Quantitative Analysis on Immigrants' Self-Selection and its Implications

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Abstract

In this paper I investigate the interaction between human capital accumulation and labor mobility across countries. To this end, I build a model economy with two locations populated by households that take decisions on migration and their level of human capital. In my model economy there is positive or negative self selection depending on: differences in TFP between both economies, a pecuniary migration cost and a time migration cost that affects the effective units of labor. I contrast quantitative implications of the model with the data. I take three cases: immigrants from Mexico, India and UK to US. For each case the model is able to generate average years of schooling for immigrants and natives and relative earnings of immigrants with respect to US born-natives. I find that investment in human capital is higher in a world where households can migrate from one location to another one than in a world where they cannot. Finally, I find that when the TFP of the sending country is close to the TFP of the host country then output per capita difference decreases with mobility of human capital but if differences in TFP are large then output per capita difference increases.

Keywords: Migration, self-selection, human capital, TFP, brain drain, years of schooling.
JEL Classification: E20, F22, J61, O11.

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1   Introduction

How is the investment in human capital affected by the possibility of future migration? Who is
actually migrating? And how are affected differences in output per capita by mobility of human
capital? Brain drain theory suggests that the migration of people with higher human capital has
a negative effect in the source country. On the other hand, the possibility of migration may have
the positive effect that the source country invests more in human capital. I examine under which
circumstances one effect dominates the other. Moreover, data on immigrants' average years of
schooling from India and Mexico to US shows that while immigrants from India have 15.6 average
years of schooling, immigrants from Mexico have 7.5. But average years of schooling of non-
immigrants from India is 4 and from Mexico it is 6.3. Then, why the positive self-selection is so
stronger from India than from Mexico? I present a model economy with heterogeneous agents that
decide endogenously investment in human capital and migration. This original approach permits
me to answer these questions 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 critically on the
pattern of immigrants' self-selection. Although the migration literature usually has focus on the
effects of immigrants in the hosting country, international migration has effects in the source country
too. The brain drain theory stresses this idea and suggests that the migration of population that
has relatively high human capital 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' self-selection, we can quantify the
effects in differences in output per capita across countries and test different migration policies.

The main features of the model economy 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 pecuniary migration cost that can be interpreted as travel expenses and a time migration cost that affects the effective units of labor.

I find that for a given TFP differences the self-selection depends on the trade off between the pecuniary migration cost and the time migration cost. If there is only a pecuniary migration cost, then there exist an asset level for which all the households decide to migrate, then the distribution in the South is truncated because up to that level all the households are in the North at the steady state. The time migration cost has the effect that for households with higher initial level of human capital migration is costlier. When the pecuniary migration cost is relatively more important then immigrants are negative self-selected. If the time migration cost is relatively more important then immigrants are positive self-selected. The idea is that higher initial human capital implies a higher time migration cost but it also implies higher earnings which means that it is easier to pay the pecuniary migration cost. The self-selection depends on this mechanism. I contrast the model for immigrants from Mexico, India and UK to US. These three cases present so many different features among them that are good candidates to compare the model in different dimensions. I find that the model can replicate real selection patterns of immigrants for acceptable parameter values. I get that average years of schooling of Mexican immigrants is 7.2 and for Mexican natives it 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 obtain that average years of schooling is 13.5 for immigrants and it is 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 natives. I find an earnings ratio between immigrants from UK and US natives of 1.27 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 economy supports the induced education hypothesis. Investment in human capital increases when there is the possibility of future migration. The effect is quite significant. I quantify the increase in the average years of education from 9% to 36% depending on the case. Moreover, this effect is present even in the case of negative self-selection. Finally, I compute differences in output per capita in two environments. In an open economy model and in a closed economy model. I find that mobility of human capital decreases 2.6% differences in output per capita when the sending country has a TFP ratio of 0.7 with respect the host country but migration amplifies output per capita differences broadly 7% when the sending country has a TFP ratio of 0.5 and 0.3.

The brain drain theory begins in the 60's. People starts to be concerned about the negative effect

of migration in the source country. Berry and Soligo (1969) show that migration can decrease the income per capita in the source country in a model of partial equilibrium. Bhagwati and Hamada (1974) study fiscal policies that compensate the Brain Drain in the source country. The positive effect of brain drain comes up with the growth models of endogenous human capital accumulation and it is called the brain gain. The idea is simple, migration can affect the accumulation of human capital. In fact, the source country may invest more in human capital due to the possibility of future migration and, under different assumptions, this has a positive effect in the sending country. For instance, Mountford (1997) finds that, depending on the migration probability, the induced education effect by migration dominates the loss of human capital. In this case the brain drain has a positive effect in the origin country. Stark, Helmenstein, and Prskawetz (1997) say that in the case of asymmetric information and different structure of incentives the brain gain can compensate the brain drain.

