

Essays in Macroeconomics with Heterogeneous Agents

by

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To Adriana Victoria, Sebastian, Aida, Felix, and my family in Perú.

Curriculum Vitae

The author was born in Andahuaylas, Perú on March 9, 1973. He attended the *Pontificia Universidad Católica del Perú* from 1996 to 2000 and graduated with a Bachelor's degree in Economics. He also attended the *Universidad Nacional Agraria la Molina*, from which he graduated with a Bachelor's degree in Statistics and Computer Science. He commenced his graduate studies in economics in the fall of 2005 at the University of Rochester. He received fellowships from the Fulbright Program from 2005 to 2007, from the Central Bank of Perú from 2007 to 2010, and from the Department of Economics at the University of Rochester from 2005 to 2010. He pursued his research in Macroeconomics with Heterogeneous Agents under the guidance of Yongsung Chang and Arpad Abraham and received a Master of Arts degree from the University of Rochester in 2007.

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Abstract

This thesis is a collection of essays on development economics from a macro-quantitative perspective. These issues are studied in subsequent chapters.

In Chapter 1, I study migration from a quantitative perspective. 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 large amounts 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 I develop a model that is consistent with these facts. I use this model to address some important issues in the migration literature from a theoretical perspective. I study the general equilibrium effects of migration, its long-term effects, its welfare effects, and evaluate whether the joint effect of return migration and remittances is strong enough to offset the effects of the brain drain (effects of skilled migration). In a final step, I evaluate the effectiveness of policy interventions that attempt to offset the effects of the brain drain.

In Chapter 2, I study the economic effects of an anti-poverty conditional cash transfers (CCT) policy by using a stylized dynamic general equilibrium model. I look at the program's impact on output, human capital, poverty and income inequality. I also study its welfare implications and its effects on the intergenerational transmission of poverty. The quantitative analysis reveals that a long-term implementation of this anti-poverty program helps to reduce the intergenerational transmission of poverty. In aggregate terms the welfare gain is small but varies

across agents; the winners are those who are in the lower tail of the income distribution and the losers are those located in the upper tail. Finally, this program increases the human capital of households and, through this channel, induces a consistent reduction of both poverty and income inequality.

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Chapter 1

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

1.1 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 A.1 shows. 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 A.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 I 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 literature¹ stressed this phenomenon as a negative effect for developing economies, since it creates a scarcity of skilled workers. However, the recent literature² stresses that migration can have positive economic implications for source countries that can potentially offset the initial negative effects of skilled migration.³ According to this literature, migration 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. I provide additional evidence that supports the insurance argument of remittances; specifically, I 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, I find that they are negatively related, a finding that is consistent with the insurance history of remittances (see Figure A.3).

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

²Vidal (1998); Beine et al. (2001); Chen (2006); and Faini (2007).

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

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 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 a 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 a human capital externality may also justify a public policy intervention that attempts to offset the effects of a brain drain. This 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 a brain gain. Some studies show that, on average, a returning 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 this approach includes the most important channels by which migration may affect economic outcomes, I 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 the two-period life-cycle OLG model applied first to the migration literature by Galor and Stark (1990) and Galor and Stark (1991). The welfare effects of migration have also not been fully addressed by the literature.

The contributions of the paper are twofold. First, I 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). I use abundant evidence from the empirical literature in order to discipline, or calibrate, the model. Second, I use the model to address some specific issues regarding the economic effects of migration; among them, I consider the following: a) I 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) I deal with

⁴The 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 remittances over real exchange rate fluctuations and the evolution of the current account. For example, Lartey (2008) 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 by 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 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.

the welfare effects of migration, an issue that introduces a discussion about the political economy implications of migration. c) I 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) I study the effectiveness of a policy intervention that attempts to reduce the negative effects of skilled migration. I restrict the 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 this chapter are [Vidal \(1998\)](#), [Docquier and Rapoport \(2007\)](#) and [Chami et al. \(2006\)](#). Vidal builds a general equilibrium model from [Galor and Stark \(1990\)](#). His approach, however, differs from the one developed in this chapter, since I 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 and Rapoport \(2007\)](#) study from an analytical perspective the consequences of skilled migration for source countries; they use a one-period representative agent general equilibrium model. They find that the optimal high-skilled migration rate is positive. Additionally, they introduce 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 underlying 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 the results. Finally, in section 5 I conclude.

1.2 The Model

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

1.2.1 Environment

The structure of the model comprises a small open economy inhabited by infinitely lived risk-averse 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, I 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, I can identify up to $n + 1$ households that differ among each other due to the within-household distribution of skills.⁵ I let i , $i \in \{1, 2, \dots, n + 1\}$, denote the i -th household type and j , $j \in \{1, 2, \dots, n\}$, 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. Note that both the wage and the human capital can take only two values according to the worker's 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's 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 high probability. The joint household productivity process, Z_i , $Z_i = [z_{i1}, \dots, z_{in}]$,

⁵When 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.

follows a continuous $VAR(1)$ process $Z'_i = \rho Z_i + v_i$, where $v \sim N(0, \Sigma)$, Σ is the variance-covariance matrix, and ρ denotes the autoregressive coefficient of each worker's productivity process.

Human capital is produced according to the following production function, $h_{ij} = \varphi \exp(\phi_0 s_{ij} + \phi_1 \bar{S})$, where s_{ij} represents years of education, \bar{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 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's 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, I call this the stayer household, is represented by the following functional form.

$$u(c) = n \frac{c^{1-\sigma}}{1-\sigma} \tag{1.1}$$

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 the potential migrant abroad if the offer is good enough.

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

$$u(c) = (n - 1) \frac{c^{1-\sigma}}{1-\sigma} + \frac{\tilde{c}^{1-\sigma}}{1-\sigma} \quad (1.2)$$

The decision on remittances is taken by the household and it depends on the prevailing economic conditions in both the source and the host country. I believe that households with a migrant abroad face uncertainty surrounding the remittances that they could potentially receive. I 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} , $\pi_{re} = \text{Prob}(R = 1)$. Formally, R is a two-state stochastic variable that follows an *iid* process.⁶ The migrant may send remittances every period except the migration period; additionally, once the remittances option is realized, the household decides about the optimal monetary value of remittances through the policy rule $Re(\cdot)$. Labor income abroad (\bar{w}_U , \bar{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.

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

Migration is an absorbing state. Once a worker migrates, he stays in the host country forever. This assumption will be relaxed later when I 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. \(2000\)](#). I will explain the production process in detail later.

1.2.2 Recursive Representation

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 $\Theta = \{h_{i1}, h_{i2}, \dots, h_{in}\}$ is the household's stock of human capital. Similarly, $Z = \{z_{i1}, z_{i2}, \dots, z_{in}\}$ is the household's idiosyncratic productivity shock, and $\Theta_{-k} = \{h_{i1}, \dots, h_{ik-1}, h_{ik+1}, \dots, h_{in}\}$ 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:

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

$$V(a, \Theta, Z; i) = \max_{\{c \geq 0, a' \geq a, DR'\}} \left\{ \begin{array}{l} n \frac{c^{1-\sigma}}{1-\sigma} + \\ \beta(p_i E[Max\{V_k^1(a', \Theta'_{-k}, Z'_{-k}; i), V(a', \Theta', Z'; i)\}] \\ + (1-p_i)E[V(a', \Theta', Z'; i)]) \end{array} \right\} \quad (1.3)$$

Subject to

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

$V_k^1(a, \Theta_{-k}, Z_{-k}; i)$ 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 I mentioned before, the migration decision implies a two-step procedure. In the first 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. $DR(\cdot)$ represents the household's migration decision rule at the beginning of the current period: $DR(\cdot) = 1$ if migration is the best option, $V_k^1(a, \Theta_{-k}, Z_{-k}; i) > V(a, \Theta, Z; i)$, and $DR(\cdot) = 0$ 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:

$$V_k^1(a, \Theta_{-k}, Z_{-k}; i) = \max_{\{c, \tilde{c}, a' \geq a\}} \left\{ \begin{array}{l} (n-1) \frac{c^{1-\sigma}}{1-\sigma} + \frac{\tilde{c}^{1-\sigma}}{1-\sigma} \\ + \beta E[V_k^m(a', \Theta'_{-k}, Z'_{-k}, R; i)] \end{array} \right\} \quad (1.4)$$

Subject to

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

$V_k^m(a', \Theta'_{-k}, Z'_{-k}, R; i)$ denotes the lifetime value of a type i household in which its k -th member had migrated sometime before the current period. I 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:

$$V_k^m(a, \Theta_{-k}, Z_{-k}, R; i) = \max_{\{c, \tilde{c}, a', Re\}} \left\{ \begin{array}{l} (n-1) \frac{c^{1-\sigma}}{1-\sigma} + \frac{\tilde{c}^{1-\sigma}}{1-\sigma} \\ + \beta E[V_k^m(a', \Theta'_{-k}, Z'_{-k}, R'; i)] \end{array} \right\} \quad (1.5)$$

Subject to

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

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 ($R = 1$), 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. I 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: $a'(\Omega; i)$; $c(\Omega; i)$; $\tilde{c}(\Omega; i)$; $DR(\Omega; i)$; and $Re(\Omega; i)$.

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. \(2000\)](#):

$$Y = F(K, H_U, H_S) = \left[\chi \{ \eta K^\rho + (1 - \eta) H_S^\rho \}^{\frac{\delta}{\rho}} + (1 - \chi) H_U^\delta \right]^{\frac{1}{\delta}} \quad (1.6)$$

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

1.3 The Stationary Competitive Equilibrium

Definition 1.1. A recursive competitive equilibrium consists of a set of policy rules for the household regarding consumption, savings, migration and remittances: $c\{\Omega; i\}$; $\tilde{c}\{\Omega; i\}$; $a'\{\Omega; i\}$; $DR\{\Omega; i\}$; $Re\{\Omega; i\}$; 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, $V(\cdot)$; $V^1(\cdot)$; $V^m(\cdot)$, such that the following conditions hold:

- i) Given r, w_U and w_S , agents' decision rules $\{c(\cdot); \tilde{c}(\cdot); a'(\cdot); DR(\cdot); Re(\cdot)\}$ solve the household problem (from 1.3) to (1.5).
- ii) The goods market clears.

$$F(K, H_U, H_S) - (1 - \delta_k)K = \sum_{i=1}^{n+1} \alpha_i \left\{ \begin{array}{l} \int_{\Omega} [\mathbf{1}_{[M=0]}nc(\cdot) + \mathbf{1}_{[M=1]}(n-1)c(\cdot) + \\ a'(\cdot) + \mathbf{1}_{[DR=1]} * \Delta - \mathbf{1}_{[R=1]} * Re(\cdot)] d\mu_i \end{array} \right\} \quad (1.7)$$

⁸The 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 in both the stayers' and the migrants' households: $N_{\tau} = \int_{\Omega, M=0} nd\mu_i(\cdot) + \int_{\Omega, M=1} (n-1)d\mu_i(\cdot)$. The aggregate stock of physical capital is estimated from $K = \sum_i \alpha_i \{ \int a'(\Omega; i) d\mu_i \}$. 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 revenues. 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 household is one.

