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A Quantitative General Equilibrium Approach to Migration, Remittances and Brain Drain

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Abstract

Developing countries have experienced an outstanding outflow of skilled workers (brain-drain) over the last several decades. Additionally, migrants tend to be tied to their country of birth, since they send a large amount of remittances to their relatives. Furthermore, migration is not permanent, since a considerable number of workers return to their country of birth after a migration spell. In this paper we develop a model that is consistent with these facts. We use our model to address some important issues in the migration literature from a theoretical perspective. We study the general equilibrium effects of migration, its long-term effects, and its welfare effects, and we see whether the joint effect of return migration and remittances is strong enough to offset the effects of skilled migration. Finally, we evaluate the effectiveness of policy interventions that attempts to offset the effects of a brain drain.

JEL Classification:

Keywords: Migration, General Equilibrium, Brain drain, Remittances, Heterogeneous Agents.

1 Introduction

There have been three recurring features in the recent migration literature: First, migrants are mostly educated, since the skilled migration rate is almost 5.8 times as large as the average unskilled migration rate. This phenomenon has been called a brain drain by the relevant literature, and it seems to be a common phenomenon of many developing economies, as Figure 1 shows.

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Second, migrants are economically tied to their country of origin, since most of them send remittances to their relatives. These remittances are very important in aggregate terms for these economies, since they represent on average around 2% of GDP (2005). Interestingly, there is a considerable heterogeneity in the amount of remittances received by some countries, as Figure 2 shows: in 45 economies, from a sample of 155 countries, remittances represented on average more than 5% of GDP in 2005. Remittances as a source of external resources for developing economies were also stressed in World Bank (2006) reports; according to this source, remittances are the second largest source of external resources for developing economies, behind only FDI, and they are even larger than total foreign aid resources. Finally, return migration is becoming important for the source country, since around $10-20\%$ of migrants return to their birthplace after a migration spell. The migration literature has widely studied these three topics, as we detail in this section.

Migration of skilled workers can be detrimental for the source country's economy, since education or human capital is a major determinant of long-term economic growth (Lucas, 1998). More specifically, investment in education is lost when a trained and/or educated individual leaves the country. The early migration literature[1] stressed this phenomenon as a negative effect for developing economies, since it creates a scarcity of skilled workers. However, the recent literature[2] stresses that migration can have positive economic implications for source countries that can potentially offset the initial effects of skilled migration.[3] According to this literature, migration prospects can foster investment in education because of higher returns abroad (Beine et al. (2001); Mountford (1997); Docquier and Rapoport (2007); Chen (2006); Vidal (1998)).

The role of migration and remittances as a household strategy to mitigate the effects of idiosyncratic shocks has also been studied by the migration literature (Lucas and Stark (1985), Rosenzweig and Stark (1989)). This literature supports the claim that households use migration and remittances as a tool to smooth consumption and to reduce the risk exposure in developing economies. The evidence supports this claim, since income and remittances seem to be negatively related. We provide additional evidence that supports the insurance argument of remittances; specifically, we relate the source country's relative income (source country GDP/ host country GDP ratio) with the remittances-GDP ratio. After regressing these two ratios in logs and controlling for the country-specific fixed effects, we find that they are negatively related, which is consistent with the insurance history of remittances (see Figure 3).

Several studies have documented the role of remittances from an empirical point of view. From an aggregate perspective, for example, remittances contribute to economic growth, investment

[1] Grubel and Scott (1966), Johnson (1967), Bhagwati and Hamada (1974), Kwok and Leland (1982).

[2] Vidal (1998); Beine, Docquier, Rapoport(2001); Chen(2006); and Faini (2007).

[3] This branch of the migration literature considers mainly the beneficial economic effects of remittances and return migration.

and aggregate savings. Fajnzylber and López (2007), by using intensive panel data techniques and country case studies, evaluate the role of remittances over growth, investment and income inequality in Latin American countries. From a microeconomic perspective, remittances affect the allocation of time and resources within the household; Fajnzylber and López (2007) and Acosta (2006) show how remittances reduce the time devoted to work in El Salvador and Nicaragua. This literature has also documented the role of remittances over income distribution, poverty, output and economic growth.

Another branch of the literature studies the role of remittances and skilled migration in a unified setup. The literature that studies the combined effect of remittances and skilled migration has produced considerable econometric evidence of the significant economic effects of both brain drain and remittances in developing economies (Faini (2007); Docquier and Rapoport (2007)).

An issue that has not been studied by the migration literature is the indirect effect of the departure of skilled workers that acts through an externality channel. The argument behind this issue is that the reduction of the human capital stock due to skilled migration may cause a reduction of the return to other factors in the economy, such as physical capital and labor (Hall and Jones (1999)). The presence of externalities of human capital may also justify a public policy intervention that attempts to offset the effects of a brain drain. Our approach contributes to this branch of the migration literature, since it captures the externality channel of skilled migration.

Return migration has also received special attention recently. This interest was driven by the fact that around one fifth of the migrants return to their birth country after a migration spell. The economic implications of this phenomenon are important, since return migrants may promote the source country's human capital, a phenomenon called brain gain. Some studies show that, on average, a return migrant has a human capital stock that is 20% higher compared to his human capital before migration. The economic effects of return migration have been studied from a theoretical and empirical perspective; an important question addressed by this literature concerns the significance of the economic implications of return migration. Furthermore, the debate also concerns whether the effects of return migration and remittances are strong enough to compensate for the negative effects of skilled migration. The current literature has provided some answers to this question; however, the approaches are still limited and the debate is not over yet. Since our approach includes the most important channels by which migration may affect economic outcomes, we provide some clues about the significance of the return migration channel.

A feature that arises from the literature review is that migration has mainly been studied from an empirical and/or partial equilibrium perspective. There are few papers that study migration in a general equilibrium framework,[4] and the theoretical efforts in this direction have followed

[4]The literature that studies remittances from a general equilibrium perspective in small open economies has not explicitly addressed the welfare effects of remittances. In fact, the studies are mainly focused on the role of

the two-period life-cycle OLG model applied first to the migration literature by Galor and Stark (1990, 1991). The welfare effects of migration have also not been fully addressed by the literature.

The contributions of the paper are twofold. First, we extend the neoclassical model so that it explains some of the most important empirical features of migration from the source country's perspective (brain drain, remittances and return migration). We use abundant evidence from the empirical literature in order to discipline, or calibrate, the model. Second, we use the model to address some specific issues regarding the economic effects of migration; among them, we consider the following: a) we measure the general equilibrium effects of skilled migration and remittances. This is interesting, since skilled migration and remittances may affect the allocation of resources in the economy through price changes. b) We deal with the welfare effects of migration, an issue that introduces a discussion about the political economic implications of migration. c) We see whether the combined effects of remittances and return migration may be strong enough to offset the negative effects of a brain drain. Given that the model includes skilled migration, remittances and return migration, it seems to be the natural laboratory to address this issue. d) We study the effectiveness of a policy intervention that attempts to reduce the negative effects of skilled migration. We restrict our analysis to the following policies: skilled return migration policy; migration cost policy; remittances policy, and a policy that directly affects the probability of migration.

The papers that are closely related to ours are Vidal (1998), Docquier et al. (2007) and Chami et al. (2006). Vidal builds a general equilibrium model from Galor and Stark (1990,1991). His approach, however, differs from ours, since we use a completely specified general equilibrium model with heterogeneous agents instead of a two-period life-cycle representative agent OLG model. Vidal also uses his model to explore from an analytical perspective the effect of migration on human capital formation and output: he shows that migration may be constructive for economic growth by providing an incentive for human capital formation in the source country. On the other hand, Docquier et al. (2007) study from an analytical perspective the consequences of skilled migration for source countries; they use a one-period representative agent general equilibrium model. They found that the optimal high-skilled migration rate is positive. Additionally, they introduced

remittances over real exchange rate fluctuations and the evolution of the current account. For example, Lartey (2007) examines the implications of an increase in capital inflow for real exchange rate movements and resource reallocation in a small open economy. Dutch disease effects of remittances have also been studied under a general equilibrium framework (Acosta et al. (2007)). The optimality of fiscal (labor income tax) and monetary policy (money growth) under remittance flows has also been evaluated by Chami et al. (2006) in a general equilibrium model with representative agents; their model suggests that remittances affect the optimal allocation of distortionary labor income taxes (a la Ramsey). They also use their model to evaluate the welfare effects of remittances; however, their welfare analysis is performed for a representative agent and it does not consider the transition path after a remittances shock.

analytical predictions of the effects of migration and education policies on human capital: they claim that policies that restrict the international mobility of high-skilled persons could decrease the long-run level of human capital stock (output). Finally, Chami et al. (2006) evaluate the optimality of labor income taxes and monetary growth in the presence of remittances; they use a general equilibrium model with representative agents to evaluate the effects of remittances on welfare and output. However, their model does not include the underlined features of the migration literature; it does not include human capital, it does not consider migration decisions and there is no heterogeneity among agents.

The rest of the paper is organized as follows. Section 2 describes the model economy. Section 3 defines the competitive equilibrium. Section 4 describes the calibration procedure. Section 5 presents our results. Finally, in section 5 we conclude.