Borjas (1994) has been the pioneer in the migration literature. He tried to answer the self-selection question using a partial static model derived from the Roy's model. 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. 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 where they will finish in the distribution of human capital in the host country. Since, usually, 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 Bellettini and Ceroni (2007). Chiswick finds positive self-selection adding in his theoretical model a migration cost that is less important the more skilled 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.

In the closest work to mine, Urrutia (2002) 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 fixed 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 fixed cost is relatively high then the opposite happens. In his model the ability is exogenous while in my model investment in human capital is endogenous. 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, his quantitative results do not take into account realistic TFP differences across countries.

A paper where migration is endogenous is Klein and Ventura (2007). They are interested in studding an efficient reallocation of labor in the world. In these paper agents are endowed with birthplace dependent efficiency units of labor so, again, there is no accumulation of human capital. Another difference compared to my paper is that in his model there is no migration at the steady state.

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 other hand Klenow and Rodriguez-Clare (1997), Hall and Jones (1999) and Bils and Klenow (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) and, mainly Erosa, Koreshkova, and Restuccia (2007). These authors stress 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 labor mobility. But if we are concerned about human capital in international accounting we must be worried about migration because migration is nothing else that mobility of human capital across countries. My paper contributes to this debate quantifying the effect of migration in cross-country output differences.

The paper is organized as follows. Section 1 describes the model economy. In section 2 I show the calibration of the parameters, the targets and their values and I present the benchmark economy. In section 3 I present the results of the immigrants' self-selection of immigrants. In section 4 I use the model to compare three real cases, immigrants from Mexico, India and UK to

US. In section 5 I test the induce education hypothesis. In section 6 I quantify the effect of mobility of human capital in cross-country output differences. Section 7 concludes.

2   The Model Economy

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

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

where Y_i is output and K_i and H_i are aggregated physical capital and aggregated human capital respectively in economy i[1]. I make the assumption that the north economy is more productive than the south economy, $A_1 > A_0$.

I follow Erosa, Koreshkova, and Restuccia (2007) [hereafter 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:

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

where $z^{'}$ is a stochastic shock that refers to the individual ability to accumulate human capital.

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[1]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 overlapping generation of dynasties that are altruistic toward the dynasty. There is 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 agents, then 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 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:

$$N_1' = (1 + n_1)N_1 + m(1 + n_0)N_0 \tag{2.1}$$

$$\text{and} \quad N_0' = (1 + n_0)(1 - m)N_0, \tag{2.2}$$

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 instant utility function takes the form:

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma}.$$

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

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[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

locations.

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, this is i'. If they take the migration decision all their descendants migrate and start abroad the next period. There are two migration costs. The first cost is a fixed migration cost θ_f. I interpret this cost as travel expenses between both locations. 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 second cost θ_t represents a loss in the effective labor hours of the old agent. This cost can be interpreted as the time that a household expends making all the preparations 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, 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 languages 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.

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 ψ. This parameter is to control for the life cycle profile of wages. I have normalized to 1 the equivalent parameter for old agents.

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

is:

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

$$s.t. \quad c + (1+n_1)e + (1+n_1)a' \quad \leq \quad w_1 h + (1+n_1)(1-s)w_1\psi + Ra$$

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

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

The problem faced by a household in country 0 is similar but presents the particularity that households decide where to start the next period. If they migrate then $i' = 1$ and they have to pay θ_f and experiment a reduction in their effective labor hours due to θ_t. The problem is:

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

$$s.t. \quad c + (1+n_0)e + (1+n_0)a' \quad \leq \quad w_0 h + (1+n_0)(1-s)w_0\psi + Ra - i'(\theta_f + \theta_t w_0 h)$$

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

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

2.6 Steady State Equilibrium

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

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

$$and \quad w_i = (1-\alpha)A_i \left(\frac{K_i}{H_i}\right)^{\alpha} \quad for \quad i \in \{0, 1\}.$$

2. Given μ, aggregate factors and prices, the functions $\{v(x), g^c(x), g^a(x), g^h(x), g^e(x), g^s(x), g^i(x)\}$ solve the household's problem.

3. Population growth rates are equal in both economies, equation (9.3) holds.

4. Markets clear:

$$H_1 = \int_{X_1} h \quad d\mu(x_1) + \int_{X_1} (1 - g^s(x_1))\psi \quad d\mu(x_1),$$

$$H_0 = \int_{X_0} h \quad d\mu(x_0) + \int_{X_0} (1 - g^s(x_0))\psi - \int_{X_0} g^i(x_0)\theta_t h,$$

$$K_0 + K_1 = \int_X a \quad d\mu(x),$$

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

5. The world resource constraint is satisfied:

$$Y_0 + Y_1 = \int_X [g^c(x) + g^e(x)] \quad d\mu(x) + I + \int_{X_0} g^i(x_0)\theta_f \quad d\mu(x_0).$$

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

3 Calibration

3.1 Parameters and Targets

The procedure of calibration takes two steps. First, I calibrate the benchmark economy to join US data in a closed economy. Second, I calibrate the open economy with labor mobility. The open

TABLE 1: Parameters and their values in the Benchmark Economy.

