The Impact of Brain Drain on Education Policies[1]

Aysegul Kayaoglu[2]
Catholic University of Louvain, IRES
Draft Version-April,1 2009

1 Introduction

It is a strongly accepted fact that higher levels of income per capita can be attained most importantly through higher physical capital per worker, higher levels of total factor productivity and higher human capital. Therefore, the importance of the high-skilled workers cannot be ignored for the growth of an economy. The problems associated with the emigration of high-skilled individuals from developing countries are stressed since the beginning of the 1960s especially in the economics literature. There exist mainly three waves in the literature: the first strand of which focuses on non-negative aspects of high-skilled migration (see Grubel and Scott, 1966 and Berry and Soligo, 1969). Second stream starts with the writings and propositions of J.Bhagwati during 1970s and argues that there is negative impact of high-skilled migration on the welfare of developing countries (Bhagwati and Hamada, 1974; Bhagwati and Rodriguez, 1975; Haque and Kim, 1995). After a long recognition of highly skilled emigration as a negative phenomenon for developing countries, a new literature started to emerge suggesting that brain drain can be, in fact, transformed to a brain gain through its positive spillovers such as its stimulating effects on the production of the human capital in source countries (see for example Mountford, 1997; Beine, Docquier and Rapoport , 2001; Stark and Wang, 2002; Docquier, Faye and Pestieau , 2008). This paper follows and builds on the arguments in the two recent papers: Stark and Wang (2002) and Docquier et al. (2008).

Stark and Wang (2002) argue that emigration of the highly-skilled has the similar impact on the individual human capital investment levels as the educational subsidies since migration prospects give an incentive to invest more in education. They argue that an exogenous (and controlled) rate of migration can boost the human capital investment to its socially optimal level without utilizing subsidies for a given education policy. Docquier, Faye and Pestieau (2007)revisited the substitution proposition of Stark and Wang (2002) by introducing distortions and efficiency costs into their analysis. By endogenizing

[1]PRELIMINARY VERSION. PLEASE DO NOT QUOTE WITHOUT PERMISSION.

[2]I am grateful to Professor Frédéric Docquier for many useful discussions and comments. All errors are mine.

education subsidies they found that education subsidies and migration are not good substitutes if fiscal distortions are not high when educational subsidies implemented. They also analyzed the relationship between educational subsidies and migration prospects and found evidence for the existence of negative relation for 105 countries over 108. Moreover, endogeneity of public subsidies is found to magnify the welfare losses due to brain drain phenomenon.

Both of these papers assume the probability of migration as exogenous. However, it is a well-known fact that probability of migration cannot be fully exogenously determined in a globalized and democratic world and it is also not feasible to assume a strictly controlled level of emigration in today's world. Furthermore, in their analysis about the substitutability between education subsidies and migration prospects, Stark and Wang (2002) consider both policies separately and do not examine an economy in which both of these policies coexist. One of the main problems of today's developing countries is the role of education policies, mainly education subsidies, in the creation of large outflows of the high-skilled workers. It is the question of governments whether or not those investments in education are actually a deadweight loss in a welfare economics terminology. Governments in developing countries often complain about the loss of their investment in education since they continue to lose a 'cream portion' of their population after increase in education investments. It is a waste of investment in this respect. On the other hand, there is also a risk of losing their skilled (or high-ability) population if they under-invest in education since those people will search for other opportunities for their human capital investments. Therefore, the problems arising from under-investment or over-investment in education are among the main concerns of developing countries since these can have negative spillover effects for the further skilled emigration through providing more incentive for it.Thus, it is of crucial importance for governments to invest at the optimal level not to fail to keep their skilled population at home.

The aim of this paper is, then, to search for an answer to this crucial level of education investments for developing countries and draw policy implications about the optimal level of education subsidies in a world of international migration. In other words,it aims to find the cut-off subsidy level, s^*, below or above which there will be adverse effects of high-skilled emigration on the welfare of developing countries. By keeping all these concerns in its core, two different types of models are considered. Firstly, an open economy model in which governments care about the *average* level of human capital in the economy and subsidize the education will be analyzed. Secondly, an open economy model in which governments are concerned with the *stock* value of human capital will be examined in detail which is equivalent to the case with the existence of heterogeneous agents in the labour market. Analyzing the effects of both the probability of the skilled migration and the education policy parameters simultaneously will allow us to conclude about the interaction between brain drain and education policies in developing countries. Building upon the strong evidence that migration prospects positively impact on people's decisions to invest in higher education, we try to find optimal level of public education subsidies in developing countries, assuming that emigration is not costly and there is a positive self-selection in the migration process (only high-skilled workers can choose to emigrate).