2 The Model

Our departing point is the stochastic neoclassical growth model with heterogeneous agents and incomplete markets (Aiyagari (1994)). The Aiyagari's basic structure is extended so that our suggested model is able to capture some important features of an economy in which migration, remittances, return migration, and brain drain are quantitatively important. Our model includes the following features: First, we study migration in an incomplete market setup. In this environment we may be able to uncover the insurance component of migration and remittances. Second, we allow for optimal migration decisions at the household level. This is particularly important, since most of the migration literature has suggested that migration is a family decision. Third, we include workers' human capital. Fourth, we include a schooling externality. This assumption captures the negative effect of brain drain on the productivity of workers; this also justifies an anti-brain drain policy intervention. Fifth, we consider endogenous remittances. In our model a household with a migrant abroad decides on the optimal monetary value of remittances. Sixth, we consider competitive firms with a CRS production function in which there is capital skilled-labor complementarity. Finally, we model the previously discussed issues in a stylized general equilibrium framework.

2.1 Environment

The structure of the model comprises a small open economy inhabited by infinitely lived risk-adverse workers. Agents value future consumption by using β^* as the subjective discount factor. The number of households in this economy is constant, and without loss of generality, it is normalized at 1; furthermore, we consider that households are born and die at the same constant rate ϕ every period, so that the aggregate number of households is constant. A newborn household has no assets. Under this formulation the effective discount factor can be represented by $\beta = (1-\phi)\beta^{*}$.

A first level of heterogeneity in this economy is the household size; the number of workers in each household differs according to the migration state. In the non-migration state each household is populated by n workers, and in the migration state, by $n-1$ workers. Workers can be ex ante heterogeneous according to their skill level. Two skill levels are considered; unskilled workers are indexed by "U" and skilled workers by "S."

Households are ex ante heterogeneous due to the within-household distribution of skills. Since there are n workers per household and each worker can be skilled or unskilled, we can identify up to $n+1$ households that differ among each other due to the within-household distribution of skills.[5] We let i, $i \in \{1, 2, ..., n+1\}$, denote the $i-th$ household type and j, $j \in \{1, 2, ..., n\}$, denote the $j-th$ household member.

Each individual is endowed with one unit of time that has to be spent at work. Gross labor income of the $i-th$ household is denoted by $\sum_{j=1}^{n} w_{ij} h_{ij} z_{ij}$, where w_{ij} is the wage per efficiency units of hours of work of the $j-th$ household member in the $i-th$ household type. Likewise, h_{ij} denotes the human capital stock and z_{ij} is the idiosyncratic productivity shock. Notice that both the wage and the human capital can take only two values according to the worker skill level: $w_{ij} \in \{w_U, w_S\}$ and $h_{ij} \in \{h_U, h_S\}$.

Government has a twofold role in this economy. It taxes the workers' total income at a rate "τ" and it returns the collected tax revenues to each household as the lump sum transfer "Λ_1."

The idiosyncratic productivity of the household members is correlated among each other. If a household member is hit by a good productivity shock, then the remaining members may also be hit by a similar productivity shock with higprobability. The joint household productivity process Z_i, $Z_i = [z_{i1}, ..., z_{in}]$, follows a continuous $VAR(1)$ process $Z_i' = \varrho Z_i + \upsilon_i$, where $\upsilon \sim N(0, \Sigma)$, Σ is the variaze-covarianze matrix, and ϱ denotes the autoregressive coefficient of each worker's productivity process.

Human capital is produced according to the following production function, $h_{ij} = \varphi \exp(\phi_0 s_{ij} + \phi_1 \overline{S})$, where s_{ij} represents years of education, $\overline{S}$ is the average, or aggregate, years of education, φ is a scale parameter that is introduced in this formulation in order to standardize the values of human capital, ϕ_0 represents the private return to education, and ϕ_1 captures the externality induced by the average years of education in the economy. In this model skilled migration may induce a negative externality since it reduces the country-wide human capital. Furthermore, the

[5]When the household size is three, for example, we can distinguish four types of households according to the within-household distribution of skills. Household type 1, $i = 1$, is populated by three unskilled workers; household type 2, $i = 2$, is populated by two unskilled workers and one skilled worker; household type 3 is populated by one unskilled worker and two skilled workers; and household type 4 is populated by three skilled workers.

introduction of the schooling externality may be used to rationalize the implementation of a group of policies that attempt to prevent or mitigate the negative effects of skilled migration.

Households are allowed to save and there is only one asset available for this purpose: a denotes saving and $a \in A$, where A is a compact set that represents the savings state space. Households are borrowing constrained ($a \geq \underline{a}$, $\underline{a} = 0$) and they can finance expenses (consumption, migration cost and savings) only with labor income or the interest generated by the household wealth. In this environment the market is incomplete, since there is only one asset that can be used by the household to insure against idiosyncratic shocks.

The household utility is represented by $u(c)$ and it is strictly increasing and concave in consumption ($u'(c) > 0$ and $u''(c) < 0$). The instant utility of a household with no migrants abroad, we call this the stayer household, is represented by the following functional form.

$$u(c) = n\frac{c^{1-\sigma}}{1-\sigma} \tag{1}$$

Each stayer household decides optimally every period about per capita consumption, saving and migration. Migration is a family decision, since each stayer household decides to send one of its family members abroad. Every period a stayer household receives a migration offer, and this offer arrives with a positive probability that depends on the household's type (p_i). Migration cost is denoted by Δ and it is paid from the household budget during the migration period.

The migration decision is based on a two-step comparative advantage mechanism. In the first step, the household chooses the potential migrant from among members of the family. It is done by comparing the household lifetime value of migration for each member. In the second step, and once the migration offer arrives, the household decides to send abroad the potential migrant if the offer is good enough.

Labor income abroad is exogenous. We let $\overline{w}_U$ denote unskilled migrants' labor income and $\overline{w}_S$ denote skilled migrants' labor income. A migrant household values the utility of each of its members, including the member that works abroad. We denote by $\widetilde{c}$ the consumption of the migrant worker and the instant utility of a migrant household is represented by the following functional form.

$$u(c) = (n-1)\frac{c^{1-\sigma}}{1-\sigma} + \frac{\widetilde{c}^{1-\sigma}}{1-\sigma} \tag{2}$$

The decision on remittances is taken by the household and it depends on the prevailing economic condition in both the source and the host country. We believe that households with a migrant abroad face uncertainty surrounding the remittances that they could potentially receive. We introduce the variable R, which denotes the migrant's option to send remittances. R can take two values: $R = 0$ if the migrant has the option to send remittances and $R = 1$ otherwise. The uncertainty of remittances is captured by the probability of sending remittances π_{re}, $\pi_{re} = \Pr ob(\mathrm{Re} = 1)$. Formally, R is a two-state stochastic variable that follows an *iid* process.[6] The migrant may send remittances every period but the migration period; additionally, once the remittances option is realized, the household decides about the optimal monetary value of remittances through the policy rule $Re(.)$. See that labor income abroad ($\overline{w}_U$, $\overline{w}_S$) and π_{re} summarize the economic conditions in the host economy; good economic conditions may translate into both higher remittances and a higher probability of sending back remittances.

Migration is an absorbing state. Once a worker migrates, he stays in the host country forever. This assumption will be relaxed later when we allow for return migration in an extended version of the model. Finally, production takes place in a competitive market according to a CRS production function similar to Krusell, et al. (2002). We will explain in detail the production process later.

2.2 Recursive Representation

2.2.1 Household problem

Denote by $V(a, \Theta, Z; i)$ the lifetime value function of a type i stayer household, where a accounts for the household's asset position, and $\Theta = \{h_{i1}, h_{i2}..., h_{in}\}$ is the household's stock of human capital. Similarly, $Z = \{z_{i1}, z_{i2}, ...z_{in}\}$ is the household's idiosyncratic productivity shock, and $\Theta_{-k} = \{h_{i1}, ...h_{ik-1}, h_{ik+1}, ..., h_{in}\}$ represents the household's stock of human capital when the $k - th$ family member has migrated. Likewise Z_{-k} is the household's productivity shock when the $k - th$ member has migrated.[7]

The stayer household problem. The problem of a household with no migrants abroad has the following recursive representation:

$$V(a, \Theta, Z; i) = \max_{\{c \geq 0, a' \geq \underline{a}, DR'\}} \left\{ \begin{array}{c} n\frac{c^{1-\sigma}}{1-\sigma} + \\ \beta(p_i E[Max\left\{V_k^1(a', \Theta'_{-k}, Z'_{-k}; i), V(a', \Theta', Z'; i)\right\}] \\ +(1-p_i)E[V(a', \Theta', Z'; i)]) \end{array} \right\} \quad (3)$$

[6]The remittances process is iid; however, it can be generalized to account for a realistic degree of persistence.

[7]Wages abroad are also represented in a similar way: $\overline{w_i} = \{\overline{w}_{i1}, \overline{w}_{i2}, ..., \overline{w}_{in}\}$, where $\overline{w}_{ij}$ is the wage abroad that the $j - th$ household member may receive if he migrates. due to the two skill levels assumption $\overline{w}_{in} \in \{\overline{w}_U, \overline{w}_S\}$.

