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« New Economics of Brain Drain and Risk Aversion : Theory and Empirical Evidence »

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ABSTRACT
This is a contribution to the new economics of brain drain with emphasis on the impacts of skilled emigration on developing economies origins of departure of skilled labor. A risk aversion model is developed and used to test empirically the theoretical results attained. The findings appear similar to those suggested by other authors but additional results are induced by the introduction of risk aversion. The impacts on human capital in the source country can be gains under some circumstances but losses in other cases. The new important finding is that the amplitude of gains when they exist is lower than that predicted by models of risk neutrality. A developing country can consequently enhance its benefits through further monitoring its education and knowledge bases besides its emigration and cooperation policies.

RESUME
Cet article est une contribution à la nouvelle économie du « brain drain » avec un accent mis sur l’impact de l’émigration de travailleurs hautement qualifiés sur les économies source. Un modèle avec aversion pour le risque est développé et utilisé pour tester empiriquement les résultats théoriques obtenus. Les résultats sont similaires à ceux que suggèrent d’autres auteurs mais des conclusions originales sont obtenues du fait de l’introduction de l’aversion au risque. L’impact sur la formation de capital humain dans le pays source peut être un gain dans certains cas et une perte dans d’autres circonstances. La découverte principale est que l’amplitude des gains quand ils existent est moindre que celle qui est prédit par les modèles de neutralité vis-à-vis du risque. Un pays en développement a donc intérêt à développer une politique volontariste en matière d’éducation et de recherche afin d’obtenir des gains plus importants que ceux qui résulteraient simplement d’un politique d’émigration et de coopération.

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Introduction

More recent papers about the emigration of skilled labor have introduced further optimistic views about the impacts of emigration on developing economies through using new economic models that support the gains that accompany the emigration of skilled labor from developing economies. But, while these new views have contributed to putting an end to the pessimistic ones that prevailed earlier, there is not a final position with regard to the magnitude of the dissymmetric benefits between source and destination countries. Furthermore, most of the new economics of skilled labor migration has not been empirically extensively tested.

This paper is an additional contribution to the new economics of skilled labor migration. It uses a constant relative risk aversion economic model as a framework for the empirical analyzes.

This paper is composed of three major parts. The first one sets the literature review. The second introduces the economic model that focuses on risk aversion with the implied individual and aggregate decision rules. The third part is devoted to the empirical analyzes in relation to the theoretical framework developed in the second part.

I. Literature Review

Migration of skilled labor or brain drain was considered having negative impacts on the source countries. But, the new economics of skilled labor has identified potential gains that could benefit developing economies. This new literature has emerged following the contributions of Mountford (1997), Vidal (1998), Beine et al. (2003), Stark et al. (2005), Duc Thanh (2004) and M. Schiff (2005), among others.

Open economies with immigration are assumed to be attractive since wages of skilled workers are most of the time lower in source countries. According to Beine & al (2002), the human capital migration can be globally beneficial to the country of origin. Here, the brain effect dominates the drain effect for the country of emigration.

Stark’s theory points to the fact that the prospect of migration may result in the formation of a socially desirable level of human capital. The expected higher returns to human capital in the destination country influence the decisions about the acquisition of skills in the country of origin (Stark, 2005).

Nguyen Duc Thanh (2004) introduces a theoretical model that accounts for the heterogeneity of workers’ talents. He shows that the distribution of talents is important, that the effects of the outflows of human capital might not take place under specific conditions and that under emigration constraints the gain from brain drain depends on the characteristics of each economy. It can be positive or negative depending on the relative wages and the probability of emigration.

However, the analysis of the behavior of skilled labor denotes some degree of aversion towards risk that is not really taken into consideration by the literature on skilled labor migration. So, the analysis of labor decisions under risk is important in the process of identifying the optimal human capital and the optimal emigration rates for skilled labor (Schechter, 2005 ; Schechter, 2006). Other authors emphasized the relationships between
the levels of initial wealth, income and levels of risk aversion (Rabin, 2000; Rabin & Thaler, 2001; Chetty, 2003).

Estimates of the constant relative risk aversion (CRRA) coefficient appear to be varying throughout the economic literature but all estimations tend to 1. Chetty (2003) found that positive uncompensated wage elasticity can result in a CRRA coefficient below 1.25, while the labor supply literature indicates that CRRA coefficient is close to 1. Szpiro (1986) found that the degree of relative risk aversion (the inverse of the CRRA coefficient) is approximately 2 (meaning a CRRA of 0.5). Cicchetti and Dublin (1994) estimated the degree of relative risk aversion to be of 0.6 (equivalent to a CRRA of 1.66). Fullenkamp et al (2003) considered that significant variations exist in the degree of relative risk aversion (between 0.64 and 1.76) meaning a CRRA of 0.83. Hartley, Lanot and Walker (2005) tried to estimate the degree of risk aversion and the way it varies across individuals using data from a popular TV game-show. The major result of this analysis is that the constant relative risk aversion coefficient is 1.

Halek and Eisenhower (2001) address the issue distinguishing between pure and speculative risks in order to understand risk aversion. Among their findings, they established that under both pure and speculative risks, individuals who already proved to be risk-takers by migrating across national borders are less risk averse compared with the native population. Also, unemployed people are more disposed to risk their current income for the possibility to double it (Halek and Eisenhower, 2001).

II. The Theoretical Economic Model

This part starts with the basic assumptions underlying the model before dealing with decisions under neutrality to risk. A version accounting for risk aversion is then introduced with its implied decision rules that are the optimal human capital and the emigration rate. The effects of changes in risk attitudes on these decision rules are then considered. This theoretical part ends with a discussion of the results and the propositions derived.

Model Assumptions:
The variable $\beta$ refers to a measure of labor productivity in a given economy. It is equivalent to private returns to labor, as in Stark et al (2005). In the context of this model, $\beta$ is assumed to be either $\beta_s$ in the source or $\beta_D$ in the destination countries. The private returns in the destination countries are considered to be higher than those in the sending countries ($\beta_D > \beta_s$). It is assumed here that emigration decisions are based on the levels of $\beta$ that can be either $\beta_D$ or $\beta_s$ with respective probabilities $m$ and $(1-m)$.

