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Migration and human capital in an endogenous fertility model

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Abstract. What is the impact of high-skilled emigration on fertility and human capital in migrants' origin countries? This question is analyzed within an overlapping generations model where parents choose to finance higher education to a certain number of their children. It follows that families are composed of high- and low-skilled children who may both emigrate with a certain probability when they reach adulthood. It is found that a brain drain leads to a change in children's skill composition, with parents choosing to provide higher education to a larger number of their children. A calibration of the model suggests that, following a brain drain, the additional children benefiting from higher education might in the long run compensate for the loss of high-educated workers and lead to a brain gain.

Keywords: Migration, human capital, fertility.
JEL Classification: F22, J13, J24.

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1 Introduction

At the world level, the number of international migrants rose from 76 million in 1960 to 175 million in 2000, but, considering population growth, the world share of migrants remained quite stable (2.5% in 1960 to 2.9% in 2000). However, the *structure* of world migration has considerably evolved. Recent datasets on migration pattern indicate that migration is increasingly skill-biased, and that South to North migration is becoming more and more important. As a matter of fact, the immigration rate in high income countries doubled between 1970 and 2000 (from 4% to 8%, see UN 2003 and IOM 2005). Docquier and Marfouk (2006) document that between 1990 and 2000, the number of high skilled immigrants in OECD countries increased by about 64%, while it was only about half as much for low-skilled immigrants. This rise in skilled migration was even stronger for immigrants from developing countries (up 93 percent). These trends are likely to be reinforced in the coming decades. In fact, the attractiveness of developed countries for workers from developing regions is ascending with the increased interdependence among countries, globalization, rising income inequality, enhanced transportation technology, decreasing transportation costs, and stronger demographic disparities between developed and developing countries. Moreover, as rich countries tend to apply more skilled-biased immigration policies, migration of skilled individuals is expected to amplify. Brain drain is thus a major concern in developing countries.

The economic literature has not yet found a consensus about the impact of skilled emigration on migrants' source countries. While the early theoretical literature of the 60s pointed out that a brain drain has basically no impact on migrants' origin countries and should not be a cause for worry (Grubel and Scott, 1966), during the 70s economists, and foremost Bhagwati and Hamada (1974), stressed that skilled emigration induces a negative externality on sending countries and that "there *is* a loss to those left behind". In recent years, economists took a fresh look at the issue and highlighted a range of positive side-effects of skilled emigration.[1] Besides the positive impact of remittances sent home by emigrants, one benefit of the brain drain is attributed to return migration which enables the transfer at home of knowledge acquired abroad (Dustmann and Kirchkamp, 2002) and the choice of self-employment and entrepreneurial activities (Santos and Postel-Vinay, 2003). Moreover, Kugler and Rapoport (2007) find strong evidence of a complementarity between FDI and skilled migration, pointing out that migrant networks may favor FDIs by reducing informational barriers and thus enhance the attractiveness of the home country to foreign investors. Another major positive externality of brain drain is that it induces greater incentives for individuals to educate because of a higher expected skill premium. Then, if the newly educated individuals outweigh those leaving the country, human capital at origin is enhanced compared to a situation without brain drain (Mountford, 1997; Stark et al., 1997; Vidal, 1998; Beine et al., 2001). Skills emigration may then be considered as a substitute for educational subsidies (Stark and Wang, 2002).

The aim of this paper is to analyze how permanent skilled emigration shapes parents' fertility choices and thus affects human capital formation at origin. We develop an overlapping generations (OLG) model with endogenous fertility, where children have a certain probability to emigrate when adult. A more liberal immigration policy (or a more generous exit visa policy) induces more grown-up children to leave the origin country. It is shown that brain drain induces parents to raise a higher number of high skilled children and to reduce the number of low-skilled children. Another finding is that brain drain decreases the total number of children within a family. Furthermore, a calibration of the model on a developing country shows that permanent high skilled emigration reduces human capital in the short run, but raises it in the long run, as the additional children benefiting from higher education more than compensate the initial loss of high skilled

[1] In an extensive survey, Docquier (2006) describes the different positive externalities linked to skilled emigration.

workers.

The bulk of the economic literature on the brain drain takes population as constant and does not analyze fertility decisions. However, economists pointed out that the decisions parents face in terms of fertility and of investment in the education of their children are central for a country's economic development, see for instance Becker and Barro (1988), as well as de la Croix and Doepke (2003). The quality-quantity trade-off in terms of children, i.e., between the number and the education of children, influences human capital formation and is, thus, crucial for a country's economic growth. Little attention has been devoted to the impact of emigration on parents' fertility choices. In a recent work, Beine et al. (2008) empirically analyze the factors explaining the observed fertility convergence between migrants' source and destination countries. Mountford and Rapoport (2007) develop a two-country growth model with endogenous fertility to examine the impact of brain drain on the world distribution of income and population. The aim and approach of our study are however more closely related to Chen (2006) who also focuses on migrants' sending countries.

In endogenous fertility models, households usually decide on the total number of children and on the amount of education to grant to these offsprings. Since educational investment is transformed into human capital, it typically follows that individuals are characterized by a uniform level of human capital. This is, in particular, the case in Chen (2006).[2] In reality and particularly in developing economies, parents are not necessarily able to support every child's higher education. Moreover, if parents' financial resources are not sufficient to provide every child with a *complete* education program, the assumption of a uniform (higher) education level no longer holds since children would unrealistically receive partial qualification. In

[2]To introduce skill heterogeneity, endogenous fertility models assume that human capital accumulation also depends on children's ability level or parents' human capital level, which differ across the population (see e.g. de la Croix and Doepke, 2003). In Chen (2006) parents' human capital enters the human capital production function, but parents have all the same level of education.

our paper we therefore assume that parents need to decide on how many children obtain higher education. This view is consistent with the sociological literature. Indeed, Williams et al. (1997) examine parents' decisions about educating some or all of their children beyond primary school in rural Thailand. This indicates clearly that parents limit educational investment to a subset of their children.