Subject to

$$
\begin{aligned}
nc + a' &\leq (1-\tau)\sum_{j=1}^{n} w_{ij}h_{ij}z_{ij} + \Lambda_1 + (1+(1-\tau)r)a \\
Z' &= \varrho Z + \nu; \quad \nu \sim N(0,\Sigma) \\
\Theta' &= \Theta \\
V_k^1(a', \Theta'_{-k}, Z'_{-k}; i) &= Max\{V_j^1(a', \Theta'_{-j}, Z'_{-j}; i)\}_{j=1}^{n}
\end{aligned}
$$

$V_k^1(a, \Theta_{-k}, Z_{-k}; i)$ denotes the lifetime value of a type i household in which its $k-th$ family member migrated at the beginning of the current period. As we mentioned before, the migration decision implies a two-step procedure. In the fist step, the family chooses its potential migrant by a comparative advantage mechanism; formally, the $k-th$ family member is the potential migrant if $V_k^1(a, \Theta_{-k}, Z_{-k}; i) = Max\{V_j^1(a, \Theta_{-j}, Z_{-j}; i)\}_{j=1}^{n}$. In the second step, the household faces the migration decision, which is made by comparing the household's lifetime value of staying in the source country with the household's lifetime value when the potential migrant migrates. $DR(.)$ represents the household's migration decision rule at the beginning of the current period: $DR(.) = 1$ if migration is the best option, $V_k^1(a, \Theta_{-k}, Z_{-k}; i) > V(a, \Theta, Z; i)$, and $DR(.) = 0$ otherwise.

First-period migration problem. The problem of a type i household in which its $k-th$ member migrated at the beginning of the period has the following recursive representation:

$$
V_k^1(a, \Theta_{-k}, Z_{-k}; i) = \max_{\{c, \widetilde{c}, a' \geq \underline{a}\}} \left\{ \begin{array}{c} (n-1)\frac{c^{1-\sigma}}{1-\sigma} + \frac{\widetilde{c}^{1-\sigma}}{1-\sigma} \\ +\beta E[V_k^m(a', \Theta'_{-k}, Z'_{-k}, R; i)] \end{array} \right\} \tag{4}
$$

Subject to

$$
\begin{aligned}
(n-1)c + a' + \Delta &\leq (1-\tau)\sum_{j\neq k}^{n} w_{ij}h_{ij}s_{ij} + \Lambda_1 + (1+(1-\tau)r)a \\
Z'_{-k} &= \varrho Z_{-k} + \nu_{-k}; \quad \nu_{-k} \sim N(0, \Sigma_{-k}) \\
\Theta'_{-k} &= \Theta_{-k} \\
\widetilde{c} &= \overline{w}_{ik}
\end{aligned}
$$

$V_k^m(a', \Theta'_{-k}, Z'_{-k}, R; i)$ denotes the lifetime value of a type i household in which its $k-th$ member had migrated sometime before the current period. We include R as a state variable in this case, since the optimal monetary value of remittances is chosen conditional on the realization of the opportunity to send remittances.

Migration problem. The problem of a type i household in which its $k-th$ member lives abroad has the following recursive representation:

$$V_k^m(a, \Theta_{-k}, Z_{-k}, R; i) = \max_{\{c,\widetilde{c},a',\mathrm{Re}\}} \left\{ \begin{array}{c} (n-1)\frac{c^{1-\sigma}}{1-\sigma} + \frac{\widetilde{c}^{1-\sigma}}{1-\sigma} \\ +\beta E[V_k^m(a', \Theta'_{-k}, Z'_{-k}, R'; i)] \end{array} \right\} \tag{5}$$

Subject to

$$\begin{aligned} (n-1)c + a' &\leq (1-\tau)\sum_{j\neq k}^{n} w_{ij}h_{ij}s_{ij} + \Lambda_1 + (1+(1-\tau)r)a + R * \mathrm{Re} \\ Z'_{-k} &= \varrho Z_{-k} + \nu_{-k}; \quad \nu_{-k} \sim N(0, \Sigma_{-k}) \\ \widetilde{c} + R * \mathrm{Re} &\leq \overline{w}_{ik} \\ \Theta'_{-k} &= \Theta_{-k} \\ R &\sim iid \end{aligned}$$

The problem of a migrant household includes a decision on remittances (Re). This is conditional on the realization of the opportunity to send remittances. Once the migrant is allowed to send remittances ($R = 1$), then the household will decide on the optimal monetary value of the transfer; otherwise, remittances are zero and the migrant abroad consumes his income.

For easy notation and without loss of generality, the state of the economy is denoted by Ω. It includes all possible values of the state variables: wealth, human capital, productivity shock, migration status and remittances. We also include the index variable M, $M \in \{0, 1\}$, to keep track of the current migration status of each household: households without migrants are denoted by $M = 0$, and those with a migrant abroad are denoted by $M = 1$. Then, the policy rules that solve the household problem can be represented in the following manner: $a'(\Omega; i)$; $c(\Omega; i)$; $\widetilde{c}(\Omega; i)$; $DR(\Omega; i)$; and $\mathrm{Re}(\Omega; i)$.

2.2.2 Production

Production takes place in a competitive environment. There is a continuum of firms that have access to a nested CES production function as used in Krusell et al.(2000).

$$Y = F(K, H_U, H_S) = \left[\chi\left\{\eta K^\rho + (1-\eta)H_S^\rho +\right\}^{\frac{\delta}{\rho}} + (1-\chi)H_U^\delta\right]^{\frac{1}{\delta}} \tag{6}$$

where χ and η are the share parameters. δ governs the elasticity of substitution between skilled labor input and physical capital, ρ governs the elasticity of substitution between skilled labor input and physical capital. K is the aggregate capital stock that depreciates at a constant rate δ_k, H_U is the aggregated efficiency units of unskilled labor and H_S is the aggregated efficiency units of skilled labor. In this type of production function capital and skilled labor complementarity may be higher than the capital and unskilled labor complementarity. This feature of the production function allows us to capture one of the most widely documented features of the brain-drain literature: the departure of skilled workers is bad for the source country, since it may adversely affect the return to capital due to the scarcity of a skilled labor force. Aggregate variables are computed by adding up the corresponding variables at the individual level.[8]

3 The Stationary Competitive Equilibrium

Definition 1 *A recursive competitive equilibrium consists of a set of policy rules for the household regarding consumption, savings, migration and remittances:* $c\{\Omega;i\}$*;* $\widetilde{c}\{\Omega;i\}$*;* $a'\{\Omega;i\}$*;* $DR\{\Omega;i\}$*;* $\mathrm{Re}\{\Omega;i\}$*; a stationary probability measure of households* $[\mu_i]$*; aggregate factors, output and prices:* $K, H, H_U, H_S, Y, r, w_{U,}; w_S$*; total tax revenues* TAX *and total transfers* TRA*;*[9] *and household value functions,* $V(.)$*;* $V^1(.)$*;* $V^m(.)$*, such that the following conditions hold:*

i) Given r, w_U and w_S, agents' decision rules $\{c(.); \widetilde{c}(.); a'(.); DR(.); \mathrm{Re}(.)\}$ solve the household problem (from 3) to (5).

ii) The goods market clears.

$$F(K,H_U,H_S) - (1-\delta_k)K = \sum_{i=1}^{n+1} \alpha_i \left\{ \begin{array}{c} \int_{\Omega} [\mathbf{1}_{[M=0]} nc(.) + \mathbf{1}_{[M=1]}(n-1)c(.) + a'(.) + \\ \mathbf{1}_{[DR=1]} * \Delta - \mathbf{1}_{[R=1]} * \mathrm{Re}(.)] d\mu_i \end{array} \right\} \qquad (7)$$

iii) The factors market clears. Aggregate capital and aggregate labor are computed from individual decisions.

iv) Firms maximize profits in a competitive market. Prices are defined by the following conditions.

[8] The measure of households of type i is denoted by α_i It is computed from the stationary distribution $\mu_i(\Omega)$, $\int_{\Omega} d\mu_i(\Omega) = \alpha_i$. The total measure of households is normalized to one: $\sum_{i=1}^{n+1} \alpha_i = 1$. Furthermore, given that the economy is inhabited by households of different sizes, the number of persons is represented by $N = \sum_{i=1}^{n+1} \alpha_i N_i$, where N_i represents the number of persons of type i. The latter is computed by adding up the persons of both the stayers' and the migrants' households: $N_\tau = \int_{\Omega, M=0} n d\mu_i(.) + \int_{\Omega, M=1} (n-1) d\mu_i(.)$. The aggregate stock of physical capital is estimated from $K = \sum_i \alpha_i \left\{ \int a'(\Omega;i) d\mu_i \right\}$. Similarly, aggregate labor in efficiency units of each skill type (H_U, H_S) is computed by aggregating the efficiency units of labor provided by each type of worker. This aggregation considers both the idiosyncratic productivity shock and the human capital stock of each worker.

[9] TAX denotes the aggregate tax revennues. It is computed by adding up each worker's tax payments. Likewise, TRA denotes aggregate transfers; it is equal to Λ_1 since government transfers are lump sum and the measure of housheold is one.

$$r + \delta_k = \frac{\partial}{\partial K} F(K, H_U, H_S) \quad (8)$$

$$w_U = \frac{\partial}{\partial H_U} F(K, H_U, H_S) \quad (9)$$

$$w_S = \frac{\partial}{\partial H_S} F(K, H_U, H_S) \quad (10)$$

v) Government balances its budget: aggregate tax revenues are equal to total lump sump transfers

$$TAX = TRA$$

vi) Aggregate and individual years of education are consistent.[10]

$$\overline{S} = \frac{s_U N_U + s_S N_S}{N}$$

vii) The law of motion of distribution is stationary.

$$\mu_i' = \mu_i$$

We now turn to describing the calibration procedure.