In this economy, each individual seeks a level of education $h$ (considered as an investment in human capital) under the linear cost function $ch$ with $c$ being the unit cost of education. Furthermore, the level of education $h$ is valued through a production function $g(h) = ah^\gamma$ (the output of human capital) where $0 < \gamma < 1, g'(h) > 0, \ g''(h) < 0$ and $a$ is the talent of individuals.
Each agent is consequently assumed to set the level of education $h$ based on the maximization of an objective function that is $V(h) = \beta_s g(h) - ch$ in the absence of emigration (closed economy) and his expected utility in case of emigration possibilities (open economy). In this context agents are assumed to be risk averse with the utility function of the type $U(x) = \frac{x^\alpha}{\alpha}$, where $x$ is the random argument, and $\alpha$ is a coefficient that is defined in $]0,1[$. It can be noted that this utility function exhibits constant relative aversion with $(1 - \alpha)$ being the constant relative risk aversion coefficient.

The assumption related to $\alpha$ being defined in $]0,1[$ means that the CRRA coefficient is included in $]0,1[$, which is consistent with most of the estimates found in the literature and permits to focus the effect of risk-aversion on the size and sign of the brain drain/gain. Obviously, when the CRRA coefficient is equal to zero, that means alpha equals to one and $U(x) = x$, meaning risk-neutrality.

**Emigration under risk neutrality:**

Each individual in the economy is assumed to emigrate with probability $m$ in order to achieve an overall net benefit in relation to the realization of the random variable $\beta$ ($\beta_D$ and $\beta_S$ respectively with probabilities $m$ and $(1-m)$).

This implies that the overall objective function in case of risk neutrality is represented by the expected possible earnings related to this choice:

$$V(h) = m \beta_D g(h) + (1-m) \beta_S g(h) - ch$$

Under risk neutrality, the necessary and sufficient conditions (concavity of $g(h)$) for a maximum $V$ to hold are given by the optimal value of $h$, that is:

$$h_{RN}^* = \left[ \frac{c}{\gamma a \left[ m (\beta_D - \beta_S) + \beta_S \right] \gamma - 1} \right]$$

The aggregate stock of skilled human capital in case of risk neutrality is given by:

$$H_{RN} = N \left[ \frac{c}{\gamma a \left[ m (\beta_D - \beta_S) + \beta_S \right] \gamma - 1} \right]$$

where $N$ is the total working aged population.

The aggregate stock of human capital remaining in the country is:

$$H_{RN} = (1-m) N \left[ \frac{c}{\gamma a \left[ m (\beta_D - \beta_S) + \beta_S \right] \gamma - 1} \right]$$

(1)

The relative domestic human capital is given by:

$$\left( \frac{H}{H_0} \right)_{RN} = (1-m) \left[ \frac{\beta_D}{\beta_S} - 1 \right] + 1$$

(2)
Emigration under Risk Aversion:
In case of risk aversion, the popular constant relative risk aversion (CRRA) function is used (Harrison & al, 2005): \( U(x) = \frac{x^{1-r}}{1-r} \) or \( U(x) = \frac{x^\alpha}{\alpha} \), (\( \alpha \in [0,1] \)), where \( \alpha = 1-r \) and \( r \) is the CRRA coefficient. Under the above assumptions, the objective function can be formulated as:
\[
V(h) = mU(\beta_D g(h)) + (1-m)U(\beta_S g(h)) - ch
\]
\[
V(h) = \frac{m}{\alpha} \beta_D^a a^\alpha h^{r\alpha} + \frac{(1-m)}{\alpha} \beta_S^a a^\alpha h^{r\alpha} - ch
\]
Given the concavity of \( V(h) \), the necessary and sufficient condition for a maximum leads to the maximal level of education to be:
\[
h^* = \left[ \frac{c}{\gamma a^\alpha \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]} \right]^{\frac{1}{\gamma r-1}}
\]
(3)
The aggregate stock of skilled human capital in case of risk aversion under emigration is given by:
\[
H_T = N h^* = N \left[ \frac{c}{\gamma a^\alpha \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]} \right]^{\frac{1}{\gamma r-1}}
\]
The human capital remaining in the source economy, in case of emigration under risk aversion is given by:
\[
H = (1-m)H_T \quad \text{or:}
\]
\[
H = (1-m)N \left[ \frac{c}{\gamma a^\alpha \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]} \right]^{\frac{1}{\gamma r-1}}
\]
(4)

Proposition 1: From the results of sensitivity analysis (Appendix, Demo 1), it appears that the optimal domestic educational level in an open economy under risk aversion increases (decreases) when:
- the level at which education is valued (\( a \)) increases (decreases),
- both labor productivities at source and destination countries increase (decrease),
- the emigration rate \( m \) increases (decreases), and
- the unit cost of education decreases (increases).

Changes in Optimal Human Capital:
The variations of the domestic human capital formation \( H \) in relation to \( m \) are considered also important to be taken into account. These variations are analyzed using the first and second derivatives of \( H \) that are respectively given by (Appendix, Demo 2):
\[
\frac{\partial H}{\partial m} = H \cdot \frac{(1-m)(\beta_D^a - \beta_S^a) - (1-\gamma \alpha) \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]}{(1-m)(1-\gamma \alpha) \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]}
\]
\[
\frac{\partial^2 H}{\partial m^2} = H \left( \beta_D^a - \beta_S^a \right) \left\{ \frac{\gamma \alpha (1-m) (\beta_D^a - \beta_S^a) - 2(1-\gamma \alpha) \left[ m (\beta_D^a - \beta_S^a) + \beta_S^a \right]}{(1-m)(1-\gamma \alpha)^2 \left[ m (\beta_D^a - \beta_S^a) + \beta_S^a \right]^2} \right\}
\]

Under the condition \( \frac{\beta_D^a}{\beta_S^a} \geq \frac{(2-\gamma \alpha)(1-m)}{[\gamma \alpha - m(2-\gamma \alpha)]} \), the second derivative of \( H \) is negative implying that \( H(m) \) is concave and that the maximum of \( H \) is obtained through the necessary and sufficient condition that is \( \frac{\partial H}{\partial m} = 0 \) (Appendix, Demo 3). This implies that the optimal value for the emigration rate is given by:

\[
m^* = \frac{\beta_D^a - (2-\gamma \alpha) \beta_S^a}{(\beta_D^a - \beta_S^a)(2-\gamma \alpha)} \tag{5}
\]

The optimal emigration rate that can be obtained for the maximization of \( H \) appears to be directly related to most of the parameters of the problem. It has to be noted though that the numerator should be positive in order to meet the conditions imposed on \( m \). This leads to the following restriction: \( 1 \leq (2-\gamma \alpha) \leq \frac{\beta_D^a}{\beta_S^a} \) (i). This condition implies that \( (2-\gamma \alpha) \) is the minimal value for the relative productivity or relative wage below which migration is not optimal.