Furthermore, in a context of uncertainty regarding future migration opportunities and of higher earnings abroad, migration prospects foster investments (this induces an incentive or "gain" effect) which can compensate the loss from actual emigration (flight or "drain" effect), with the sign of the net effect on human capital formation being positive or negative depending on which effect dominates. Thus, this paper also aims to find the determinants of gain-drain compensation in case of endogenous probability of migration.

After reviewing the theoretical models in section 2, hypotheses are tested empirically to see whether findings will be verified by the data. Empirical evaluation of the models are presented in section 3 using the latest data at hand on brain drain and education policies in developing countries and conclusion is given in section 4.

2 Theoretical Framework

2.1 Model I- Using Average Level of Human Capital

Lets assume that productivity of a worker in home country, $f(H_h)$, depends on her own human capital (H) and also on the economy-wide average level of human capital ($\overline{H}$) in the country by keeping the definition of individual productivity function in Stark and Wang (2002). With a similar argument, productivity of an emigrant worker, $f(H_f)$, depends on the private returns at the destination country for his own human capital and some other welfare-enhancing factors. Thus,

$$\begin{aligned} f(H_h) &= \alpha H + \eta \overline{H} \\ f(H_f) &= \beta H + C \end{aligned}$$

β is private return for skills abroad and C is other welfare enhancing factors in destination countries. α and η are private and social returns of human capital at home, respectively. It can be inferred that η resembles the positive externalities due to human capital investment.

The cost of education , $C(H_h)$, is assumed to be convex and is defined as;

$$C(H_h) = \frac{k}{2} H^2$$

In an open economy where there is no migration costs and individuals have a chance to emigrate with a probability of p, the canonical welfare function becomes:

$$\Omega_i = \delta p[\beta H + C] + (1-p)[\alpha H + \eta \overline{H}] - (\frac{k-s}{2})H^2 - \tau$$

, where δ is weight given to emigrants and this weight is positively correlated with the beneficial feedback effects of the emigration to source countries. In other words, it can imply the magnitude ot remittances sent back home or other kinds of diaspora externalities which affect the source country economies positively and also resembles the connection of the emigrant with her origin country. It is equal to 1 for individual welfare function and $\delta \in [0,1]$ for governments' welfare function. If $\delta = 1$, it means that governments care both about emigrants and stayers. In the extremely opposite case where δ is equal to zero, governments only care about the well-beings of stayers in the country. k is the cost of human capital investment, s is public subsidies for education and τ is a lump-sum tax. p is the endogenous probability of migration which linearly depends on the human capital investment and other exogenous determinants of migration (i.e., exogenous migration rate) p_0. Thus, we implicitly assume that the higher the level of human capital a worker has, the higher will be the probability of migration for that worker which implies a positive self-selection process;

$$p = p_0 H$$

Individuals maximize their welfare function $\Omega_i(\delta; H; \overline{H}; s, \tau; p_0) = \Omega(1; H, \overline{H}; s, \tau; p_0)$ with respect to their level of human capital to obtain the optimal level of human capital investment;

$$H^o = \frac{p_0 C + \alpha}{p_0(2\alpha - 2\beta + \eta) + (k-s)}$$

$$\frac{\partial H^0}{\partial p_0} = \frac{C(k-s) - (2\alpha - 2\beta + \eta)\alpha}{[p_0(2\alpha - 2\beta + \eta) + (k-s)]^2} > 0$$

The value of optimal level of human capital is an increasing function of the probability of migration under our assumptions that $\beta \geq \alpha + \eta$ and $k - s > 0$. Thus, it can be inferred that migration prospects provide human capital investment incentives for individuals. The second-order condition ($\frac{\partial^2 \Omega}{\partial H^2} < 0$) gives that $p_0 < \frac{k-s}{2\beta - 2\alpha - \eta}$ for reaching a maximum level of welfare. When the gap between returns to education in destination and home countries widens, the level of human capital investment would increase since individuals will have more incentive to invest in their human capital due to migration prospects.

