Quantitative Analysis of Immigrants Self-Selection and its Implications

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Abstract

How is affected the investment in human capital by the possibility of future migration? Who is actually migrating? And, what is the effect of international migration in differences in output p.c. across countries? I present a model with heterogeneous agents that decide endogenously investment in human capital and migration. I find that the possibility of migration induce to overinvest in human capital. I conclude that the migration pattern of self-selection is not unique. Finally, I test if the model can replicate migration patterns for three different cases: Mexico, India and UK to US. I match the data in average years of schooling for immigrants and natives and relative earnings of immigrants with respect to US born-natives.

Key words:

PACS:

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1 Introduction

How is affected the investment in human capital by the possibility of future migration? Who is actually migrating? And, what is the effect of international migration in differences in output p.c. across countries? I present a model with heterogeneous agents that decide endogenously investment in human capital and migration. This original approach permits me to answer these question linking two literatures, migration and economic growth. Moreover, if the accumulation of human capital is affected by the possibility of future migration, then there is no sense in study separately these questions as has been made in previous works.

Are immigrants positive or negative self-selected? This is a traditional question in migration literature. It is important because the effects of international migration depend crucially on the pattern of immigrants. Although the migration literature has focus mostly on the effects of immigrants in the hosting country, international migration has effects is the source country too. The brain drain theory stresses this idea and suggests that the migration of population that is relatively high skill has negative effects in the source country. At this point there is controversy too. If people become more educated because they know that in the future they will migrate may be the case that the brain drain has positive effects. This is called the induced education effect. Obviously, to test all these ideas we need a model where accumulation of human capital and migration decision are endogenous, otherwise it is impossible. Finally, once we know who is migrating and what determine the pattern of immigrants, we can quantify the effects in differences in output per capita across countries and try to test different migration policies.

The main particularities of the model are: (i) It is an international model with two economies and perfect physical capital mobility. (ii) There are OG of dynasties composed by households. (iii) Households are heterogeneous and decide consumption, physical capital investment, human capital investment and migration. (iv) Human capital is produced using two inputs, time and expenditure in goods. (v) Migration is costly. I will consider two types of costs. A fix migration cost that can be interpreted as travel expenses and a time migration cost. For the moment think in the time migration cost as all the time that you need to prepare the migration. This cost affects the effective units of labor.

I find that optimal investment in human capital of immigrants is clearly above the investment in human capital in a closed economy most of the cases. This supports the thesis of induce education effect of brain drain theory. The significance of the induce education effect depends on the relative size of the migration costs, the TFP of and the migration rate. Related with this I find
that the migration pattern of self-selection is not unique. For the same migration costs Immigrants are positive self-selected for higher TFP countries while they are negative self-selected for lower TFP countries. To increase the time cost, all the rest constant, decreases the migration rate and implies higher positive self-selection. I have tested the model for the case of Mexico, India and UK. These three cases present so many different particularities among them that are good candidates to test the model in different dimensions. I find that the model can replicate real selection patterns of immigrants for acceptable parameter values. I find that average years of Mexican immigrants is 7.2 and Mexican natives is 5.1 Data for Mexican immigrants is 7.5 and 6.3 for natives. For the Indian case I find a strong positive self-selection as data indicates. I find that average years of schooling is 12.88 for immigrants and 4 for natives. Data for Indian immigrants is 15.6 and 5 for natives. I also get that immigrants from UK earns more than US native. I find a earnings ratio of 1.2 when real ratio is 1.3. Average years of schooling of immigrants from UK is 14.8 and in data it is 14.6.

Borjas has been the pioneer in the migration literature. He tried to answer the self-selection question using a simple partial static model derived from the Roy’s model. In Borjas (1994) he finds that immigrants are positive self-selected when correlation of skills is sufficiently high and distribution of earnings is higher in the hosting country. But if the source country has higher earnings dispersion than the hosting country then immigrants are negative self-selected. It is well to point out that Borjas defines positive self-selection as having above average earnings in both the source and the host country and in an equivalent way for negative self-selection. When I talk of positive self-selection I mean that the average level of human capital of immigrants is higher than those in the source country. Independently of whether they will finish in the distribution of skills in the host country. Since US dispersion of earnings distribution is lower than dispersion of earnings distribution in developing countries, Borjas’ model supports the thesis of negative self-selection. But if we take I look to data, there is a high brain drain in the Caribbean, some Africa countries and India and the dispersion of earnings in these economies are higher than in US. Stark (1994) defends that in case of asymmetric information it is possible to have negative self-selection since employers can not know the type of the immigrant. Other statical models are Chiswick (1999) and (2000) and Belletini and Berti (2006). Chiswick finds positive self-selection adding in his theoretical model a migration cost that is less important the more skill is the immigrant. Belletini and Berti find that the lower is the wage level in the hosting country the higher is the percentage of skilled people among the immigrants. In all these works there is no investment in human capital and migration decision. They perform a statical comparison of earnings in both countries and study under which conditions earnings are higher in the foreign country. They are very far from what I am doing here.
In the closest work to mine, Urrutia (2001) analyzes in a dynastic OG model the effect of migration costs on the self-selection of immigrants. In his model there are two migration costs. A fix cost and a loss of ability. He finds that when the fixed cost is relatively low, immigrants are selected from the bottom of the distribution of abilities while if the fix cost is relatively high then the opposite happens. Although he finds different selection patterns depending on the relative size of the costs, in his model the ability is exogenous so he can not explain the relationship between investment in human capital and migration. And this relationship may be affecting the self-selection of immigrants. Moreover he abstracts the results from real differences in TFP across countries.