Parameter		Value
TFP	A_1	1
US natural population growth rate	n_1	0.59%
US population growth rate	n_1^p	0.92%
Discount Factor	β	0.945
CRRA	σ	2
Physical capital share	α	0.33
Physical capital depreciation	δ	0.0668

economy requires additional parameters values as for instance south natural population growth rate and the migration costs. 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_1^p is 0.92%[4]. I set $\delta = 0.0668$ and $\alpha = 0.33$ from Cooley and Prescott (). The coefficient of the CRRA utility function σ is set equal to 2, which is in the range of usually accepted values in this literature[5]. I calibrate β to match an annual interest rate of 5%. I sum up the parameters and their values in table (1). All the values are in annual terms.

It remains to choose the parameters related to the human capital investment. These parameters are: η, ξ, ψ 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:

$$log(z') \quad = \quad \rho_z log(z) + \epsilon_z, \quad \text{where} \quad \epsilon_z \sim N(0, \sigma_z^2).$$

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 ρ_z and σ_z^2. Then, I have to calibrate 5 parameter values. To do this I use U.S. cross-sectional data. The targets are:

1. As Seshadri and Manuelli (2007) I take average years of education equal to 12.08 from Barro and Lee (1996). In E-K-R average years of education is 12.9 from U.S. Department of Education 2004.

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[4]U.S. Census Bureau, International Data Base, year 2005
[5]See for instance Keane and Wolpin (2001),Klein and Ventura or E-K-R

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. E-K-R and Bils and Klenow (2000) follow Psacharopoulos (1994) that estimates a Mincer return of 10% for the US for the period (1990-1995).

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%.

3.2 The Benchmark Economy

In table (2) I link each target with its parameter and its parameter's value. Moreover, I compare US data for each parameter with data from the benchmark economy.

TABLE 2: Targets, US data, benchmark economy data, parameters and parameters' values.

Target	US data	B.E.	P	V
Av. years of schooling	12	11.9	ψ	0.10
Intergenerational corr. of log-earnings	0.5	0.5	ρ_z	0.06
Variance of log-earnings	0.36	0.35	σ_z	0.43
Mincer returns to schooling	10%	7.7%	ξ	0.7
People with college education or higher	54%	54%	η	0.75

The benchmark economy replicates quite well the targets, even though I am underestimating mincer returns. Although it is not obvious how to relate 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 3: Ratios of total median earnings for different levels of highest education attainment.

	US data	BE
Primary/Secondary	0.65	0.57
Secondary/Secondary	1	1.
College/Secondary	1.86	1. 83

The benchmark economy is able to generate a distribution of earnings very close to US data. I find a ratio of 1.83 for college/secondary and the data for this ratio is 1.86. The model economy slightly underestimates the ratio primary with secondary. Of course there is always a problem when we try to link data with model data in these kind of model since time is continuous and does not take into account completion of degrees. 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. I have calculated 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. Manuelli and Seshadri use as a target that expenditures in schooling as a fraction of GDP is 3.77% from OECD. I have found an upper bound of expenditures in schooling of 6.6% using OECD data for 2004. I get in the benchmark economy a expenditure ratio of 2.12%.

4   Results on the Immigrants' Self-Selection

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 ($n_0 = 0.95\%$). TFP takes three different values 0.3, 0.5 and 0.7. Since the TFP level in the benchmark economy has been normalized to 1, the ratio between South and North TFP for each value is the same that the TFP level in the South. I present the results in table (4):

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, Manuelli and Seshadri report that for output per worker ratio to US of 0.146 the average is 4.64 and 5.18 for an output per worker ratio of 0.244. For an output ratio of 0.38 the average years of schooling falls in the interval (5.88-7.54). I find an average years of schooling of 6.3. For an output per worker ratio of 0.6 the average years of schooling is broadly 8.5 and I find 8.3. E-K-R find an average years of schooling of 4.3 for a TFP ratio of 1/3 and an average years of schooling 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 the Pecuniary Migration Cost

Equation (9.3) must hold in a open economy with migration at 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 percentage of immigrants, or I fix as a target the percentage of immigrants and this implies a South natural population growth rate. I have decided to fix a target of 1% of immigrants with respect to the South population. 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 $n_0 = 0.953\%$. 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

Table 4: Results in a closed economy for different TFP values.