[Graph 1]

In the first-best solution, government maximizes the level of social welfare by internalizing the social return of human capital investment. Therefore, the objective function for government becomes $\Omega_g = \Omega(\delta; H, H; 0, 0; p_0)$

$$\Omega = \delta p[\beta H + C] + (1-p)(\alpha+\eta)H - (\frac{k}{2})H^2$$

FOC provides us the socially optimal level of human capital;

$$H^* = \frac{\delta p_0 C + \alpha + \eta}{2p_0(\alpha+\eta) - 2\delta p_0 \beta + k}$$

Second-order condition ($\frac{\partial^2 \Omega}{\partial {H^*}^2} < 0$) gives that $p_0 < \frac{k}{2(\delta\beta - \alpha - \eta)}$. The relationship between the socially optimal level of human capital and the probability of migration does not follow an exact pattern as the one between the individually optimal level of human capital and the migration prospects. Moreover, as it is noted earlier $\delta > 0$ if emigrants sent back remittances.

Ambiguity of the change in H^* with respect to a change in p_0 depends on the parameters at hand and the attitudes of governments towards their citizens;

$$\frac{\partial H^*}{\partial p_0} = \frac{\delta C k - 2(\alpha+\eta)(\alpha+\eta-\delta\beta)}{[2p_0(\alpha+\eta-\delta\beta)+k]^2}$$

,which is negative if $\delta = 0$ and positive if $\delta = 1$ and it is ambiguous when $0 < \delta < 1$.

If governments do not pay attention to emigrants, then it is obvious that social planner's optimal level of human capital invesment would be a decreasing function of probability of migration. Thus, emigration is regarded as detrimental for human capital investments which inserts negative impacts on the human capital investment decisions. It is the other way around if $\delta = 1$ which is a case where government cares about all of her citizens without paying attention to their residence. For the values of $0 < \delta < 1$, the change in socially optimal level of human capital investment with respect to p_0 is ambiguous and depends on the values of parameters which forms the cut-off level δ^*. (see Appendix) Any values of δ above that level results a positive relationship between H^* and p_0 as it can be observed from the graph belove. In other words, $\frac{\partial^2 H^*}{\partial p_0 \partial \delta} < 0$ for any values of $\delta < \delta^*$.

[Graph 2]

Decentralization gives that the optimal level of education subsidies should be:

$s^* = \frac{p_0^2[2C\alpha(\delta-1)+C\eta(\delta-2)]+p_0[(\delta-1)(Ck+2\alpha\beta)+\eta(\alpha+\eta-2\beta)]+k\eta}{\delta p_0 C+\alpha+\eta}$. Therefore, $s^* = \frac{k\eta}{\alpha+\eta}$ when there is no emigration which means that subsidy rate increases when cost of education and social return of human capital investment are increasing even without the possibility of emigration.

$\frac{\partial s^*}{\partial p_0}$ is always negative. (it is more negative in case of $\delta = 0$) Thus, there is always a negative relation between subsidy rate and probability of migration

implying that governments are less willing to subsidize when p_0 increases because they foresee that there is a high risk of losing this investment through brain drain. This proposition confirms the "crowding out" effect of skilled migration upon subsidies which is also argued by DFP (2008).

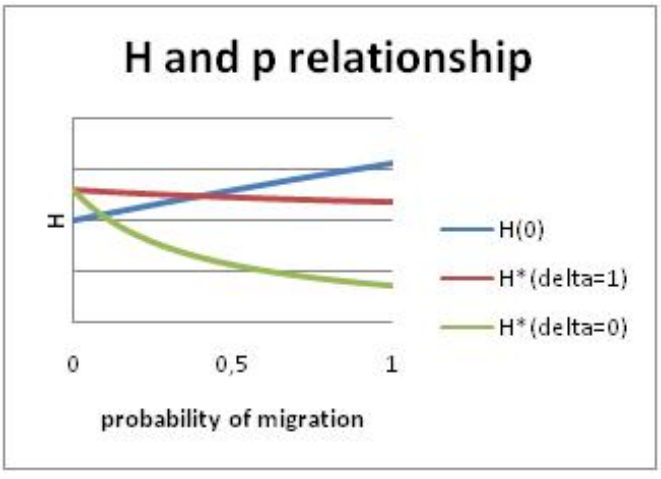
[Graph 3]