The above results are shown in Figure 1 where point A refers to the maximum of \( H \) attained at \( m^* \). Point B corresponds to \( m^{**} \) where \( H \) starts getting lower than \( H_0 \).
**Proposition 2**: A net human capital gain (brain gain) results when the value of human capital, under different values of emigration rate, is superior to the value of the initial human capital under the absence of emigration. The human capital gain can reach a maximal value at $m^*$ and returns to its initial value at $m^{**}$, while brain drain starts when human capital is lower than $H_0$.

**Effects of Changes in risk attitudes**: In order to refine the understanding of aggregate decisions, variations with respect to the level of risk aversion ($\alpha$) are useful as aggregate decisions include a large variation of risk attitudes of skilled labor migrants. For that purpose, the relative human capital ($H/H_0$) as well as the optimal ($m^*$) emigration rate are analyzed in relation to changes in risk attitude ($\alpha$). The functions for the relative human capital and its first derivative are respectively given by (Appendix, Demo 4):

\[
\frac{H}{H_0} = (1-m) \left\{ \frac{\left[ m \left( \beta^a_D - \beta^a_S \right) + \beta^a_S \right]^{\alpha}}{\beta^a_S} \right\}^{1/\alpha} 
\]

\[
\frac{\partial (H/H_0)}{\partial \alpha} = \frac{1-m}{1-\gamma\alpha} \left[ m(\beta^a_D / \beta^a_S - 1) + 1 \right]^{\alpha/\alpha-1} \left\{ m \left[ \ln \left( \beta^a_D / \beta^a_S \right) \right] (\beta^a_D / \beta^a_S) + 
\right.
\]

\[
+ \left[ m(\beta^a_D / \beta^a_S - 1) + 1 \right] \ln \left[ m(\beta^a_D / \beta^a_S - 1) + 1 \right] \frac{\gamma}{(1-\gamma\alpha)} \right\}
\]

Since $\alpha \in [0,1]$, $\frac{\partial (H/H_0)}{\partial \alpha}$ is positive and the function $H/H_0$ is increasing with $\alpha$ (Appendix, Demo 4).

Furthermore, using expressions (2) and (6), it can be easily shown that for any $\alpha \in [0,1]$, $H/H_0 < (H/H_0)_{RN}$. Equality in relative human capital occurs when $\alpha = 1$. 

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**Figure 1**: Domestic human capital stock with emigration and risk aversion

A graph showing the domestic human capital stock with emigration and risk aversion is depicted. The figure illustrates the net human capital gain and loss with respect to different emigration rates ($m$) and risk aversion ($\alpha$). The critical points $m^*$ and $m^{**}$ are highlighted, indicating the transition from net human capital gain to loss. The graph visually represents the proposition that a net human capital gain occurs when the value of human capital under different emigration rates is superior to the initial human capital under the absence of emigration, reaching a maximal value at $m^*$ and returning to the initial value at $m^{**}$.
Figure 2 shows the shape of \( H/H_0 \) as function of \( \alpha \). It has to be noted though that the function starts at value higher than \( (1-m) \) as \( \alpha = 0 \) is not included. When \( \alpha = 1 \), this is the case of risk neutrality. In addition, the sign of the second derivative of \( H/H_0 \) as function of \( \alpha \) is positive (Appendix, Demo 4).

**Figure 2 : Effects of the Level of Risk Aversion on the Relative Domestic Human Capital Curve**

\[ H/H_0 \]

\[ (H/H_0)_{RN} \]

\[ 1-m \]

\[ 0 \quad 1 \]

\[ \alpha = 1 - CRRA \]

**Proposition 3**: \( H/H_0 \) under relative risk aversion is lower than the level occurring under risk neutrality. This says that higher attainment in relative human capital is achieved under neutrality to risk.

Regarding the optimal level of skilled labor migration, the derivative of \( m^* \) (expression (5)) is given by (Appendix, Demo 5):

\[
\frac{\partial m^*}{\partial \alpha} = \frac{\beta_D^\alpha \beta_S^{\alpha(2-\gamma\alpha)}(1-\gamma\alpha)[\ln(\beta_D^\alpha) - \ln(\beta_S^{\alpha})] + \gamma \beta_D^\alpha (\beta_D^{\alpha} - \beta_S^{\alpha})}{(\beta_D^{\alpha} - \beta_S^{\alpha})^2 (2-\gamma\alpha)^2}.
\]

This derivative is always positive within the interval of definition of \( \alpha \in [0,1] \), implying that \( m^* \) increases (decreases) with increases (decreases) in \( \alpha \) (Appendix, Demo 5).

The maximum value of \( m^* \) is obtained for \( \alpha = 1 \), that is \( m^*(1) = \frac{[\beta_D - (2-\gamma)\beta_S]}{(2-\gamma)(\beta_D - \beta_S)} \), which equals the value of \( m^* \) under risk neutrality (Appendix, Demo 6):

\[
m^*_{RN} = m^*(1) = \frac{[\beta_D - (2-\gamma)\beta_S]}{(2-\gamma)(\beta_D - \beta_S)} \tag{8}
\]

In addition, it can be easily shown from expressions (5) and (8) that for any \( \alpha \in [0,1] \), \( m^* < m^*_{RN} \).

Figure 3 draws the shape of \( m^* \) as function of \( \alpha \).
Proposition 4: The optimal emigration rate \( (m^*) \) under relative risk aversion is lower than the level occurring under risk neutrality. This says that higher attainment in optimal emigration is reached under neutrality to risk.