4 Calibration

In this section we calibrate the parameters of the model so that the stationary equilibrium closely replicates some important economic features of a representative small economy in which migration, remittances and a brain drain play an important role. Guatemala is economy that fulfills those requirements: First, the migration rate[11] in Guatemala is high, since around 11% of the adult population lives abroad. Second, brain drain is important, since the skilled migration rate is around three times the unskilled migration rate. Finally, the yearly remittances flow in Guatemala represents around 10% of GDP during the period 2004-2009.

We calibrate the parameters of the model following a two-step strategy. In the first step, the value of a group of parameters is chosen based on the fact that each of them is closely related to the value of a specific moment or target. In the second step, the remaining parameters are estimated following the simulated method of moments. We briefly explain our calibration strategy.

[10] N_S (N_U) is the number of skilled (unskilled) workers.

[11] In this paper, the migration rate is defined as the number of adults born in the source country who live abroad (those who had migrated in the past) divided by the total number of adults born in the source country.

The length of time is one year. The probability of dying is chosen so that a worker spends on average 45 years working ($\phi = 0.02$). The risk-aversion parameter is fixed at $\sigma = 2.5$, which is consistent with the common use in the neoclassical literature.

Skills are not observable. We follow a common procedure from the labor economics and migration literature and we relate skills with school attainment (Heckman et al., 1998; Docquier and Marfouk, 2005). Workers in our model are 25 years or older and the number of skilled agents is approximated by the number of persons who finished secondary or high school education. Similarly, unskilled workers are those with, at most, a primary education. The number of workers per household is set at $n = 3$, which is consistent with the average number of persons per household of working age in Guatemala.

The measure of households of each type (α_i) is estimated from ENCOVI-2006[12]. Skilled workers are identified by their education level and the following rule is used to compute α_τ. Type 1 is represented by those households in which the proportion of skilled workers is less than or equal to 25% ($\alpha_1 = 0.51$); type 2 is represented by those households in which the proportion of skilled workers is more than 25% but less than or equal to 50% ($\alpha_2 = 0.04$); in type 3 the proportion of skilled workers is more than 50% but less than or equal to 75% ($\alpha_3 = 0.16$); and in type 4, the proportion of skilled workers is more than 75% ($\alpha_4 = 0.29$).

Remittances arrive with probability $\pi_{re} = 0.30$. This choice is consistent with the fact that around 30% of households with migrants abroad receive remittances (ENCOVI-2006).

Three parameters characterize the $VAR(1)$ productivity process. Both the autoregressive coefficient (ϱ) as well as the standard deviation (σ_v) of the idiosyncratic productivity shock are similar for each family member. Additionally, we consider that the correlation coefficient of the productivity shock between two family members (ρ_v) is similar for each pair of workers. We set $\varrho = 0.70$ and $\rho_v = 0.5$. σ_v will be estimated by the simulated method of moments. Due to limitations of household-level data in Guatemala we cannot relate these values to an empirical counterpart; however, these values are similar to the corresponding estimated values for Mexico (Cespedes (2010)). Each of the idiosyncratic productivity processes is discretized to a 5-state discrete shock using an extension of the Tauchen (1986) procedure for multivariate processes.

We borrow some parameters of the production function from the corresponding literature. The elasticity of substitution between skilled labor and capital ($\frac{1}{1-\rho} = 0.6$) is consistent with the values reported by Krusell, et al. (2000). We consider that capital is relatively more complementary to skilled labor than it is to unskilled labor ($\frac{1}{1-\delta} = 2$). Given that our model is being applied to a representative developing economy in which skilled labor is scarce, our assumption may be realistic enough. This assumption, however, needs to be tested by using specialized household surveys that are scarce in developing economies like Guatemala. The share parameters, χ and η,

[12] ENCOVI 2000 (*Encuesta Nacional sobre Condiciones de Vida 2000*)

are closely related to the wage premium and the capital income share. They are estimated by the simulated method of moments as we will explain later. The physical capital depreciation rate is set at $\delta_k = 9\%$.

Two moments are used to identify the labor income abroad ($\overline{w}_S$ and $\overline{w}_U$): the skill gap abroad ($\frac{\overline{w}_S}{\overline{w}_U}$) and the relative earnings between the host and the source country ($\frac{W^{Host}}{W^{Source}}$). We set the skill gap abroad equal to 2.8 consistent with the values reported from the CPS (2000); furthermore, we use the ratio $\frac{GDP^{USA}}{GDP^{Guatemala}} = 8.0$ in per capita terms as a proxy for the relative labor earnings between these two countries. $\overline{w}_U$ is set based on the value of the skill gap ($\overline{w}_U = 2.8\overline{w}_S$) abroad and $\overline{w}_S$ is estimated together with the remaining parameters.

The tax rate, τ, is set at 0.1 so that the tax revenue is around 10% of GDP. The lump-sum transfer $tr1$ is set in equilibrium and it balances the government budget. We target an equilibrium in which the average years of education is around 8.5, which is close to the average years of education of the adult population who finished at least a primary education (ENCOVI-2006).

The parameters of the human capital production function are chosen so that the private return to education as well as the externality of education is supported by the empirical evidence. The private return of one additional year of education is similar to the values estimated from the Mincer-Equation literature, $\phi_0 = 0.1$. Furthermore, the externality of having one additional year of education, in aggregate terms, is similar to Cespedes (2010), $\phi_1 = 0.01$, who uses a similar parameter for Mexico. The scale parameter φ is set at $\frac{1.0}{7.5}$. This value is chosen so that the saving policies belong to a computationally feasible space.

The remaining eight parameters $(\beta, p_i, \Delta, \chi, \eta, \sigma_v, \overline{w}_S)$ are jointly estimated by using the Nelder–Mead (1965) algorithm. Briefly, the method consists of choosing iteratively these parameters such that the moments delivered by the model are close enough to the empirical moments.[13,14]

We compute the stationary equilibrium for each set of parameters, or during each iteration of the Nelder-Mead algorithm. This is done by iterating over prices, lump sum transfer, and

[13] The parameters considered are exactly identified by the eight moments. Briefly, the discount factor identifies the capital output ratio. The type-specific migration probabilities identify the type-specific migration rates. The migration cost identifies the migration cost - labor income ratio. The skill premium is closely related to η and the capital income share is identified by χ. The skilled labor income abroad is related to the host country - source country labor income gap. Finally, the standard error of the productivity sock identifies the labor income standard error.

[14] This algorithm allows us to estimate a set of parameters such that the distance between the empirical moments and the simulated moments by the model is small enough. If we denote by M the row-vector of the difference of the moments between the observed and estimated moments, then a set of parameters is chosen such that $M \times W \times M'$is minimized. W denotes the weighting matrix. We consider an equal weight for every moment (W is the identity matrix).

average years of education so that the competitive equilibrium conditions are fulfilled; that is, until prices equal factor marginal productivities, average years of education are consistent with individual schooling status, and aggregate transfers and aggregate tax revenues are consistent.[15] The calibrated parameters of the model are summarized in Table 3. In Appendix A.2 we explain our computational procedure.

We compare the moments delivered by the model with the corresponding targets in Table 1. Our model closely replicates the capital-output ratio: the model predicts a value of 2.09, which is close to the observed value of 2.2. The migration rate for each ability type is also similar to the corresponding observed values; the skilled migration rate in the model is 19.8% and the targeted value is 17%. Similarly, the unskilled migration rate is 5.5% in the model and 6.0% in the data. In terms of inequality, the model generates a skill gap of 4.7, close to the empirically observed value.

One interesting feature of our model is that it generates an endogenous brain drain. The skilled migration rate delivered by the model is almost three times as large as the unskilled migration rate. The model also predicts that remittances represent around 10% of GDP, close to the corresponding 2008 empirical value. These are indicators of the models' performance, since they were not targeted by the calibration procedure and they were endogenously delivered by the model.

Finally, after comparing the empirical moments and the moments generated by the model, we conclude that our model is a good approximation of the economy under consideration. We now attempt to use the model to perform a set of experiments in order to answer some of the questions posed.

Table 1: Moments

	Moments	Data	Model
1	Capital/Output	2.2	2.09
2	Skilled Migration Rate	17.0%	19.8%
3	Unskilled Migration Rate	6.0%	5.5%
4	Migration Cost/Labor Income	0.5	0.50
5	Skill Premium	5.5	4.71
6	Aggregate Labor Income Share	0.7	0.72
7	Income Standard Deviation (log)	1.1	0.97
8	$Income^{USA}/Income^{Source}$	~8.0	7.30

[15] The following prices, lump-sum transfer and average years of education support the competitive equilibrium of the model with migration: $r = 0.0414972$, $w_S = 0.755519$, $w_U = 0.285484$, $\overline{S} = 8.41279$, $\Lambda_1 = 0.0699406$.

5 Results

5.1 Accounting for the quantitative effects of migration

In this section we perform a counterfactual experiment in order to uncover the general equilibrium as well as the welfare effects of migration. The experiment consists of comparing the outcomes of the previously solved model with the outcomes of a counterfactual economy in which migration is not allowed. The latter is called the non-migration model and the former is called the migration model.