TFP	1	0.7	0.5	0.3
Output ratio	1	0.6	0.38	0.2
r	5%	5.11%	5.12%	5.24%
Av. years of schooling	12	8.3	6.3	4.1
Mincer returns to schooling	7.7%	11%	14.8%	21.6%

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and Mexico natural population growth rate is 1.6% (from US Census Bureau, 2005).

To stress the role of the pecuniary migration cost in the model I set in this section $\theta_t = 0$. It means that the unique migration cost is the pecuniary migration cost. Once I have fixed the migration target, I proceed in the following way. I find the pecuniary migration cost for a TFP value of 0.5 that implies 1% of immigrants. The pecuniary migration cost is calibrated proportionally to average annual earnings in the benchmark economy. This means that I define the pecuniary cost as $\theta \bar{w}_1$ where $\bar{w}_1$ is per year average earnings of an old agent in the North in the benchmark economy. Then I calibrate θ to match 1% of immigrants. Once I obtain this value for θ I run the program for a TFP value of 0.3 and 0.7. Results are presented in table (5).

TABLE 5: Results in an open economy with pecuniary migration cost for different TFP values.

TFP	0.7	0.5	0.3
r	5%	5.6%	5.36%
Immigrants	8.7%	1%	0.22%
South non-immigrants av. years of schooling	4.8	3.5	3.6
Immigrants av. years of schooling	9	5.9	4.3
ϕ_1	0.8	0.1	0.02
θ	3	3	3

Results suggest that immigrants are positive self-selected because average years of schooling of immigrants are higher than those who do not emigrate. Anyway, there is a pecuniary cost for which this result reverses and the average years of schooling of immigrants is lower than average years of schooling of those who do not emigrate. Self-selection is very sensitive to the size of the pecuniary migration cost. Equivalently, it is sensitive to the TFP level since to increase the TFP of the sending country is equivalent to decrease the pecuniary cost. When there is only a pecuniary cost there exist an initial asset level for which all the households decide to migrate. It means that if the household can pay the pecuniary migration cost, then the optimal decision is migration. Note that higher initial level of human capital means higher income and, therefore, it is easier to pay the pecuniary migration cost for any initial asset level. The result is that the pecuniary migration cost is truncating the South distribution from the top of assets and human capital. So, if we look at the steady state in the South there are households that we cannot observe because they are already in the North. Obviously these households that we do not observe in the South are also a measure of the brain drain. For higher pecuniary migration cost the average years of schooling increases for all the natives in the South (immigrants and non-immigrants) and the reason is that for higher pecuniary migration cost the South distribution is less truncated so it is more similar

to the distribution in the South in a closed economy. The self-selection depends on the size of the pecuniary migration cost and reason is related to the previous mechanism. When the pecuniary migration cost is higher, after the households pay the migration cost they have less income to invest in human capital accumulation. Then, immigrants are possibly negative self-selected while if the pecuniary migration cost is low then the households can pay the cost and invest in human capital and potentially immigrants can overtake the investment in human capital done by non-immigrants.

If I choose the country with a TFP value of 0.3 to calibrate the pecuniary migration cost that gives 1% of immigrants then $\theta = 1.5$ and immigrants' average years of schooling is 1.6 while for non-immigrants it is 2.6. So, there is negative self-selection but for a country with TFP value of 0.5 the self-selection is positive.

We learn from this model that the pecuniary migration cost truncates the South distribution. In section (6) I consider carefully the implications of this result in the objective of testing the induce education hypothesis.

4.3 Open Economy with both Migration Costs

In this section I consider both types of migration costs. The calibration of θ_f and θ_t has to be made very carefully. For the moment, just to understand the trade off between these two migration costs I am going to choose the pecuniary cost as 1/3 of the previous section and I will calibrate θ_t following the previous procedure. It means that I will find the θ_t that gives 1% of immigrants in the country with TFP level of 0.5. The effect of each migration cost 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 figures (1), (2) and (3). These are the migration policy functions for different TFP levels and initial shocks z. Each line leaves to the left the households that decide not migration for an initial level of assets and schooling years of education. Equivalently each line leaves to the right those households that migrate for initial levels of assets and years of schooling. So, the line shows the frontier between those who do not migrate and immigrants. The graph is for initial schooling years of education because human capital is a function of the initial shock and therefore I cannot do the graph for each initial shock. Figure (1) is for a country with TFP level of 0.3. In the graph you see that for higher initial shocks the migration frontier moves to the left. It means that for the same initial level of a and s more households will