Discussion of the theoretical results:
In an open economy, the human capital formation varies with the probability of emigration. The level of this human capital is equal to the initial human capital plus the human capital induced by emigration. When the aggregate human capital formation in an open economy (in case of risk aversion) is greater than the initial human capital formation, there is a brain gain. When the aggregate human capital formation is lower, there is human capital loss or brain drain.

The sensitivity analysis shows that both the level at which education is valued, the labor productivity and the emigration rate, positively affect the formation of domestic human capital in case of risk aversion in an open economy. The increase in the unit cost of education always negatively affects the domestic human capital formation. In addition, the relative human capital under relative risk aversion is lower than the one prevailing under risk neutrality. The same conclusion is reached regarding the optimal emigration rate that is greater under risk neutrality than under aversion to risk.

As stated by M. Schiff (2005), the size of brain gain and its impact on welfare and growth are overestimated when not accounting for risk aversion. Aversion to risk decreases the human capital formation and the brain gain resulting from skilled labor emigration. By the concavity property of the human capital under risk aversion, the ways for testing the existence or absence of brain gains are confirmed to be similar to those under risk neutrality (Stark, 2005 & Duc Thanh, 2004). Furthermore, optimal aggregate human capital formation remaining in the source economy is smaller under risk aversion.

These results support the theoretical findings of Duc Thanh (2004) and Stark (2005) that underline the existence of special conditions that govern the existence or absence of brain drain. Under risk aversion, there are also special conditions under which, brain drain can or cannot exist.
This contribution is another addition to the theoretical frameworks developed so far. It definitely expands the overall economic frameworks to account for the impacts of risk attitudes on emigration of skilled labor and its impacts on education in the source countries. The propositions developed within this new framework are then submitted to empirical tests and simulations, based on the data available.

III. Empirical Estimation

The empirical estimations and simulations undertaken below are based on the new datasets made available by international organizations. After a brief description of the data used, emphasis is placed on the estimations and simulations with a special focus on testing empirically the propositions derived from the theoretical model.

Description of variables and data used
The index of skilled labor emigration \( m \) is taken from Docquier & Marfouk (2005). The investment per capita in higher education \( c \) is measured by the expenditure per student devoted to tertiary education (This is computed using the expenditure per student in tertiary education as percentage of per capita GDP (World Bank database, 2005) multiplied by the GDP per Capita, PPP, current international $ (WDI database)). The variables \( \beta_d \) and \( \beta_s \) are labor productivities considering the USA as a reference country (International Labor Organization, 2006). The variable \( N \) is the population of each country as considered to be the working aged residents (total) in thousands and is taken from Docquier and Marfouk data (year 2000).

In the economic model, the output of human capital is valued through a production function \( g(h) = ah^\gamma \) where \( 0 < \gamma < 1 \) and \( h \) is the investment in human capital. In order to estimate the parameters of this function \( (a \) and \( \gamma \)), measures of the country aggregate levels for human capital and its output are given (human capital is measured by the normalized average years of schooling (AYSN) of workers in 2000 (World Bank Institute, 2007)). The output of human capital could be considered to be the normalized Gross Tertiary Enrollment (GTEN) in 2004, published in the WBI website.

The empirical results obtained are introduced below.

Empirical Results
Besides a regression analysis showing the meaningfulness of the theoretical model, underlined above, simulations are conducted in order to estimate \( \gamma \) and \( a \). Based on the empirical data available mainly for \( \alpha, \beta \) and the migration rate \( (m) \), the optimal skilled emigration probability is computed for each country. Then \( H/H_0 \) is computed for each developing country that is in the sample to determine if there is a brain gain or a brain drain.

Based on the theoretical model, the empirical approach undertakes the two major issues that are related to the impact of risk aversion and to the existence or absence of brain gain opportunities to the economies under study. The evaluation of the countries’ variations in
relation to emigration rates and human capital levels, with changes in risk attitudes are ways of addressing the above issues.

1. Overall Results:
In the economic model, the human capital and the parameter estimates are provided by the following regression results:

**Regression results for γ and α estimations:**

<table>
<thead>
<tr>
<th>Regression result</th>
<th>$R^2$</th>
<th>Obs.</th>
<th>$γ$</th>
<th>$a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ln(\frac{GTEN}{AYSN}) = 0.49 + 0.73 \ln(AYSN)$</td>
<td>0.70</td>
<td>86</td>
<td>0.73</td>
<td>1.64</td>
</tr>
</tbody>
</table>

The results of this regression show significant intercept and coefficient (t-stat given below each estimate). From this result, the estimate of the level of talent is obtained as the exponential of the intercept (0.49) in consistence with the definition of $g(h)$. The exponent of $h$ in $g(h)$ is also obtained to be 0.73. Using these parameter estimates of the production function and given different values of $\alpha$, country specific effects of the brain drain under different hypotheses of risk aversion are assessed.

2. Country Results:
As in proposition 2 in the theoretical part of this paper, to determine the existence of brain drain or gain, the relative human capital is computed. Concerning the countries of the sample, the level of risk aversion has a major influence on migration probability and consequently on the human capital gain. While the constant relative risk aversion coefficient is decreasing (or while $\alpha$ is increasing), the human capital gain is increasing. From Table A-1 (Appendix), different country groups are distinguished based on the level of their risk aversion ($\alpha$). Estonia is identified as a country having a human capital loss (brain drain) for every probability level of risk aversion. In Slovenia and Cyprus, brain drain can be beneficial only when $\alpha$ is greater than 0.75 and 0.9 respectively. Within these intervals, there is a human capital gain for any level of skilled emigration probability in those countries. The remaining sample countries present different human capital gains starting from a definite value of risk aversion (Appendix, Table A-1).

