation whose race group was identical to the young generation.

earnings between races[10]. 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 races; but their average values should be same as that in Kim and Hewings (2010). See the appendix for the assumptions and estimation procedure of the initial human capital distribution of each race.

In order to derive the labor-market participation rate for each race, the average value for civilians (age≥20) during 2003-2008 in US was adopted. Since the model assumes that someone participating in the labor market is always employed, the labor participation rate applied to the model is defined as follows:

Labor market participation rate = (labor force-unemployed persons) / population.

Therefore, the labor market participation rates (v^q) were set to be 65.09% for Whites, 61.49% for Blacks and 65.78% for Others group (table 10).

4-2 Second model: focused on Migration

In the second model in this paper, unlike the first model, estimation of the age-population structure of Illinois in the future is assumed to be not provided;[11] only the initial year distribution is known, that being for 2001. Instead, the age-cohort structure of Illinois is assumed to be basically maintained. That is, 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. In this paper, this will be referred to as basic population structure of Illinois. However, the population structure will be affected by migration so that the actual age-population structure will be significantly different

[10] log(1+x)≈x when x is small.
[11] US Census Bureau provides each state's age-cohort structure until 2030 in its website. But now we do not use this estimation.

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 number of international in-migrants and out-migrants[12] per age-cohort for every year in the future. Table 11 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).

[12] 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.

Figure 5 presents the growth rate of the retirees in the two models. Both of them show quite similar movements; it is possible to confirm again 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 morphs into the characteristics of the residents. However, the characteristics as an international in-migrant are not assumed to disappear permanently.

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. Since the interpretation of the empirical results and the general procedure of calibrating parameters of return to education (B^q) and degree of human capital transmission ($\pi^{hc,q}$) and initial human capital distribution are the same as that of prior section, the details of calibration procedure will not be repeated here. Also see the appendix for the assumptions and procedure for estimating the initial human capital stock distribution. Tables 12 and 13 show the parameter values assigned in the 2nd model dealing with the heterogeneity of migration status. Note that the labor market participation rate (v^q) is set to be equal to 0.6472,[13] regardless of migration status.

5 Computational results

5-1 Result from the 1st model: Model with heterogeneity due to races

The model projects that per-capita output of Illinois in 2050 will be 48.9% larger than that in 2001. The growth rate of per-capita output will continue to decrease until mid 2020s and then will recover partially (figure 6). As Kim and Hewings (2010) revealed, the improvement of the

[13] This is actual average value of all civilians during 2003-2008. Please see table 10.

human capital stock resulting from investment in education mitigates the negative effect of an ageing population. Since the new model incorporates the heterogeneity of different races, it is possible to explore the development of human capital stock of each race. Table 14 shows average human capital stock per worker (excluding non-participants in labor market) from 2001 to 2050. Black's human capital stock grows at 83.57% between 2001 and 2050. Even though the Black's growth rate is higher than the other races, their human capital stock level will be still lower than the other races in 2050. The reason why Black's human capital stock does not catch up with the other races' is because their educational investment lags behind those of other races for most of the years. Figure 7 shows the changes of average investment in education, which is denoted as percentage of endowment time, of each race over time.

Development of average welfare including non-participants in the labor market is presented in figure 8. As per-capita output increases, each individual's welfare also improves. However, the results imply that the gaps between races will not be narrowed in the future even though Black's return to education is much higher than White's. This is mainly because the educational investment of Whites will continue to be much more than those of the other races in the future. In the model, it is certain that differences of educational investment will result in gaps of human capital stock levels and subsequently individual incomes.

Next, the following experiments are intended to explore some policy implications. First, as noted in the previous section focusing on calibration measures, Black's participation rate in working is relatively low, compared to the other races, by about 4% points. This is because the unemployment rate for Blacks is substantially higher, although there is no significant difference of participation rate in labor force between races (table 15).