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:

$$r + \delta_k = \frac{\partial}{\partial K} F(K, H_U, H_S) \tag{1.8}$$

$$w_U = \frac{\partial}{\partial H_U} F(K, H_U, H_S) \tag{1.9}$$

$$w_S = \frac{\partial}{\partial H_S} F(K, H_U, H_S) \tag{1.10}$$

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

$$TAX = TRA$$

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

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

vii) The law of motion of distribution is stationary.

$$\mu'_i = \mu_i$$

I now turn to describing the calibration procedure.

¹⁰ N_S (N_U) is the number of skilled (unskilled) workers. s_S (s_U) is the years of education of skilled (unskilled) workers.

1.4 Calibration

In this section I 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 an economy that fulfills those requirements: First, the migration rate¹¹ in Guatemala is high, since around 11% of the adult population lives abroad. Second, a 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.

I 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. I briefly explain my calibration strategy.

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. I follow a common procedure from the labor economics and migration literature, and I relate skills to school attainment (Heckman et al. (1998); Docquier and Marfouk (2005)). Workers in the model are 25 years or older and the number of skilled agents is approximated by the number of persons who finished secondary school or high school. 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

¹¹In 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.

¹²ENCOVI 2006 (*Encuesta Nacional sobre Condiciones de Vida 2000*)

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, I consider that the correlation coefficient of the productivity shock between two family members (ρ_v) is similar for each pair of workers. I set $\rho = 0.70$ and $\rho_v = 0.5$. σ_v will be estimated by the simulated method of moments. Due to limitations on the availability of household-level data in Guatemala, I 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.

I 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). I consider that capital is relatively more complementary to skilled labor than it is to unskilled labor ($\frac{1}{1-\delta} = 2$). Given that the model is being applied to a representative developing economy in which skilled labor is scarce, the 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 , are closely related to the wage premium and the capital income share. They are estimated by the simulated method of moments as I will explain later. The physical capital depreciation rate is set at $\delta_k = 9\%$.

Two moments are used to identify labor income abroad (\bar{w}_S and \bar{w}_U): the

skill gap abroad ($\frac{\bar{w}_S}{\bar{w}_U}$) and the relative earnings between the host and the source country ($\frac{W^{Host}}{W^{Source}}$). I set the skill gap abroad equal to 2.8 consistent with the values reported from the CPS (2000); furthermore, I 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. \bar{w}_U is set based on the value of the skill gap ($\bar{w}_U = 2.8\bar{w}_S$) abroad and \bar{w}_S is estimated together with the remaining parameters.

The tax rate, τ , is set at 0.1 so that tax revenue is around 10% of GDP. The lump-sum transfer $tr1$ is set in equilibrium and it balances the government budget. I 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 that in [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 ($\beta, p_1, p_2, \Delta, \chi, \eta, \sigma_v, \bar{w}_S$) 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}

I compute the stationary equilibrium for each set of parameters or during each

¹³The 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 deviation of the productivity shock identifies the labor income standard deviation.

¹⁴This 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 I 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. I consider an equal weight for every moment (W is the identity matrix).

iteration of the Nelder-Mead algorithm. This is done by iterating over prices, lump-sum transfers, and average years of education so that the competitive equilibrium conditions are fulfilled; that is, until prices equal the marginal productivity of factors, 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 A.2. In Appendix A.2 I explain the computational procedure.

I compare the moments delivered by the model with the corresponding targets in Table A.1. The 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 model's 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, I conclude that our model is a good approximation of the economy under consideration. I now attempt to use the model to perform a set of experiments in order to answer some of the questions posed.

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

1.5 Results

1.5.1 Accounting for the quantitative effects of migration

In this section I 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 I set the migration probability equal to zero for each household type ($p_i = 0$ for $i = 1, \dots, n$). 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. I also compute the competitive transition path along the two steady-state solutions.

Table A.3 summarizes the quantitative long-run effects of migration. Migration affects the source country's economy in three respects: it decreases output, it reduces income inequality and it induces a welfare improvement for the population. I 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. Note that the scarcity of skilled workers in relative terms, due to a brain drain, is the driving force behind the increase in skilled wages and the decrease in unskilled wages.

Inequality: Migration contributes to increasing income inequality. There are several competing forces behind the change in income inequality. First, migration and a 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 I have

the effect of wages and remittances. The decrease in unskilled workers' wages as well as the increase in skilled workers' wages promotes higher income inequality. Similarly, remittances may promote income inequality, since migration is biased toward skilled workers.

Brain drain: The 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's 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. I provide evidence that supports the view that migration is used as a household insurance strategy to protect against the effects of labor market risks. The consumption standard deviation 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 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 could be characterized as a closed economy from a migration point of view, since the migration rate was very close to zero. Similarly, I relate the migration model to Guatemala in 2000-2010. Figure A.5 shows the transition path of the migration rate generated by the model and Figure A.6 the observed migration rate of Guatemala. We can see that the model delivers a slow transition of the migration rate compared with the path observed in the data.

Welfare analysis

I 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 [Flodén \(2001a\)](#) and [Heathcote \(2005\)](#). 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. $\{c_t(\cdot)\}_{t=0}^{\infty}$ denotes the equilibrium choices in the baseline equilibrium and $\{\hat{c}_t(\cdot)\}_{t=0}^{\infty}$ 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 $\psi(\cdot)$ and it solves the following expression:

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

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

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

In this particular case, to evaluate the welfare effects of migration I 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 A.5](#) shows the model-predicted transition path of the migration rate by skill type (the transition paths of the other variables are presented in [Figure A.4](#)).

After computing the transition path between these two solutions, I find 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 A.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 (Table A.5). 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 in a majority rule election by more than 50% of the population.

General equilibrium effects of migration

I have shown that migration has significant long-run effects. In this section I decompose the previously stated effects of migration into two components. The first component is the general equilibrium effects of migration, which are related to its indirect effects that act through price changes. The second component is the direct effects of migration. This element does not consider the effect of price changes. I 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; I 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

I find that around 10% of the change in output is related to changes in price. I find this amount big enough to support the claim that the general equilibrium effects of migration are quantitatively important. Table A.4 shows the results of this experiment in more detail.

The second experiment consists of the following simulation. I pick two identical stayer households in period 0; after this period, one household sends a migrant abroad. I follow the evolution of the utility of these two households along the estimated competitive transition path. Note that in the simulation the migrant household receives endogenous remittances; however, in order to isolate the effects of remittances, I 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, the 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.

1.5.2 Policy intervention

Migration cost

In this section I measure the potential economic effects of a policy intervention based on the migration cost. I assume that the government is able to affect the migration cost directly, for example through the increase in transaction costs.

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

Note that this policy affects mainly the new migrants, since now they have to spend more resources in order to support the new cost.

I consider that the migration cost increases from 0.1 to 0.2 (100% increase); the latter is equivalent to around \$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 A.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 in 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 a brain drain at all. Given that poor agents are the most affected, 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.

Remittances

I use the model to evaluate the quantitative effects of a shock on remittances. Recall that the model delivers endogenously the monetary value of remittances; however, I 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 policy maker. I can rationalize the 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 who used to send remittances. Column C of Table A.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, a result that

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.

Migration probability

I 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. I 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 I show in the last column of Table A.6. However, the 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.

Return migration

In this section I 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 income tax revenues so that we keep the competitive general equilibrium feature of the model. Note 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; note that it is an extension of the previously described stayer household problem:

$$V_k^m(a, \Theta_{-k}, Z_{-k}, R; i) = \max_{\{c, \tilde{c}, a', Re, DR2\}} \left\{ (n-1) \frac{c^{1-\sigma}}{1-\sigma} + \frac{\tilde{c}^{1-\sigma}}{1-\sigma} + \beta E \max \left\{ \begin{array}{l} V_k^m(a', \Theta'_{-k}, Z'_{-k}, R'; i); \\ V_k^{re}(a', \bar{\Theta}'_k, Z'; i) \end{array} \right\} \right\} \quad (1.11)$$

Subject to

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

where $DR2(\cdot)$ is the return migration policy rule; it takes two values: $DR2(\cdot) = 0$ if return migration is an optimal choice and $DR2(\cdot) = 1$ otherwise. $\bar{\Theta}_k = \{h_{i1}, \dots, h_{ik-1}, \bar{h}_{ik}, h_{ik+1}, \dots, h_{in}\}$ 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 \bar{h}_{ik} and it is proportional to the before-migration stock of human capital ($\bar{h}_{ik} = \zeta h_{ik}$). The term $\zeta > 1$ represents the human capital gain during the migration spell. Finally, I 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:

$$V_k^{re}(a, \bar{\Theta}_k, Z; i) = \max_{\{c, a'\}} \left\{ n \frac{c^{1-\sigma}}{1-\sigma} + \beta E[V_k^{re}(a', \bar{\Theta}'_k, Z'; i)] \right\} \quad (1.12)$$

Subject to

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

where $V_k^{re}(a, \bar{\Theta}_k, Z; i)$ 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 . I calibrate these parameters by considering two 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 with 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 (see column a of Table A.6).

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

¹⁸According 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.

I 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.

1.6 Final Remarks

I 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. I 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, I find that migration improves the welfare of the source country's 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 words, migration has an insurance component.

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

Finally, I 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 policy based

on migration cost, for example, affects mainly poor households and it mainly prevents the 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.

Chapter 2

General Equilibrium Analysis of Conditional Cash Transfers

2.1 Introduction

Poverty is widespread in developing economies.¹ According to the World Bank, around 20% of the population in developing economies spend less than \$2 a day; this high incidence of poverty seems to be robust to several specifications of the threshold used to identify the population's poverty status. These economies have been implementing many anti-poverty policies, and the most widely used intervention in recent years is the so-called conditional cash transfer (CCT) program (Coady *et al.*, 2004).