Moreover, there will be no subsidies if p_0 is above a critical value $\overline{p}$ (see appendix for details). $\overline{p}$ is negatively related with $[\beta - (\alpha + \eta)]$ which implies that positive migration prospects cause a decline in the cut-off level of probability above which the provision of subsidies would be abolished to prevent further fiscal losses. Moreover, it is positively related with α and η which means that governments decide to subsidize education even for higher rates of the probability of emigration if returns to education investments increase at home which in turn results less incentive to go abroad for a given level of β. Thus, the probability of wasting public investments decreases. Besides, governments subsidizes for higher probability of emigration if the cost of education is higher in a country which has a negative impact on individual decisions for human capital investment. Furthermore, an increase level of δ means a higher level for $\overline{p}$.as it can be easily observed from Graph 3.

When the relationship between δ and education subsidies is considered, it can be seen below that the more a government is concerned about the general population of its citizens (both leavers and stayers), the more she will be willing to subsidize education.

$\frac{\partial s^*}{\partial \delta} = \frac{p_0^3[2C^2(\alpha+\eta)]+p_0^2[C(\alpha(1+2\beta)+\eta(1-\alpha-\eta+2\beta))+C^2k]+p_0[(Ck+2\alpha\beta)(\alpha+\eta)]+k\eta}{[\delta p_0 C+\alpha+\eta]^2} > 0$ under the assumptions.

Graph 4:



Thus, for the case 1 where we analyzed the impact of education subsidies on the probability of emigration, it is observed that the higher the rate of emigration the lower will be the subsidy provided by governments. This negative

relationship is also found by DFP (2007). However, we will test this hypothesis using many different indications for education policies in developing countries. Moreover, we also found that the the higher a government concerns about emigrants the higher will be the rate of subsidies for the same level of probability of migration.

Another prediction from our calibration is that invesment in human capital is not always positively correlated with the probability of migration. For small probabilities of emigration, individuals have less incentive to invest in their human capital depending on the magnitude of the cost of education and the skill price at home. Decreased subsidy rates have a negative effect on human capital investment for small values of probability of migration. However, when the probability of migration gets higher investment in human capital also increases without having education subsidies or not. This prediction will also be tested using recent data on brain drain and many indications of education policies.

2.2 Model II- Introducing Stock of Human Capital as Externality

In this model, we consider an open economy in which the productivity of an individual depends on his private human capital and also on the economy's aggregate stock of knowledge which implicitly implies more potential detrimental effects of highly-skilled emigration for an economy due to many different side-effects such as the impact of total human capital on research and development, on social capital formation and so on. In other words, it can be assumed that this way of defining the individual level of human capital incurs a higher social welfare loss in case of brain drain phenomenon. This kind of model specification will also give us the opportunity to analyze the effect of high-skilled emigration by taking into account the complementarity of high- and low-skilled workers.

$$\Omega(\delta; H, \overline{H}; s, \tau; p_0) = \delta p_0 H[\beta H + C] + (1 - p_0 H)[\alpha H + \eta(1 - p_0 \overline{H})\overline{H}] - (\frac{k-s}{2})H^2 - \tau$$

Individuals maximizes $\Omega_i = \Omega(1; H, \overline{H}; s, \tau; p_0)$ with respect to H and since $f''(\Omega) < 0$ at H^o, the optimal level of welfare is reached at this level. Thus;

$$H^0 = \frac{p_0(2\alpha + \eta - 2\beta) + (k-s) - \sqrt{(p_0(2\beta - \eta - 2\alpha) - (k-s))^2 - 4p_0^2\eta(p_0 C + \alpha)}}{2p_0^2\eta}$$

For feasible values of H^0 , there is a positive relationship between individuals' chosen level of human capital investment and p_0 as in the first model. In other words, individuals have more incentive to invest in their human capital in case of increased chance of emigration and , thus, that of obtaining higher return to their human capital. Moreover, $\frac{\partial^2 H^0}{\partial p_0 \partial \beta} > 0$ which in line with intiution means that higher levels of private return to human capital abroad triggers human capital investment motives at home. Thus, H^0 curves moves upwards (both slope and intersection) if β increases.