Others papers where emigration is endogenous are Klein and Ventura (2006) and (2007). They are interested in studying an efficient reallocation of labor in the world. In these papers agents are endowed with birthplace dependent efficiency units of labor so, again there is no accumulation of human capital.

There is a long debate on why differences in output per capita are so big across countries. Mankiw, Romer and Weil (1992) used an augmented Solow model and estimated that output differences were caused by human capital differences. On the contrary Klenow and Rodriguez-Clare (1997), Hall and Jones (1999), Bils and Klenow (2000) and Parente and Prescott (2000) support that differences in output per capita are due to differences in TFP. The most recent work is Hendricks (2002) who estimates human capital of different countries from immigrants in the US job market doing the same work and supports the TFP thesis. For the production function of human capital I will follow Seshadri and Manuelli (2007) [hereafter M-S] and, mainly Erosa, Koreshkova, and Restuccia (2007) [hereafter E-K-R]. These authors stresses the idea of the importance of education quality. Once they take into account that education quality may differ among countries they conclude that relatively small differences in TFP levels accounts for big output differences across countries. The common problem in the human capital theory is that it does not take into account migration. But if we are concerned about importance of human capital in international accounting we must be worried about migration because migration is nothing else that mobility of human capital across countries.

The paper is organized as follows. Section 1 describes the model. In section 2 I show the calibration of the parameters, the targets and values and I present the benchmark economy. In section 3 I present the results for a closed economy, for an open economy with fix migration cost and for an open economy with both migration costs. In section 4 I use the model two mach two real cases, immigrants from Mexico and India to US. The effect of immigrants in differences in output per capita across countries are showed in section 5. Section 6 concludes.
2 The Model

Since I will consider the steady state equilibrium I use the usual convention of denote by primes next period variables.

2.1 Locations

There are two economies that I identify with the index \( i \in \{0,1\} \). I interpret economy indexed by 0 as a developing country and economy indexed by 1 as a developed country. As it is usual in international economics literature I will refer to country 0 as the South economy and country 1 as the North economy. Locations only differ in two features, their level of TFP and their natural population growth rates. I will be more precise in how they differ in the following sections. Finally, physical capital is perfect mobile in the world economy.

2.2 Technologies

There are two technologies. One for goods and another for human capital. Output is produced in each economy according to the the technology

\[
Y_i = A_i K_i^\alpha H_i^{1-\alpha} \quad for \quad i \in \{0,1\}
\]

where \( Y_i \) is output and \( K_i \) and \( H_i \) are aggregated physical capital and aggregated human capital respectively in economy \( i \). I make the assumption that the north economy is more productive than the south economy, \( A_1 > A_0 \).

I follow E-K-R to model the production function of human capital. Per capita human capital is produced with two inputs, time \( s \in [0,1] \) and expenditure in goods allocated to education \( e \) and takes the form:

\[
h' = z'(s^\eta e^{1-\eta})^\xi \quad \eta, \xi \in (0,1)
\]

where \( z' \) is a stochastic shock that refers to the individual ability to accumulate human capital.

\footnote{Note that factor shares are equal in both economies. Gollin (2002) supports the assumption that labor shares are equal in both economies}
2.3 Demographic Structure

Each economy is modelled as an OG of dynasties that are altruistic toward the dynasty. There are a large number of dynasties that are composed by households. In a household there are two types of agents. Agents live two periods. In the first period they are young agents and in the second period they are old agents. Young agents live in the household with an old agent and when they become old a new household is realized. So, in a household there is always an old agent and young agents.

Old agents take all the decisions inside the household in a sense that I will be more precise shortly. But in order to understand dynamics of the population consider that an old agent decides where their descendants start a new household\(^2\). Then, using in advance the result that migration pattern is from economy 0 to economy 1 (south to north) I can write population dynamics in each economy as:

\[
N'_1 = (1 + n_1)N_1 + m(1 + n_0)N_0 \\
N'_0 = (1 + n_0)(1 - m)N_0
\]

where \(N_i\) is total population and \(n_i\) denotes natural population growth rate in country \(i\). I assume that natural population growth rate is higher in country 0 (see appendix for a full description of population dynamics and its implications). Since migration is unidirectional \(m\) stands for the proportion of households in country 0 that decide to leave the native country and establish in country 1\(^3\).

2.4 Preferences and Endowments

The household gets utility from consumption. The utility function takes the form:

\[
u(c) = \frac{c^{1-\gamma}}{1-\gamma}
\]

\(^2\) It means that old agents take the migration decision for their descendants. The alternative that young agents decide if migrate does not change results but computationally is costlier

\(^3\) Since the number of young agents per household is constant and equal for all the dynasties the proportion of households that migrate is the same that the proportion of population migrating
Young agents receive an idiosyncratic shock to their ability $z \in \mathcal{Z} = \{z_1, ..., z_n\}$ and it is an unobservable for old agents. This shock follows a markovian process with transition matrix $\pi_{z,z'}$. This shock is the same for all the members of the household. Moreover, is the same process in both countries.