Our model setting thus departs from the traditional model setting. This has also the advantage to explicitly introduce skill heterogeneity among agents by allowing families to be composed of high- and low-skilled children.[3] When having reached adulthood, people migrate with a certain probability and we show that brain drain leads to a change in the skill-composition of children. This is another distinct feature from Chen (2006), in which migration needs to be random to affect fertility choices. We find that additional high skilled migration induces *both high- and low-skilled* parents to provide higher education to a larger number of their children, because the increased opportunity for high skilled to migrate raises the expected income of high skilled children. This effect is similar to the incentive effect highlighted in the above-mentioned studies (e.g. Mountford, 1997; Vidal, 1998; Beine et al., 2001), except that in our study it originates from parents' fertility choices. We further show that increased skills emigration diminishes fertility in the sending country. This result is identical to that of Mountford and Rapoport (2007), but it is obtained in a different way. In our model, rising brain drain fosters educational investment but each additional high skilled child substi-

[3]Mountford and Rapoport (2007) also allow for skill-heterogeneous children. Their framework is however different from ours, since individuals choose the number of children and a threshold ability level above which all children will be educated. Our approach is different since we assume that parents decide separately on the number of educated and non educated children. So fertility and education choices are achieved in a unique decision. Moreover, another distinct feature is that, in their study, rich and poor families have the same number of total children and the same skill-composition of children. In our framework, the economic background of each family affects fertility decisions, which is closer to reality of some developing countries. For instance the World Bank study of Azam and Blom (2006) points out that participation in tertiary education in India differs between students from rich and poor families.

tutes for more than one low-skilled child. This contributes to a decrease in total fertility. In Mountford and Rapoport (2007), the same result is achieved through direct substitution between consumption and fertility.

In the same way as Chen (2006), we calibrate our model to the Philippines. We show that the additional supply of high skilled children, generated by a change in fertility choices, compensates in the long run the direct loss of high skilled workers due to increased high skilled emigration. Our result contrasts with Chen (2006), who finds that brain drain is detrimental for the Philippines in the long run. An important source of divergence probably stems from the fact that Chen (2006) does not model intergroup mobility. Indeed, in her numerical application she splits the population into a high and a low-skilled group, where children belong to the same skill-group as their parents. Increased high skilled emigration induces a reduction in the number of children of the high skilled group but has no impact on the low-skilled population. Despite a higher investment in education of the high skilled group resulting from increased brain drain, the lack of intergroup mobility implies that the high skilled population shrinks while the low-skilled one remains unchanged. This finally leads to a negative impact of brain drain in the migrants'sending countries. In our model we allow for intergroup mobility as both skill-types of parents raise high- and low-skilled children, and thus skilled emigration affects the decisions of both types of parents.

The paper is organized as follows. Section 2 introduces the model and explains the theoretical effects of increased skilled emigration. The calibration on the case of the Philippine economy is presented in section 3. Section 4 concludes.

2 The Economic Model

We consider an overlapping generation economy where individuals live for 3 periods: childhood, adulthood, and old age. Each individual has one parent, which creates the connection between generations. Individuals have either a low (superscript l) or a high education level (superscript h). Higher education is costly, while lower education is offered for free by society.[4] During their childhood, individuals who attend school do not work, whether they obtain higher education or not. Also, agents work only in their adulthood and earn a wage that depends on their education level. High skilled adults earn a wage w^h, while low-skilled earn w^l with $w^h > w^l$.

We consider a small open economy where capital is perfectly mobile, which implies a given international interest rate R^*. Both high- and low-skilled wages are also set exogenously. Both low and high skilled labor in this small open economy can emigrate to an advanced economy and earn a higher salary, w^{*i} ($i = h, l$), which is exogenously given with $w^{*i} > w^i$. Finally, we assume that emigration is not large enough to affect the economy of the destination country.

2.1 Individual behavior

All decisions are made by the individual during her adulthood. Thus at time t, each adult with education level i cares about her own old age consumption S^i_{t+1} and about the expected income of her children, V^i_{t+1}. It is assumed that individuals consume only when old. Thus there is no arbitrage opportunity for consumption, which is purchased through savings. The individual also cares about the return from her "education investment", that is, the expected income of her children, V^i_{t+1}, which represents the altruistic component in the utility. Contrarily to most endogenous fertility models, the

[4]For instance, individuals with a college degree could be considered as high skilled and individuals without such a degree as low skilled. Then education after high school would be costly, while education below college level would be free.

individual does not decide uniformly upon the total number of her children and their education level (or investment in their education), but directly about how many low (n_t^i) and high educated children (m_t^i) she would like to have. In other words, parents choose how many children will be provided with higher education and how many will not.

At the beginning of their adulthood, individuals with education level i can emigrate to a more advanced economy with a probability p^i, $(i = h, l)$. Hence the expected income of a child with education level $i = h, l$ is

$$\overline{w}^i = (1 - p^i)w^i + p^i w^{*i}, \ i = h, l \tag{1}$$

where p^i is exogenous. The probability p^h for high skilled to emigrate will serve as a policy variable in the comparative statics as well as in the numerical example. A rise in p^h can either be associated with a more selective immigration policy of a destination country, (e.g., a reduction of the entry barriers for high skilled), or with more liberal emigration policies in the origin country (e.g., more exit quotas).