[Graph 5]

At the first-best solution, government maximizes the social welfare function $\Omega_g = \Omega(\delta; H, \overline{H}; 0, 0; p_0)$ with respect to the level of human capital again by internalizing the stock level of human capital in the economy. Relative maximum is reached at H^* and therefore socially optimal level of human capital is:

$$H^* = \frac{2p_0(2\eta + \alpha - \delta\beta) + k - \sqrt{(2p_0(\delta\beta - 2\eta - \alpha) - k)^2 - 12p_0^2\eta(\delta p_0 C + \alpha + \eta)}}{6p_0^2\eta}$$

Socially optimal level of human capital investment does not follow the same pattern as the one of individuals and its path with respect to the probability of migration is very much related with the behaviour of government towards emigrants(δ) and β.

$\frac{\partial^2 H^*}{\partial p_0 \partial \delta} > 0$ implies that higher levels of δ increases the value of socially optimal level of human capital. If governments do not care about emigrants for any reason then as intuition suggests there will be always a negative relationship between H^* and p_0 and this result does not change with respect to β. However, if governments starts to pay more attention to emigrants, this may reverse the existing negative relationship after some value of p_0 meaning that higher probability rates of migration results increased level of socially optimal human capital. (see Graph 6) Governments can change their attitudes towards emigrants due to some self-seeking reasons such as higher amounts of remittances sent back home or due to other positive externalities of emigration.

[Graph 6]

Decentralization gives us the optimal level of education subsidies where $H^* = H^0$ (see appendix for details)

$\frac{\partial s^*}{\partial p_0} < 0$ as in the previous model, where we used average level of human capital as an externality, the subsidy rate is always negatively related with the probability of migration for positive values of s^*, and this finding confirms the substitutability of education subsidies and migration prospects. Increase in δ causes higher levels of subsidy rate for the same level of probability of migration and as it can be guessed cut-off level p ($\overline{p}$) increases as the weight given to emigrants gets higher. It suggests that governments are ready to subsidize education more if emigrants attain more importance for them.

[Graph 7]

When it comes to the effect of higher private returns abroad, it can be said that higher levels of β has negative impact on the subsidy levels of governments. The higher the private returns abroad, the lower will be the cut-off level $\overline{p}$, and the lower will be the slope and intercept of s^* curve as it can be seen from the graph below.

[Graph 8]

As it can be seen from the graph 9 and graph 10, human capital investments will drastically increase for small levels of probability of migration as the difference between β and $(\alpha + \eta)$ widens. This occurs eventhough government subsidizes the education less because there is no need to use this incentive by governments as individuals have already enough incentive to invest more in their accumulation of human capital.

[Graph 9]

[Graph 10]

The comparison of the two models leads us to the conclusion that optimal level of human capital investments are higher for small values of migration probability if stock level of knowledge is utilized as an externality. However, socially optimal level of human capital becomes not feasible for governments when the probability of migration increases in the second model since it incurs higher costs for individuals. Moreover, subsidy provided for the investment incentive is lower in the second case than the one we use average level of human capital as an externality because emigration becomes more costly for the economy and developing countries.

Another important fact is that contrary to the general belief about the positive relationship between human capital investment and probability of migration, we found that for the small values of migration probability this positive relationship does not necessarily hold. In our calibration, it is found that human capital investment first decreases with respect to probability of migration and after some level it starts to increase again. Therefore, it can be concluded that for small values of emigration rate the positive externality effect that is found in the recent literature may not hold. These predictions will be tested using the recent data on brain drain in later sections.

3 Empirical Analysis

There are two main predictions of the theoretical model analyzed in the previous sections. First of all, human capital investment is not always positively correlated with the rate of migration. The theoretical model predicts that there exists a negative relationship between human capital invesment and the migration probabiliry until a cut-off level $\overline{p}$ and the opposite relationship occurs after that level of probability. This prediction is against the arguments that is suggested by the paper of Stark and Wang (2002) which states that migration prospects are good substitutes for the education subsidies for any migration probability upto a certain threshold point. Secondly, theoretical model predicts that increase in migration probability should have a negative impact on the public subsidy rates. This argument is also investigated by DFP (2008) and they have found the existence of a negative relationship. Here, the same proposition will be tested by using a recent data and with a different model specification.