Conditional cash transfer programs have become one of the most important anti-poverty policy interventions after one such program was successfully implemented in Mexico in the late 1990s.² The main feature of this type of program is that the government provides monetary transfers to families in poverty. The transfers are conditional upon children's school attendance and participation in other

¹In this paper I adopt the standard and widely used definition of poverty: A person is in poverty when he does not attain a minimum level of well-being. Empirically, the minimum level of well-being is defined in monetary terms as the poverty line. People whose consumption is below the poverty line are considered poor. The proportion of poor people in the population defines the poverty rate.

²Currently, CCT programs have spread to several countries, among them: Mexico, Brazil, the UK, Colombia, Peru, Nicaragua, and Bangladesh.

complementary anti-poverty policies, such as food supplements.³ The strength of this program is based on its well-designed goals: The short-run goal of the program is to increase school attendance and to reduce school drop out rates by providing monetary compensation for each child the family sends to school. The long-term goal is to reduce the vulnerability of the population in poverty by promoting human capital production.

The positive outcomes of conditional cash transfer programs have been extensively documented over the last two decades by studying mainly the benchmark Mexican CCT program. This literature provides evidence of the effectiveness of the program in the short-term: an increase in enrollment rates, a reduction in child labor, a reduction in school drop out rates and a reduction in poverty. However, since the benchmark CCT program started in 1997, the available information is not yet suitable for evaluating its effects in the following three categories: long-term effects, welfare implications and intergenerational transmission of poverty.

The long-term effects comprise the study of the outcomes⁴ of this program when it is implemented continuously over a long period of time. Some efforts have been made to identify these long-term effects; however, this is part of a growing literature that has provided only partial answers.

The welfare analysis of the CCT program has interesting implications, since our concern is to identify the winners and losers if the government decides to implement this program. In other words, we may be able to see if individuals have enough incentives, generated by the program, to support the anti-poverty policy. The literature in this area is scarce, and our study may uncover some features of the welfare effects of this program.

The literature on the intergenerational transmission of poverty or, more generally, the poverty trap literature, has pointed out that children inherit poverty from their parents with a positive probability. Whether the CCT program reduces the persistence of poverty is an open question.

³The program in Mexico covered around 2.6 million beneficiaries in 2000; the transfers represent around 30% of the beneficiaries' incomes, which in aggregate terms represents 0.2% of Mexico's GDP (Coady and Lee-Harris (2004))

⁴I am interested in outcomes such as output, income inequality, poverty, wages, years of education, and human capital.

In this paper, I use a competitive general equilibrium model that will allow us to uncover the effectiveness of a CCT program along these three dimensions. Our contribution to the macro and development literatures is that I use the neoclassical growth model with heterogeneous agents to study one of the most widely used anti-poverty policies. Since the approach is mainly theoretical, I will provide complementary evidence of the effects of CCT programs that may be used, together with the current knowledge of its effects, to guide anti-poverty interventions in developing economies.

Our approach captures the following features of an economy in which the anti-poverty CCT program under consideration is implemented. I model both parent and child labor supply decisions; given that a cash transfer can be seen as an additional source of household income, the income effect induced by this transfer may affect the allocation of resources within the household. I model schooling choice; this is one of the most important features of the model, since the goal of the program is to promote early school attendance. I model human capital accumulation over the life cycle of the household members; it is the main channel by which the CCT program attempts to reduce household vulnerability in the long-run. In our model economy, the government has incentives to promote schooling of the population, since schooling has a positive externality that affects workers' productivity. Finally, I use flexible prices (wage and interest rate) in order to capture the price changes induced by the conditional transfers.

The results of our simulations reinforce the well-known positive outcomes of the Mexican-type conditional cash transfers program. The general equilibrium effects of this program are significant enough such that in the long-run, the program delivers a remarkable increase in output (6.5%), human capital (6.7%), and years of education (10.9%), and a reduction in poverty (21.6%) and income inequality (3.0%). However, most of these effects may be observable during the lifetime of the current generation, which implies that the long-term effects of this program are stronger than its short-term effects.

Regarding the welfare implications of this program, I find that the aggregate welfare effect is small (0.85%); however, the majority of households will gain in welfare terms after the implementation of the CCT program. Finally, poor

parents are able to educate their children by using the resources provided by the CCT program. As a result, the intergenerational correlation of poverty decreases and the program will deliver a noticeable reduction in the poverty trap in the long-run.

2.1.1 Related literature

The effectiveness of CCT programs has been studied from several perspectives during the last two decades. In this section I briefly describe some of these efforts in order to locate the contribution of our study to this specialized literature.

The most extensive literature that has studied CCT programs has used the experimental design approach. This branch of the literature has mostly evaluated the Mexican case, since it provides a suitable source of data. Additionally, there is a growing literature that has applied this methodology to other developing countries with results similar to the Mexican case. The evidence provided for Mexico seems to be optimistic; several studies (Behrman et al. (1999); Schultz (2000)) conclude that the program increases the enrollment rate, reduces the drop-out rate, and reduces the poverty rate, among other positive outcomes.

CCT programs have also been studied by using structural models of individual behavior (schooling choice models) in Todd and Wolpin (2006) and Attanasio et al. (2005). This approach tries to capture the fact that a cash transfer program may change the relative price of education and child labor (the opportunity cost of attending school). This approach allows evaluation of the effectiveness of the program along several dimensions that were not suitable to the experimental approach. However, this approach is still a partial equilibrium analysis, and the results derived from the Mexican case are consistent with the results found in the previous literature.

Our justification is that this policy may not only have direct partial equilibrium effects but it may also affect the behavior of the agents, especially if the program is implemented continuously over a long period of time, and it may have secondary effects induced by price changes. Under a general equilibrium framework, I may be able to measure not only the direct effects of the program but I may also be able to uncover the indirect effects induced by the anti-poverty policy intervention

that work through changes in prices such as wages and interest rates.

The general equilibrium effects of CCT programs have been studied using computable general equilibrium models (CGE). This methodology was applied to evaluate the effects of a cash transfers program in Mexico by [Coady and Lee-Harris \(2004\)](#). Additionally, several other studies have used CGE models to analyze policy interventions and their effects on poverty and inequality ([Hans et al. \(2002a\)](#), [Hans et al. \(2002b\)](#); [Robilliard et al. \(2001\)](#)). The general idea of this methodology is that policy intervention instruments are linked to poverty indicators by using the relationship among national accounts, social accounting matrixes and household surveys. In short, the structure of the national accounts (aggregate variables) is linked to household survey data (microeconomic variables) using elasticities and/or coefficients such that the effect of economic shocks on poverty and inequality can be evaluated through these elasticities. Under the competitive approach used in this paper, I have consistency at both the macro and the individual levels, and I will be able to properly measure both the welfare and the long-run effects of the CCT program.

Our study is also related to the literature that addresses the role of early childhood education from a macro-quantitative perspective. This topic has been covered in several studies, among them [Aiyagari et al. \(2001\)](#) and [Restuccia and Urrutia \(2002\)](#). These documents evaluate the role of early childhood investment in education and the intergenerational correlation of income in the United States.

The rest of the paper is organized as follows. In section 2 I describe the features of our model economy. In section 3 I describe the calibration procedure. In section 4 I present the results. In section 5 I summarize the findings.

2.2 The Model

I use a dynastic overlapping generations model (DOLG) with incomplete markets.⁵ The basic framework of the DOLG model is extended in such a way that it captures most of the features of an economy in which an anti-poverty conditional cash

⁵The DOLG model has been implemented in several studies. [Fuster et al. \(2003\)](#), [Fuster et al. \(2007\)](#) and [Restuccia and Urrutia \(2002\)](#).

transfers program is implemented.

2.2.1 Environment

The model represents a closed economy inhabited by households that are heterogeneous in ability. There are N types of ability, each of them indexed by i ($i = 1, 2, \dots, N$). The ability distribution is known and I denote the measure of households of type i by α_i . Without loss of generality I normalize the number of households to 1 ($\sum \alpha_i = 1$). Each household has two members: a parent and a child.

Each household belongs to a dynasty that lives forever. A household is born at the beginning of the first period with two members: a 36-year-old parent and a 6-year-old child. Each household lives for 30 years. The life-cycle feature of the model may be summarized by the following events that happen during the household's lifetime: During the first 6 periods the parent works and the child attends primary school. From period 7 through 12 the child may attend secondary school or may work, according to the parent's decision at the beginning of period 7. From period 13 through 17, the child may attend tertiary school or may work, according to the parent's decision at the beginning of period 13.⁶

From period 18 through period 30 the parent and the child work in the labor market. In period 30, the 66-year-old parent dies and he leaves an endogenous bequest to his 36-year-old child.⁷ At the beginning of the next period, the child becomes a new parent, since at this period a 6-year-old child is born. The new parent and the newborn child start a new household and thus continue the immortal dynasty.

⁶The timing of the schooling decision of the model attempts to capture the education system of Mexico. Primary education in Mexico lasts for 6 years ('Educacion Primaria'). Secondary education lasts for 6 years; it comprises two levels: lower-secondary ('Educacion Secundaria') for 3 years and upper-secondary ('Educacion Media Superior') for 3 years. Finally, tertiary education lasts for 5 years ('Educación Superior').

⁷The assumption that the child leaves her parent's house at age 36 may not affect the policy experiment. From the point of view of our policy evaluation, what matters is both the age at which the schooling decision is made and the length of time over which each individual accumulates human capital. In our model, each agent may keep studying for at most 17 years, and after these schooling periods, he accumulates human capital during his lifetime. Both parent and child accumulate human capital while they work.

A household has instantaneous utility represented by $u(c_t, l_{p,t}, l_{k,t})$. It is defined over household consumption (c_t), parent's time spent working ($l_{p,t}$) and child's time spent working ($l_{k,t}$). Utility is additively separable between consumption and time spent working $u(c_t, l_{p,t}, l_{k,t}) = u_1(c_t) + u_2(l_{p,t}) + u_3(l_{k,t})$. In this economy the parent decides optimally every period over consumption (c_t), saving (a_{t+1}), hours of work ($l_{p,t}, l_{k,t}$) and, during the first 17 periods, schooling. There is also a bequest decision that is taken at period 30.