Since the major economic problem during the ageing era (the period in which the percentage of the population over 65 will approach 20%) will stem from the deficiency of workers, one of the easiest policy measures is to try to increase the participation rates of Blacks in the workforce to the level of the other races by absorbing the unemployed Blacks (we can refer to this as "employment policy" in this paper). For example, the government could subsidize the industry if it employs an unemployed Black person or provide incentives to Blacks to enhance their skills in anticipation of increasing the probability of their being employed. We will present the simulation result when we increase Black participation rate by 4 percentage points (to 65.49% in the model).

Secondly, the other policy alternative is to improve the degree of human capital transmission between generations of Blacks. As table 9 reveals, the degree of efficiency of inter-generational human capital transmission of Black has been calibrated to be substantially lower in the model compared to the other races; policy makers could try to improve this efficiency. For instance, a problem could be devised to try to lower the high school dropout rates of young black people so that older generation's accumulated human capital stock could be more effectively transmitted to young generations of black people. The opportunity presented here may be amplified by the fact that the state of Illinois state ranked[14] 4th in black high school students' dropout rate for the academic year 2003-2004 (table 16). The learning ability acquired in the earlier life-time from either formal or non-formal institutions could affect seriously the learning ability in the later time. So improvement of the educational environment for young Blacks will help to increase the efficiency of the human capital transmission between the generations of Blacks through either learning-by-doing or training at the workplace, improving the average human capital stock level of Blacks eventually.

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[14] Michigan: 11.9%, Washington: 11.2%, Louisiana: 11.1%.

The simulation results will be derived by setting the parameter of human capital transmission for Blacks to be equal to the average of the other races (that is, π^{hc} =1.0672). The simulation result implies that educational policy, that targets the upgrading of the transmission channel of human capital stock from old generation to young generation of black people, is preferable to the employment policy in a long-term. In the beginning year when each policy is implemented, the employment policy increases per-capita output by 0.76% while the educational policy raises it by 0.01%. However, in 2050, employment policy increases per-capita output by 0.62% while educational policy could increase it by 2.37% (figure 9). The accelerated long-term positive effects of educational policy stem mainly from the fact that the benefit of the enhanced education system is accumulated generation by generation, creating a temporal synergistic effect. On the contrary, the employment policy effect is only marginally accumulated into succeeding generations.

Further, educational policy is more beneficial in terms of average social welfare than employment policy. In 2050, average social welfare is increase by 2.0% under educational policy, compared to the baseline economy. However, in the same year, average social welfare decreases by 1.0% under employment policy, compared to the baseline economy. This is because a simple policy of employment expansion without consideration of improvement in productivity lowers the worker's wage rate due to competition; it also increases the social security tax due to increase of recipients of retirement pension instead.

5-2 Result from the 2nd model: Model with heterogeneity due to migration status

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 10).

The computational results imply that the gaps of human capital levels between continuing residents ("native") and international immigrants will be maintained in the future.[15] International immigrants' human capital level is 58.0% smaller in 2001 and will be still 46.4% smaller than natives in 2050 (figure 11).

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. 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 educational tax on household's income and reimburse proportionally to his/her opportunity cost stemming from time spent on educational investment. In our experiment, the government's educational transfer policy targets the individuals with relatively low productivity-international immigrants. We set

[15] 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.

the reimbursement rate is .20 (say). So we assume government reimburses part of opportunity cost of schooling investment of *only international immigrant workers*.

This educational transfer policy for international immigrants should be supported by the following data. According to the statistics published in 2003 by the Urban Institute, 18% of all foreign-born workers attained less than 9th grade; on the contrary, only 1% of native workers attained less than 9th grade. Even in a same group of low-wage workers, defined as workers earning less than 200 percent of state minimum wage, the gaps of formal schooling between the international immigrant and native workers are obvious: 28% foreign-born workers finished less than 9th grade while only 2% of native workers attained less than 9th grade. Also, 46% of all foreign-born workers are "limited English proficient". Without fiscal incentives, these lacks of formal schooling and English proficiency would continue to play as a barrier to international immigrant workers' participation in postsecondary schooling with sacrificing their current income for their future human capital.