The non-migration model is a particular case of the migration model in which we set the migration probability equal to zero for each household type ($p_i = 0$ for $i = 1, ..., n$). The competitive equilibrium of the no-migration model is computed by using the same parameters of the migration model so that the differences in the outcomes between the two models are due to the effects of migration and remittances only. We also compute the competitive transition path along the two steady-state solutions.

Table 4 resumes the quantitative long-run effects of migration. Migration affects the source country's economy in three aspects: it decreases output, it reduces income inequality and it induces welfare improvement of the population. We briefly discuss the driving forces behind these results.

Output: Output decreases 14.4% due to migration. This theoretical prediction is driven by the reduction of physical capital as well as the reduction of the aggregate efficiency units of labor. The reduction in the skilled labor force is stronger than the reduction in both the unskilled labor force and capital, which drives the interest rate reduction. Notice that the scarcity of skilled workers in relative terms, due to brain drain, is the driving force behind the skilled wage increase and the unskilled wage decrease.

Inequality: Migration contributes to increasing income inequality. There are several competing forces behind the change in income inequality. First, migration and brain drain by themselves may generate a reduction in income inequality; this is due to the demographic effect of the departure of skilled workers. In other terms, the number of workers in the upper tail of the income distribution decreases due to skilled migration. Among the forces that increase income inequality we have the effect of wages and remittances. The unskilled workers' wage decrease as well as the increase of the skilled workers' wage promotes higher income inequality. Similarly, remittances may promote income inequality, since migration is biased toward skilled workers.

Brain drain: Our model generates an endogenous brain drain. The average human capital per worker decreases 3% due to migration. The result is driven by two features of the model: first, the migration cost is paid from the household's total income, and second, the migration probability differs according to household type. The fact that the migration cost is paid from the family income restricts migration to those wealthy families that can support the migration cost; poor households, which are also borrowing constrained, may not be able to migrate. Similarly, since skilled agents are wealthier and migration offers arrive more frequently for them, they migrate at a higher rate than unskilled agents.

The insurance component of migration. We provide evidence that supports the view that migration is used as a household insurance strategy to cope against the effects of labor market risks. The consumption standard error decreases 0.8% due to migration, which is consistent with the idea that households use migration in order to smooth consumption.

The model also predicts that the transition from the closed economy without migration to the economy in which migration is allowed to occurs mainly during the 30 years after the economy is open to migration. This can be related to the observed evolution of the migration rate in Guatemala since 1960. In 1960 Guatemala can be characterized as a closed economy from a migration point of view, since the migration rate was very close to zero. Similarly, we relate the migration model to Guatemala in 2000-2010. Figure 5 shows the transition path of the migration rate generated by the model and Figure 6 the observed migration rate of Guatemala. See that our model delivers a slow transition of the migration rate compared with the path observed in the data.

5.1.1 Welfare analysis

We compute the welfare effects of migration decisions by using the consumption equivalence variation approach (CEV). Our approach follows the procedure for welfare analysis in models with heterogeneous agents implemented by Floden (2001) and Heathcote (2004). The CEV is defined as the proportional change in consumption at each date and in each event needed to make a household indifferent between two stationary equilibria: the baseline stationary equilibrium and the stationary equilibrium after the introduction of the policy under consideration. $\{c_t(.)\}_{t=0}^{\infty}$ denote the equilibrium choices in the baseline equilibrium and $\{\hat{c}_t(.)\}_{t=0}^{\infty}$ the corresponding equilibrium choices along the transition path after the introduction of the policy under consideration; then the CEV for each state is denoted by $\psi(.)$ and it solves the following expression.

$$E_0 \sum_{t=0}^{\infty} \beta^t u \left\{[1+\psi(.)]c_t(.)\right\} = E_0 \sum_{t=0}^{\infty} \beta^t u \left\{\hat{c}_t(.)\right\}$$

The average CEV is computed integrating the individual consumption equivalent variation across the stationary distribution of the baseline equilibrium.

$$CEV = \sum_{i=1}^{n+1} \alpha_i \int \psi(.) d\mu_i(.)$$

In our particular case, to evaluate the welfare effects of migration we consider as a baseline equilibrium the model without migration; meanwhile, the equilibrium of the model after allowing for migration stands for the second economy. Figure 5 shows the model-predicted transition path of the migration rate by skill type (the transition path's of the other variables are presented in Figure 4).

After computing the transition path between these two solutions, we found that on average migration improves the welfare of the population. A household on average gains 1.4% of its lifetime consumption if it goes through the transition path compared with the scenario in which it stays in the source economy forever.

Even though migration seems to be a good policy in general, the welfare effects of migration seem to be heterogeneous. Figure 7 presents the CEV by household wealth for each type of household. Two interesting features arise from this figure: First, since the CEV is increasing in wealth, rich households may benefit more from migration compared to poor households. Two effects drive this result; first, poor households will be adversely affected due to the indirect effects of migration; most of these agents are borrowing constrained and they cannot support the migration cost. Second, wealthy families can support the migration cost and they may receive most of the direct and indirect benefits of migration.

There is significant heterogeneity of the welfare effects of migration. Unskilled households (Type 1) may report negative CEV (-3.38%); this type of household may be adversely affected mainly by the indirect effects of migration (unskilled wage decrease and interest rate decrease). Skilled households (Type 4) may gain more in CEV terms due to migration; this type of household may benefit directly from migration (remittances) and indirectly due to an increase in wages. Type 2 and Type 3 households report a positive CEV.

Summing up, there are winners and losers due to migration. The winners are mainly the skilled workers and the losers are the unskilled ones. In net terms migration may produce positive welfare effects This implies that a policy that allows migration will be supported by a majority rule election by more than 50% of the population.

Table 2: CEV by Household Type (% Change)

	Type 1 (UUU)	Type 2 (UUS)	Type 3 (USS)	Type 4 (SSS)	All
CEV	-3.38	0.93	5.90	7.38	1.40

5.1.2 General equilibrium effects of migration

We have shown that migration has significant long-run effects. In this section we decompose the previously stated effects of migration into two components. The first component is the general equilibrium effect of migration, which are related to the indirect effects of migration that acts through price changes. The second component is the direct effects of migration. This element does not consider the effect of price changes. In this section we perform two experiments in order to uncover the general equilibrium effects of migration.

The first experiment consists of solving the migration model by using the prices of the no-migration model; we call this the constant-price model. A direct comparison between the outcomes of the constant-price model and the no-migration model identifies the direct effects of migration; meanwhile, the indirect effects can be identified as the residual between the total effects and the previously computed direct effects. [16]

We find that around 10% of the output change is related to changes in price. We find this amount big enough to support our claim that the general equilibrium effects of migration are quantitatively important. Table 5 shows the results of this experiment with more detail.

The second d experiment consists of the following simulation. We pick two identical stayer households in period 0; after this period, one household sends a migrant abroad. We follow the evolution of the utility of these two households along the estimated competitive transition path. Notice that in our simulation the migrant household receives endogenous remittances; however, in order to aisle the effects of remittances, we consider an additional household: a migrant household without remittances. The three households are exposed to the same history of productivity shocks so that we can relate the welfare change of the stayer household along the transition path to the general equilibrium effects of migration. Summing up, our simulation generates 3 types of households: i) a stayer household, ii) a household with a migrant without remittances, and iii) a household with a migrant with remittances.

The following results arises from the simulation: First, migration without remittances does not have significant general equilibrium effects; the utility path of the stayer household (i) and the utility path of the household with a migrant without remittances (ii) are similar. Second, remittances are the main driving force of the general equilibrium effects of migration; the utility path of the household that receives remittances is higher than the utility path of the stayer household.

[16] Notice that the constant-price model is not a competitive solution, since prices differ from marginal productivities. This is basically a partial equilibrium experiment and it may give us some clues to the magnitude of the general equilibrium effects of migration.

5.2 Policy Intervention

5.2.1 Migration cost

In this section we measure the potential economic effects of a policy intervention based on the migration cost. We assume that the government is able to affect the migration cost directly, it may be through the increase in transaction costs, for example. Notice that this policy affects mainly the new migrants since now they have to spend more resources in order to support the new cost.

We consider that the migration cost increases from 0.1 to 0.2 (100% increase); the latter is equivalent to aroun $2000 in monetary terms. The main result of this exercise is that the policy under consideration has small economic effects, as is shown in column B of Table 6. Output decreases marginally and the main effect is on the unskilled migration rate (35% reduction). The reason behind this result is that this policy affects mainly middle-income households which may find that migration is not optimal anymore after the increase of the migration cost.

This policy, or the size of it, is reasonable enough to be implemented by a government that attempts to prevent a brain drain; however, it has small aggregate effects and it does not prevent brain drain at all. Given that the most affected are poor agents, this policy is better suited to preventing migration in general. When the migration cost increases to 1.0, for example, there are few migrants, most of them are skilled and the aggregate outcomes are similar to those in the model without migration.

5.2.2 Remittances

We use the model to evaluate the quantitative effects of a shock on remittances. Recall that our model delivers endogenously the monetary value of remittances; however, we assume that the opportunity to send remittances is driven by the economic conditions of the host economy and, from our small economy perspective, this variable cannot be affected directly by the source country's police maker. We can rationalize our experiment by assuming that the reduction in the probability of remittances is driven by a deep recession in the host economy that forces a reduction in the number of migrants that used to send remittances. Column C of Table 6 shows the competitive solution delivered by the model when the migration probability π_{re} decreases from 0.30 to 0.15, a 50% reduction.