All countries are affected by the rate of skilled labor emigration and this is clear from the estimations of the relative human capital curves for some countries in the sample chosen at random (Appendix, Figures A-1 & A-2). The level of risk aversion has an important impact on the shape of the relative human capital gain/loss. For all these countries, the human capital gain can reach a maximal value at $m^*$ (the optimal emigration rate). From the empirical estimations of $m^*$ given the different risk attitudes, Table A-2 (Appendix) results. Since the emigration rate is defined in the interval $[0,1]$, the negative values of $m^*$ are not considered. The optimal level of skilled emigration probability is increasing when $\alpha$ is increasing (when the CRRA coefficient is decreasing). In certain countries, the effective level is higher than the optimal level of skilled emigration given a certain level of risk aversion $\alpha$. This is the case of Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Poland and Slovenia, where the minimal possible $\alpha$ is considered.
Therefore, some skilled migration reduction policies can be beneficial in these countries in order to increase their human capital gain.

Using the optimal emigration rate estimated above for each county given different risk attitudes, the optimal relative human capital ($H^*/H_0$) is estimated. This latter doesn’t have significant values for all levels of risk aversion related to those countries. There are countries which have significant optimal human capital gain starting from a value of $\alpha$ equal to 0.35 and above, while others start to have significant values from a CRRA of 0.1 and below (Appendix Table A-3). The human capital gain resulting from an optimal migration policy has only slightly improved for the different cases of country risk aversion coefficient given that the ratio $H^*/H_0$ is just higher than 1 when the constant relative risk aversion approaches 1. The human capital gain in these countries smoothly increases with risk aversion $\alpha$ (Appendix, Table A-3). These increases show different trends given the geographical, economic and policy types of countries.

As in proposition 3 (theoretical model), the comparison between the relative human capital ($H/H_0$) under risk aversion and the relative human capital under risk neutrality (the first term being lower than the second) is confirmed with the empirical results (Appendix, Table A-4). From these results we can conclude that the preceding literature overestimated the gains in human capital resulting from skilled labor migration because aversion to risk wasn’t taken into consideration. Using the same reasoning, the optimal emigration rate ($m^*$) under risk aversion is lower than the level reached under neutrality to risk (Appendix, Table A-5).

**Discussion of empirical results**:

The introduction of risk aversion has definitely showed that the human capital gains expected from previous risk neutral economic models have been overestimated, as predicted by M. Schiff (2005). The empirical findings based on the current estimates of risk aversion and the availability of new databases (Marfouk & Docquier, 2005) support the theoretical implications of the model suggested in this study. The skilled labor migration index estimations, taken from Docquier and Marfouk’s database are identified to be important contributions to the development of skilled labor migration.

Concerning the estimation of $\alpha$, the range is known but there are variations among countries. While more research is needed for the assessment of $\alpha$ by country, the current evidence shows that the CRRA coefficient is close to 1.

Both these estimations allow the determination of the likelihood of directions in net human capital (brain drain/gain). The human capital gains are definitely higher when $\alpha$ is high and minimal when $\alpha$ is low. This means that the theoretical and empirical models, not accounting for aversion to risk, have overestimated the level of human capital gain, up to now.
The empirical evidence obtained so far shows the existence of human capital gain in source economies even under risk aversion, but only under certain conditions related to labor productivity, level of emigration rate and of risk aversion.

These results support the theoretical findings cited above and part of them matches those of N. Duc Thanh (2004) regarding the shape of the human capital curve. The effect of risk aversion on the human capital formation is also visible. The lower is the CRRA coefficient \( CRRA = 1 - \alpha \), the higher is the relative human capital (brain gain) and the higher is the optimal emigration rate. These results confirm M. Schiff’s theoretical findings about the effects of risks in overestimating the likely brain gain associated with skilled labor migration.

The empirical evidence attained so far, opens the door for further investigations on skilled labor migration on the human capital outcomes. It shows, though that aversion to risks overestimates the levels of brain gains when they exist, but does not show the details related to each country. Lack of disaggregated data is also a problem that limits these outcomes.
Conclusion

The effects of emigration of skilled labor from developing to developed economies appear to be mitigated depending on the level of emigration attained by each source country. While some countries enjoy brain gains, others are in situation of brain drains. Previous economic models have mainly considered emigration under risk neutrality. The present contribution has emphasized the issue of emigration of skilled labor with homogenous agents under risk aversion. While this approach lowers the likely gains as in M. Schiff (2005), the estimations still show large possibilities of brain gains in some countries. Variations among countries are related to the rate of emigration already achieved but also to the parameters related to the valuation of education, differential in wages between destination and source countries and mainly to the risk aversion parameter in each country.

In an open economy, the human capital formation varies with the probability of emigration. Brain gains result when the optimal aggregate human capital formation in case of risk aversion is greater than the initial human capital formation. As stated in M. Schiff (2005), uncertainty can decrease the brain gain resulting from skilled labor emigration which implies that the optimal aggregate human capital formation remaining in the source economy is smaller under high risk aversion.

The empirical findings show that the effect of constant relative risk aversion on the optimal migration level, and on the human capital formation varies by country. There are countries which have a net human capital loss for any emigration rate and for any constant relative risk aversion coefficient. Others have a net human capital gain for any emigration rate only for a given constant relative risk aversion coefficient. Thus, skilled labor emigration can be considered as a human capital growth opportunity. The empirical results support the theoretical findings in this paper and some results are consistent with those of N. Duc Thanh regarding the shape of the human capital curve. The effect of risk aversion on the human capital formation is also visible. The lower is the CRRA coefficient; the higher is the human capital gain. These results confirm M. Schiff theoretical findings about the overestimation of brain gain when not accounting for risk.

The findings of this paper are still limited because of the lack of data about the labor productivity in general and in different sectors, the education related variables and other emigration related data. These latter either do not exit or are unavailable for a large number of countries. These empirical estimations are not sufficient to have a closer view of the effect of skilled labor migration on the human capital outcomes.

Under the above conditions and taking the results into consideration, economic policies should be more restrictive in their emigration policies through creating incentives for retaining skilled labor, placing more investment in domestic education and enhancing the yield.

Future papers can focus on sectoral case studies especially the health care sector, from a risk aversion side.
References


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International Labor Organization (2006), Labor productivity and unit labor costs, Key indicators of the labor market.


Schiff, Maurice (2005), “Brain Gain: Claims about its size and impact on welfare and growth are greatly exaggerated” *IZA DP* No. 1599.