I assume that a household at time zero (or at the beginning of period 1 when the household is born) sorts its random streams of consumption and hours of work according to the lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_{p,t}, l_{k,t}) \quad (2.1)$$

The parameter β is the subjective discount factor. In our model β has two interpretations. It measures time preference within the lifetime of a generation. It also measures the intergenerational altruism of a given generation; a generation leaves a bequest for the future generation in a given dynasty and β may affect the discounted value of a future generation's preferences. The following utility function is considered:

$$u(c, l_p, l_k) = \frac{c^{1-\sigma}}{1-\sigma} - B_p \frac{l_p^{1+1/\psi}}{1+1/\psi} - B_k \frac{l_k^{1+1/\psi}}{1+1/\psi} \quad (2.2)$$

where ψ represents the Frisch elasticity of labor supply, $B_p > 0$ ($B_k > 0$) represents the preference parameter related to the parent's (child's) disutility of hours of work.

Both parent (p) and child (k) face an idiosyncratic productivity shock that is realized at the beginning of each period before any decision is taken. I assume that the parent's and child's idiosyncratic productivity shocks are correlated. This correlation is measured by the correlation coefficient ρ_{pk} . I denote the parent's (child's) productivity shock by $e_{p,t}$ ($e_{k,t}$). Idiosyncratic productivity shocks follow

a VAR(1) process: $\ln(e_{j,t}) = \varphi_j \ln(e_{j,t-1}) + v_{j,t}$, $j = p, k$; with the shocks v_p and v_k following a bivariate normal distribution:

$$\begin{bmatrix} v_p \\ v_k \end{bmatrix} \sim N \left\{ \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{v_p}^2 & \sigma_{v_{pk}} \\ \sigma_{v_{kp}} & \sigma_{v_k}^2 \end{bmatrix} \right\}$$

and

$$\rho_{pk} = \frac{\sigma_{v_{pk}}}{\sigma_{v_p} \sigma_{v_k}}$$

where σ_{v_p} and σ_{v_k} are the standard deviations of the parent's and child's productivity shock, and $\sigma_{v_{pk}}$ is the covariance between the parent's and child's productivity shocks.

Households are allowed to save and there is only one asset available for this purpose. Savings is denoted by $a' \in A$, where A is a compact set that represents the savings state space. Households are borrowing constrained ($a' \geq \underline{a}$) and they can finance expenses only with labor income, savings and government transfers. In this environment the market is incomplete, since there is only one asset that can be used by the household to insure against the idiosyncratic productivity shocks that affect the working family members.

The government taxes the household's total income at a constant rate (τ), and the collected tax revenues are used by the government to finance monetary transfers to households. There are two types of transfers: a lump-sum transfer (tr) that is given by the government to each household and a conditional cash transfer (ctr) that represents the government's anti-poverty policy. The government provides ctr only to those households that qualify as beneficiaries of the anti-poverty program. Two conditions must be filled in order to qualify as a beneficiary of the program: the household must be in poverty and the child must be attending primary or secondary school. I assume that a household is in poverty if its disposable income is below a threshold (poverty line) denoted by *line*. Since the government may not be able to reach 100% of the eligible beneficiaries, I consider that the government provides cash transfers to a proportion η of the potential beneficiaries of the program.

Education is costly, and the education cost depends on the child's level of education. If the child attends primary school, the parent pays a cost denoted by $cost_{pr}$; similarly, the secondary education cost is denoted by $cost_{se}$ and the tertiary education cost by $cost_{te}$. Since education in developing economies is mainly public, this education cost represents the household's education expenses in order to keep the child enrolled in school. Households with a child attending school face a utility cost that represents the psychological cost of sending a child to school. The utility cost differs according to the level of education: ζ_{pr} , ζ_{se} and ζ_{te} denote the utility cost of pursuing primary, secondary or tertiary education, respectively.

Workers are paid a wage by efficiency units of labor denoted by w . The pre-tax labor income of a parent is represented by $wh_p l_p e_p$,⁸ where h_p stands for the human capital stock, l_p stands for hours of work and e_p stands for the parent's idiosyncratic productivity shock. The parent's and child's human capital evolve according to a Mincer-type production function $h_p = f(i, s_p, x_p)$, where i stands for parent ability, s_p stands for parent schooling level, and x_p denotes parent labor market experience. The human capital production function has the following functional form:

$$f(i, s_p, x_p) = \exp(\phi_{01} + \phi_{0i}1_{[i>1]} + \phi_{11}s_p + \phi_{1i}1_{[i>1]}s_p + \bar{\phi}_1\bar{S} + \phi_2x_p + \phi_3x_p^2) \quad (2.3)$$

where $1_{[i>1]}$ is an indicator function that takes the value of one if the ability type is higher than one. The child's human capital has a similar representation: $h_k = f(i, s_k, x_k) = \exp(\phi_{01} + \phi_{0i}1_{[i>1]} + \phi_{11}s_k + \phi_{1i}1_{[i>1]}s_k + \bar{\phi}_1\bar{S} + \phi_2x_k + \phi_3x_k^2)$. Note that we differentiate the human capital production function by ability types; high-ability agents have higher private return to education compared with low-ability agents ($\phi_{1i+1} + \phi_{11} > \phi_{1i} + \phi_{11}$). Similarly, high-ability agents have a higher initial level of human capital ($\phi_{0i+1} + \phi_{01} > \phi_{0i} + \phi_{01}$).

In this economy there is a positive externality generated by the average years

⁸Similarly, the pre-tax child labor income is denoted by $wh_k l_k e_k$.

of schooling of the population. The government has an incentive to promote children's schooling attendance, since higher years of education increase workers' productivity.⁹ The term $\bar{\phi}_1 \bar{S}$ captures the externality induced by the average years of education. I include the schooling externality in the human capital production function in order to justify the government's policy intervention: the government may want to induce a higher schooling level of the population through conditional cash transfers, since every agent in the economy will be positively affected by this policy through the externality. Note that under our formulation in equilibrium, when \bar{S} equals the average years of education of the whole economy, the social return to an additional year of education ($\phi_{11} + \phi_{1i} + \bar{\phi}_1$) is higher than the private return ($\phi_{11} + \phi_{1i}$) for each ability type.

Production takes place in a competitive market, which implies that a factor's price (wages or the interest rate) is equal to its marginal productivity. Output is produced according to a Cobb-Douglas production function that uses capital and two types of labor as production factors. Two skill levels are considered: skilled and unskilled. I relate skills to the schooling level of the agents; the unskilled workers have either primary or secondary education and the skilled workers are those with tertiary education. Finally, I assume that the labor inputs of different skill levels are not perfect substitutes.

2.2.2 Recursive representation

I describe the recursive representation of the household's problem. In this section I also describe the representative firm's problem.

Household's problem

The life-cycle feature of the model allows us to separate the recursive representation of the household's problem according to household age. I index the household's age by t ; since a household lives for 30 years, t takes discrete values from 1

⁹The use of a human capital externality at an aggregate level was introduced by Lucas (1998) and Mankiw et al. (1992).

I model the schooling externality by using the Mincerian approach of human capital production. Our approach is similar to that in Rauch (1993), Acemoglu and Angrist (2000), and Ciccone and Giovanni (2002).

to 30. Note that t helps to keep track of both the parent's and the child's ages; a child's age at t is $t + 6$ and the parent's age at the same period is $t + 36$.

I denote by $V_{i,t}(a, e_p, s_p, e_k, s_k)$ the lifetime value of a t -year-old household with ability type i . In general terms, the state space is represented by the household's asset position a , the parent's and child's schooling levels (s_p, s_k) and the parent's and child's idiosyncratic productivity shocks (e_p, e_k) . I denote the state by $\Theta = \{\Theta_p, e_k, s_k\}$, where $\Theta_p = (a, e_p, s_p)$ and $\Theta'_p = (a', e'_p, s_p)$. At the beginning of period 1 the child begins his life with zero years of schooling and he accumulates one year of schooling if he attends school. The government cash transfer policy is represented by ctr . Since I consider that the government can reach only a fraction η of the potential beneficiaries, ctr is a state variable for the first 12 periods (when a child is attending primary and secondary school). I consider that ctr follows a two-state *iid* process: $ctr > 0$ for those who get transfers and $ctr = 0$ for those potential beneficiaries who cannot be reached by the government policy.

Household's problem for periods 1 through 5. The household's problem has the following recursive representation:

$$V_{i,t}(\Theta_p, e_k = 0, s_k, ctr) = \max_{\{c \geq 0, a' \geq a, l_p\}} \left\{ \begin{array}{l} u(c, l_p, 0) - \zeta_{pr} + \\ + \beta EV_{i,t+1}(\Theta_p, e'_k = 0, s_k + 1, ctr') \end{array} \right\} \quad (2.4)$$

S.t.

$$c + a' + \cos t_{pr} \leq (1 - \tau)w_i h_p l_p e_p + (1 + (1 - \tau)r)a + tr + \psi ctr$$

$$h_p = f(i, s_p, t + 36 - s_p - 6)$$

During these periods the child is studying, and he does not face any idiosyncratic productivity shock; we denote this event by $e_k = 0$. The CCT policy is represented by the indicator function ψ , which is a function of the disposable income and it takes two values according to the household's poverty status: $\psi = 1$ if the household is in poverty or when $(1 - \tau)(w_i h_p l_p e_p + ra) < \underline{line}$ and 0 otherwise.

The definition of ψ is similar when the child is attending primary or secondary school.

Household's problem at period 6. At period 6 the household's problem is similar to the problem faced during the previous 5 periods; however, the continuation value of period 6 changes to reflect the child's secondary schooling at the beginning of period 7. The household's problem now has the following recursive representation:

$$V_{i,t}(\Theta_p, e_k = 0, s_k, ctr) = \max_{\{c \geq 0, a' \geq a, l_p\}} \left\{ \beta EMax \left[\begin{array}{c} u(c, l_p, 0) - \zeta_{pr} + \\ V_{i,t+1}(\Theta'_p, e'_k = 0, s_k + 1, ctr'); \\ V_{i,t+1}(\Theta'_p, e'_k, s_k) \end{array} \right] \right\} \quad (2.5)$$

S.t:

$$c + a' + \cos t_{pr} \leq (1 - \tau)w_i h_p l_p e_p + (1 + (1 - \tau)r)a + tr + \psi ctr$$

$$h_p = f(i, s_p, t + 36 - s_p - 6)$$

where $V_{i,t+1}(\Theta'_p, e'_k = 0, s_k + 1, ctr)$ denotes the value function of the household at the beginning of period 7 when the child attends secondary school. Similarly, $V_{i,t+1}(\Theta'_p, e'_k, s_k)$ denotes the value function when the child does not go to secondary school. Note that in the latter case the child faces an idiosyncratic productivity shock e'_k . The decision rule to attend secondary education is denoted by $DR(\cdot)$; specifically, $DR(\cdot) = s_k + 1$ if sending the child to secondary school produces a higher value for the household than a working child [$V_{i,t+1}(\Theta'_p, e'_k = 0, s_k + 1, ctr') \geq V_{i,t+1}(\Theta'_p, e'_k, s_k)$]. On the other hand, $DR(\cdot) = s_k$ if the household with a working child is greater than the value of sending him for secondary education [$V_{i,t+1}(\Theta'_p, e'_k = 0, s_k + 1, ctr') < V_{i,t+1}(\Theta'_p, e'_k, s_k)$].