For simulation, we assume that government's social security system and educational transfer system are operated independently from each other. Also we 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 (23):

$$\tau_t^e\left(\left(\sum_q\sum_{j=1}^{j^*} v^q N_{t,j}^q\left((1-e_{t,j}^q)w_t h_{t,j}^q\right)\right)+\left(\sum_q\sum_{j=1}^{J} v^q N_{t,j}^q\left(r_t a_{t,j}^q\right)\right)\right)=\mu\sum_{j=1}^{j^*} v^{\text{int}} N_{t,j}^{\text{int}}\left(e_{t,j}^{\text{int}} w_t h_{t,j}^{\text{int}}\right) \qquad (24)$$

where 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 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 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 12).

This is mainly because aggregate human capital stock is more positively affected by educational policy (table 17). In 2050, aggregate human capital stock under educational transfer policy regime is 4.27% higher than baseline economy where no government policy is involved. On the contrary, human capital under restrictive immigration policy is barely (0.66%) higher than the baseline economy. It should be noted that educational transfer policy, which 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 does not improve the natives. This could be interpreted that there exist the positive spillover effect between native and international immigrant's human capital stock.

6 Conclusion

In this paper, we have developed two-sector OLG model with intra-generational heterogeneity over individual's race and migration status. Also we examined the impact of population ageing on the regional economy; and checked the effect of government's policy measures on the economy. For this, we set up the empirical model to draw the implication for heterogeneity over race and migration status. We found out that there are significant gaps of return to education between races and migration status in Illinois: Return to education was larger in order of black > white > others; and domestic in-migrant > out-migrants > natives > international immigrants. However, there are overall noteworthy negative effects of being black or international immigrants on individual's earnings. Also, we revealed with empirical data that young and low-income residents outside Illinois are more probable to in-migrate into Illinois; and old and high-income residents inside Illinois are more probable to out-migrate from Illinois.

Using two-sector OLG model, we demonstrated growth of Illinois economy will be decelerated substantially until mid 2020's due to population ageing and then partially recover. We drew some implications for policy makers. First, policy that makes low productive people to get better education is preferable to the policy that encourages the firms to employ the low productive people, in terms of long-run effectiveness on per-capita income and social welfare. Secondly, positive effects of policy that restricts employment of the international immigrants are very limited in terms of per-capita income, welfare and aggregate productivity. On the contrary, tax and transfer policy that induces international in-migrants to invest more in their education works well. Even though the regime's direct beneficiary is an international immigrant, the native's human capital stock also improves significantly because of positive spillover effect.

Overall, with the limited fiscal budget constraint, government policies should be focused on facilitating the growth of the human capitals of the disadvantaged groups (such as Blacks and 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.

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

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 should 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-homothetic hierarchic preferences, whose property eventually enables individual's consumption composition exhibits different pattern according to development of individual's income level. In his paper, the general equilibrium features the continuous structural change along the long-run growth path and the economy converges to constant growth rate.

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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

Table 3-1: 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	2.195	4.270	4.172	2.875
	(0.039)	(0.324)	(0.751)	(0.039)	(0.255)
age	0.191	0.250	0.168	0.192	0.233
	(0.002)	(0.016)	(0.041)	(0.002)	(0.013)
age^2	-0.002	-0.003	-0.002	-0.002	-0.002
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
schooling year	0.129	0.190	0.109	0.130	0.159
	(0.002)	(0.014)	(0.030)	(0.002)	(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 3-2: Mincerian regression results: different races

	I. White	II. Black	III. Others	Current residents in IL (I+II+III)
constant	4.114	3.264	4.847	4.176
	(0.044)	(0.146)	(0.113)	(0.039)
age	0.191	0.195	0.186	0.193
	(0.002)	(0.006)	(0.005)	(0.002)
age^2	-0.002	-0.002	-0.002	-0.002
	(0.000)	(0.000)	(0.000)	(0.000)
schooling year	0.137	0.166	0.091	0.129
	(0.002)	(0.007)	(0.003)	(0.002)
d_black				-0.266
				(0.015)
d_others				0.065
				(0.014)
obs.	54,705	5,946	6,995	67,646
R^2	0.2591	0.2763	0.2673	0.2644

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 householdincome	-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)
schoolingyear	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: Population of Illinois by Race