migrate if the initial shock is higher. The reason is that if the initial shock is higher, earnings of the old agent are higher too so it is easier to pay the pecuniary migration cost. This is the mechanism that I explained in the previous section. In figure (3) we see the migration policy functions for a country with TFP level of 0.7. In this case the migration frontier moves to the right when the initial shock is higher. The reason is that the time migration cost is relatively higher for higher initial shocks. Then, for the same initial a and s less households decide to migrate if the initial z is higher. Which is the difference between the first case and this case? In the first case, a country with TFP level of 0.3, the pecuniary migration cost is relatively more important than the time migration cost. But for a country with TFP level of 0.7 the time migration cost is relatively more important than the pecuniary migration cost. It is easy to see this trade-off in figure (2). In figure (2) there are the migration policy functions for initial shocks z_3, z_4 and z_5 for a country with TFP level of 0.5. Consider de graph for a middle initial shock z_3. This line or migration frontier goes to the left because the pecuniary migration cost is dominating the trade-off. But for higher initial shocks the migration frontier goes to the left and then it moves to the right. The point where it changes is exactly where the time migration cost starts to dominate the trade-off between both migration costs.

Consider that I fix the TFP level of a country and I move the migration costs. Then, if there is only a pecuniary migration cost, then there is an asset level for which the distribution in the South is truncated because up to that level all the households are in the North at the steady state. The time cost has the effect that now for households with higher initial level of human capital migration is costlier. Then, when the time cost is high immigrants are from the middle of the South distribution and migrate with more assets. The reason is that since households with higher levels of human capital find very costly migration they invest in human capital and accumulate physical capital. In this case immigrants are weakly positive self-selected. When the time cost is not so high, it has two effects. On one hand it is true that for higher initial level of human capital the migration cost is higher but on the other hand a higher initial level of human capital also implies higher income and then it is easier for them to pay the pecuniary migration cost. This second effect dominates and in this case immigrants are from the top of the human capital distribution of the South and migrate with less assets. To sum up, when the time migration cost is relatively low, for a household with higher initial human capital the effect that they have more income to pay the pecuniary migration cost dominates the time migration cost. But when the time migration cost is relatively high, then dominates the effect that migration is relatively costlier for higher initial human capital and there is weak positive self-selection.

Now that we understand the trade-off between both migration costs it is easier to analyze the quantitative results. I repeat the same exercise that in the previous section and results are presented in table (6).

TABLE 6: Results in an open economy with both migration costs for different TFP values.

TFP	0.7	0.5	0.3
r	5,4%	5.6%	5.7%
Immigrants	1.79%	1%	0.54%
South non-immigrants			
average years of schooling	8.45	5.45	3.1
Immigrants av. years of schooling	23	13.72	2.2
ϕ_1	0.18	0.097	0.048
θ	1	1	1
θ_t	0.29	0.29	0.29

For countries with low TFP immigrants are negative self-selected and for countries with high TFP immigrants are positive self-selected. Immigrants are negative self-selected for a TFP level of 0.3 because in this case the pecuniary migration cost is relatively more important. It implies that the South distribution is truncated from the top of human capital and assets and that immigrants pay the pecuniary migration cost and then invest in human capital but this investment is lower that the investment of non-immigrants. The positive self-selection for the other two cases means that they are in the situation where the effect that higher initial human capital means that it is easier to pay the pecuniary migration cost dominates the effect that higher initial human capital means higher time migration cost. The average years of schooling in the South considering all the households is 3.25, 5.53 and 8.75 for TFP ratios of 0.3, 0.5 and 0.7 respectively. 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 the number of immigrants decreases with the TFP level depending on the calibration of the migration costs.

5   Immigrants from Mexico, India and UK

In this section I will compare results of the model with three specific countries, immigrants from Mexico, India and UK to US. Chiquiar and Hanson (2005) 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 suggests a strong positive self-selection. Mexico and India differ in their TFP, in their migration rates to US and in the distance to US.

I set relative TFP ratios for Mexico and India to US as 0.6 and 0.3 respectively from Urrutia. Then, I fix $\theta^M = 1.$ for Mexico and $\theta^I = 3.$ for India. This tries to reflect the fact that the pecuniary migration cost is higher from India than from Mexico due to the distance. It remains to choose θ_t for both countries? Since I know from previous studies the average years of schooling of the immigrants from Mexico and India, I calibrate the θ_t^M and θ_t^I that better match the data. Results are presented in table (7).

TABLE 7: Results for Mexico, India and UK.