Household's problem for periods 7 through 11. In these periods there are two types of households according to the child's secondary school attendance.

The problem of a household with a child attending secondary school has the following recursive representation:

$$V_{i,t}(\Theta_p, e_k = 0, s_k, ctr) = \max_{\{c \geq 0, a' \geq a, l_p\}} \left\{ \begin{array}{l} u(c, l_p, 0) - \zeta_{se} + \\ + \beta EV_{i,t+1}(\Theta_p, e_k = 0, s_k + 1, ctr') \end{array} \right\} \quad (2.6)$$

S.t:

$$c + a' + \cos t_{se} \leq (1 - \tau)w_i h_p l_p e_p + (1 + (1 - \tau)r)a + tr + \psi ctr$$

$$h_p = f(i, s_p, t + 36 - s_p - 6)$$

The problem of a household with a working child has the following recursive representation:

$$V_{i,t}(\Theta_p, e_k, s_k) = \max_{\{c \geq 0, a' \geq a, l_p, l_k\}} \{u(c, l_p, l_k) + \beta EV_{i,t+1}(\Theta_p', e_k', s_k)\} \quad (2.7)$$

S.t:

$$c + a' \leq (1 - \tau)w_i h_p l_p e_p + (1 - \tau)w_i h_k l_k e_k + (1 + (1 - \tau)r)a + tr$$

$$h_p = f(i, s_p, t + 36 - s_p - 6)$$

$$h_k = f(i, s_k, t + 6 - s_k - 6)$$

Since employment is an absorbing state (a working child cannot return to

school), the problem of a household with a working child will have the same recursive representation in the remaining periods.

Household's problem at period 12. At period 12 the household faces a problem similar to the previous period's problem; however, at the beginning of period 13, the parent will decide whether the child will attend college. In order to decide on college attendance, the parent compares the value of sending the child to college, $V_{i,t+1}(\Theta'_p, e_k = 0, s_k + 1)$, with the value of sending him into the labor market, $V_{i,t+1}(\Theta'_p, e'_k, s_k)$. Note that in the latter case, the child's idiosyncratic productivity shock is realized before his schooling decision.

The problem of a household with a child attending secondary school has the following recursive representation:

$$V_{i,t}(\Theta_p, e_k = 0, s_k, ctr) = \max_{\{c \geq 0, a' \geq a, l_p\}} \left\{ \beta E \max \left[\begin{array}{l} u(c, l_p, 0) - \zeta_{se} + \\ V_{i,t+1}(\Theta'_p, e_k = 0, s_k + 1); \\ V_{i,t+1}(\Theta'_p, e'_k, s_k) \end{array} \right] \right\} \quad (2.8)$$

S.t:

$$c + a' + \cos t_{se} \leq (1 - \tau)w_i h_p l_p e_p + (1 + (1 - \tau)r)a + tr + \psi ctr$$

$$h_p = f(i, s_p, t - s_p - 6)$$

Household's problem for periods 13 through 16. The problem of a household with a child attending college (tertiary education) has the following recursive representation:

$$V_{i,t}(\Theta_p, e_k = 0, s_k) = \max_{\{c \geq 0, a' \geq a, l_p\}} \left\{ \begin{array}{l} u(c, l_p, 0) - \zeta_{te} + \\ + \beta EV_{i,t+1}(\Theta'_p, e_k = 0, s_k + 1) \end{array} \right\} \quad (2.9)$$

S.t:

$$c + a' + \cos t_{te} \leq (1 - \tau)w_i h_p l_p e_p + (1 + (1 - \tau)r)a + tr$$

$$h_p = f(i, s_p, t - s_p - 6)$$

Household's problem at period 17. At the end of this period the studying child will finish his tertiary education, and at the beginning of the next period, he will start working according to some idiosyncratic productivity shock (e'_k).

The problem of a household with a child pursuing tertiary education has the following recursive representation:

$$V_{i,t}(\Theta_p, e_k = 0, s_k) = \max_{\{c \geq 0, a' \geq a, l_p\}} \left\{ \begin{array}{l} u(c, l_p, 0) - \zeta_{te} + \\ + \beta EV_{i,t+1}(\Theta'_p, e'_k, s_k + 1) \end{array} \right\} \quad (2.10)$$

S.t:

$$c + a' + \cos t_{te} \leq (1 - \tau)w_i h_p l_p e_p + (1 + (1 - \tau)r)a + tr$$

$$h_p = f(i, s_p, t + 36 - s_p - 6)$$

Household's problem for periods 18 through 29. During these periods all household members are working and the household's problem has the following recursive representation:

$$V_{i,t}(\Theta_p, e_k, s_k) = \max_{\{c \geq 0, a' \geq a, l_p, l_k\}} \{u(c, l_p, l_k) + \beta EV_{i,t+1}(\Theta'_p, e'_k, s_k)\} \quad (2.11)$$

S.t.

$$c + a' \leq (1 - \tau)w_i h_p l_p e_p + (1 - \tau)w_i h_k l_k e_k + (1 + (1 - \tau)r)a + tr$$

$$h_p = f(i, s_p, t + 36 - s_p - 6)$$

$$h_k = f(i, s_k, t + 6 - s_k - 6)$$

Household's problem at period 30. At period 30 the household decides bequests for future generations in its dynasty. For the previous 29 periods, I denote the household's saving decision by a' ; however, at the end of period 30, the parent dies and I let a' denote the household's bequest decision. Note also that at this period the parent values the child's future value function due to his altruistic concern for the future of his child. The household's problem has the following recursive representation:

$$V_{i,t}(\Theta_p, e_k, s_k) = \max_{\{c \geq 0, a' \geq a, l_p, l_k\}} \{u(c, l_p, l_k) + \beta EV_{i,1}(a', e'_k, s_k, 0, 0, ctr')\} \quad (2.12)$$

S.t.

$$c + a' \leq (1 - \tau)w_i h_p l_p e_p + (1 - \tau)w_i h_k l_k e_k + (1 + (1 - \tau)r)a + tr$$

$$h_p = f(i, s_p, t + 36 - s_p - 6)$$

$$h_k = f(i, s_k, t + 6 - s_k - 6)$$

The policy functions that solve the household problem are those determining household consumption, savings, bequest, hours worked by the parent, hours worked by the child, and the secondary and tertiary schooling attendance decision. The optimal policies depend on the state space, and for easy notation I denote them by: $c(\Theta; i, t)$; $a'(\Theta; i, t)$; $l_p(\Theta; i, t)$; $l_k(\Theta; i, t)$; and $DR(\Theta; i, t)$.

Firm's problem The representative firm produces in a competitive market according to a Cobb-Douglas production function.

$$Y = F(K, L) = zK^\theta L^{1-\theta}$$

where K and L are the aggregate capital and labor inputs, respectively. Y is output, z is the economy-wide productivity and θ represents the capital share parameter. Since the labor inputs of different schooling levels are not perfect substitutes for each other, aggregate labor is calculated by adding up the efficiency units of labor of each skill level (L_j) by using the following CES function

$$L = \left\{ \sum_{j=1}^2 \chi_j L_j^\gamma \right\}^{1/\gamma}$$

where the agent's skill is indexed by j . Since I consider two schooling levels, $j = 1$ denotes the primary or secondary education level, while $j = 2$ denotes the tertiary education level. χ_j represents the share, or the relative productivity, of the individuals with schooling level j , and $\frac{1}{1-\gamma}$ denotes the elasticity of substitution between labor inputs of different skill levels.

The marginal productivity of labor equals $mpl_j = F_{L_j}(K, L) = (1-\theta)\frac{Y}{L}\left(\frac{L}{L_j}\right)^{1-\gamma}\chi_j$ and the marginal productivity of capital equals $mpk = F_k(K, L) = \theta\frac{Y}{K}$.

2.2.3 Definition of equilibrium

Definition 2.1. A stationary recursive competitive equilibrium consists of a set of policy rules for the households regarding consumption, saving, bequest, hours of work and schooling decision ($c(\Theta; i, t)$, $a'(\Theta; i, t)$, $l_p(\Theta; i, t)$, $l_k(\Theta; i, t)$, $DR(\Theta; i, t)$); a stationary probability measure of households ($\mu'_i = \mu_i(\Theta)$); aggregate factors, output and prices ($K, L, \{L_i\}_{i=1}^N, Y, r, \{w_j\}_{j=1}^2$); tax revenues (Tax); aggregate transfers (TR) and household value functions ($V_{i,t}(\Theta)$) such that the following conditions hold:

i) Aggregate capital (K), labor (L), transfers (TR) and tax revenues (Tax) are calculated from individual policies by using the following formulas:

$$K = \sum_{i=1}^N \alpha_i \left\{ \int a'(\Theta; i, t) d\mu_i \right\} \quad (2.13)$$

$$L_j = \sum_{i=1}^N \alpha_i \left\{ \int [h_p l_p(\Theta; i, t) e_p 1_{[j]} + h_k l_k(\Theta; i, t) e_k 1_{[j]}] d\mu_i \right\}^{10} \quad (2.14)$$

$$Tax = \tau \sum_{j=1}^2 w_j L_j + \tau r \sum_{i=1}^N \alpha_i \left\{ \int a d\mu_i \right\} \quad (2.15)$$

$$TR = tr + \sum_{i=1}^N \alpha_i Pov(i) ctr(i) \quad (2.16)$$

where $Pov(i)$ represents the measure of households of ability type i that are beneficiaries of the anti-poverty program.

ii) Given r and $\{w_j\}_{j=1}^2$, decision rules $\{c(\cdot); a'(\cdot); l_p(\cdot); l_k(\cdot), DR(\cdot)\}$ solve the household's problem (2) through (10)

iii) The goods market clears.

$$F(K, H) + (1 - \delta_k)K = \sum_{i=1}^N \alpha_i \left\{ \int c(\Theta; i, t) + a'(\Theta; i, t) + E \cos t(t, e_k) d\mu_i \right\}^{11} \quad (2.17)$$

iv) Firms maximize profits in a competitive market.

$$r + \delta_k = mpk \quad (2.18)$$

$$w_j = mpl_j \quad (2.19)$$

v) The government balances its budget constraint.

$$Tax = TR \quad (2.20)$$

¹⁰ $1_{[j]}$ denotes an indicator function that is one when the schooling level is j .