	2000	2010	2020	2030
White	9,142,005 (73.48)	9,310,030 (70.11)	9,553,780 (66.73)	9,671,937 (63.89)
Black	1,880,101 (15.11)	1,981,006 (14.92)	2,094,687 (14.63)	2,150,187 (14.20)
Asian	424,291	628,663	872,341	1,094,499
Other	994,449	1,359,392	1,795,679	2,222,226
Asian + Other	(11.40)	(14.97)	(18.64)	(21.91)
All	12,440,846 (100.0)	13,279,091 (100.0)	14,316,487 (100.0)	15,138,849 (100.0)

Note: Asian and other in this table is categorized into same “Others” group in the model.
Source: http://www.ildceo.net/dceo/Bureaus/Facts_Figures/Population_Projections/

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

	Coefficient of schooling year	Exp (Coef.)	Value assignment to *B*
White	0.137	1.1468	0.2803
Black	0.166	1.1806	0.2886
Others	0.091	1.0953	0.2678
Weighted Average			0.2800

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

	Coefficient multiplied by dummy variable	Value assignment to π^{hc}
White	0	1.0335
Black	-0.2661	0.7585
Others	0.0652	1.1009
Weighted Average		1.0000

Table 10: Employment status by races of US

		2003	2004	2005	2006	2007	2008	Average
Population: A (Civilian, age≥20)	White	168,765	170,045	171,756	173,408	175,210	176,456	172,607
	Black	23,304	23,643	24,036	24,442	24,845	25,168	24,240
	Others	13,003	13,446	13,893	14,287	14,830	15,089	14,091
Labor force: B	White	114,572	115,156	116,348	117,826	119,139	119,991	117,172
	Black	15,755	15,876	16,210	16,443	16,695	16,953	16,322
	Others	9,012	9,255	9,599	9,878	10,278	10,485	9,751
Unemployed person: C	White	5,401	4,957	4,504	4,208	4,338	5,563	4,829
	Black	1,532	1,488	1,433	1,296	1,210	1,543	1,417
	Others	590	496	468	378	429	533	482
(B-C) / A (%)	White	64.69	64.81	65.12	65.52	65.52	64.85	65.09
	Black	61.03	60.86	61.48	61.97	62.33	61.23	61.49
	Others	64.77	65.14	65.72	66.49	66.41	65.96	65.78

Source: Labor Force Statistics from the Current Population Survey, Bureau of Labor Statistics

Table 11: 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 12: 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 13: 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 14: Average human capital stock per worker

	2001 (A)	2010	2020	2030	2040	2050 (B)	B/A
Black	1.2819	1.5690	1.8029	2.0060	2.1904	2.3532	1.8357
White	1.8444	2.0515	2.2389	2.4284	2.6090	2.7792	1.5068
Others	1.8323	1.9696	2.1228	2.3086	2.5028	2.6828	1.4642
Total	1.7624	1.9725	2.1600	2.3491	2.5318	2.7026	1.5335

Table 15: Employment statistics of US in 2007

	White	Black	Asian	Total
Participation rate in labor force (age>=16)	66.4%	63.7%	66.5%	66.0%
Unemployment rate (age>=16)	4.1%	8.3%	3.2%	4.6%

Table 16: Public high school event dropout rates by race and ethnicity during 2003-04

	White	Black	Hispanic	Asian	American Indian	Total
Illinois	3.5%	9.6%	8.2%	2.5%	5.0%	5.3%
U S	2.9%	6.4%	5.9%	2.5%	7.2%	3.9%

Note: 1. Asian includes Pacific Islander and American Indian includes Alaska native.

2. The event dropout rate estimates the percentage of both private and public high school students who left high school between the beginning of one school year and the beginning of the next without earning a high school diploma or its equivalent (e.g., a GED).