### 2.5 The Household’s Problem

In a household there are two types of agents, the young agent and the old agent. In the second period of their life young agents become old agents and start a new household as an old agent. Old agents take all the decisions inside the household and they are altruistic toward their descendants. An old agent decide per capita consumption $c$ and per capita assets for the next period $a'$. Note that $a'$ will be the bequest for the next generation. Furthermore, they decide how much time and expenditure in goods must be allocated in the human capital production function of their children. Finally, old agents decide where their descendants are going to start the new household. If they take the migration decision all their descendants migrate and start abroad the next period. For the moment I will assume that if they migrate they only have to pay a fix migration cost $\theta$. I interpret this cost as travel expenses. The literature always relates this cost with the distance from the source country to the host country. For instance, Urrutia defines this cost as travel expenses and the cost of keep in contact with the native country.

The household gets income from old agent earnings, from young agents earnings and from assets. Note that young agents earnings depend on the remaining time after investment in education and also depends on $\psi$. This parameter is to control for the life cycle profile of wages. I have normalized to 1 this parameter for old agents.

The problem faced by a household in country 1 taking into account that they do not migrate is:

$$V(a, h, z, 1) = \max_{c,e,s,a} \{ u(c) + \beta(1 + n_1) \sum_{z'} \pi_{z,z'} V(a', h', z', 1) \}$$

$$c + (1 + n_1)e + (1 + n_1)a' \leq w_1h + (1 + n_1)(1 - s)w_1\psi + Ra$$

$$h' = z'(s^\eta e^{1-\eta})^\xi$$

$$a', e \geq 0, \quad s \in [0, 1]$$

The problem faced by a household in country 0 is very similar but presents the particularity that households decide whether to start the next period. If they migrate then $i' = 1$ and they have to pay $\theta$. The problem is:
\[ V(a, h, z, 0) = \max_{c,e,s,a'} \{ u(c) + \beta (1 + n_0) \sum_{z'} \pi_{z,z'} V(a', h', z', i') \} \]
\[ c + (1 + n_0)e + (1 + n_0)a' \leq w_0 h + (1 + n_0) (1 - s) w_0 \psi + Ra - i' \theta \]
\[ h' = z'(s^n e^{1-\eta})^\xi \]
\[ i' = \{0, 1\}, \quad a', e \geq 0, \quad s \in [0, 1] \]

3 Calibration

3.1 Parameters and Targets

The calibration strategy takes two steps. First, I calibrate the benchmark economy to join US data in a closed economy. Second, I calibrate the open economy with migration. The open economy requires additional parameters values as for instance south natural population growth rate and the fix migration cost. For the moment I will focus on the calibration of the closed economy.

The length of a period is 30 years. I model the life of an agent from age 6 to age 66. I start modelling from age 6 to capture better human capital investment decision and it is a common strategy in human capital literature. Age 66 is roughly retirement age. I normalize TFP of country 1 equal to 1 \((A_1 = 1)\). In US the natural population growth rate \(n_1\) is 0.59% and population growth rate \(n_{p1}\) is 0.92%\(^4\). I set \(\delta = 0.0668\) and \(\alpha = 0.33\) from Cooley and Prescott \((\cdot)\). The coefficient of the CRRA utility function \(\sigma\) is set equal to 2, which is in the range of usually accepted values in this literature\(^5\). I calibrate \(\beta\) to match an annual interest rate of 5%. I sum up the parameters and their values in table \((\#)\)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFP</td>
<td>(A_1)</td>
</tr>
<tr>
<td>US natural population growth rate</td>
<td>(n_1)</td>
</tr>
<tr>
<td>US population growth rate</td>
<td>(n_{p1})</td>
</tr>
<tr>
<td>Discount Factor</td>
<td>(\beta)</td>
</tr>
<tr>
<td>CRRA</td>
<td>(\sigma)</td>
</tr>
<tr>
<td>Physical capital share</td>
<td>(\alpha)</td>
</tr>
<tr>
<td>Physical capital depreciation</td>
<td>(\delta)</td>
</tr>
</tbody>
</table>

\(^4\) U.S. Census Bureau, International Data Base, year 2005

\(^5\) See for instance Keane and Wolpin (2001), Klein and Ventura (2007) and E-K-R
It remains to choose the parameters related to the human capital investment. These parameters are: $\eta, \xi, \psi$ and the shock $z$ for the ability. I calibrate the shock $z$ as in E-K-R where ability follows in logs an AR(1) process\(^6\). I use 5 shocks to approximate this process with a Markov chain. To calibrate the shocks I use the procedure in Tauchen (1986). This process implies 2 additional parameters values $\rho_z$ and $\sigma_z^2$. Then, I have to calibrate 5 parameter values. To do this I use U.S. cross-sectional data. The targets are:

(1) M-S take average years of education equal to 12.08 from Barro and Lee (1996). In E-K-R average years of education are 12.9 from U.S. Department of Education 2004.

(2) Intergenerational correlation of log-earnings of 0.5 from Mulligan (1997).

(3) Variance of log-earnings of 0.36 from Mulligan (1997).

(4) Mincer returns to schooling of 10% in average.

(5) Percentage of people with college education or higher equal to 54%. It means that percentage of people with less than college (Elementary and High School) is 46%.