Raising one child takes a fraction $\phi \in (0, 1)$ of an adult's time and the higher education entails a cost x per child. This cost can, for example, be interpreted as a tuition fee and as such represents a fixed amount per child enrolled in higher education. Therefore, saving S_{t+1}^i results from an adult's labor earningminus raising and educational costs

$$S_{t+1}^i = R^*[w^i(1 - \phi(n_t^i + m_t^i)) - xm_t^i], \tag{2}$$

where the interest rate R^* is assumed to be fixed.

The utility function of an individual who is an adult with education level i at time t is then given by

$$U(S_{t+1}^i, V_{t+1}^i) = \ln(S_{t+1}^i) + \ \beta \ln(V_{t+1}^i), \tag{3}$$

with

$$V^i_{t+1} = (n^i)^\epsilon \overline{w}^l + (m^i)^\epsilon \overline{w}^h.$$

Apart from the fact that we explicitly introduce heterogeneity among the types of children, the non-linear term in V^i_{t+1} is similar to Becker and Barro (1988), Barro and Becker (1989) and Doepke (2005), where $\epsilon(\in (0,1))$ is the elasticity of utility with respect to children. Besides, $\beta(> 0)$ is the weight assigned to the altruisic component of the utility. As mentioned by Barro and Becker (1989), this form of the altruism term means that, for a given expected income per child $\overline{w}^i$, "parental utility $U(\cdot)$ increases, but at a diminishing rate, with the number of children"(here n^i and m^i).

Thus, combining the above informations, each adult is facing the following problem

$$\max_{n^i,m^i} U^i = \max_{n^i,m^i}\{\ln(S^i_{t+1}) + \beta \ln(V^i_{t+1})\}, \qquad i = l, h \tag{4}$$

which consists into the maximization of her lifetime utility by choosing the number of low (n^i) and high skilled children (m^i).

2.2 Solving the individual problem

In appendix, we show that the first order condition of maximizing U^i with respect to n^i_t is

$$\frac{R^*\phi w^i_t}{S^i_{t+1}} = \frac{\overline{w}^l_{t+1}\beta\epsilon(n^i_t)^{\epsilon-1}}{V^i_{t+1}}, \tag{5}$$

which states that for an adult of type i $(= l, h)$, the marginal cost of raising a low-skilled child evaluated at time $t + 1$ in terms of consumption (S^i_{t+1}), should equal the marginal utility gain from a low-skilled child's expected income in terms of the future value of total children (V^i_{t+1}). If this equality does not hold, raising children is either too costly (it is then optimal to have no children), or not costly enough (then individuals choose to have as many children as possible).

Similarly, the first order condition of maximizing U^i with respect to m_t^i becomes

$$\frac{R^*(\phi w_t^i + x)}{S_{t+1}^i} = \frac{(1-\alpha)\overline{w}_{t+1}^h \beta\epsilon (m_t^i)^{\epsilon-1}}{V_{t+1}^i}, \tag{6}$$

which reads that that for an adult of type i $(= l, h)$, the marginal cost of raising and educating one child in terms of consumption (left hand side) should be equal to the marginal benefit from educating a child.

Since the second order conditions of the agents' maximization problem are satisfied, the conditions (5) and (6) are sufficient for characterizing optimal household decisions. The following proposition may thus be stated

Proposition 1. *Combining the above two conditions (see appendix), we obtain explicit solutions for m and n,*

1. *The number of high and low educated children are*

$$m_t^i = \frac{\beta\epsilon \overline{w}_{t+1}^h w_t^i}{(1+\beta\epsilon)(\phi w_t^i + x)\left[\overline{w}_{t+1}^l \sigma_{n,m}^i + \overline{w}_{t+1}^h\right]} \tag{7}$$

and

$$n_t^i = (\sigma_{n,m}^i)^{\frac{1}{\epsilon}} m_t^i, \tag{8}$$

where

$$\sigma_{n,m}^i = \left(\frac{B_t}{A_t^i}\right)^{\frac{\epsilon}{1-\epsilon}}, \text{ with } A_t^i = \frac{\phi w_t^i}{\phi w_t^i + x}, \quad B_t = \frac{\overline{w}_{t+1}^l}{\overline{w}_{t+1}^h}. \tag{9}$$

2. *high skilled parents will have more high educated children than low-skilled parents, while low-skilled parents will have more low educated children than high skilled parents:*

$$m^h > m^l, \quad n^l > n^h.$$

In part 1 of proposition 1, A_t^i represents the ratio of the cost of a low educated child and a high educated one (see (5) and (6)), while B_t is the ratio of the contribution of a low educated child to a high educated child in parental utility. If ϵ is the elasticity of utility with respect to children, $\sigma^i_{n,m}$ can be considered as the elasticity of substitution between high and low educated children in each household of type i $(= l, h)$.

Furthermore, part 2 of proposition 1 states that high skilled parents provide higher education to a larger number of children than low-skilled parents. This result is not at odds with the empirical evidence. In a recent World Bank study, Azam and Blom (2006) examine the participation in tertiary education in India using nationally representative household surveys. For instance, the data show that in 2004, a young person from the top expenditure quintile was 14.5 times more likely to enroll in tertiary education than a young person from the bottom quintile. Moreover, their econometric analysis confirms the important role of household income as a determinant for entry in tertiary education and thus for the enrollment gap between rich and poor.

Given the explicit expression of m^i and n^i, we can study the change in these two choice variables with respect to p^h. In the appendix we prove the following proposition.