Source: *Digest of Education Statistics 2007*, Institute of Education Sciences, US Department of Education

Table 17: 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%

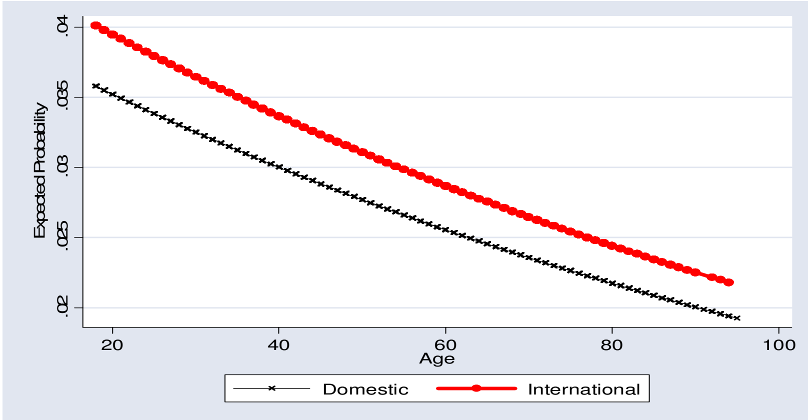

Figure 1: Expected probability of selecting move into IL from ROUS

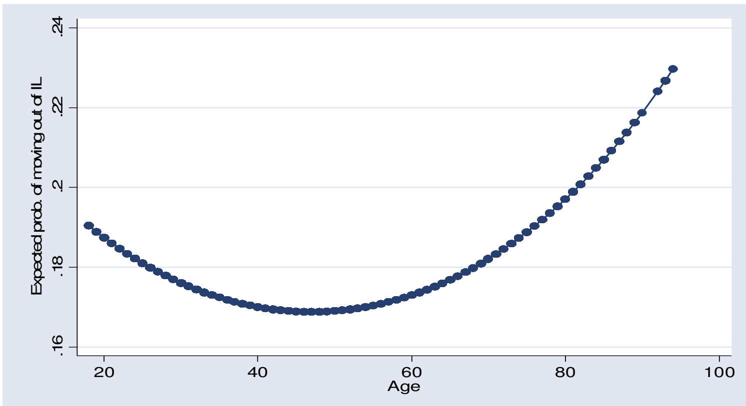

Figure 2: Expected probability of selecting moving out of IL to ROUS

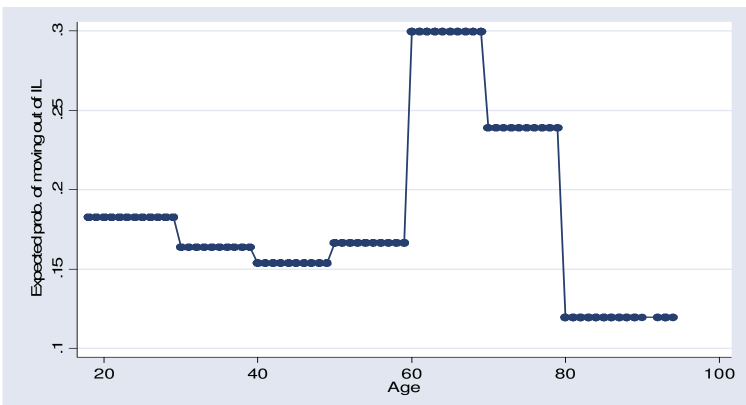

Figure 3: Expected probability of selecting moving out of IL to ROUS (alternative)