¹¹I use $Ecost(t)$ to denote the education cost at period t of those households with a child attending school. $Ecost(t)$ has the following functional form:

$$Ecost(t, e_k) = \begin{cases} \cos t_{pr}; & t = 1, 2, \dots, 6 \\ \cos t_{se}; & t = 7, 8, \dots, 12; e_k = 0 \\ \cos t_{te}; & t = 13, \dots, 17; e_k = 0 \\ 0; & \text{Otherwise} \end{cases}$$

vi) The aggregate schooling level is consistent with individual schooling decisions.

$$\bar{S} = \sum_{i=1}^N \alpha_i \left\{ \int \frac{1}{2}(s_p + s_k) d\mu_i \right\}$$

vii) The law of motion of distribution of households is stationary.

$$\mu'_i = \mu_i \tag{2.21}$$

2.3 Calibration

In this section, I solve the model for a representative developing economy in which the CCT program was implemented. I consider Mexico as the natural choice, since its program was first introduced in 1997. Additionally, there is an abundant empirical literature based on the Mexican experience that will guide the calibration process.

I perform a counterfactual experiment in order to measure the economic effects of the CCT program. The counterfactual economy includes the CCT policy, which was fully described in the previous section. The baseline model represents an economy without conditional cash transfers, a situation in which the anti-poverty policy is based on transfers that are independent of school attendance. I call this solution the unconditional cash transfers model (UCT). Note that the baseline economy results after relaxing some assumptions of the CCT model as I will explain carefully later.

The Baseline Model

The baseline equilibrium represents the Mexican economy in 1996, one year before the Mexican government introduced the conditional cash transfers program. The parameters of the baseline model (Table B.1) are chosen such that the model generates a group of moments that are close to their corresponding observed moments in Mexico.

The moments shown in Table B.4 are correlated among each other, which in fact implies that I cannot perfectly target a particular moment by using a specific parameter without affecting the value of the remaining moments. I address this issue by iterating over the whole set of parameters such that the competitive equilibrium supported by them represents a reasonable approximation of the Mexican economy. In this section I discuss the rationale behind the values of the parameters of the baseline model.

Each person's ability level is identified by using the Raven test. This test is part of the Mexican Family Life Survey (MxFLS), and it is reported as an index and measures the cognitive ability of each person based on a set of questions designed for this purpose. The ability index is discretized in order to have a feasible number of states. I consider two ability levels ($N = 2$): high ability and low ability. I consider that 50% of the population has high ability ($\alpha_1 = \alpha_2 = 0.5$).¹²

The risk-aversion parameter is fixed at $\sigma = 1.4$, consistent with the common usage in the neoclassical literature. The available time of each family member is set to one and the values of the parameters, ψ, B_p, B_k , are chosen such that in equilibrium the average hours of work are around 0.35. The Frisch elasticity of labor supply (ψ) is set at 0.30 and $B_k/B_p = 50/30$. Note that when $B_k/B_p = 50/30$ ¹³ we have a smooth transition of the child's hours of work when he becomes a parent; this is the life-cycle profile of hours of work.

The parameters of the production function take standard values: $\theta = 0.33$, $z = 1$. The annual physical capital depreciation rate is set at $\delta_k = 6.5\%$. The parameters of the human capital production function cannot be estimated directly since human capital is not observable; however, it is easy to see that these parameters are closely related to the parameters of the Mincer equation, which relates hourly labor income to schooling and experience. Under our strategy, the pa-

¹²The standardized ability index goes from 0 to 1 and the median ability (0.45) is the threshold that identifies each ability type.

¹³From the FOC of the household problem when both the parent and the child are working, it is easy to show that the parent-child hours of work ratio is affected by the B_p/B_k ratio:

$$\frac{l_k}{l_p} = \left\{ \frac{B_p}{B_k} \frac{h_k E_k}{h_p E_p} \right\}^\psi$$

parameters of the human capital production function are estimated by the indirect inference method, and they are chosen such that the Mincer equation estimated by using model-simulated data is similar to the empirical Mincer equation estimated by using household survey data, MxFLS(2002, 2005). Appendix B.3 describes the Mincer equation estimation.

Table B.2 and Table B.5 show the OLS estimators of the parameters of the Mincer equation by using both the model-generated data and real data. The estimated return to education is around 7%, which is consistent with the empirical evidence. We also report a positive ability premium of the return to education: a high-ability agent's return to education is 20% higher than that of a low-ability agent. I normalize the intercept of the human capital production function in order to have a feasible number of grid points for the saving policy function.¹⁴ Since I have two ability levels, each ability type intercept is normalized such that the difference of the intercepts of the Mincer equation according to ability type is similar in both the model and the data.

The parameter that identifies the externality of education, $\bar{\phi}_1 = 0.0035$, is chosen such that the social return to education is around 0.35% above the private return. This value was reported as a lower bound for the US (Moretti, 2002), and I use this value as a proxy for the social return to education in Mexico.¹⁵

I consider two levels of education. The first level comprises primary and secondary education and the second level includes tertiary education. The degree of substitution between these two schooling levels is measured by the elasticity of substitution $\frac{1}{1-\gamma} = 2$. This value is consistent with the estimated degree of substitution between these two schooling levels; however, in order to evaluate the

¹⁴The normalization of the ability parameter will affect only the model's units. Note that the efficiency units of time of a parent are represented by the following expression: $l \exp(\phi_{01} + \phi_{0i} + \phi_{11}s_p + \phi_{1i}s_p + \phi_2x_p + \phi_3x_p^2 + \ln e_p)$. After some arrangement I express this term by $l \exp(\phi_{01} + \phi_{0i}) \exp(\phi_{11}s_p + \phi_{1i}s_p + \phi_2x_p + \phi_3x_p^2 + \ln e_p)$. From the last expression, the term $\exp(\phi_{01} + \phi_{0i})$ may be normalized without loss of generality.

¹⁵Moretti (2002) reports that the social return to education in the US ranges from 0.6%–1.2%, above and beyond the private return to education. Since the private return to education was around 10%, the externality represents between 6% and 12% of the private return to education.

I assume the social return to education in Mexico is at the lower bound of the corresponding value for the US. Since the estimated private return to education in Mexico is around 7%, the value of the externality parameter is set at $\bar{\phi}_1 = 0.0035$ such that the social return to education is around 6% higher than the corresponding private return.

robustness of this assumption I will perform, later, a sensitivity analysis considering different values of the elasticity of substitution.

The autoregressive coefficient and the standard deviation of the idiosyncratic productivity shock are similar for both parents and children, $\varphi = \varphi_p = \varphi_k = 0.65$ and $\sigma_v = \sigma_{v_p} = \sigma_{v_k} = 0.75$. These parameters are estimated from the residual of the Mincer regression (see Appendix B.3 for details). Each of the idiosyncratic productivity processes is discretized to a 4-state discrete shock using an extension of the procedure described in Tauchen (1986) for multivariate processes. I set the correlation of the parent and child productivity shock, $\rho_{pk} = 0.685$, such that the intergenerational correlation of labor income (correlation of log-income of two consecutive generations) is around 0.5.¹⁶

The income tax rate is fixed at 7% so that the income tax revenue is around 5% of GDP. The education cost structure is chosen so that private spending on education is equivalent to 4% of household consumption (ENIG 1996). I consider the following education cost structure: $\text{cost } t_p = 0.005$; $\text{cost } t_s = 0.006$; $\text{cost } t_{te} = 0.498$. This set of cost parameters, together with the utility cost of pursuing education ($\xi_{pr} = \xi_{se} = 0, \xi_{te} = 0.27$), helps us match the schooling levels of the Mexican adult population. I consider the education distribution of the adult population (25 years or older) reported by the Mexican Statistical Institute (INEGI) for 2000: 27% have completed primary education, 57.6% have some level of secondary education and 15.4% have some level of tertiary education.

I use the labor share parameters χ_1, χ_2 and the poverty line *line* to target both the inequality of household consumption and the poverty rate. The joint values of $\chi_1 = 0.25513$, $\chi_2 = 0.74487$ and *line* = 0.101 match the poverty rate (23%) and the inequality of household consumption (Gini=0.53) for 1996 (ENIG 1996).¹⁷ Note that the value of the poverty line is consistent with the monetary

¹⁶We do not have an estimator for the intergenerational correlation of earnings in Mexico; however, there is a considerable literature that has measured this indicator for the US. According to Solon (2002), Aiyagari et al. (2001), and Restuccia and Urrutia (2002) the father's and son's earnings correlation in the US is somewhere between 0.4 and 0.65. I assume that in Mexico the intergenerational correlation between parent and child is around 0.5, close to the value estimated for the US.

¹⁷ENIG stands for the Mexican Household Survey of Income and Expenses (*Encuesta Nacional de Ingresos y Gastos*)

value of the poverty line (\$2 a day) that is used in Mexico to measure the poverty rate.¹⁸

In the baseline UCT model the anti-poverty policy is independent of school attendance; then, the previously described recursive representation of the model is modified in order to reflect this feature.¹⁹ I denote the unconditional transfer by tr_{poor} . I set tr_{poor} such that the government spends around 0.1% of GDP as part of its anti-poverty policy. Since the unconditional transfers are stochastic, similar to the CCT model, I set $tr_{poor} = 0.01$ if the household receives the unconditional transfer and $tr_{poor} = 0$ if the household does not. Each potential beneficiary of the unconditional program receives a positive transfer with 0.6 probability ($\eta = 0.6$). The rationale of this choice will be explained below when we discuss the CCT calibration.

The discount factor, $\beta = 0.91645$, is consistent with a capital-output ratio equal to 3. Finally, we iterate over interest rate, wages, lump-sum transfer and average years of education in order to find the competitive equilibrium. This is supported by the following: $r = 4\%$, $w_1 = 0.2170$, $w_2 = 1.0292$, $tr = 0.0354$, and $\bar{S} = 9.96$. The lump-sum transfer, tr , helps to balance the government budget and the value of \bar{S} ²⁰ is chosen such that the aggregate and individual years of education are consistent.