The process of matching each parameter with its target is quite complicated. I have run several experiments to arrive to the following conclusions. Intergenerational correlation of log-earnings is mainly affected by $\rho_z$ and variance of log-earnings depends mainly on $\sigma_z^2$. I relate $\psi$ with average years of schooling because the main effect of this parameter is that it moves all the distribution (primary, secondary and college) to the right or to the left. Mincer returns and percentage of people with college or higher are related because the less people are with college the higher the mincer returns are. But, Mincer returns are more sensitive to variations in $\xi$ and $\eta$ affects more the percentage of people with college. In table (##) I link each parameter with its target and its value in the calibrated model.

\[^6\] AR(1) process for ability in logs takes the form:

\[
  \log(z') = \rho_z \log(z) + \epsilon_z \quad \text{where} \quad \epsilon_z \sim N(0, \sigma_z^2)
\]
<table>
<thead>
<tr>
<th>Target</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of people with college</td>
<td>( \eta )</td>
<td>0.76</td>
</tr>
<tr>
<td>Mincer returns</td>
<td>( \xi )</td>
<td>0.55</td>
</tr>
<tr>
<td>Average years of schooling</td>
<td>( \psi )</td>
<td>0.06</td>
</tr>
<tr>
<td>Variance of log-earnings</td>
<td>( \sigma_z^2 )</td>
<td>0.46</td>
</tr>
<tr>
<td>Intergenerational correlation of log-earnings</td>
<td>( \rho_z )</td>
<td>0.13</td>
</tr>
</tbody>
</table>

3.2 The Benchmark Economy

Table (†) presents the US data targets and the benchmark economy.

<table>
<thead>
<tr>
<th>Target</th>
<th>US data</th>
<th>BE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average years of education</td>
<td>12.9</td>
<td>12</td>
</tr>
<tr>
<td>Intergenerational correlation of log-earnings</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Variance of log-earnings</td>
<td>0.36</td>
<td>0.35</td>
</tr>
<tr>
<td>Mincer returns to schooling of</td>
<td>10%</td>
<td>7.7%</td>
</tr>
<tr>
<td>Percentage of people with college education or higher</td>
<td>54%</td>
<td>55%</td>
</tr>
</tbody>
</table>

The benchmark economy replicates quite well the targets, even though I am underestimating mincer returns. Although it is not obvious how to relate real data on Mincer returns with data from the model since the length of the periods are quite different. I have calculated some others facts for which the model has not been calibrated. For instance, the ratios of total median earnings for different levels of highest education attainment. These ratios are:

<table>
<thead>
<tr>
<th>Target</th>
<th>US data</th>
<th>BE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary/Secondary</td>
<td>0.65</td>
<td>0.57</td>
</tr>
<tr>
<td>Secondary/Secondary</td>
<td>1</td>
<td>1.</td>
</tr>
<tr>
<td>College/Secondary</td>
<td>1.86</td>
<td>1.83</td>
</tr>
</tbody>
</table>

I am doing quite well in the ratio of college with secondary and I am underestimating the ratio primary with secondary. Of course there is always a problem when we try to link this real data with data from the model where investment in time is continuous. If I do an interval taking as a lower bound the value for some degree of completion and as an upper bound full completion, then my results fall in this interval.
As a measure of inequality I have computed the Gini index for the benchmark economy. The US Gini index is 0.611 for earnings from 1998 Survey of Consumer Finances and I get a Gini index of 0.70. It does not seem that the model does a good job to explain inequality, maybe a solution would be to increase the number of shocks. I have compute expenditures in education. Haveman and Wolfe (1995) reports that total expenditures in children from 0 to 18 are 14.5% of GDP. They also report that expenditures on elementary, secondary and post-secondary schooling are 6.6% of GNP (U.S. Bureau of the Census 1992). E-K-R get a ratio of 12% that is close to Haveman and Wolfe’s result when foregone parental earning are subtracted. M-S use as a target that expenditures in schooling as a fraction of GDP is 3.77% from OECD. The data I found suggests an upper bound of 6.6% from the OECD for 2004. I get in the benchmark economy a expenditure ratio of 2.12% which is lower.

4 Results

4.1 Closed Economy

In this section I run a closed economy that differs in two features with respect to the benchmark economy. These features are natural population growth rate and TFP. I will refer to this economy as the south. South natural population growth rate is \( n_0 = 0.953813\% \). TFP takes three different values. The ratio between south and north TFP for each value is 0.3, 0.5 and 0.7. Remember that I have normalized north TFP equal to 1. I present the results in the following table:

<table>
<thead>
<tr>
<th>TFP ratio</th>
<th>1</th>
<th>0.7</th>
<th>0.5</th>
<th>0.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output ratio</td>
<td>1</td>
<td>0.6</td>
<td>0.38</td>
<td>0.2</td>
</tr>
<tr>
<td>( r )</td>
<td>5%</td>
<td>5.11%</td>
<td>5.12%</td>
<td>5.24%</td>
</tr>
<tr>
<td>Av. years of schooling</td>
<td>12</td>
<td>8.3</td>
<td>6.3</td>
<td>4.1</td>
</tr>
<tr>
<td>Mincer returns to schooling</td>
<td>7.7%</td>
<td>11%</td>
<td>14.8%</td>
<td>21.6%</td>
</tr>
</tbody>
</table>