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Appendix

Demo 1: Sensitivity analysis related to Proposition 1

\[(H)^\prime_a = H \cdot \frac{\alpha}{a(1 - \gamma \alpha)} > 0\]  
(A-1)

\[(H)^\prime_{\beta_0} = H \frac{\alpha}{(1 - \gamma \alpha)} \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right] > 0\]  
(A-2)

\[(H)^\prime_{\beta_s} = H \frac{\alpha}{(1 - \gamma \alpha)} \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right] > 0\]  
(A-3)

\[(H)^\prime_m = H \frac{1}{(1 - \gamma \alpha)} \left[ (\beta_D^a - \beta_S^a) \right] > 0\]  
(A-4)

\[(H)^\prime_c = -H \cdot \frac{1}{c (1 - \gamma \alpha)} < 0\]  
(A-5)

Demo 2: Signs of the first and second derivatives of \(H\)

\[H = (1 - m)N \left[ \frac{c}{\gamma a^a} \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right] \right]^{\frac{1}{\gamma a - 1}} \]

\[\frac{\partial H}{\partial m} = N \left[ \frac{c}{\gamma a^a} \right]^{\frac{1}{\gamma a - 1}} \left\{ \frac{1}{1 - \gamma a} \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]^{-\frac{1}{\gamma a - 1}} \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]^{-\frac{1}{\gamma a - 1}} \right\} \]

\[\frac{\partial H}{\partial m} = N (1 - m) \left[ \frac{c}{\gamma a^a} \right]^{\frac{1}{\gamma a - 1}} \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]^{-\frac{1}{\gamma a - 1}} \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]^{-1} \left[ \frac{\beta_D^a - \beta_S^a}{1 - \gamma a} \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]^{-1} \right] \]

\[\frac{\partial H}{\partial m} = H \left\{ \frac{\beta_D^a - \beta_S^a}{(1 - \gamma a) \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]} - \frac{1}{1 - m} \right\} \]

Let \(A = \frac{\beta_D^a - \beta_S^a}{(1 - \gamma a) \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]} - \frac{1}{1 - m} \)

So, \(\frac{\partial H}{\partial m} = HA\)

\[\frac{\partial^2 H}{\partial m^2} = H^2 A + HA^2 = H \left( A \right)^2 + HA^2 = H \left( A^2 + A^2 \right) \]

\[A^2 = \frac{\left( \beta_D^a - \beta_S^a \right)^2}{(1 - \gamma a)^2 \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]^2} + \frac{1}{(1 - m)^2} - \frac{2 \left( \beta_D^a - \beta_S^a \right)}{(1 - m)(1 - \gamma a) \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]^2} \]

\[A^2 = \frac{\left( \beta_D^a - \beta_S^a \right)^2}{(1 - \gamma a)^2 \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]^2} - \frac{1}{(1 - m)^2} \]

\[A^2 + A^2 = \frac{(1 - m) \left( \beta_D^a - \beta_S^a \right)^2 - 2 \left( \beta_D^a - \beta_S^a \right)(1 - \gamma a) \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right] - (1 - m)(1 - \gamma a) \left( \beta_D^a - \beta_S^a \right)^2}{(1 - m)(1 - \gamma a)^2 \left[ m(\beta_D^a - \beta_S^a) + \beta_S^a \right]^2} \]
\[ \frac{\partial^2 H}{\partial m^2} = H \left( \beta_D^a - \beta_S^a \right) \left\{ \frac{(1-m)\left(\beta_D^a - \beta_S^a\right) - (1-m)(1-\gamma\alpha)\left(\beta_D^a - \beta_S^a\right) - 2(1-\gamma\alpha)\left[m(\beta_D^a - \beta_S^a) + \beta_S^a\right]}{(1-m)(1-\gamma\alpha)^2\left[m(\beta_D^a - \beta_S^a) + \beta_S^a\right]^2} \right\} \]

\[ \frac{\partial^2 H}{\partial m^2} = H \left( \beta_D^a - \beta_S^a \right) \left\{ \frac{\gamma\alpha(1-m)\left(\beta_D^a - \beta_S^a\right) - 2(1-\gamma\alpha)\left[m(\beta_D^a - \beta_S^a) + \beta_S^a\right]}{(1-m)(1-\gamma\alpha)^2\left[m(\beta_D^a - \beta_S^a) + \beta_S^a\right]^2} \right\} \]

Sign of \( \frac{\partial^2 H}{\partial m^2} \) = Sign of \( \left\{ \gamma\alpha(1-m)(\beta_D^a - \beta_S^a) - 2(1-\gamma\alpha)\left[m(\beta_D^a - \beta_S^a) + \beta_S^a\right] \right\} \)

So, this sign depends on the following conditions:

If \( \frac{\beta_D^a}{\beta_S^a} < \frac{(2-\gamma\alpha)(1-m)}{\gamma\alpha - m(2-\gamma\alpha)} \) then \( \frac{\partial^2 H}{\partial m^2} > 0 \)

If \( \frac{\beta_D^a}{\beta_S^a} > \frac{(2-\gamma\alpha)(1-m)}{\gamma\alpha - m(2-\gamma\alpha)} \) then \( \frac{\partial^2 H}{\partial m^2} < 0 \)

If \( \frac{\beta_D^a}{\beta_S^a} = \frac{(2-\gamma\alpha)(1-m)}{\gamma\alpha - m(2-\gamma\alpha)} \) or if \( m = \frac{\gamma\alpha\beta_D^a + (\gamma\alpha - 2)\beta_S^a}{\beta_D^a - \beta_S^a (3\gamma\alpha - 2)} \) then \( \frac{\partial^2 H}{\partial m^2} = 0 \)

**Demo 3 : Conditions related to the sign of** \( H^* \)

\[ 0 < \gamma < 1 \]

\[ \alpha \leq 1 \]

\[ \gamma\alpha < 1 \]

\[ -\gamma\alpha > -1 \]

\[ 2 - \gamma\alpha > 1 \]

\[ -m(2-\gamma\alpha) < -m \]

\[ \gamma\alpha - m(2-\gamma\alpha) < 1 - m(2-\gamma\alpha) < 1 - m \]

Then, \( \gamma\alpha - m(2-\gamma\alpha) \) is either positive or negative.