I summarize the moments generated by the model as well as the empirical moments in Table B.4. The capital-output ratio, the consumption-output ratio and the taxes-output ratio represent the traditional moments that characterize the aggregate features of Mexico. I also show another set of indicators, such as consumption inequality and the poverty rate. From this table we can conclude

¹⁸The annualized value of the poverty line is around 730 US\$, which represents around 25% of per capita GDP of Mexico for the period 1990-1995. The value of the poverty line used in the model ($line = 0.101$) represents around 30% of per capita GDP.

¹⁹In the UCT model the anti-poverty transfer, tr_{poor} , goes to the poor households' budget constraint either when the child is working or when he is studying. Note that this model still considers that tr_{poor} is stochastic, similar to the CCT model.

²⁰The model does not consider illiteracy and incomplete primary education. The average years of education in 2002 for the whole population was 6.02 years (MxFLS 2002); however, excluding illiteracy and those individuals who do not complete a primary education, the average years of education was 9.5 years. The former is close to the model estimated average years of education: 9.96 years.

that the baseline economy is a reasonable approximation of Mexico's economy.

The CCT Model

I compute the CCT competitive equilibrium by using the parameters of the UCT solution. As stated before, the main difference between these two models is the anti-poverty transfers. In this section I discuss the calibration of the parameters that characterize the CCT model.

In the CCT model the anti-poverty transfer is represented by ctr . I set $ctr > 0$ for those who effectively receive the monetary transfer and $ctr = 0$ for those who don't receive the transfer. I include two additional features of the Mexican program in order to make the CCT model more realistic. First, the Mexican CCT program differentiates between the amounts transferred according to the child's education level; those beneficiaries with a child in secondary education receive more transfers than those beneficiaries with a child attending primary school. I include this feature in the model by providing $ctr = tr_p$ for the former and $ctr = tr_s$ for the latter ($tr_s > tr_p$). Second, the CCT program in Mexico does not provide transfers during the first two years of primary education. In the model, I set to zero the cash transfers during the first two years of primary education.

Three parameters need to be determined in the CCT model: tr_p , tr_s and η . The percentage of potential beneficiaries that receive cash transfers, η , is chosen such that the number of beneficiaries of the program is around 5 million households (5% of Mexican households were covered by the CCT program in 2007, [World-Bank \(2009\)](#)). With a value of $\eta = 0.6$ the CCT program covers around 8.0% of households nationwide.²¹

Meanwhile, with $tr_s = 0.043$ and $tr_p = 0.0172$ the model matches the aggregate amount that the government spent on this program, which is around 0.5% of GDP ([World-Bank, 2009](#)). Note that, consistent with the program in Mexico, the amount transferred to those beneficiaries with a child attending primary school is around 40% of the amount transferred for those beneficiaries with a child in secondary school. Table [B.6](#) summarizes the general equilibrium prices, transfers and other outcomes in both models.

²¹The empirical value of the participation rate (η) is around 0.55. This value was used by [Freije et al. \(2006\)](#).

The CCT competitive equilibrium is computed by iterating over prices, tax rate and average years of education. Contrary to the UCT model, in the CCT model we iterate over the tax rate in order to balance the government budget. Our assumption is that the CCT anti-poverty policy is mainly supported by tax revenues. Table B.6 shows the CCT equilibrium.

2.4 Quantitative Results

2.4.1 Long-run effects

I measure the long-term effects of the CCT program by comparing the outcomes of both solutions. We consider that these effects are observable only when the policy is implemented continuously for several years. This suggests that there is a transition period before the full effects of the policy are observed as I will explain later when I describe the competitive transition.

First, the main channel by which the conditional cash transfers policy affects the economic outcomes in the long-run is through human capital accumulation. The human capital induced by the higher school attendance increases workers' productivity; as a result, the CCT model delivers more efficiency units of labor, compared with the UCT model, that act as a positive labor supply shock. In aggregate terms, this abundance of human capital causes a 6.8% increase in labor (in efficiency units), a 6.0% increase in physical capital and a 6.5% increase in output.

In terms of average years of education, it increases 1.1 years due to the CCT program. I find this amount higher than the values reported by the literature. [Todd and Wolpin \(2006\)](#), for example, report that, in the long-run, the conditional cash transfer program in Mexico may generate an increase of 0.54 years of the children's mean years of completed education at age 16. [McKee and Todd \(2009\)](#) simulate the long-term effects of a 0.6-year increase in schooling attainment of the Mexican CCT program. Table B.6 presents the main indicators that capture the long-term effects of the CCT program; I briefly discuss some indicators.

Poverty. CCT has stronger effects on poverty. The poverty rate decreases

by 21.6% due to the effects of the CCT program. The driving force behind the reduction in poverty is the higher human capital induced by conditional transfers. Poor families are able to support their children at school by using the resources provided by the program. The children who participate in the program will accumulate more schooling, and they will be more productive workers in the future. In the CCT model, the high productivity workers will have more labor income and they will be able to support more consumption, which in fact will reduce the poverty rate.

Inequality. The consumption Gini decreases 3.0%, from 0.485 to 0.470, due to the CCT program. The increase in low-income workers' productivity reduces income inequality. Similarly, both the skilled wage reduction and the unskilled wage increase also contribute to the reduction in income inequality. Note that the tax rate and interest rate changes may not be responsible for the reduction in inequality, since they affect the whole population equally. The modest reduction in the inequality induced by a CCT program in the long-run was also mentioned by [McKee and Todd \(2009\)](#).

Hours of work. The model predicts that people will work fewer hours due to the anti-poverty transfers. The results are consistent with some empirical evidence about the change in the allocation of time within the household induced by CCT. I find a small change in the parents' hours of work due to CCT (Table B.6); however, I also find that the CCT program may cause a significant reduction in children's hours of work. The empirical counterparts of these results are consistent with our findings.

2.4.2 General equilibrium effects

I measure the general equilibrium effects as prices change due to the CCT program. Going from the UCT equilibrium to the CCT equilibrium, the interest rate increases 1.2%, the wage of unskilled agents increases 0.2% and the wage of skilled agents decreases 0.6%. Since these changes seem to be small, they may support the current view that states that the general equilibrium effects of the CCT program are small. However, these effects are in the long-run when the total effects of

the program are observed. We can see from the estimated competitive transition²² that the long-run effects of the program will be fully observed in two generations, with most of its effects happening during the lifetime of one generation, that is, 60 years after the introduction of the CCT program.

As I mentioned before, the current literature has pointed out that the general equilibrium effects of the Mexican type CCT program may not be significant enough and a partial equilibrium analysis may be good enough to measure most of its economic effects (Todd and Wolpin (2006), McKee and Todd (2009)). Unfortunately, it is not supported by the model predictions.

Our model allows us to extend the study of the general equilibrium effects of the CCT program along the competitive transition. We may want to ask if there are differences among the short-term effects, the middle-term effects and the long-term effects of the CCT program. In this direction, I provide additional insights about the dynamics of the general equilibrium effects of the anti-poverty program along the competitive transition between the pre-program period and the final period in which the effects of the program are fully observed. From Figure B.1 we can see that the change in prices along the transition are not monotonic, and the dynamics of prices are also not negligible, since we observe a lot of action during the following 60-70 years after implementation of the program.

From Figure B.3 I divide the transition of prices into three stages: short-term, mid-term and long-term. The first stage comprises the first 5 – 6 years. During this period, the wage of unskilled agents increases and the wage of skilled agents decreases. This price change is driven by the initial labor supply effects of the program; given that the program promotes attending school and reduces child labor, the relative scarcity of an unskilled labor force (child labor) in efficiency units pushes for an increase in the unskilled wage. This scarcity effect lasts only through the 5 initial years following the introduction of the program. Note that the wage of skilled and unskilled agents moves in opposite directions due to the imperfect substitution between these labor inputs.

The second stage is characterized by a wage reduction of poorly educated

²²Appendix B.1 describes the details of the computational procedure that I follow to find the competitive transition.

agents (reduction of wages between the 5th year and the 60th year) and a persistent increase in the average human capital that lasts for around 55 years. During this stage, the new generation of workers will gradually replace the previous generation; this may last for around 55 years, the length of time in which the current generation of workers will be fully replaced by the new generation of more educated workers. The third stage is mainly that of convergence to the new equilibrium; this period lasts for around 60 years.

The demographic feature of the model allows us to support the claim that the effects of the program will be fully absorbed during the lifetime of two generations after the introduction of the anti-poverty program. Since most of the increase in the population's schooling happens during the first 60 years after the introduction of the program, we may be able to observe most of the effects of the program in one generation. The direct implication of this finding from the policy perspective is that the CCT program may not deliver its main results in the short-run; even though the documented short-run effects of this program are extremely optimistic, its long-run effects may be even stronger.

One interesting feature to mention is the evolution of the poverty rate along the competitive transition. Figure B.3(i) shows that the poverty rate dynamic is not monotonic. It may increase a bit during the early periods right after the introduction of the conditional cash transfer program.²³ The driving force of this result is the increase in the tax rate (overshooting) that happens mainly during the early periods of the program. In our model the tax rate affects the whole population in the same proportion; some non-poor households may suffer a reduction in consumption due to the tax increase and eventually they may be poor. There is also a group of non-poor households that will become poor due to the tax rate increase; these agents may be characterized as being poor since their consumption levels are close to the poverty line threshold.

²³This feature of the model may not be supported by empirical evidence since the poverty rate should decrease monotonically. The reason is that in our model CCT is supported by resources collected from a constant income tax rate that affects the whole economy in the same proportion.

2.4.3 The welfare effects

Our approach follows the procedure for welfare analysis in models with heterogeneous agents implemented by [Flodén \(2001b\)](#) and [Heathcote \(2005\)](#). I measure the welfare effects of the CCT program by the consumption equivalence variation (CEV), which is defined as the proportional change in consumption at each date and in each event needed to make a household indifferent between the stationary equilibria of two economies: the baseline stationary equilibrium in which there is no conditional cash transfers policy and the stationary equilibrium after the introduction of the conditional cash transfers program. The latter equilibrium is computed along the competitive transition between the two models. [Figure B.3](#) shows the competitive transition of some important variables of the model.

I estimate a CEV of 0.85%, which implies that on average households will be better off, in welfare terms, after the implementation of the CCT program. The main feature of the CEV is that there is significant heterogeneity in terms of the welfare effects of this program ([Figure B.1](#)).