In line with E-K-R results, I get that output per capita ratios are lower than TFP ratios. This points out the amplification effect of human capital. The amplification effect of human capital means that with lower differences in TFP it is possible to get big differences in output per capita across countries. Human capital investment is amplifying TFP differences. They find an output ratio of 0.13 and 0.30 for TFP ratios of 1/3 and 1/2 respectively. I find an output ratio of 0.2 and 0.38 for TFP ratios of 0.3 and 0.5 respectively. My ratios are higher. This implies a lower amplification effect of human capital. The reason
is that in E-K-R’s model the time that an agent invests in human capital accumulation is costly too. It makes the amplification effect higher. Average years of schooling are in concordance with previous works. For instance, M-S report that for output per worker ratio to US of 0.244 the average is 5.18 and 5.88 for an output per worker ratio of 0.354. For output ratios of 0.5 and 0.7 the average falls in the intervals (7.54-8.12) and (8.7-9.72) respectively. E-K-R find an average of 4.3 for a TFP ratio of 1/3 and an average of 7.1 for a TFP ratio of 1/2. Mincer returns decreases with higher average years of education. I obtain Mincer returns of 11%, 14.8% and 21.6% for TFP ratios of 0.7, 0.5 and 0.3. E-K-R get results very similar. They estimate Mincer returns of 14.5 and 22.6 for TFP ratios of 1/2 and 1/3. Finally, I report endogenous interest rate. Remember that the benchmark economy has been calibrated to match an interest rate of 5%. Then, for lower TFP values, the interest rate increases.

4.2 Open Economy with fix migration cost

Equation (5) must hold in a open economy with migration in the steady state equilibrium. This equation relates natural population growth rates and migration in order to keep constant north and south ratios over the world population or, equivalently, to equalize population growth rates in both economies. There are two different approaches to proceed. Either, I fix south natural population growth rate and this implies a ratio of immigrants, or I fix as a target the ratio of immigrants and this implies a south natural population growth rate. I have decided to fix a target of 1% of immigrants. Since the model period is 30 years, it means broadly 0.033% of immigrants per year. The south natural population growth rate implied by this target is \( n_0 = 0.953813\% \). To understand the magnitude of these numbers take as example data from Mexico. Mexico presents the biggest rate of migration to US and it is 0.15% per year and Mexico natural population growth rate is 1.6% (from US Census Bureau, 2005).

Once I have fixed the migration target, I proceed in the following way. I calibrate the fix cost for a TFP ratio of 0.5 that gives 1% of immigrants. The migration cost is calibrated as a fraction of average annual earnings in the benchmark economy. This means that I define the fix cost as \( \theta \bar{w}_1 \) where \( \bar{w}_1 \) is per year average earnings of a household in the north in the benchmark economy. Then I calibrate \( \theta \) to match 1% of immigrants. Once I obtain this value for \( \theta \) I run the program for a TFP ratio of 0.3 and 0.7. Results are presented in the next table.
Results suggest that immigrants are positive self-selected because average years of schooling of the immigrants are higher than those who do not emigrate. Anyway, this result is sensitive to the size of the fix cost. There is a fix cost size for which this result reverses and average years of education of immigrants are lower. Obviously, this effect is more important the lower is the TFP ratio of a country because the cost is relatively more important. A household pays the fix migration cost and then invests in human capital. If the cost is low, the household has resources to invest in human capital and can overtake human capital investment of those who do not migrate. But, if the cost is sufficiently high, then, when immigrants pay the fix migration cost the quantity of resources available is not enough to overtake investment of native households. Imagine that I would have chosen the country with a TFP ratio of 0.3 to calibrate the fix migration cost that gives 1% of immigrants. In that case $\theta = 1.5$ and immigrants average years of education is 1.6 while for south natives is 2.6. So, there is negative self-selection but for a country with TFP ratio of 0.5 the selection is positive.

Then, the model with fix migration cost has three main implications. First, for two countries with the same fix migration cost and different TFP level, the immigrants from the country with higher TFP have higher average years of schooling and, are more probably positive self-selected. Second, for two countries with the same TFP level and different emigration cost, the immigrants from the country with higher emigration cost are less educated and, are more probably negative self-selected. Third, for a country with TFP ratio of 0.7 we observe that average years of education are 9. The same country but in a closed economy has 8.2 average years of education. Then, there is the induce education effect that makes the south invest more in human capital when migration is possible. This effect is much stronger in next section.

Anyway, this model does not do a good job simulating migration pattern in different dimensions. There are two main limitations. The first problem with the fix migration cost is that once a household can afford to pay the cost, the household migrates. Since the fix cost is relatively less important for countries with higher TFP, the model implies higher migration ratios for countries with

<table>
<thead>
<tr>
<th>TFP ratio</th>
<th>0.7</th>
<th>0.5</th>
<th>0.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$</td>
<td>5%</td>
<td>5.6%</td>
<td>5.36%</td>
</tr>
<tr>
<td>Immigrants</td>
<td>8.7%</td>
<td>1%</td>
<td>0.22%</td>
</tr>
<tr>
<td>South av. years of schooling</td>
<td>4.8</td>
<td>3.5</td>
<td>3.6</td>
</tr>
<tr>
<td>Immigrants av. years of schooling</td>
<td>9</td>
<td>5.9</td>
<td>4.3</td>
</tr>
<tr>
<td>$\phi_1$</td>
<td>0.8</td>
<td>0.1</td>
<td>0.02</td>
</tr>
<tr>
<td>$\theta$</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
higher TFP. The second problem is related. I am studying the steady state equilibrium. In the steady state equilibrium can not be any household in the south that can pay the fix cost. They have migrated in a theoretical transition. This is the reason why average years of schooling in the south are lower with respect to a closed economy.