In general terms, a reduction in the probability of remittances has negative welfare effects; however, output increases due to aggregate capital gain and the increase in the labor force in efficiency units. In terms of welfare, a reduction in the probability of remittances affects mainly the skilled worker; which is related to the fact that migration is biased toward skilled agents and they are more sensitive to a reduction in the opportunities for remittances.

5.2.3 Migration probability

We compute the quantitative effects of a shock on offers to migrate. The underlying assumption is that the government can influence the migration offer in order to prevent a brain drain. We can also justify the change in migration probability as a policy implemented in the host economy in order to prevent migration; it may be due to a change in migration quotas, for example.

A 50% reduction in offers to migrate generates significant aggregate effects in terms of output, capital and labor, as we show in the last column of Table 6. However, our model predicts that this kind of intervention may not be a good anti-brain drain policy since the migration rate decreases more for unskilled workers than for skilled workers.

This policy has strong aggregate effects; however, a caveat of this policy is that it would not be easily implemented: the source country government may not be able to directly affect the migration offers, since they are driven by events in the host economy.

5.2.4 Return migration

In this section we use the model to measure the economic effects of return migration. The basic model is briefly modified in order to capture the most important features of return migration.

The extended model endogenously generates return migration driven by a policy based on monetary transfers; specifically, the government wants to promote skilled return migration by providing a monetary transfer (Λ_2), which is conditional on the returning migrant's skill level. These transfers are supported by distortionary income tax revenues so that we keep the competitive general equilibrium feature of our model. Notice also that in the extended model the government has incentives to promote skilled return migration, since the increase in the average human capital of the economy may promote a welfare increase through the externality channel.

The following recursive representation captures the return migration decision of a household with a migrant abroad; we can see that it is an extension of the previously described stayer household problem.

$$V_k^m(a, \Theta_{-k}, Z_{-k}, R; i) = \max_{\{c,\widetilde{c},a',\mathrm{Re},DR2\}} \left\{ \begin{array}{c} (n-1)\frac{c^{1-\sigma}}{1-\sigma} + \frac{\widetilde{c}^{1-\sigma}}{1-\sigma} \\ +\beta E[\max\{V_k^m(a', \Theta'_{-k}, Z'_{-k}, R'; i); V_k^{re}(a', \overline{\Theta}'_k, Z'; i)\}] \end{array} \right\} \tag{11}$$

Subject to

$$\begin{aligned}
(n-1)c + a' &\leq (1-\tau)\sum_{j\neq k}^{n} w_{ij}h_{ij}z_{ij} + \Lambda_1 + (1+(1-\tau)r)a + R * \text{Re} \\
Z'_{-k} &= \varrho Z_{-k} + \nu_{-k}; \quad \nu_{-k} \sim N(0, \Sigma_{-k}) \\
\widetilde{c} + R * \text{Re} &\leq \overline{w}_k \\
\Theta'_{-k} &= \Theta_{-k} \\
R &\sim iid
\end{aligned}$$

where $DR2(.)$ is the return migration policy rule; it takes two values, $DR2(.) = 0$ if return migration is an optimal choice and $DR2(.) = 1$ otherwise. $\overline{\Theta}_k = \{h_{i1,}...h_{ik-1,}\overline{h}_{ik,}h_{ik+1,}...h_{in,}\}$ represents the human capital stock of a family when its $k-th$ member returns from the host country. We consider that the migrant may gain in terms of human capital during his migration spell. The human capital of the returning migrant is denoted by $\overline{h}_k$ and it is proportional to the before-migration stock of human capital ($\overline{h}_k = \zeta h_k$). The term $\zeta > 1$ represents the human capital gain during the migration spell. Finally, we assume that the returning migrant worker will stay in the source country; in terms of the model it means that return migration is an absorbing state.

The problem of a return migrant household, whose $k-th$ member has returned, has the following recursive representation.

$$V_k^{re}(a, \overline{\Theta}_k, Z; i) = \max_{\{c,a'\}} \left\{ n\frac{c^{1-\sigma}}{1-\sigma} + \beta E[V_k^{re}(a', \overline{\Theta}'_k, Z'; i)] \right\} \tag{12}$$

Subject to

$$\begin{aligned}
nc + a' &\leq (1-\tau)(\sum_{j\neq k}^{n} w_{ij}h_{ij}z_{ij} + w_k\overline{h}_k z_k) + (1+(1-\tau)r)a + \Lambda_1 + 1_{[\Xi_{ik}=S]}\Lambda_2 \\
Z' &= \varrho Z + \nu; \quad \nu \sim N(0, \Sigma) \\
\overline{\Theta}'_k &= \overline{\Theta}_k
\end{aligned}$$

where $V_k^{re}(a, \overline{\Theta}_k, Z; i)$ denotes the value of a household with a return migrant. The two terms Λ_2 and $1_{[\Xi_{ik}=S]}$ capture the government's return migration policy: Λ_2 is the monetary transfer for return migrants and $1_{[\Xi_{ik}=S]}$[17] is an indicator function that is equal to one only when the returning migrant is skilled ($\Xi_{ik} = S$).

Return migration brings into the model two additional parameters: the return migration transfer Λ_2 and the brain-gain parameter ζ. We calibrate these parameters by considering two

[17] The skill level of $i-th$ household type is represented by the array $\Xi_i = [\Xi_{i1}, \Xi_{i2}...., \Xi_{in}]$, where $\Xi_{ij} \in \{S, U\}$ for $j = 1, ..., n$.

empirical moments that identify them: the percentage of migrants who return and the average human capital increase of returning migrants. The return migration literature has documented the values of these moments; on average, 20% of migrants return to their birth country after a migration spell. Meanwhile, a returning migrant may experience a 20% increase in his human capital in respect to his before-migration level. With $\zeta = 1.2$[18] and $\Lambda_2 = 0.2$ the model generates moments that are close to the corresponding empirical ones.

The results show that return migration and remittances are not strong enough to compensate for the negative effects of skilled migration. The return migration solution delivers an output that is 3.0% higher compared with the result of the migration model; however, output is still below the value delivered by the non-migration model. The remaining effects of return migration seem to be in the expected direction; the return migration policy decreases the wage of skilled workers and it increases the wage of unskilled workers.

We stress the fact that the model delivers modest effects of return migration for reasonable values of the parameters, which is the case in an average developing economy. However, the effects of this policy may be significant in some economies. This may be the case in an economy in which the initial stock of human capital is small (so that returning migrants may have significant gains in human capital) and the incentives provided by the return migration policy is good enough. In the latter case, the model predicts that remittances and return migration may offset the effects of skilled migration.

6 Final Remarks

We develop a macro-quantitative model that closely reproduces the main economic features of a representative developing economy in which skilled migration, remittances, and return migration are quantitatively important. The model is able to generate endogenous migration, remittances and return migration. We find that migration has significant economic and welfare implications when it is modeled in a general equilibrium framework. Our results suggest that migration is one important driving force behind the economic growth of developing economies in which skilled migration and remittances are quantitatively important. Additionally, we find that migration improves the welfare of the source country population; however, there are some population groups, mainly poor households, that may not report a welfare gain after the economy is open to migration.

The theoretical model also suggests that households use migration as an optimal strategy in order to smooth consumption and cope with the effects of idiosyncratic risks. In other terms,

[18] According to Mayr and Peri, 2008 ζ may be as large as 2.8. This means that a migrant may gain up to 280% of his initial human capital due to his migration spell.

migration has an insurance component.

Regarding return migration policy, we find that the incentives provided by a reasonable skill-biased transfer policy do not generate strong aggregate effects; in other terms, the joint effects of return migration and remittances are not strong enough to compensate for the negative effects of skilled migration.

Finally, we consider a group of policies that attempt to reduce the effects of skilled migration. In general terms, the policies under consideration have limited aggregate effects, at least for a reasonable size of these policies. A migration-cost-based policy, for example, affects mainly poor households and it mainly prevents migration of unskilled workers. A return migration policy based on skill-biased transfers has small aggregate effects in terms of output and prices. Finally, a shock that reduces the number of migrants who send remittances may also have small aggregate effects.