When \( [\gamma\alpha - m(2-\gamma\alpha)] > 0 \), then \( \frac{1-m}{\gamma\alpha - m(2-\gamma\alpha)} > 1 \)

\[ \frac{(1-m)}{[\gamma\alpha - m(2-\gamma\alpha)]} > 1 \] means that \( \frac{(2-\gamma\alpha)(1-m)}{[\gamma\alpha - m(2-\gamma\alpha)]} > (2-\gamma\alpha) \)

So if \( \frac{\beta_D^a}{\beta_S^a} > \frac{(2-\gamma\alpha)(1-m)}{[\gamma\alpha - m(2-\gamma\alpha)]} \), then: \( \frac{\beta_D^a}{\beta_S^a} > (2-\gamma\alpha) \) which is always true since \( m^* > 0 \) always holds.

However, when \( [\gamma\alpha - m(2-\gamma\alpha)] < 0 \), then \( \frac{(1-m)}{[\gamma\alpha - m(2-\gamma\alpha)]} < 0 < 1 \) meaning that:

\[ \frac{(2-\gamma\alpha)(1-m)}{[\gamma\alpha - m(2-\gamma\alpha)]} < 0 < (2-\gamma\alpha) \]

So, condition \( \frac{\beta_D^a}{\beta_S^a} > \frac{(2-\gamma\alpha)(1-m)}{[\gamma\alpha - m(2-\gamma\alpha)]} \) is always true since we have: \( \frac{(2-\gamma\alpha)(1-m)}{[\gamma\alpha - m(2-\gamma\alpha)]} < 0 < \frac{\beta_D^a}{\beta_S^a} \).
So, the results depend on whether \([\gamma \alpha - m(2-\gamma \alpha)]\) is positive or negative. The necessary condition to have \([\gamma \alpha - m(2-\gamma \alpha)] > 0\) is \(m < \frac{\gamma \alpha}{2-\gamma \alpha}\) since \((2-\gamma \alpha) > 0\).

**Demo 4: Sign of the first derivative of \(H/H_0\)**

\[
\frac{H}{H_0} = \frac{(1-m)N}{N} \left[ \frac{c}{\gamma \alpha \beta S} \left[ m(\beta D^\alpha / \beta S^\alpha - 1) + 1 \right] \right]^{1/(\gamma \alpha - 1)} = (1-m)[m(\beta D^\alpha / \beta S^\alpha - 1) + 1]^{1/(\gamma \alpha)}
\]

\[
\frac{H}{H_0} = (1-m)u^\gamma = (1-m)e^{\gamma \ln(u)}
\]

\[
\frac{d(e^{\gamma \ln(u)})}{d\alpha} = e^{\gamma \ln(u)} \frac{d(v \ln(u))}{d\alpha} = e^{\gamma \ln(u)} \left[ \frac{\partial \gamma \ln(u)}{\partial \alpha} + v \frac{d \ln(u)}{d\alpha} \right] = u^\gamma \ln(u) \frac{\partial \gamma}{\partial \alpha} + u^{\gamma-1} \frac{\partial u}{\partial \alpha}
\]

\[
\frac{\partial}{\partial \alpha} \left( \frac{H}{H_0} \right) = (1-m) \left\{ \frac{1}{1+\gamma \alpha} \left[ m(\beta D^\alpha / \beta S^\alpha - 1) + 1 \right]^{1/(\gamma \alpha - 1)} \cdot \left[ \ln(\beta D / \beta S) \right] (\beta D^\alpha / \beta S^\alpha) + \right.
\]

\[
+ \left[ m(\beta D^\alpha / \beta S^\alpha - 1) + 1 \right]^{1/(\gamma \alpha)} \cdot \ln(\beta D^\alpha / \beta S^\alpha - 1) + 1 \right] \cdot \frac{\gamma}{(1-\gamma \alpha)^2} \}
\]

\[
\frac{\partial}{\partial \alpha} \left( \frac{H}{H_0} \right) = \frac{1-m}{1-\gamma \alpha} \left[ m(\beta D^\alpha / \beta S^\alpha - 1) + 1 \right]^{1/(\gamma \alpha - 1)} \cdot \left[ \ln(\beta D / \beta S) \right] (\beta D^\alpha / \beta S^\alpha) + \right.
\]

\[
+ \left[ m(\beta D^\alpha / \beta S^\alpha - 1) + 1 \right] \cdot \ln(\beta D^\alpha / \beta S^\alpha - 1) + 1 \right] \cdot \frac{\gamma}{(1-\gamma \alpha)} \}
\]

For \(\alpha > 0\), \(\left\{ m \cdot \ln(\beta D / \beta S) \right\} (\beta D^\alpha / \beta S^\alpha) > 0\) and \(\beta D^\alpha / \beta S^\alpha > 1\)

So, \(m(\beta D^\alpha / \beta S^\alpha - 1) + 1 > 0\) and \(\ln(\beta D^\alpha / \beta S^\alpha - 1) + 1 > 0\)

Therefore, the function \(\partial \left( \frac{H}{H_0} \right) / \partial \alpha\) is positive so the function \(\frac{H}{H_0}\) is increasing with \(\alpha\).

The second derivative of \((H/H_0)\) as function of \(\alpha\) is given by:

\[
\frac{d^2}{d\alpha^2} \left( \frac{H}{H_0} \right) = \frac{1-m}{1-\gamma \alpha} \left[ m(\beta D^\alpha / \beta S^\alpha - 1) + 1 \right]^{1/(\gamma \alpha - 1)} \cdot \left[ \ln(\beta D / \beta S) \right] (\beta D^\alpha / \beta S^\alpha) + \right.
\]

\[
+ \left[ m(\beta D^\alpha / \beta S^\alpha - 1) + 1 \right] \cdot \ln(\beta D^\alpha / \beta S^\alpha - 1) + 1 \right] \cdot \frac{\gamma}{(1-\gamma \alpha)} \}
\]

\[
\frac{d^2}{d\alpha^2} (H / H_0) / \partial \alpha^2 = \partial(ABC) / \partial \alpha = \partial A / \partial \alpha \cdot BC + \partial B / \partial \alpha \cdot AC + \partial C / \partial \alpha \cdot AB
\]

\[
A = \frac{1-m}{1-\gamma \alpha}
\]

\[
\partial A / \partial \alpha = \frac{(1-m)\gamma}{(1-\gamma \alpha)^2}
\]