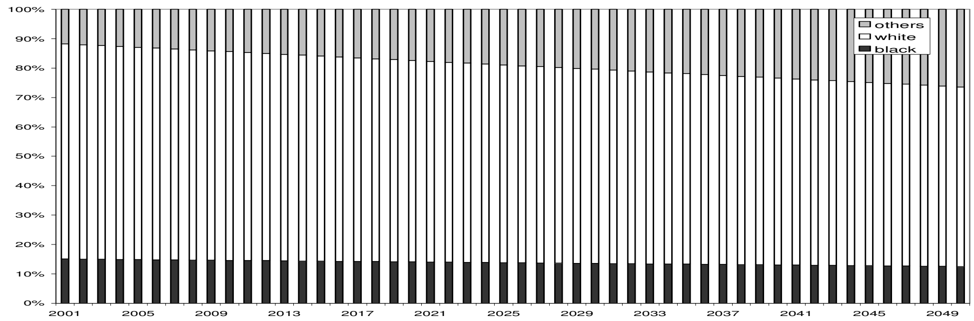

Figure 4: Composition of races of Illinois in the model

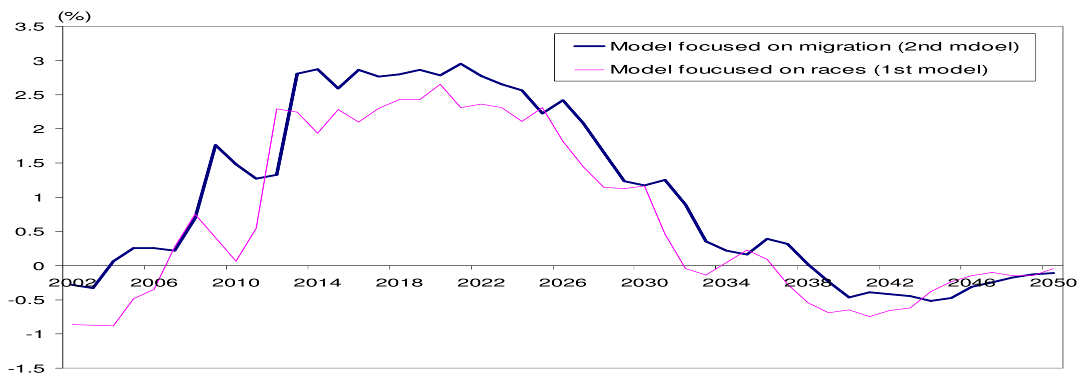

Figure 5: Growth rate of retired age group

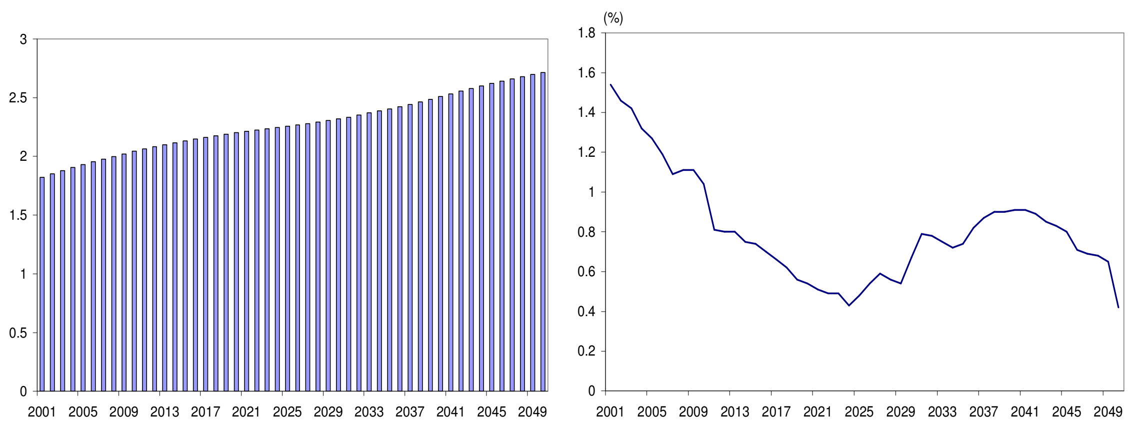

Figure 6: Projection on per-capita output of Illinois and its growth rate

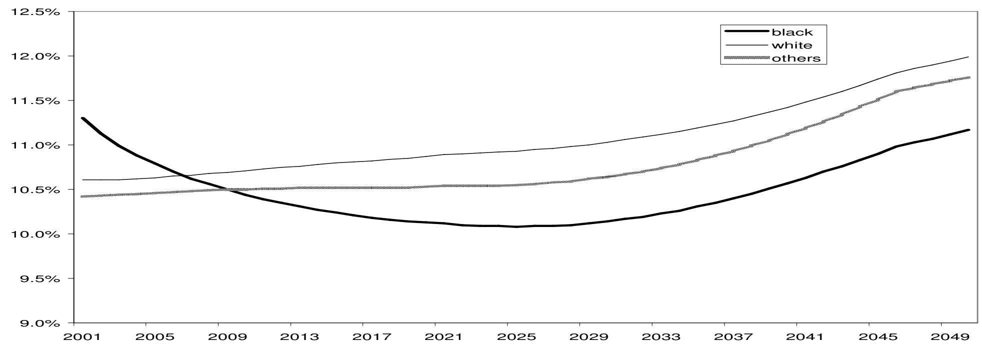

Figure 7: Educational investment per worker

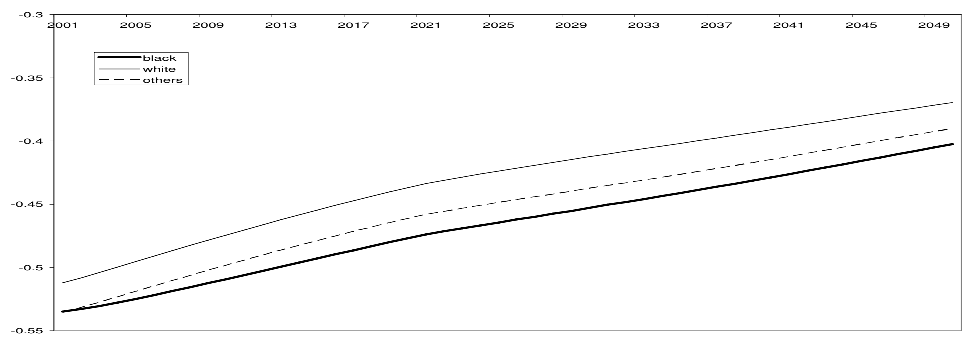

Figure 8: Average welfare of each race

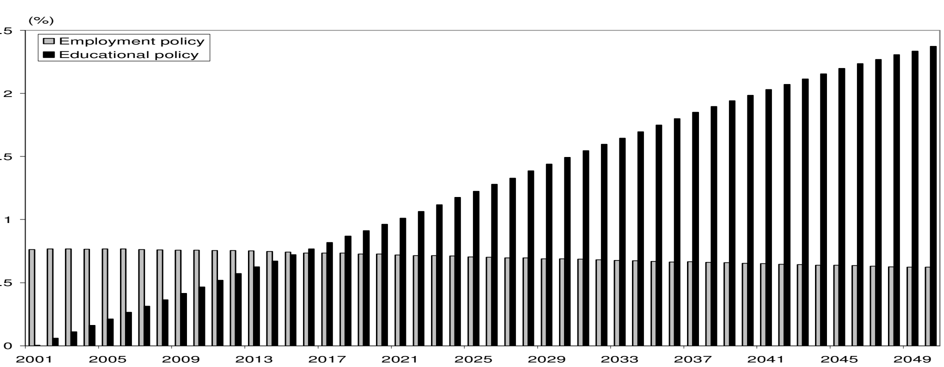

Figure 9: Effects on per-capita output of two policy measures

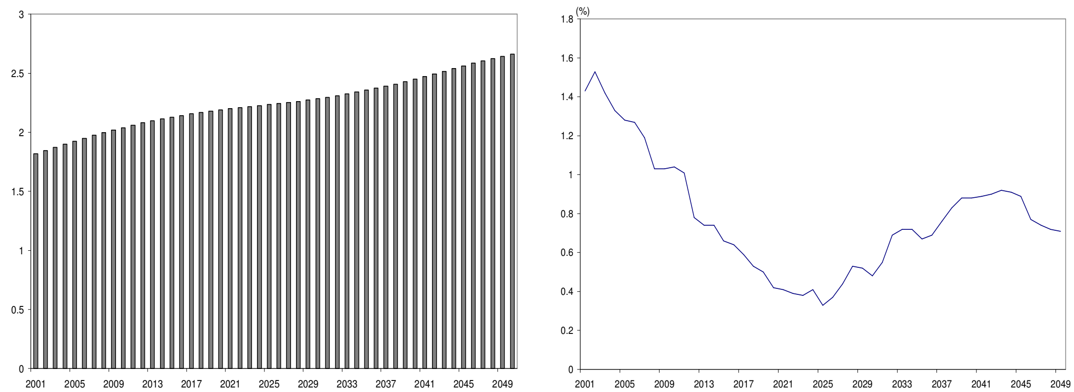

Figure 10: Per-capita output and its growth rate

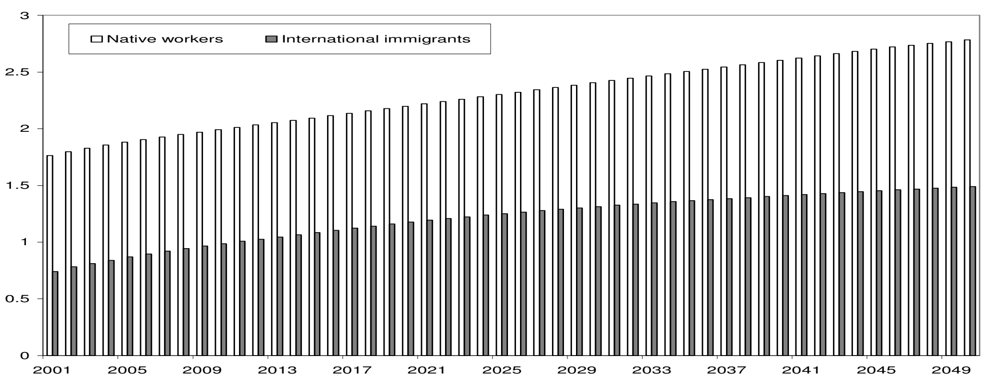

Figure 11: Average human capital stock per worker