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A Appendix

A.1 Migration and Remittances facts

Figure 1

Figure 2

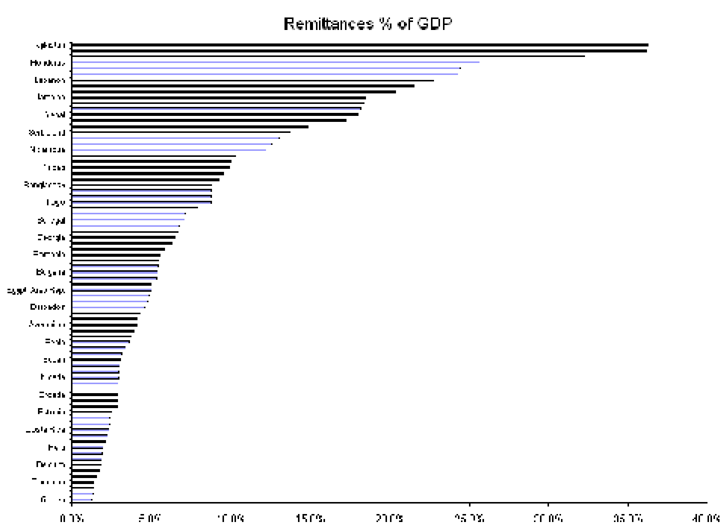
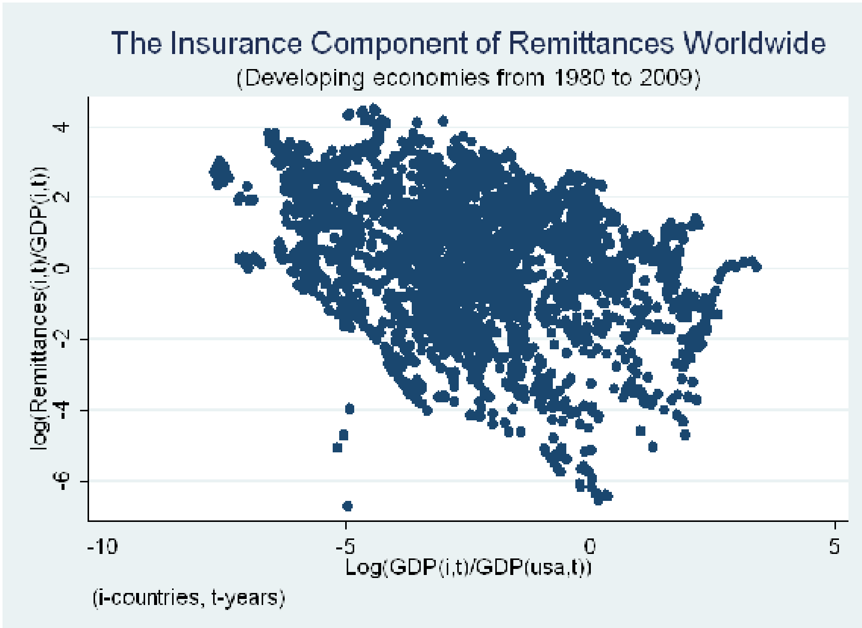


Figure 3



A.2 Computing the Optimal Solution

We describe our procedure to compute the optimal solution of the problem of a household with a migrant abroad who sends remittances to illustrate our procedure. The problem of a stayer household, or the first-period migrant, can be characterized following a similar procedure.

Denote by λ the Lagrange multiplier of the budget constraint, then the Lagrangian can be expressed by the following expression,

$$L = \left\{ \begin{array}{c} (n-1)\frac{c^{1-\sigma}}{1-\sigma} + \frac{\widetilde{c}^{1-\sigma}}{1-\sigma} + \beta E[V^m(a', \Theta'_{-k}, Z'_{-k}, R'; i)] + \\ \lambda[(1-\tau)\sum_{j\neq k}^{n} w_{ij}h_{ij}z_{ij} + (1+(1-\tau)r)a + \Lambda_1 - \widetilde{c} + \overline{w}_{ik} - (n-1)c - a'] \end{array} \right\} \quad (13)$$

The first-order conditions of this problem are:

$c : (n-1)c^{-\sigma} - (n-1)\lambda = 0$

$\widetilde{c} : \widetilde{c}^{-\sigma} - \lambda = 0$

$a' : \beta E V^m_{a'}(a', \Theta'_{-k}, Z'_{-k}, R'; i) = \lambda$

Using FOC we analytically characterize $\widetilde{c}$ and Re.

$\widetilde{c} = c$

$\mathrm{Re} = \overline{w}_{ik} - c$

A.2.1 Steps to compute solution

We apply the standard value function iteration method to find the optimal household policies. The following steps describe our procedure.

- Place a grid on the asset space: a : a$\in A$
- Place an initial guess for the value functions
- Given a and for each potential value of a' in the asset space calculate consumption by using the budget constraint $\widehat{c}(a, a')$.
- Plug $\widehat{c}()$ in the Bellman equation and find optimal policies for consumption and the optimal value function too. The migration decision rule is also computed in this step for the stayer households' problem; for this case we follow the two-step comparative advantage mechanism.
- Use the calculated value functions as a new initial guess and repeat the procedure until convergence.

A.2.2 Computing the general equilibrium solution

We solve for prices (wages and interest rate), lump-sum transfer, and the average years of education that support the general equilibrium solution. The following steps allow us to find the competitive equilibrium during each iteration of the Nelder-Mead algorithm.

- Guess initial values for interest rate, wages, years of education and the lump-sum transfer.
- Solve the model for each set of parameters and the initial guesses. Compute the stationary distribution. Compute the marginal productivities delivered by the model. Compute the average years of education and the aggregate tax revenues delivered by the model.
- Compare the marginal productivities, tax revenues and years of education delivered by the model with the corresponding initial guesses. Stop if they are close enough.
- If there are differences, update the initial guess by using the average between the current guess and the values delivered by the model.
- Repeat the procedure with the new guesses until convergence.

A.2.3 Computing the stationary distribution

We compute the stationary distribution by using the transition matrix method. The following steps describe our procedure for a particular household type:

- Place a finer grid on the asset feasible set.
- Interpolate the saving policy function (a') and the value function for the new grid points.
- Compute the transition matrix. This is the matrix that defines the next period state given the current state. Denote this matrix by Q_i. Each row represents the next period state given the current state.
- Initialize the probability distribution $\mu_i^{(0)}$.
- Update the probability distribution by using the initial guess and the transition matrix. $\mu_i^{(1)} = Q_i \times {\mu_i}^{(0)}$.
- Use $\mu_i^{(1)}$ as the new initial guess ($\mu_i^{(0)} = \mu_i^{(1)}$) and continue the iteration procedure until convergence: $\left|\mu_i^{(0)} - \mu_i^{(1)}\right| < \varepsilon$.
- Repeat the procedure for each household type.

A.3 Computing the competitive transition

We use a backward induction procedure to find the transition dynamic between steady states. Our procedure is described in the following steps:

- Compute the initial steady-state equilibrium with no migration. Compute the final steady state when migration is allowed. Set the length of the transition, $T = 200$.
- Guess an initial path for the interest rate, wages, lump-sum transfer, and years of education, call them r^{old}, w_S^{old}, w_U^{old}, Λ_1^{old}, s^{old}.
- We solve for the whole sequence of value functions and policy rules along the transition path by backward induction.
- At $t = 0$ the stationary distribution corresponds to the stationary distribution of the equilibrium with no migration The period t distribution is calculated from the period $t - 1$ distribution by using the corresponding transition matrix.
- Calculate the model-delivered marginal productivities, lump-sum transfer and years of education; call them: r^{new},w_S^{new},w_U^{new}, Λ_1^{new}, s^{new}.
- Verify convergence criterion; stop if $max \left|r^{old} - r^{new}\right|, \left|w_S^{old} - w_S^{new}\right|, \left|w_U^{old} - w_U^{new}\right|, \left|s^{old} - s^{new}\right|, \left|\Lambda_1^{old} - \Lambda_1\right.$ is small enough.
- Iterate until convergence; update the initial guess by using the average between the old and new values.

A.4 Parameters of the model with migration

Table 3: Parameters of the Calibrated Model

Description	Parameter	Values
Preferences	β	0.955
	σ	2.5
Household size	n	3
Probability of dying	ϕ	0.002
Technology		
	χ	0.78
	η	0.50
	ρ	-0.67
	δ	0.50
Physical capital depreciation	δ_k	0.09
Type size	α_i	51%; 4%; 16%; 29%
Productivity process		
	ϱ	0.70
	σ_v	0.41
	ρ_v	0.50
Migration probability	p_i	0.22%; 0.22%; 1.23%; 1.23%
Remittances probability	π_{re}	0.30
Migration cost	Δ	0.11
Skilled wage abroad	$\overline{w}_S$	1.750
Unskilled wage abroad	$\overline{w}_U$	0.625
Tax rate	τ	0.10
Human capital		
Private return of education	ϕ_0	0.10
Externality of education	ϕ_1	0.01
Unskilled education	S_U	6.0
Skilled education	S_S	12.5
Scale parameter	φ	1/7.5

A.5 Results According to Models

Table 4

Summary of Quantitative Effects of Migration

	No migration (a)	Migration (b)	% Change (b)/(a)
Interest rate	4.554%	4.150%	-8.9
Unskilled wage	0.292	0.285	-2.4
Skilled wage	0.739	0.756	2.3
Years of Education	8.665	8.413	-2.9
Lump sum transfers	0.082	0.070	-15.1
Aggregate variables			
Output	1.013	0.862	-14.9
Capital	2.096	1.804	-13.9
Unskilled labor input	0.573	0.512	-10.7
Skilled labor input	0.759	0.633	-16.6
Human capital	1.082	0.931	-14.0
Percapita variables			
Output	0.338	0.324	-4.0
Capital	0.699	0.679	-2.9
Unskilled labor input	0.324	0.306	-5.5
Skilled labor input	0.617	0.642	3.9
Human capital	0.361	0.350	-3.0
Skill premiun	4.816	4.712	-2.1
Consumption	0.271	0.314	15.8
Labor income	0.243	0.221	-8.9
Migration rate	-	11.4%	
Migration rate (unskilled)	-	5.5%	
Migration rate (skilled)	-	19.8%	
Remittances/Output	-	0.104	
Consumption standard error (log)	0.565	0.561	-0.8

Table 5

Model With Constant Prices

	No Migration (I)	Migration (II)	Constant Prices (III)
Interest rate	4.554%	4.150%	4.554%
Unskilled wage	0.292	0.285	0.292
Skilled wage	0.739	0.756	0.739
Years of Education	8.665	8.413	8.665
Lump sum transfers	0.082	0.070	0.082
Aggregate variables			
Output	1.013	0.862	0.876
Capital	2.096	1.804	1.911
Unskilled labor input	0.573	0.512	0.513
Skilled labor input	0.759	0.633	0.634
Human capital	1.082	0.931	0.932
Percapita variables			
Output	0.338	0.324	0.330
Capital	0.699	0.679	0.719
Unskilled labor input	0.324	0.306	0.307
Skilled labor input	0.617	0.642	0.644
Human capital	0.361	0.350	0.351
Skill premiun	4.816	4.712	4.495
Consumption	0.271	0.314	0.321
Labor income	0.243	0.221	0.219
Migration rate	-	11.4%	11.4%
Migration rate (unskilled)	-	5.5%	5.4%
Migration rate (skilled)	-	19.8%	19.9%
Remittances/Output	-	0.104	0.102
Consumption standard error (log)	0.565	0.561	0.538

I: Model without migration.