Proposition 2. *Increased brain drain induced by a larger probability p^h has the following impact on fertility*

1. *The number of high educated children rises, while the number of low educated children declines if there is increased brain drain. Formally, we have*

$$\frac{\partial m^i_t}{\partial p^h} > 0, \quad \frac{\partial n^i_t}{\partial p^h} < 0, \quad \forall t, \; i = l, h.$$

2. *Total fertility $n^i_t + m^i_t$, is decreasing with respect to p^h.*

The underlying intuition is straightforward. Part 1 of the proposition means that further brain drain leads to a trade-off between high- and low-skilled children in favor of more educated children. This result hinges on the fact that higher migration opportunities for high-skilled increase the expected income of higher educated children, which differs from Mountford (1997) and Stark and Wang (2002), where individuals choose their own education level and increased migration prospects raise their returns to education. Part 2 indicates that a rise in p^h reduces the total number of children, $n_t^i + m_t^i$, which follows from the reasonable assumption that raising high skilled children is more expensive. In fact, since increased brain drain does not raise parents' income, one high skilled child substitutes for more than one low-skilled child, thus inducing a decrease in total fertility.

Is there any evidence supporting that migration might positively impact child education?[5] Based on micro-data from rural Pakistan, a World Bank study of Mansuri (2006) provides empirical support for a relationship between temporary migration and investment in child schooling. The author finds that school dropout rates for children aged between 10 to 15 are lower in families where a household member has emigrated. Moreover, children in migrant households spend more years in school. The study of Mansuri (2006) suggests that migration exerts positive effects on children's human capital accumulation, which is consistent with part 1 of proposition 2, if one abstracts from the fact that the above study is not limited to skills emigration.

The link between migration and total fertility has also found empirical support. However, most studies focus on emigrants' fertility, which has been observed to decrease in destination countries where fertility is low. Research has also been conducted, though at a lesser extent, on the potential impact of migration on fertility rates in migrants' countries of origin. Recently, Fargues (2007) analyzed fertility behavior in three source countries and observed that fertility rates in migrants' origin countries tend to adapt to the fertility rates of their destination countries. This author shows that fertility rates decreased in countries having a large diaspora located in low fertility countries as Morocco and Turkey[6].

[5]Based on panel data, Beine et al. (2001) found that migration might raise a country's human capital level.

[6]Beine et al. (2008) go a step further and investigate the causes that might explain

2.3 The impact of brain drain on human capital

Before studying the dynamic impact of an increase in p^h on human capital, we analyse the long-run behavior of the economy. Let N_t^h and N_t^l be respectively the high- and low-skilled labor forces at time t, which are composed of non-emigrated individuals born at time $t-1$.

$$N_t^l = (1-p^l)(N_{t-1}^l n_{t-1}^l + N_{t-1}^h n_{t-1}^h), \tag{10}$$

$$N_t^h = (1-p^h)(N_{t-1}^l m_{t-1}^l + N_{t-1}^h m_{t-1}^h). \tag{11}$$

The growth rates of both labor types are defined as $g_t^h = \frac{N_{t+1}^h}{N_t^h}$ and $g_t^l = \frac{N_{t+1}^l}{N_t^l}$, while the ratio of the high- to low-skilled labor represents $q_t = \frac{N_t^h}{N_t^l}$.

Definition 1. *Along a balanced growth path, both types of workers grow at a uniform rate i.e.* $g^h = g^l = g$. *It follows that the ratio of the high- to low-skilled labor force is constant i.e.,* $q_{t+1} = q_t = q$.

The following proposition summarizes the behavior of the economy in the long run

Proposition 3. *If parameters and constants verify condition*

$$\widetilde{p}\left[\frac{1}{(\sigma_{n,m}^h)^{\frac{1}{\epsilon}}} - \frac{1}{(\sigma_{n,m}^l)^{\frac{1}{\epsilon}}}\right] < \frac{n^h}{n^l}\left(\frac{n^l}{n^h} + \overline{q}\right)^2,$$

where

$$\frac{n^l}{n^h} = \left(\frac{\sigma^l}{\sigma^h}\right)^{\frac{1}{\epsilon}} \frac{w^l(\phi w^h + x)(\overline{w}^l\sigma^h + \overline{w}^h)}{w^h(\phi w^l + x)(\overline{w}^l\sigma^l + \overline{w}^h)}.$$

and $\widetilde{p} = \frac{1-p^h}{1-p^l}$, *then the system globally converges to its unique steady state* $\overline{q}$, *where* $q = \frac{N^h}{N^l} = \overline{q}$ *and* $g^l = g^h = (1-p^l)(n^l + n^h\overline{q})$.

The proof of this proposition is given in the appendix.

the impact of international migration on source countries' fertility.

From the previous section, we know that parents choose to have more high- and less low-skilled children, which positively impacts the human capital formation. However, brain drain also means that more high skilled people leave their country of origin. Then the question which effect will dominate the other remains open ? Human capital at time t, denoted by H_t, can be defined as the share of high educated workers in total labor. That is

$$H_t = \frac{N_t^h}{N_t^h + N_t^l}, \tag{12}$$

Notice that $N_t^l(N_t^h)$ represents the low (high) skilled workers born at time $t-1$ from both low and high skilled families and staying in their home country.

To study the effect of high skilled emigration on human capital, we only need to consider the effect of p^h on $\frac{1}{H_t} = 1 + \frac{N_t^l}{N_t^h}$.