4.3 Open Economy with two types of migration costs

To make the model more realistic I add another migration cost in line with migration literature. Now, in addition to the fix migration cost, the households who decide to migrate experiment a loss in his effective labor hours. This cost can be interpreted as the time that a household expends making all the preparatives to leave the native country, for instance: to look for a visa, to look for a job in the hosting country, to cancel contracts in the native country, to sell and buy the house, etc. Moreover, the migration literature always uses a cost that represents a percentage of losses of earnings in the hosting country due for example to idiomatic difficulties. In some sense you can see this two ways of modelling as equivalent in my model but with the great advantage that which I am using here is much easier to compute.

Introducing these two migration cost in the model the household’s problem in the south becomes:

\[
V(a, h, z, 0) = \max_{c,e,s,a',i'} \{u(c) + \beta(1 + n_0) \sum_z \pi_{z,z'} V(a', h', z', i') \}
\]

\[
c + (1 + n_0)e + (1 + n_0)a' \leq w_0h + (1 + n_0)(1 - s)w_0\psi + Ra - i'(\theta_f + \theta_v w_0h)
\]

\[
h' = z'(s^w e^{1-s})\xi
\]

\[
i' = \{0,1\}, \quad a', e \geq 0, \quad s \in [0,1]
\]

The calibration of \(\theta_f\) and \(\theta_v\) has to be made very carefully. For the moment, just to understand the trade off between these two costs I am going to choose the fix cost as 1/3 of the previous section and I will calibrate \(\theta_v\) following the previous procedure. It means that I will find the \(\theta_v\) that gives 1% of immigrants in the country with TFP ratio of 0.5. The effect of each migration cost and its calibration is crucial in the results. Although the calibration that I am using here is arbitrary, for the moment it is enough to stress the role of the migration costs in the model. The trade off between both costs is illustrated in the following graphics. These are the migration policy functions for different TFP ratios and initial shock. Each line leaves to the left the households that do not migrate and to the right those that migrate.

When the unique migration cost considered was the fix migration cost, the
migration decision was an increasing function in the resources of the household. Resources of the household are income from assets and wages. It means that once the households can afford the fix migration cost, they decide to migrate. When the time cost is added, the migration decision is not always an increasing function in the initial level of human capital as before. A household with low initial level of human capital will be willing to migrate. The same household with more initial human capital will migrate even before since can pay easily the fix migration cost. This is because the fix migration cost is relatively more important than the time cost. But there is an initial level of human capital where if I increase the initial level of human capital of a household and I fix the same physical capital level, then the household that before decided to migrate, now decides not to migrate. This is because at this point the time cost is relatively more important than the fix migration cost. To sum up. When the fix cost is relatively more important than the time cost, then, more households will migrate for higher initial levels of human capital. When the time cost is relatively more important that the fix migration cost, then, less households will migrate for higher initial levels of human capital. Finally, these graphics show that for a country with a TFP ratio of 0.3 the fix cost is relatively more important and for a country with a TFP ratio of 0.7 the time cost dominates the fix migration cost. We can see exactly this mechanism in a country with TFP ratio of 0.5. For this country and low initial shock, the fix cost dominates the time cost but for higher initial shock the time cost starts to be present.

I repeat the same exercise that in the previous section and the results are

<table>
<thead>
<tr>
<th>TFP ratio</th>
<th>0.7</th>
<th>0.5</th>
<th>0.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>r</td>
<td>5.64%</td>
<td>5.43%</td>
<td>5.51%</td>
</tr>
<tr>
<td>Immigrants</td>
<td>2.3%</td>
<td>1%</td>
<td>0.47%</td>
</tr>
<tr>
<td>South av. years of schooling</td>
<td>8.42</td>
<td>5.45</td>
<td>3.3</td>
</tr>
<tr>
<td>Immigrants av. years of schooling</td>
<td>22</td>
<td>13.72</td>
<td>2</td>
</tr>
<tr>
<td>$\phi_1$</td>
<td>0.22</td>
<td>0.097</td>
<td>0.058</td>
</tr>
<tr>
<td>$\theta_v$</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
</tr>
</tbody>
</table>

For countries with low TFP immigrants are negative self-selected and for countries with high TFP immigrants are positive self-selected. The reason is that for low TFP countries the fix emigration cost is relatively more important that the time cost. There are two reasons that explain this. First, since the TFP is lower, the fix cost is relatively higher compared with a richer country suffering the same fix cost. Second, the investment in human capital in a poor country is lower, then, the time cost is also lower. For countries with higher TFP the time cost is relatively more important. This result is very crucial. Immigrants from higher TFP countries are positive self-selected but, further-
more, they are overinvesting in human capital with respect a situation with no migration. Since the households know that if they migrate they suffer a loss in their effective units of labor, they overinvest in human capital to compensate this cost. Although the average years of schooling for an immigrant from a country with TFP ratio equal to 0.7 is too high, these results give support to the thesis of the induce education effect.

Moreover, although the number of immigrants increases with the TFP of the native country, this effect is less important than in the previous section. Can be the case for which immigrants decrease with the TFP level depending on the calibration of the costs. Finally, interest rate may be higher in the open economy with TFP ratio of 0.7 compared to the case of 0.3 due to the overinvesting in human capital.