II: Model with migration.

III: Model with migration and prices of Model I.

Table 6

Measuring the effects of policies against brain-drain

(% change respect to the model with migration)

	Source of the policy intervention			
	Return migration (a)	Migration cost (b)	Remittances probability (c)	Migration probability (d)
Interest rate	18.9	-0.2	4.2	4.6
Unskilled wage	0.2	-0.9	1.1	0.4
Skilled wage	-3.0	0.3	-1.0	-0.8
Years of Education	0.9	-0.3	2.0	0.9
Lump sum transfers	58.7	0.6	2.5	5.7
Aggregate variables				
Output	3.0	0.6	2.4	5.5
Capital	-0.5	0.4	2.0	4.7
Unskilled labor input	2.5	2.4	0.1	4.6
Skilled labor input	4.9	0.2	3.4	6.1
Human capital	3.8	1.1	2.0	5.4
Percapita variables				
Output	0.7	-0.8	2.4	0.9
Capital	-2.7	-1.0	2.0	0.2
Unskilled labor input	2.0	0.3	4.4	1.9
Skilled labor input	-0.4	-0.2	-3.4	-1.4
Human capital	1.5	-0.3	2.0	0.9
Skill premiun	-0.9	-1.0	1.1	0.2
Consumption	-4.3	-0.9	-4.4	-4.5
Labor income	1.9	-1.4	2.1	2.3
Migration rate	-17.7	-11.1	0.0	-35.1
Migration rate (unskilled)	-8.1	-34.9	70.4	-45.5
Migration rate (skilled)	-21.6	-1.5	-28.4	-30.9
Remittances/Output	-21.6	-7.3	-61.1	-36.5

a: Return migration policy.

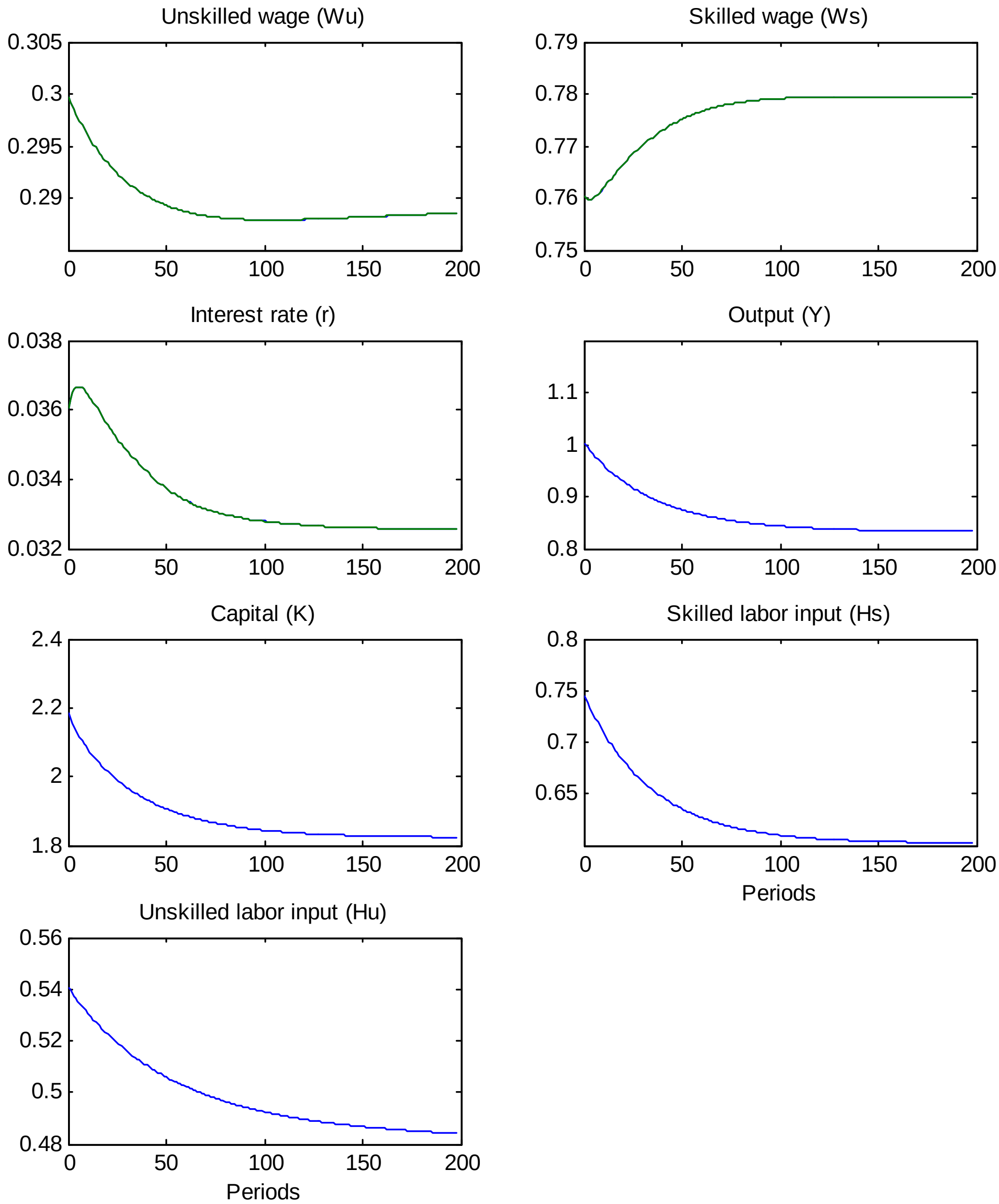
b: 50% increase of migration cost.

c: 50% reduction of migration probability.

d: 50% reduction of remittances probability.

A.6 Transition Dynamics after Migration Shock

Figure 4: Competitive Transition Dynamic



A.7 Migration Rate In Guatemala

Figure 5: Transition path of Migration Rate

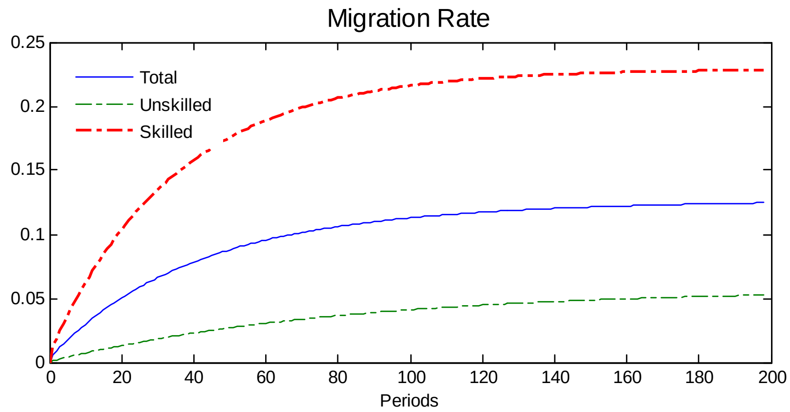
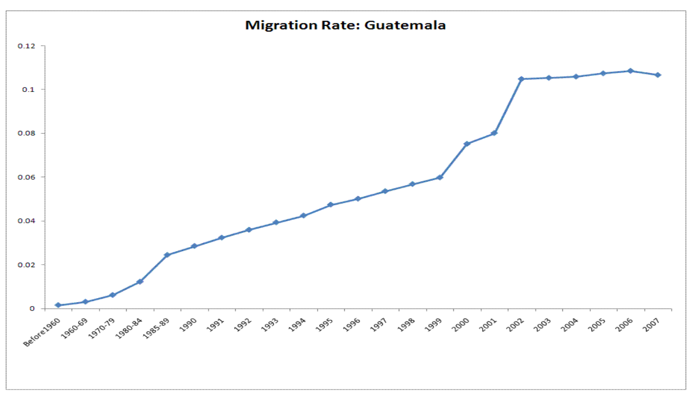


Figure 6: Migration Rate in Guatemala (%)

Source: 'Encuesta Sobre Remesas 2007'



A.8 Consumption Equivalent Variation

Figure 7: CEV by Household Wealth (% Change)