Assume a permanent increase in high skilled emigration. As a consequence parents decide to provide education to a larger number of their children. In the first period of the shock (time t), the additional high skilled children do not yet add to the labor force and brain drain leads to a decrease in human capital H because more high skilled workers leave the country. There is thus a detrimental brain drain in the short run. In successive periods (from time $t+1$ onwards), the direct effect of increased departures of high skilled workers can be compensated by the additional individuals benefiting from higher education. This is shown in the following calculations

$$\frac{\partial}{\partial p^h}\left(\frac{N_{t+1}^l}{N_{t+1}^h}\right) = G(n,m)\frac{(1-p^l)}{(1-p^h)^2} + \frac{(1-p^l)}{(1-p^h)}\frac{\partial G(n,m)}{\partial p^h}, \tag{13}$$

where

$$G(n,m) = \frac{N_t^l n_t^l + N_t^h n_t^h}{N_t^l m_t^l + N_t^h m_t^h}.$$

We know that both m^l and m^h (n^l and n^h) are increasing (decreasing) in terms of p^h. Thus a higher p^h will lead to a rise in the denominator and to a reduction in the numerator, while N_t^l and N_t^h are decided at time $t-1$ and will thus not be affected by a change in p^h happening at time $t+1$. Hence we obtain

$$\frac{\partial G(n,m)}{\partial p^h} < 0.$$

To conclude, the first term on the right hand side of (13) is positive and represents the ex post loss of human capital due to a brain drain, while the second term on the RHS stands for the ex ante stimulation of human capital due to a brain drain. Since these two effects also depend on the population size N_t^l and N_t^h, our endogenous fertility model leaves open the question whether brain drain will finally result in a brain loss or in a brain gain.[7] Calibrating our model on a typical developing country open to labor mobility will give a specific answer.

3 Numerical Analysis

In this section we provide a numerical illustration to analyze the effects of increased emigration on fertility and human capital. Higher migration can be due to the fact that destination countries adopt more liberal immigration policies. Moreover, as immigration policies tend to be more and more skilled-biased, we focus on the impact of increased *high* skilled emigration.

3.1 Calibration

Our model is calibrated to depict a typical situation of South-North migration and as such the parameters will be adjusted to match the economy of the Philippines (to be the migrants' origin country). This choice seems appropriate since international migration has been a notorious characteristic of the Philippine economy for several decades now (see the IMF study

[7] It is also theoretically unclear whether a brain drain will increase or decrease human capital in the steady state.

Table 1: Parameter values for the Philippines

$\phi = 0.15$	$\epsilon = 0.5$	$w^h = 2.54$	$p^h = 0.086$	$p^l = 0.043$
$\beta = 0.63$	$w^{*l} = 7.34$	$w^{*h} = 14.39$	$x_t^l = 0.82$	$R^* = 1.806$

of Burgess and Haksar, 2005). The destination of migration will be represented by a combination of OECD countries whose relative importance is weighted by the share of Filipino emigrants they host (see below). The initial steady state is assumed to correspond to 2000 data. The values of parameters and exogenous variables are reported in table 1 and chosen as follows.

According to Haveman and Wolfe (1995), parents spend around 15% of their time raising children, which enables us to set the raising cost parameter ϕ to 0.15. Also, the wage of a high skilled worker in the Philippines is 2.54 times larger than the one of a low-skilled.[8] Thus if w^l is set to 1, w^h equals 2.54. Since one period is considered to be 20 years, the interest factor is set to $R^* = 1.806$, which corresponds to an annual interest rate of 3%.

A next step is to choose the probabilities to emigrate, p^h and p^l, which are not directly observable. However, since one period lasts 20 years, it can be considered that the number of migrants in the OECD in 2000 reported by Docquier and Marfouk (2006) represents the number of emigrants during one period in our model, meaning that 1'678'735 Filipinos go abroad. [9] Moreover, these authors document that 67% of the Filipinos living in OECD in 2000 are skilled, thus we can set $p^h = 2\ p^l$. If the number of migrants can

[8]The data stems from the United Nations, *General Industrial Statistics* and corresponds to the skill premium in the manufacturing sector for the year 2000, see Zhu (2005).

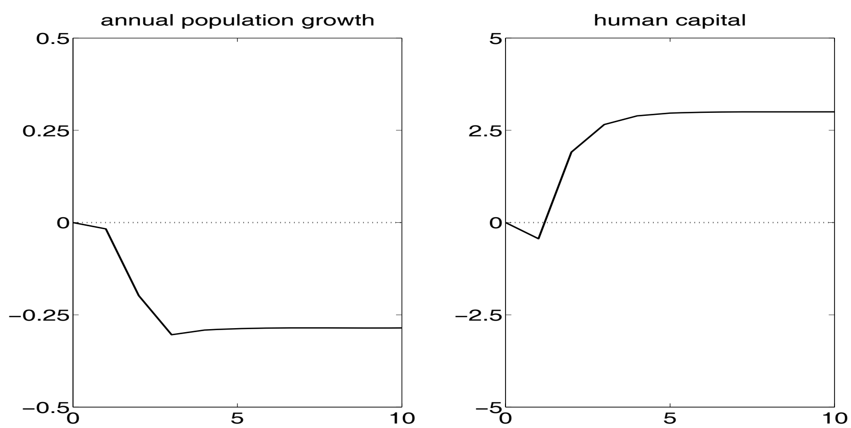
[9]This number is not exaggerated, because when considering also temporary residents (42%) and irregular migrants (21%) together with permanent residents (37%), the number of Filipinos living and working overseas was estimated to be around 7.58 million in 2002 with an increase of 1 million since 1996. This number is equivalent to almost one quarter of the domestic labor force (Burgess and Haksar, 2005; Castro, 2006)

be written as $p^l N^l + p^h N^h$ then taking figures N^l and N^h from Docquier and Marfouk (2006), we have that $p^l = 0.043094295$ and $p^h = 0.08618859$.