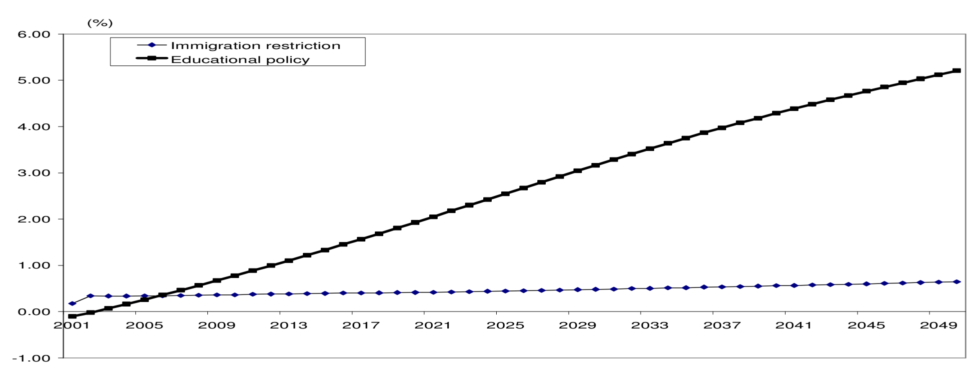

Figure 12: Deviation of per-capita output from baseline economy (%)

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

In order to get 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_black+ β_3 d_others+ β_4 age·d_black+ β_5 age·d_others+ ε

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_black, d_others, d_domestic and d_int'l denotes the dummy variables representing Black, Others, 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 race or migration status. Data set is same as the one for the former estimations in the section 2. Following table demonstrates the estimation results.

Table: Estimation results for estimating age-earning profile

	Grouping by **races**		Grouping by **migration status**
constant	9.4305 (0.0168)	constant	9.3224 (0.0153)
age	0.0168 (0.0004)	age	0.0187 (0.0003)
d_black	-0.8874 (0.0535)	d_domestic	-0.7452 (0.1055)
d_others	-0.4740 (0.0490)	d_int'l	-1.3222 (0.2143)
age · d_black	0.0141 (0.0012)	age · d_domestic	0.0196 (0.0030)
age · d_others	0.0114 (0.0012)	age · d_int'l	0.0234 (0.0060)
obs.	67,646	obs.	67,646
R^2	0.0530	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)=8.5431+ 0.0309*age for Black,
- log(annual earnings)=9.4305+0.0168*age for White,
- log(annual earnings)=8.9565+0.0282*age for Others,
- 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 every 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 groups (i.e., races and migration status) are exactly same as the initial human capital stock distribution adopted in Kim and Hewings (2010).