5 Mexico, India and UK cases

In this section I will test if the model can replicate two particular cases, immigrants from Mexico, India and UK to US. Chiquiar and Hanson (2006) estimates that “Mexican immigrants, while much less educated than U.S. natives, are on average more educated than residents of Mexico” . Hendricks reports that average years of schooling of immigrants from Mexico to US is 7.5 while average years of schooling of Mexican natives is 6.3. This implies a weak positive self-selection. For India he finds that immigrants have 15.6 years of education but natives have 5. This suggest a strong positive self-selection. Mexico and India differ in their TFP, in their migration rates to US and in distance to US.

I set relative TFP ratios for Mexico and India to US as 0.6 and 0.3 respectively. Then, I fix $\theta^M_f = 1.$ for Mexico and $\theta^I_f = 3.$ for India. This tries to reflect the fact that the fix migration cost is higher from India than from Mexico. How do I choose $\theta^v$ for both countries? Since I know from previous studies the average years of schooling of the immigrants from these countries, I will calibrate the $\theta^M_v$ and $\theta^I_v$ that better match the data.

I find that with $\theta^M_v = 0.22$ and $\theta^I_v = 0.32$ average years of schooling for Mexican immigrants is 7.2 and for Indian immigrants is 12.88. Moreover, average years of schooling of Mexican natives is 5.1 and for Indian natives is 4. Then, to match the data on average years of schooling the model suggests that the time migration cost is higher for Indian immigrants. There are several interpretations of this result. Could be that the distance to US affects too the time migration cost in the sense that two countries close may have closer cultures which makes easier the migration. Another explanation is that since the Mexican community is very important in US, this lower the time migra-
tion cost. This seems a good explanation and may be the way to estimate the time migration cost with a better procedure in the future. Note that this result is very interesting because in the previous exercises I showed that for the same calibrated costs, countries with higher TFP present stronger positive self-selection than countries with low TFP. So, to increase the TFP helps to get positive self-selection. But India’s TFP is quite lower than Mexican’s TFP. Then, both costs are playing an important role in the pattern of self-selection of immigrants.

Immigrants from Mexico represent 5% of Mexican population and Indian immigrants are 0.001% of India. This result is mainly affected by the TFP of each country. Finally, I calculate the earnings ratio of the average immigrant to the average US native. For Mexican immigrants this ratio is 0.65 and for Indian immigrants is 0.83. Data for Mexican immigrant earnings says that they earn 40% less than a US native in average. In Hendricks these ratios are 0.76 and 0.97 for Mexico and India respectively. The ratio has been adjusted for identical age, education and sex.

A completely different case is UK. UK has TFP very similar to US. Average years of schooling of immigrants from UK is 14.6 while for UK the average is 8.8. The adjusted ratio of earnings for an immigrant form UK with respect to a born-native in the US is 1.3. I fix TFP ratio equal to 0.9 and the fix migration cost equal to 2, between the cost of Mexico and India. We expect the time cost from UK to be very low. For a time cost equal to 0.025 I find that average years of immigrants from UK is 14.8. Moreover, the earnings ratio is 1.2, reflecting that they earn more than US natives.

I sum up the results in the following table.

<table>
<thead>
<tr>
<th></th>
<th>Mexico</th>
<th>India</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>data</td>
<td>model</td>
<td>data</td>
</tr>
<tr>
<td>TFP ratio</td>
<td></td>
<td>0.6</td>
<td>0.3</td>
</tr>
<tr>
<td>$\theta_f$</td>
<td>-</td>
<td>1.</td>
<td>-</td>
</tr>
<tr>
<td>$\theta_v$</td>
<td>-</td>
<td>0.22</td>
<td>-</td>
</tr>
<tr>
<td>Immigrants av. years of schooling</td>
<td>7.5</td>
<td>7.2</td>
<td>15.6</td>
</tr>
<tr>
<td>South av. years of schooling</td>
<td>6.3</td>
<td>5.1</td>
<td>5</td>
</tr>
<tr>
<td>Relative earnings</td>
<td>0.76</td>
<td>0.65</td>
<td>0.97</td>
</tr>
</tbody>
</table>
6 Implication in differences in output per capita across countries

7 Conclusion

I add the possibility of migration in a human capital growth model to answer mainly two questions. First, investment in human capital is affected by the possibility of future migration? And second, which is the pattern of selection of immigrants? I find that optimal investment in human capital of immigrants is clearly above the investment in human capital in a closed economy most of the cases. This supports the thesis of induce education effect of brain drain theory. The significance of the induce education effect depends on the relative size of the migration costs, the TFP and the migration rate. Related with this I find that the migration pattern of self-selection is not unique. For the same migration costs Immigrants are positive self-selected for higher TFP countries while they are negative self-selected for lower TFP countries. To increase the time cost, all the rest constant, decreases the migration rate and implies higher positive self-selection. For acceptable parameter values I find that the model can replicate real selection patterns of immigrants. I find that average years of Mexican immigrants is 7.2 and Mexican natives is 5.1 Data for Mexican immigrants is 7.5 and 6.3 for natives. For the Indian case I find a strong positive self-selection as data indicates. I find that average years of schooling is 12.88 for immigrants and 4 for natives. Data for Indian immigrants is 15.6 and 5 for natives. I also get that immigrants from UK earns more than US native. I find a earnings ratio of 1.2 when real ratio is 1.3. Average years of schooling of immigrants from UK is 14.8 and in data it is 14.6.