For the remaining exogenous variables no data are available. To start the simulation, the parameter ϵ belonging to the "altruistic" component of the utility function is set to 0.5, but will be subject to several robustness checks. Remaining variables are set in order to match three main characteristics of the Philippine economy. Let us now describe the procedure we follow. First, we know from Docquier and Marfouk (2006) who in turn use data of Barro and Lee (2001), that in 2000 the ratio of the low to high skilled labor force, $1/h$ $(= N^l/N^h)$, amounts to 3.5045. This value is met by fixing the education costs of a child to $x_t = 0.816754$. Second, basing on the World Development Indicators, annual population growth in the Philippines was equal to 1.98% during the period 1998-2002 (WDI, 2007). If we consider one period to be 20 years, then population growth rate g in our model equals 0.481, which is matched by setting $\beta = 0.632897$. Moreover, we can consider the wage differential between the Philippines and the OECD to be similar to the per capita GDP differential. Average per capita GDP between 1999-2004 was \$3'991 in the Philippines and \$34'268 in the OECD (PPP, constant 2000 international \$), thus 7.98 times higher in the OECD (WDI, 2007).[10] If average domestic wage is defined as $\widehat{w} = (w^h + 1/hw^l)/(1 + 1/h)$ and average foreign wage $\widehat{w}^* = (w^{*h} + 1/h^* w^{*l})/(1 + 1/h^*)$, the average wage difference $\omega = \widehat{w}^*/\widehat{w}$ equals 7.976149. Basing on the same sources as for the skill premium in the domestic economy, the average ratio of low to high skilled labor force in the OECD, $1/h^*$, was 1.096703 and the skill premium, w^{*h}/w^{*l}, 1.959279. To compute these OECD averages, we again apply the

[10] According to Docquier and Marfouk, migrants from the Philippines living in the OECD in 2000 were distributed as follows: United States (69.31%), Canada (11.41%), Australia (4.65%), Japan (4.56%), Italy (2.44%), United Kingdom (2.07%), Germany (0.75%), Korea (0.72%), Spain (0.67%), New Zealand (0.51%), Austria (0.45%), Switzerland (0.43%), Netherlands (0.34%), Greece (0.29%), France (0.28%), Norway (0.25%), Sweden (0.23%), Ireland (0.21%), Denmark (0.15%), Belgium (0.13%), Iceland (0.04%), Mexico (0.04%), Finland (0.037%), Czech Republic (0.0014%), Hungary (0.001%), Slovakia (0.0001%).

Figure 1: Impact of increased *high* skilled emigration



Values display percent deviations from the baseline.

same weights as for the distribution of migrants among OECD countries.

3.2 Results

We analyze the effects of a permanent increase of 10% in emigration flows, which means that more people leave the Philippines at each period with respect to the baseline. For instance, in the first period of the shock, the additional migrants amount to 164 thousand. To analyse the impact of permanent brain drain, we assume that all the additional migrants are high skilled, which means that p^h rises from 0.086 to 0.109.

The impact of increased high skilled emigration on different variables is reported in appendix (table 2), but can be summarized as follows. Both types of parents choose, as expected from our theoretical results, to finance higher education to a larger number of children. They also raise less low-skilled children and the result is that they decide to have less children.

In the first period of the shock, only the additional high skilled individuals leaving the country will affect population growth rate (figure 1). Thereafter, changes in parents' fertility decisions due to increased high skilled emigration will reinforce the depressing effect of departing adults on population growth. Annual population growth rate will be reduced by 0.29 percentage points in the long run. Thus after 5 periods[11] the population growth rate passes from 1.98% ,in the baseline, to 1.69%. What about human capital? The effect of a brain drain on human capital H is negative in the short run when the policy is adopted (the policy change arises from period 1 onwards). The reason is that the shock is not anticipated in period 0 and more high skilled individuals leave the country in period 1. However, in the first period parents already change their fertility decisions in favor of more high skilled children. When these additional high skilled children add to the high skilled labor force in period 2, they will more than compensate the loss of the departing high educated workers. A permanent 10% rise in emigration flows, where all additional emigrants are highly educated leads, in the long run, to a 2.97 percentage points increase in human capital (i.e., the proportion of high skilled within a generation H rises from 22.20% to 25.17%).[12] Thus, contrary to Chen (2006), we obtain that brain drain can be beneficial for the source country.

4 Conclusion

An endogenous fertility model with overlapping generations is introduced, where parents choose to finance higher education to a limited number of their children. As a consequence, families are composed of low and high educated children. We analyze the impact of high- and low-skilled emigration on parents' fertility choices and on human capital. It is found that increased high skilled emigration induces parents to provide higher educa-

[11] 5 periods correspond to 100 years.

[12] Robustness checks with respect to the choice of ϵ are provided in appendix.

tion to a larger number of their children and to raise a lower number of low-skilled children, while total fertility decreases. The long run impact on human capital is ambiguous since the permanent loss of high skilled workers may be compensated by the additional number of high skilled children.

Finally, the model is calibrated on the Philippines to provide some quantitative results. We examine the consequences of an increase of 10% in emigration flows, where all additional migrants are high skilled. Permanent high skilled emigration enhances human capital in the long run (the share of high skilled individuals rises from 22% to 25%) and population growth experiences a slowdown (annual population growth rate falls from 1.98% to 1.69%).