3.1 Data and Methodology

The data on the rate of migration is based on the recent data set on international migration by educational attainments which is described in detail in Beine et al. (2007). They classify the skilled migrants according to their age of entry to the destination country and the information on the entry age is used as a proxy for the the place of obtaining education. There are three different classifications of the skilled migrants based on the age of entry, namely the migration rate provided for for the ages above 12, 18 and 22. Although the overall rate of the skilled migrations, these three different classifications will be used as a robustness check of the empirical model. Remittances and subsidy rates data set is built using the recent data on World Development Indicators 2008 and United Nations Educational, Scientific and Cultural Organization Statistics (henceforth WDI 2008 and UNESCO-Stat). The proposed questions will be investigated only for the developing countries. Although there exist the international migration data for all the countries in the data set, number of observations is compressed due to the lack of remittances and education subsidies data for all the developing countries. Furthermore, all the data is collected for the year 2000 to have coherence with the international migration data set at hand except the remittances data which is the mean remittance values per migrant between years 1990 and 2000.

As a methodology, Intrumental Variable (IV) Method is employed because of the potential endogeneity problem between migration rate and explanatory variables in the models. The OLS method provides the inconsistent estimates in the existence of endogeneity or omitted variables problem and therefore, IV should be used to have consistent estimates although this time efficiency feature of the estimates are lost. Several diagnostic tests are conducted to test the consistency of the estimates provided by IV method. First of all, the validity and the relevance of the intruments should be tested. Estimations become more biased if the instruments are not valid or, in other words, have little explanatory power. Then, using the IV method is not useful and nothing will be gained using the IV in addition to not having efficient estimates. (Hahn and Hausman, 2002)

For the relevancy of the excluded instruments, first-stage F-statistic of the joint significance test is checked. First-stage regressions should provide F-statistic above 10 as a rule of thumb. Moreover, Anderson-Rubin Wald test statistic and Kleibergen-Paap Wald test statistic are checked again for the relevance of the excluded instruments. Hansen J-Statistic is used for the overidentification test and null hypothesis of the orthogonality assumption is checked for the validity of the instruments. Lastly, C-test is performed to see whether endogenous regressors should be entered to the model as exogeneous regressors or not. Moreover, all the tests are robust to the heteroskedasticity.

3.2 Results for the Human Capital and Migration Rate Relationship

In this section, it will be tested whether migration prospects and education subsidies are good substitutes or not as an inducement channel for higher rates

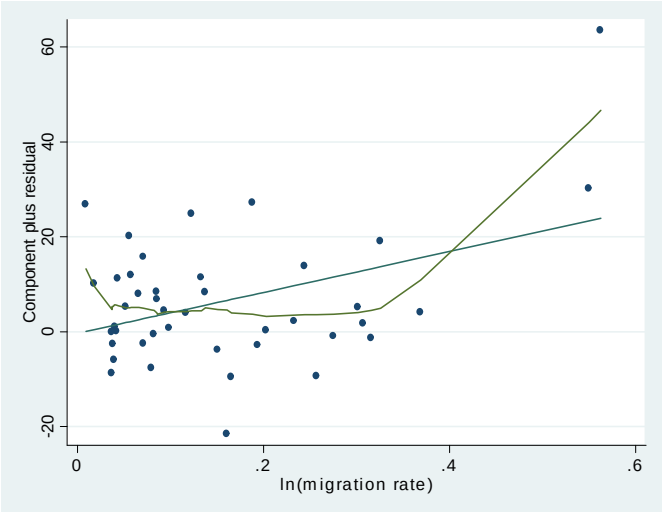
of investment in human capital. Individual level of human capital investment is proxied by using the recent data on upper-secondary gross enrollment ratio in origin countries. This data is obtained from UNESCO-Stat. Individual level of human capital investment will be regressed on:

- the log of the skilled emigration rate in 2000,
- mean of remittances rate between the years 1990 and 2000,
- log of skill prices at origin
- log of rural population as a ratio of overall population at origin in 2000,
- school age population of the upper-secondary level
- democracy index at origin country signifying the level of democracy
- regional dummies

[Table of the regression results about here- both OLS and IV]

As it can be observed from the regression results, migration prospects have a significant (at 0.001 level) and positive effect on the individual level of human capital investment. The level of remittances also have positive impacts on the human capital investment but it is found to be nonsignificant. C-test results proves the endogoneity of the migration rate and its interaction with the mean remittance levels which leads us to stick on the IV estimates since they provide consistent estimates in this case. It is also checked whether this positive relationship exists for all the values of skilled-migration rate. It can be seen from the graph below that findings confirms the theoretical predictions that migration prospects have negative impact on the human capital investment for a rate below the cut-off level $\overline{p}$.