The model has two main limitations. One has to be with dynamics of population. Since in the steady state relative size of each country with respect to the world population must be constant, this implies a relationship between population growth rates and migration rates. Moreover, for realistic migration rates, the relative size of north is very small since south natural population growth rate is higher. This affects comparative analysis because when I add immigrants in the north, the mass of these immigrants is too high compared to the north. The result is similar as in the north all the population are immigrants. The second problem is that I need the fix migration cost if I do not want that everybody migrates. But if a household can pay the fix migration cost, then migrates. So, in the steady state in the south there is not a household that can pay the fix migration cost. Is like incentives to migrate are to high and this affects the results of the south native population that not migrate.

These two problems show the line of future research. In fact, both limitations of the model have to deal with the steady state equilibrium. The natural
progress has to be the computation of the transitions. It remains a carefully calibration of the migration cost to match the model with different real cases. To solve this point it is crucial to find data on migration of human capital. Moreover, we can use the model to test different migration policies and it would be interesting to add in the model complementarity and substitutivity of skills.


8 Appendix

8.1 Population Dynamics

I define \( N \) as total world population and the fraction of people living in country \( i \) as \( \phi_i = \frac{N_i}{N} \) for \( i = \{0, 1\} \). Finally, I use the normalization \( \phi_0 + \phi_1 = 1 \). Using these definitions and equations (2) and (1) I can write population dynamics in the following way for both economies:

\[
\begin{align*}
\phi'_1 &= \frac{(1 + n_1)\phi_1 + (1 + n_0)m\phi_0}{(1 + n_1)\phi_1 + (1 + n_0)\phi_0} \\
\phi'_0 &= \frac{(1 + n_0)(1 - m)\phi_0}{(1 + n_1)\phi_1 + (1 + n_0)\phi_0}
\end{align*}
\]

(3) (4)

Equilibrium in the steady state implies that \( \phi'_i = \phi_i \) for \( i = \{0, 1\} \). It means that the size of the population relative to the world population must be constant in each economy. Equivalently, it means that population growth rates are equal in both economies in the steady state. Using this I obtain a necessary condition for the steady state:

\[
m = \phi_n \left( \frac{n_0 - n_1}{1 - n_0} \right)
\]

(5)

8.2 Steady State Equilibrium

For notation porpoise set \( x = \{a, h, z, i\} \) and \( X = \{[0, \infty] \times [0, \infty] \times Z \times \{0, 1\}\} \). Let \( B \) be the \( \sigma \) – algebra generated in \( X \) by the Borel subsets. A probability measure \( \mu \) over \( B \) describes the economy by stating how many households there are of each type. Let \( P(x, B) \) denote the transition function. Function \( P \) describes the conditional probability for a type \( x \) household to have a type in the set \( B \subset B \) tomorrow and describes how the economy moves over time by generating a probability measure for tomorrow, \( \mu' \), given a probability measure, \( \mu \) today. So, \( \mu'(B) = \int_X P(x, B) d\mu \) is tomorrow distribution of households \( \mu' \) as a function of today’s distribution \( \mu \) and the Markov chain.

Let \( X_0 \) be \( X \mid_{i=0} \) and \( X_1 \) be \( X \mid_{i=1} \) and equivalently for \( x_i \). Set \( g^j(x) \) as the policy function for \( j = c, a, h, e, s, i \). The steady state equilibrium for this economy is a set of functions for the household’s problem \( \{v(x), g^c(x), g^a(x), g^h(x), g^e(x), g^s(x), g^i(x)\} \), prices \( w_i \) and \( r \) and a measure of households, \( \mu \), such that:

(1) Markets are competitive and there are no arbitrage opportunities. Note
that since capital is freely perfect mobile, capital rental price must equalize across countries. Then factors rental prices are:

\[ r = \alpha A_0 \left( \frac{K_0}{H_0} \right)^{\alpha-1} = \alpha A_1 \left( \frac{K_1}{H_1} \right)^{\alpha-1} \]

\[ w_i = (1 - \alpha) A_i \left( \frac{K_i}{H_i} \right)^{\alpha} \]

(2) Given $\mu$, aggregate factors and prices, the functions \{\(v(x), g^r(x), g^a(x), g^b(x), g^c(x), g^g(x), g^i(x)\}\} solve the household’s problem.

(3) Population growth rates are equal in both economies, equation (5) holds.

(4) Markets clear:

\[ H_i = \int_{X_i} h \ d\mu(x_i) + \int_{X_i} (1 - g^s(x_i)) \psi \ d\mu(x_i) \quad \text{for} \quad i = \{0, 1\} \]

\[ K_0 + K_1 = \int_X a \ d\mu(x) \]

\[ I = \int_X [g^a(x) - (1 - \delta) a] \ d\mu(x) \]

(5) The world resource constraint is satisfied:

\[ Y_0 + Y_1 = \int_X [g^r(x) + g^c(x)] \ d\mu(x) + I + \int_{X_0} g^i(x_0) \theta \ d\mu(x_0) \]

(6) The measure of households is stationary $\mu(B) = \int_X P(x, B) \ d\mu$
References