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A Appendix

A.1 Appendix A: Proof of Proposition 1

Part 1. The explicit solutions for n^i and m^i are obtained in two steps. We first compute the linear relationship between n^i and m^i, and afterwards find the explicit solution m^i.

Step 1. The relationship between n^i and m^i

We are facing the following optimization problem

$$\max_{n^i,m^i} U_t^i = \max_{n^i,m^i} \left[\ln(S_{t+1}^i) + \beta \ln(V_{t+1}^i)\right],$$

with

$$S_{t+1}^i = R^*[w_t^i \left(1 - \phi(n_t^i + m_t^i)\right) - x m_t^i], \tag{14}$$

and

$$V_{t+1}^i = \overline{w}_{t+1}^l (n_t^i)^\epsilon + \overline{w}_{t+1}^h (m_t^i)^\epsilon, \tag{15}$$

First order condition of U^i with respect to n_t^i reads

$$\frac{R^*\phi w_t^i}{S_{t+1}^i} = \frac{\overline{w}_{t+1}^l \beta\epsilon (n_t^i)^{\epsilon-1}}{V_{t+1}^i}. \tag{16}$$

Similarly, the first order condition of U^i with respect to m_t^i shows

$$\frac{R^*\phi w_t^i + x}{S_{t+1}^i} = \frac{\overline{w}_{t+1}^h \beta\epsilon (m_t^i)^{\epsilon-1}}{V_{t+1}^i}. \tag{17}$$

Dividing (16) by (17) and denoting

$$A_t^i = \frac{\phi w_t^i}{\phi w_t^i + x}, \quad B_t = \frac{\overline{w}_{t+1}^l}{\overline{w}_{t+1}^h},$$

we obtain

$$n_t^i = \left(\frac{B_t}{A_t^i}\right)^{\frac{1}{1-\epsilon}} m_t^i, \quad \text{or} \quad (n_t^i)^{\epsilon-1} = \left(\frac{A_t^i}{B_t}\right)(m_t^i)^{\epsilon-1}. \tag{18}$$

Step 2. Obtaining m^i

By rewriting (16) as follows

$$R^*\phi w_t^i V_{t+1}^i = \beta\epsilon \overline{w}_{t+1}^l (n_t^i)^{\epsilon-1} S_{t+1}^i,$$

using the definition of S and V and rearranging the terms, it yields

$$(1+\beta\epsilon)\left(\overline{w}_{t+1}^l \sigma_{n,m}^i + \overline{w}_{t+1}^h\right) m_t^i = \frac{\beta\epsilon \overline{w}_{t+1}^h}{\phi w_t^i + x} w_t^i, \tag{19}$$

where $\sigma_{n,m}^i = \left(\frac{B_t}{A_t^i}\right)^{\frac{\epsilon}{1-\epsilon}}$.

Hence m_t^i can be explicitly rewritten as

$$m_t^i = \frac{\beta\epsilon\overline{w}_{t+1}^h w_t^i}{(1+\beta\epsilon)\left(\phi w_t^i + x\right)\left[\overline{w}_{t+1}^l \sigma_{n,m}^i + \overline{w}_{t+1}^h\right]}.$$

Finally, due to (18) and (7), we have

$$n_t^i = (\sigma_{n,m}^i)^{\frac{1}{\epsilon}} m_t^i.$$

Part 2. By the above explicit expressions of m^l and m^h, it is easy to see that

$$\frac{m^h}{m^l} = \frac{w^h\left(\phi w^l + x\right)\left[\overline{w}^l\sigma_{n,m}^l + \overline{w}^h\right]}{w^l\left(\phi w^h + x\right)\left[\overline{w}^l\sigma_{n,m}^h + \overline{w}^h\right]},$$

where it is straightforward that the numerator is larger than the denominator due to $\sigma_{n,m}^l > \sigma_{n,m}^h$.

Hence $m^h > m^l$. We can prove the rest in a similar way.

Appendix B: Proof of Proposition 2

From the expressions of $\sigma_{n,m}^i$ and m_t^i, it follows

$$\frac{\partial\sigma_{n,m}^i}{\partial p^h} = -\frac{\epsilon(w^{*h} - w^h)}{(1-\epsilon)\overline{w}^h}\,\sigma_{n,m}^i < 0,$$

and

$$\frac{\partial m_t^i}{\partial p^h} = \frac{m_t^i}{1-\epsilon}\,\frac{\overline{w}_{t+1}^l\sigma_{n,m}^i(w^{*h} - w^h)}{\overline{w}_{t+1}^h\left(\overline{w}_{t+1}^l\sigma_{n,m}^i + \overline{w}_{t+1}^h\right)} > 0.$$

Substituting the above two expressions into the derivative of n^i with respect to p^h, it reads

$$\frac{\partial n^i}{\partial p^h} = -\frac{\sigma_{n,m}^{\frac{1}{\epsilon}} m^i(w^{*h} - w^h)}{(1-\epsilon)\overline{w}^h}\left[\frac{\overline{w}^h}{\overline{w}^l\sigma_{n,m}^i + \overline{w}^h}\right] < 0, \quad \forall t, \quad i = l, h. \tag{20}$$

Making use of the above results yields

$$\frac{\partial(n^i+m^i)}{\partial p^h} = \frac{m^i \ (w^{*h}-w^h)(\sigma^i_{n,m})^{\frac{1}{\epsilon}}}{1-\epsilon\overline{w}^h\left(\overline{w}^l\sigma^i_{n,m}+\overline{w}^h\right)}\left[\overline{w}^l(\sigma^i_{n,m})^{\frac{\epsilon-1}{\epsilon}}-\overline{w}^h\right],$$

where

$$\overline{w}^l(\sigma^i_{n,m})^{\frac{\epsilon-1}{\epsilon}}-\overline{w}^h = \overline{w}^h\left(\frac{\phi w^i}{\phi w^i+x}-1\right)<0.$$

Hence

$$\frac{\partial(n^i+m^i)}{\partial p^h}<0.$$

This finishes the proof.