19
\[ B = \left[ m\left( \frac{\beta_D^a}{\beta_S^a} - 1 \right) + 1 \right] \frac{\gamma a}{1 - \gamma a} \]

\[ \frac{\partial B}{\partial \alpha} = \left[ m\left( \frac{\beta_D^a}{\beta_S^a} - 1 \right) + 1 \right] \frac{\gamma a}{1 - \gamma a} \left\{ \ln \left[ m\left( \frac{\beta_D^a}{\beta_S^a} - 1 \right) + 1 \right] + \frac{1 - \gamma a}{1 - \gamma a} + \ln \left( \frac{\beta_D^a}{\beta_S^a} \right) \ln \left( \frac{\beta_D^a}{\beta_S^a} \right) \right\} \]

\[ C = m\left( \frac{\beta_D^a}{\beta_S^a} \right) \ln \left( \frac{\beta_D^a}{\beta_S^a} \right) + \left[ m\left( \frac{\beta_D^a}{\beta_S^a} - 1 \right) + 1 \right] \ln \left[ m\left( \frac{\beta_D^a}{\beta_S^a} - 1 \right) + 1 \right] - \frac{\gamma a}{1 - \gamma a} \]

\[ \frac{\partial C}{\partial \alpha} = m\left( \frac{\beta_D^a}{\beta_S^a} \right) \ln \left( \frac{\beta_D^a}{\beta_S^a} \right)^2 + \left[ m\left( \frac{\beta_D^a}{\beta_S^a} - 1 \right) + 1 \right] \ln \left[ m\left( \frac{\beta_D^a}{\beta_S^a} - 1 \right) + 1 \right] - \frac{\gamma a}{1 - \gamma a} \left( \frac{\gamma a}{1 - \gamma a} + m\left( \frac{\beta_D^a}{\beta_S^a} \right) \ln \left( \frac{\beta_D^a}{\beta_S^a} \right) \right) + \frac{\gamma a}{1 - \gamma a} \left( \frac{\beta_D^a}{\beta_S^a} \right) \ln \left( \frac{\beta_D^a}{\beta_S^a} \right) \]

B,C > 0 and \( \partial A / \partial \alpha > 0, \partial B / \partial \alpha > 0, \partial C / \partial \alpha > 0 \)

Then \( \partial^2 (H / H_0) / \partial^2 \alpha > 0 \)

**Demo 5 : Sign of \( \partial m^* / \partial \alpha \)**

\[ m^* = \frac{\left( \frac{\beta_D^a}{\beta_S^a} - (2 - \gamma a) \beta_S^a \right)}{\left( \frac{\beta_D^a}{\beta_S^a} - \beta_S^a \right) (2 - \gamma a)} \]

\[ \frac{\partial m^*}{\partial \alpha} = \frac{\beta_D^a \ln \left( \frac{\beta_D^a}{\beta_S^a} \right) + \gamma \beta_S^a - (2 - \gamma a) \ln \left( \beta_S^a \right) \beta_S^a \left( \beta_D^a - \beta_S^a \right) (2 - \gamma a)}{(\beta_D^a - \beta_S^a)^2 (2 - \gamma a)^2} \]

\[ \frac{\partial m^*}{\partial \alpha} = \frac{(2 - \gamma a) \left( \beta_D^a - \beta_S^a \right) \left( \beta_D^a \ln \left( \beta_S^a \right) + \gamma - (2 - \gamma a) \ln \left( \beta_S^a \right) \right) \beta_S^a}{(\beta_D^a - \beta_S^a)^2 (2 - \gamma a)^2} \]

\[ \frac{\partial m^*}{\partial \alpha} = \frac{\beta_D^a \beta_S^a (2 - \gamma a) (1 - \gamma a) \left( \ln \left( \beta_S^a \right) - \ln \left( \beta_S^a \right) \right) + \gamma \beta_D^a \left( \beta_D^a - \beta_S^a \right)}{(\beta_D^a - \beta_S^a)^2 (2 - \gamma a)^2} \]

So \( \frac{\partial m^*}{\partial \alpha} > 0 \) for \( \alpha \in [0,1] \).

**Demo 6 : Optimal emigration rate under risk neutrality**

\[ H_{RN} = (1 - m) \frac{c}{\gamma a \left[ m \left( \beta_D^a - \beta_S^a \right) + \beta_S^a \right]} \]

\[ \frac{\partial H_{RN}}{\partial m} = H_{RN} \left[ \frac{\beta_D^a - \beta_S^a}{\gamma a \left[ m \left( \beta_D^a - \beta_S^a \right) + \beta_S^a \right]} - \frac{1}{1 - m} \right] \]

When \( \frac{\partial H_{RN}}{\partial m} = 0 \), \( \frac{\beta_D^a - \beta_S^a}{\gamma a \left[ m \left( \beta_D^a - \beta_S^a \right) + \beta_S^a \right]} = \frac{1}{1 - m} \)

So, \( m_{RN}^* = \frac{\beta_D^a - (2 - \gamma) \beta_S^a}{(2 - \gamma) \left( \beta_D^a - \beta_S^a \right)} \)
Table A-1
Identification of Brain Drain or Brain Gain starting from the estimations of $H/H_0$

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Comparisons between the effective emigration rate and the optimal one given different values of $\alpha$

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Table A-3
The Relative Optimal Human Capital (Ideal situation: the Optimal Emigration Rate $m^*$ is used to compute the optimal human capital $H^*$)

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Comparison between the relative human capital (\(H/H_0\)) under risk aversion and risk neutrality for the sample countries

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For Table A-4, the effective emigration rate \(m\) is used to compute the optimal human capital \(H\)
Table A-5
Comparison between the optimal emigration rate ($m^*$) under risk aversion and risk neutrality for the sample countries

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Figure A-1

Effects of Emigration Rate on the Relative Human Capital Curve ($\alpha = 0.35$)

Figure A-2

Effects of Emigration Rate on the Relative Human Capital Curve ($\alpha = 0.75$)