	Mexico		India		UK	
	data	model	data	model	data	model
θ	-	1.	-	3.	-	2
θ_t	-	0.22	-	0.33	-	0.025
Immigrants av. years of schooling	7.5	7.2	15.6	13.5	14.6	14.8
Non-immigrants av. years of schooling	6.3	5.1	5	4	8.8	6
Relative earnings	0.76	0.76	0.97	1.01	1.3	1.27

I find that with $\theta_t^M = 0.22$ and $\theta_t^I = 0.32$ average years of schooling for Mexican immigrants is 7.2 and for Indian immigrants is 13.5. 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 closer may have closer cultures which makes easier the migration preparations. Another explanation is that since the Mexican community is very important in US, this decreases the time migration cost. This seems a good explanation and may be a good proxy 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 lower 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 0.76 and for Indian immigrants it is 1.01. Data for earnings of Mexican immigrant 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 set TFP ratio equal to 0.9 from Urrutia and the pecuniary migration cost equal to 2, between the cost of Mexico and India. We expect the time migration cost from UK to be very low. For a time migration cost equal to 0.025 I find that average years of schooling of immigrants from UK is 14.8. Moreover, the earnings ratio is 1.27, reflecting that they earn more than US natives.

The conclusion is that this model is able to replicate correctly very diverse data in average years of schooling for different patterns of immigrants self-selection. The main features of the model to match the data are the two different migration costs and the differences in TFP across countries.

6   Induced Education Effect

In this section I perform several exercises to study the induced education hypothesis. The idea of this hypothesis is very simple. Investment in human capital may increase in the source country due to the possibility of future migration. Although this idea is simple, is very hard to test with data. The main problem is that we do not have at the same time data on two different scenarios, one where migration is possible and another where it is not. This has been a big limitation in the econometric studies that have attempted to analyze this hypothesis. But there is a second problem. I can compare average years of schooling in the closed economy with the average years of schooling of non-immigrants in the open economy. If I do this, I am answering a differing question. I would be testing if average years of schooling increases or decreases in the source country when migration is possible. But that average years of schooling in the sending country increases when there is migration does not mean that there exist an induced education effect because the distribution in the source country is different compared to the distribution in the closed economy. So, there are not the same households in both distributions. I mean, the households that we observe in the open economy model are not the same households that we observe in the closed version. For instance remember that in some cases the South distribution is truncated in the open economy model.

Although it is impossible to solve this limitation with data I am able to solve it in this paper.

TABLE 8: Induced education effect for different TFP ratios.

TFP ratio	0.7	0.5	0.3
South non-immigrants average years of schooling	8.45	5.45	3.1
South av. years of schooling in a closed economy	6.7	4.1	2.46
Adjusted South av. years of schooling in a closed economy	4.47	3.1	2
% of variation	88.95	77.52	49.16

In table (8) I do the following exercise. I compare results from table (6) with results from a closed economy. I calibrate the discount factor in the closed economy to match the interest rate in the open economy in order to maintain the same returns in physical capital and human capital in the two cases. South non-immigrants average years of schooling is the average years of schooling of those who do not migrate in the open economy. South average years of schooling in a closed economy is the average years of schooling in the South taking into account all the South distribution. The difference between this average and its equivalent in table (4) is that the discount factor in these closed economies has been calibrated to mach the interest rate in the open economy for each case. Finally, the adjusted South average years of schooling is the average years of schooling in the South in a closed economy but only of those households that you find in the South's distribution in the open economy. Then, this average gives an exact measure of the induced education effect since I am comparing investment in human capital for exactly the same households but in two different frameworks, one where there is migration and another where there is no possibility of migration.

Results indicate that there exist an induced education effect since average years of schooling is higher for the same households in the open economy than in the closed economy. This effect is quite important, mainly for countries with higher TFP level. For instance, the average years of schooling in a country with a TFP level of 0.7 when migration is possible is almost twice the average in a closed economy with the same TFP level. Although less important in a country with a TFP level of 0.3 there is also an induced education effect. In a country with a TFP level of 0.3 the possibility of future migration increases the average years of schooling in 1 year which implies an increase of broadly 50% with respect the closed economy. The measure of the average years of schooling not adjusted in the sending country in the closed economy underestimates the induced education effect. Note that for a TFP level of 0.3 the immigrants' self-selection is negative but even for this

case there exist an induced education effect. The reason is that higher investment in education increases next period earnings which implies that it is easier to pay the pecuniary migration cost. Remember that for lower TFP levels the pecuniary migration cost dominates the time migration cost. So, the induced education effect exists even in the case of negative self-selection.

Finally, I have done the same exercise but for Mexico, India and UK. It implies that I have computed for each economy the equivalent economy where there is no migration but the interest rate is the same that in the open economy version. Results are presented in table (9). First note that the average years of schooling for each country in its equivalent closed economy version is similar to data except for India where it is lower in the model. The results show that there exist the induce education. In Mexico the average years of schooling increases by 36% with respect a situation where there is no migration which implies an extra year of schooling. In India the increase is 16%. Less important is this effect for the case of UK that experiments an increase in its average years of schooling of 9%.