Appendix C: Proof of Proposition 3

At the steady state, $q_{t+1}=q_t=q$ and thus we have that

$$q=\frac{N^h}{N^l}=\widetilde{p}\,\frac{m^l+qm^h}{n^l+qn^h}$$

where $\widetilde{p}=\frac{1-p^h}{1-p^l}$. The above equality can be rewritten as

$$n^hq^2+(n^l-\widetilde{p}m^h)q-\widetilde{p}m^l=0. \tag{21}$$

There exist two solutions to the above equation

$$q=\frac{-(n^l-\widetilde{p}m^h)\pm\sqrt{(n^l-\widetilde{p}m^h)^2+4\widetilde{p}n^hm^l}}{2n^h}.$$

Since the term in the square root is larger than $n^l-\widetilde{p}m^h$, there exist one unique positive solution to equation (21), which is the steady-state value of q

$$\overline{q}=\frac{-(n^l-\widetilde{p}m^h)+\sqrt{(n^l-\widetilde{p}m^h)^2+4\widetilde{p}n^hm^l}}{2n^h}.$$

Define the function $J(q)$ as

$$J(q) = q_{t+1} = \widetilde{p}\,\frac{m_t^l + q_t m_t^h}{n_t^l + q_t n_t^h}.$$

The first derivative of this function with respect to q gives

$$J'(q) = \widetilde{p}\,\frac{\left[m_t^h(n_t^l + q_t n_t^h) - n_t^h(m_t^l + q_t m_t^h)\right]}{(n_t^l + q_t n_t^h)^2} = \widetilde{p}\,\frac{\left[m_t^h n_t^l - n_t^h m_t^l\right]}{(n_t^l + q_t n_t^h)^2}.$$

Our economy converges to its steady state, if and only if

$$J'(\overline{q}) < 1$$

which is equivalent to

$$\Leftrightarrow \widetilde{p}\left[m^h n^l - n^h m^l\right] < (n^l + \overline{q} n^h)^2.$$

After dividing both sides by n^h, using $m^i = n^i[(\sigma^i_{n,m})^{\frac{1}{\epsilon}}]^{-1}$ and rearranging, we obtain the following condition

$$\widetilde{p}\left[\frac{1}{(\sigma^h_{n,m})^{\frac{1}{\epsilon}}} - \frac{1}{(\sigma^l_{n,m})^{\frac{1}{\epsilon}}}\right] < \frac{n^h}{n^l}\left(\frac{n^l}{n^h} + \overline{q}\right)^2, \tag{22}$$

where

$$\frac{n^l}{n^h} = \left(\frac{\sigma^l}{\sigma^h}\right)^{\frac{1}{\epsilon}} \frac{w^l(\phi w^h + x)(\overline{w}^l \sigma^h + \overline{w}^h)}{w^h(\phi w^l + x)(\overline{w}^l \sigma^l + \overline{w}^h)}.$$

The proof is finished.

Appendix D: Robustness of the numerical example

Table 2 resumes the impact of brain drain on the sending country, where F and g represent respectively average fertility and annual population growth. In addition, tables 3 depicts the robustness of the impact of increased high-skilled emigration on human capital and population growth when the parameter ϵ changes.

Table 2: Impact of an increase in p^h

Impact on household decisions	Variables	Periods				
		0	**1**	**2**	**5**	**10**
High skilled children of high skilled parents	m^h	0.0	4.1	4.1	4.1	4.1
High skilled children of low skilled parents	m^l	0.0	6.6	6.6	6.6	6.6
Low skilled children of high skilled parents	n^h	0.0	-10.2	-10.2	-10.2	-10.2
High skilled children of high skilled parents	n^l	0.0	-8.0	-8.0	-8.0	-8.0
Total children of high skilled parents	$m^h + n^h$	0.0	-5.7	-5.7	-5.7	-5.7
Total children of low skilled parents	$m^l + n^l$	0.0	-3.9	-3.9	-3.9	-3.9
Average fertility	F	0.0	-5.3	-4.9	-4.7	-4.7
Growth rate of the population	g	0.0	-1.0	-11.7	-16.9	-16.8
Human capital	H	0.0	-2.0	8.6	13.4	13.5

Values display percentage *changes* with respect to the baseline.

Table 3: Robustness on the impact of an increase in p^h

Impact on human capital						
Periods	**0**	**1**	**2**	**3**	**4**	**5**
Benchmark ($\epsilon = 0.5$)	0.00	-0.44	1.91	2.66	2.89	2.97
$\epsilon = 0.25$	0.00	-0.44	1.16	1.53	1.61	1.63
$\epsilon = 0.75$	0.00	-0.44	3.58	5.76	6.93	7.57
Impact on annual population growth						
Periods	**0**	**1**	**2**	**3**	**4**	**5**
Benchmark ($\epsilon = 0.5$)	0.00	-0.02	-0.20	-0.30	-0.29	-0.29
$\epsilon = 0.25$	0.00	-0.02	-0.17	-0.25	-0.24	-0.23
$\epsilon = 0.75$	0.00	-0.02	-0.26	-0.43	-0.43	-0.43

Values display percentage *deviations* with respect to the baseline.

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