Graph 11:



3.3 Results for the Subsidy and Migration Rate Relationship

In this section, the impact of migration rate on public education subsidies at tertiary level is tested again using both OLS and IV methods. It is found that there is a negative relationship between migration rates and subsidy rates. The same model is tested using other migration rate measurements for different age of entry and the results (see Appendix) shows us the robustness of the estimates. The interesting finding is the negative impact of remittances on the subsidy rates. Theoretical model predicts that governments will invest more in education if the magnitude of the remittances gets higher. The contadiction in the empirical tests can result due to the fact that remittances are not efficiently used in developing countries (existence of corruption may occur) or governments expects more individual investment in human capital due to higher remittances received by the residences.

Another important finding from the analysis is the negative relationship between skill price and government subsidy rates. This result can also be linked the policy trade-off between investing in education or letting people invest more in their human capital. This negative relationship shows us that governments can decide to invest less on education in a country with high levels of skill-price since individuals have enough incentive to invest more in their human capital due to obtaining more income after increasing their skills. The results of the regression and diagnostic test statistics can be seen in the table below.

[**Table: Regression Results about here**]

IV regression results provides inconsistent estimates since C-test rejects the endogeneity of the intrumented variables. Thus, OLS method is more appropriate which gives both consistent and efficient estimates.

4 Conclusion

In this paper, it is proposed to analyze the impact of migration prospecst on education policies in developing countries. Following the predictions of the theoretical framework, the answers for the two main questions are investigated by the empirical analysis: what is the impact of the migration prospects on individual human capital investments?; and does the probability of emigration have a negative effect on government subsidies in education?. Using the recent data on international skilled migration, it is found that probability of migration has positive impact on individual human capital investment although partial analysis reveals the existence of negative relationship between human capital investment and migration prospects for small values of migration probability. Moreover, the regression analysis on the subsidy-migration rate trade-off confirms the findings of DFP (2008) suggesting a negative relationship between them.

5 References

[reference list here]

6 Appendix

1- $\frac{\partial H^*}{\partial p_0} = 0$ results that $\delta^* = \frac{2(\alpha+\eta)^2}{Ck+2\beta(\alpha+\eta)}$

2- $\overline{p} = \frac{(1-\delta)(Ck+2\alpha\beta)+\eta(2\beta-\alpha-\eta)-\sqrt{[(\delta-1)(Ck+2\alpha\beta)+\eta(\alpha+\eta-2\beta]^2-4k\eta[2C\alpha(\delta-1)+C\eta(\delta-2)]}}{4C\alpha(\delta-1)+2C\eta(\delta-2)}$

where $\sqrt{(.)} > (1-\delta)(Ck+2\alpha\beta)+\eta(2\beta-\alpha-\eta)$.

3- Optimal level of subsidy rate for Model 2:

$$s^* = \frac{9p_0^2(2\beta-2\alpha-\eta)^2-36\eta p_0^2(p_0C+\alpha)-18p_0k(2\beta-2\alpha-\eta)+9k^2}{6[2p_0(2\eta+\alpha-\delta\beta)+k-\sqrt{(2p_0(\delta\beta-2\eta-\alpha)-k)^2-12p_0^2\eta(\delta p_0C+\alpha+\eta)}]}$$

$$-\frac{[p_0(\eta-4\alpha-2\delta\beta+6\beta)-2k-\sqrt{(2p_0(\delta\beta-2\eta-\alpha)-k)^2-12p_0^2\eta(\delta p_0C+\alpha+\eta)}]}{6[2p_0(2\eta+\alpha-\delta\beta)+k-\sqrt{(2p_0(\delta\beta-2\eta-\alpha)-k)^2-12p_0^2\eta(\delta p_0C+\alpha+\eta)}]}$$

s^* will be defined if and only if $\sqrt{(2p_0(-\eta-\alpha+\beta)-(k-s))^2-8p_0^2\eta(p_0C+\alpha)} \geq 0$ and $\sqrt{(2p_0(\delta\beta-2\eta-\alpha)-k)^2-12p_0^2\eta(\delta p_0C+\alpha+\eta)} \geq 0$.Moreover, $s^*$is not defined if there is no probability of migration.

4- [put table for robustness check of the model specification]