TABLE 9: Induced education effect for Mexico, India and UK.

	Mexico	India	UK
Non-immigrants average years of schooling	5	4	6
Av. years of schooling in a closed economy	6.4	3.5	9.6
Adjusted av. years of schooling in a closed economy	3.7	3.4	5.2
% of variation	36.24	16.12	9

7 The Effect in Cross-Country Output Differences

The brain drain theory defends the thesis that migration of relatively high human capital has a negative effect for the sending country. With thew brain drain theory appears the induced education hypothesis. They support the idea that if the induced education effect exists, then under different assumptions it is possible that the sending country gets benefits from the brain drain. One of these assumptions is very simple. If the households invest more in human capital due to the possibility of future migration but at the end they do not migrate then the stock of human capital in the source country increases and this can be positive for the sending country. In this section I analyze the effect of brain drain in the source country but from a different point of view.

I quantify the effect of migration in cross country output per capita differences. To this end I do the following exercise. In the open economy model I fix the relative size of each country equal to 0.5. With this assumption the results do not depend on the world distribution of the population and I am able to compare the results from the open economy with those from the closed economy since the relative size of both countries in each situation is the same. Obviously the natural population growth rate in the South and the time migration cost have been modified in order to match the assumption of equal relative size of both countries. Moreover, I simulate the three cases in the closed economy version for the new parameter's values to get the ratios in output per capita when migration is not allowed. Results are presented in table (10). In this table I present the output per capita ratios for each TFP level (0.7, 0.5 and 0.3) with respect to a TFP level of 1 (the benchmark economy) in two different scenarios, in an closed economy and in an open economy. In the third row I show the % of variation between these two environments. The quantitative results implies that output per capita differences decreases broadly 2.5% for a country with TFP level of 0.7 in an open economy which implies a positive effect due to the brain drain. But the brain drain increases the output per capita differences in countries with lower TFP level which implies a negative effect in the sending countries. This effect is quite significative since for the two cases presented the output per capita differences decreases around 7%.

TABLE 10: Cross country output per capita differences.

TFP ratio	0.7	0.5	0.3
Closed economy	0.4581	0.2281	0.0842
Open economy	0.4702	0.219	0.0784
% of variation	2.64	-7.1	-6.89

8   Conclusions

I add the possibility of migration in a human capital growth model to answer mainly three questions. First, which is the pattern of self-selection of immigrants? Second, is investment in human capital affected by the possibility of future migration? And third, how are affected differences in output per capita by mobility of human capital? I find that for a given TFP differences the self-selection depends on the trade off between the pecuniary migration cost and the time migration cost. When the pecuniary migration cost is relatively more important then immigrants are negative self-selected. If the time migration cost is relatively more important then immigrants are positive self-selected.

This trade off is affected by differences in TFP level. The model economy presented in this paper is able to replicate difference patterns of self-selection. In fact, I do the cases of immigrants from Mexico, India and UK to US and the results of the model are in concordance with data. Results support the thesis of the induce education effect. Investment in human capital increases when there is the possibility of future migration. This effect is present even in the case of negative self-selection. Finally, I compute differences in output per capita in two environments. In an open economy model and in a closed economy model. I find that mobility of human capital decreases differences in output per capita when the sending country has a TFP ratio of 0.7 with respect the host country but migration amplifies output per capita differences when the sending country has a TFP ratio of 0.5 and 0.3.

The model can be used to study different migration cases. To this end it is necessary more data. First, we need data on migration of human capital from country of origin for different host countries. Second, it is crucial data on migration costs to build a theory about these migration costs ant to calibrate the model in each particular case.

The natural progress is the computation of the transitions. Computation of the transition in this model will provide more useful information and permits exercises that we cannot perform looking only at the steady state. One of these exercises is to use the model to test different migration policies. Moreover, it would be interesting to add in the model: human capital externalities and complementarity and substitutivity of skills.

9 Appendix

9.1 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 (2.2) and (2.1) I can write population dynamics in the following way for both economies:

$$\phi_1' = \frac{(1+n_1)\phi_1 + (1+n_0)m\phi_0}{(1+n_1)\phi_1 + (1+n_0)\phi_0} \tag{9.1}$$

$$\phi_0' = \frac{(1+n_0)(1-m)\phi_0}{(1+n_1)\phi_1 + (1+n_0)\phi_0} \tag{9.2}$$

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:

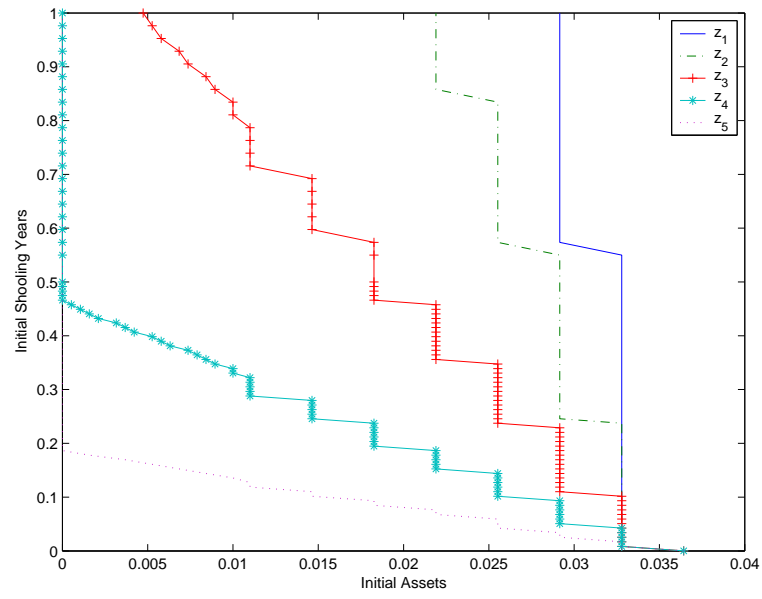$$m = \phi_1 \left(\frac{n_0 - n_1}{1 + n_0} \right) \tag{9.3}$$

FIGURE 1: Migration policy functions for each initial z for a country with TFP ratio of 0.3.
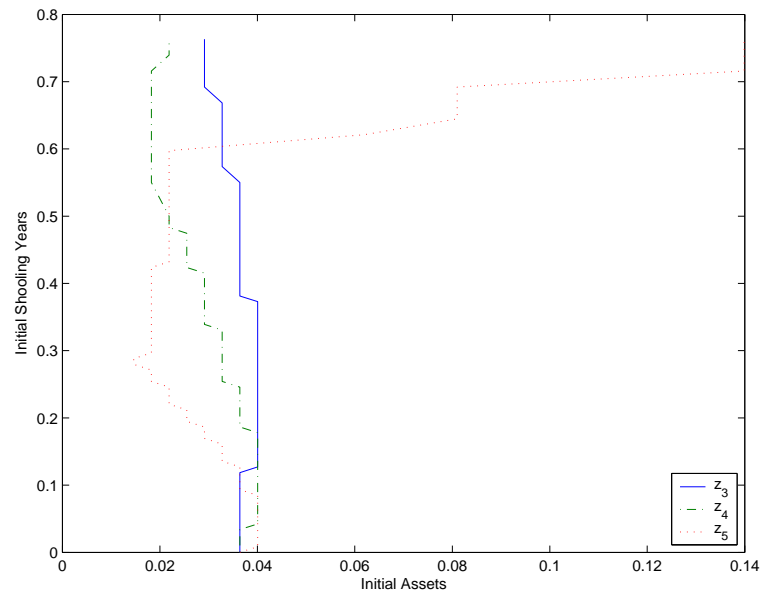

FIGURE 2: Migration policy functions for initial z_3, z_4 and z_5 for a country with TFP ratio of 0.5.
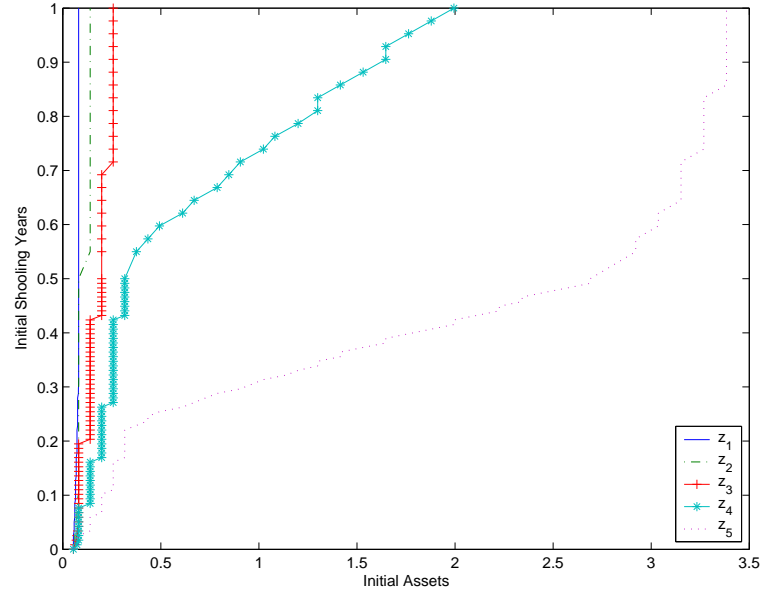
FIGURE 3: Migration policy functions for each initial z for a country with TFP ratio of 0.7.

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