In general terms, there are two groups of households in terms of CEV. The first group is represented by those agents who may strongly support the implementation of the anti-poverty program; they report a positive CEV and they are characterized as low-income households (low wealth). We can also mention that they are the winners from this policy reform, since they will gain in welfare terms due to the introduction of the program. The welfare gain of this group of agents is driven by the general equilibrium effects induced by the anti-poverty program. Note that the forces that promote welfare gain are stronger than the ones that promote welfare loss. The driving forces that promote welfare gains are the following: the conditional transfer by itself may promote welfare gain by increasing the family's disposable income; the wage increase (unskilled wage increases right after the introduction of the program); the higher schooling level (externality) and the higher interest rate. On the other hand, the higher tax rate that supports the anti-poverty transfers may adversely affect some of the low-income agents. Note that the previous claim is true even for those low-income agents who are not direct beneficiaries of the program.

The second group of agents are those who will not support the implementation

of the program; they report a negative CEV and they are the wealthiest households. These households are not allowed to participate directly in the anti-poverty program, since they do not qualify as beneficiaries; however, they are the most affected by the indirect general equilibrium effects induced by the CCT program (wage reduction, tax rate increase and interest rate increase). In net terms, the welfare gain induced by the interest rate increase is not strong enough to compensate for the welfare loss induced by the changes in wages and taxes. This feature of the welfare effects of the CCT program holds after controlling for the age of the household's child. From Figure B.2 we see that the shape of the CEV is similar when the child is at the primary, secondary or tertiary level of education.

Can the government implement the CCT program with the support of the population? This is a political economy issue, since the introduction of the reform should have the support of the population in order to be successfully implemented. To deal with this question I estimate the percentage of persons who report a positive CEV. It is a measure of the number of agents who may vote in favor of the implementation of the CCT program if they are asked to vote on it. The model predicts that around 80% of the population faces a positive CEV; this means that under a democratic election, in which each individual has a vote, a policy reform that attempts to introduce a CCT program will be supported by majority rule. An interesting implication of this result is that the CCT program will have strong support among the population in the long-run, since our calculation is based on the competitive transition.

The computed welfare effect of the anti-poverty program is consistent with some results provided by the related literature. Coady and Lee-Harris (2001) and Coady and Lee-Harris (2004) show that after the implementation of the CCT program in Mexico, welfare increased by around 9%. Even though their welfare measure²⁴ is not strictly the same as the one used in this study, our reported welfare gains are qualitatively similar; however, our welfare change seems to be significantly smaller.

²⁴Following Deaton (1997), Coady and Lee-Harris (2004) use a welfare index (\check{W}) as being the product of the mean level of consumption, $\check{\mu}$, and the Atkinson measure of inequality \check{I} : $\check{W} = \check{\mu}(1 - \check{I})$.

2.4.4 The intergenerational persistence of poverty: the poverty trap

In this section we deal with the question of whether children inherit poverty from their parents. More specifically, I study the degree to which the intergenerational persistence of poverty is affected by the anti-poverty CCT program.

Our claim is that the conditional cash transfers program reduces the intergenerational transmission of poverty by permanently breaking down the correlation between parent and child education in low-income households. I provide two indicators that support this claim. First, I compute the correlation of parent and child labor income (in logs). This correlation decreases 3%, from 0.485 to 0.470, due to the anti-poverty CCT policy.

Second, I compute the dynamic of poverty along the competitive transition for a simulated panel of households.²⁵ This simulation allows identifying the dynamic of poverty between consecutive generations. Results are provided in Table B.8. We see that the poverty rate decreases 14% during the lifetime of the first generation (from 23.3% to 20%), and during the lifetime of the second generation, it will decrease an additional 6%. In terms of the transition of poverty status, the anti-poverty program promotes a significant reduction in the persistence of the poverty rate. Around 76% of descendants of those agents who were poor in the baseline equilibrium will leave poverty after four generations; a remarkable 94% of this poverty reduction occurs after one generation. Poorly educated parents tend to have educated children under the CCT model, as Table B.9 shows; see how the distribution of adult education between consecutive generations changes when parents have access to the resources provided by the CCT program. Parents with a primary education will have children whose education level will be concentrated at the secondary and tertiary levels; better educated children will eventually escape from the poverty trap, which was previously induced by the low education level

²⁵I simulate a panel of households of measure one. This panel is represented by the households of the baseline solution. I simulate the behavior of each of those agents along the competitive transition (200 years). In each period, we identify the poverty situation and the education level of each household member by using the previously estimated policy rules. Recall that the policy rules of the households along the transition are known, since they were previously estimated when I computed the competitive transition.

of their parents.

One interesting finding from the simulation is that the effects of the CCT program will be observed mainly during the first 60 years after the implementation of this policy, that is, during the lifetime of one generation. This result is consistent with this program feature. Recall that this program promotes the education of children, and we expect to observe its outcomes when these children become adults. This is when those educated children will become parents and when they will completely replace the old generation of workers. In Figure B.3 I provide some evidence that shows how this substitution of workers between generations may work over time. During the first 60 years after the introduction of the policy, the average years of education increases monotonically, Figure B.3(d); during this period the labor market is replacing those uneducated workers with the new generation of educated workers, who will gradually enter the labor market. After this policy has been implemented during the lifetime of one generation, this substitution is almost complete and the average years of education is almost stable around its new stationary equilibrium.

2.5 Summary

Conditional cash transfer programs are currently among the most popular anti-poverty policies in developing economies. In this paper, I use an extended version of the neoclassical growth model with heterogeneous agents to evaluate the economic effects of the Mexican-type CCT program in a general equilibrium framework. Our formulation captures the effectiveness of the program in some dimensions that were not previously documented. I evaluate the long-run effects of CCT in terms of poverty, income inequality, human capital and output. I also study the welfare implications of this program as well as its effects on the intergenerational transmission of poverty.

Our results reinforce the well-known positive outcomes of the Mexican-type conditional cash transfer program. The general equilibrium effects of this program are significant enough such that, in the long-run, the program delivers a remarkable increase in output (6.5%), human capital (6.7%), and years of educa-

tion (10.9%), and a reduction in poverty (21.6%) and income inequality (3.0%). However, I also find that most of these effects may not be observable during the lifetime of the current generation, which implies that the long-term effects of this program are stronger than its short-term effects. This result is due to the demographic feature of the CCT program. The current generation of children, who will get more education as a result of the program, will fully replace the current generation of workers only after all of them die.

Regarding the welfare implications of this program, I find that the aggregate welfare effect is small (0.85%); however, the majority of households will gain in welfare terms after the implementation of the CCT program. Finally, poor parents are able to educate their children by using the resources provided by the CCT program. As a result, the intergenerational correlation of poverty decreases and the program will deliver a noticeable reduction in the poverty trap.

Summing up, the economy-wide effects of a CCT program are significant enough to encourage a long-term implementation of the program in developing economies in which the poverty rate is high.

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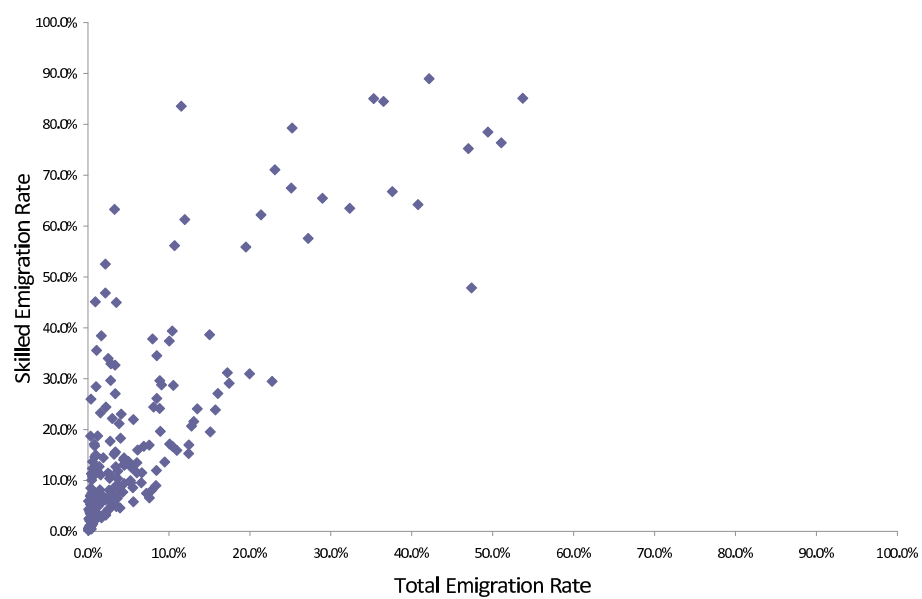
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Appendix A

Additional Material for Chapter 1

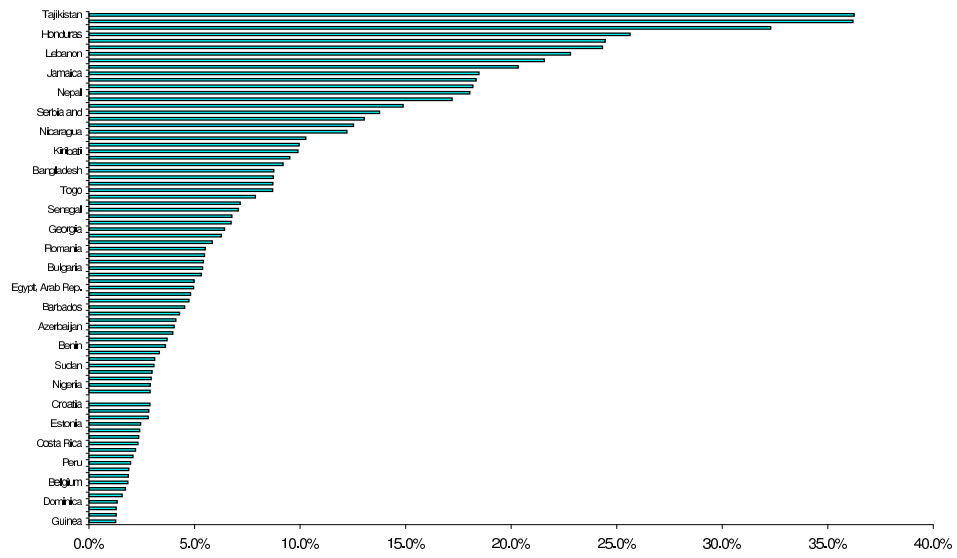
A.1 Migration and Remittances Facts

Figure A.1: Skilled Emigration Rate



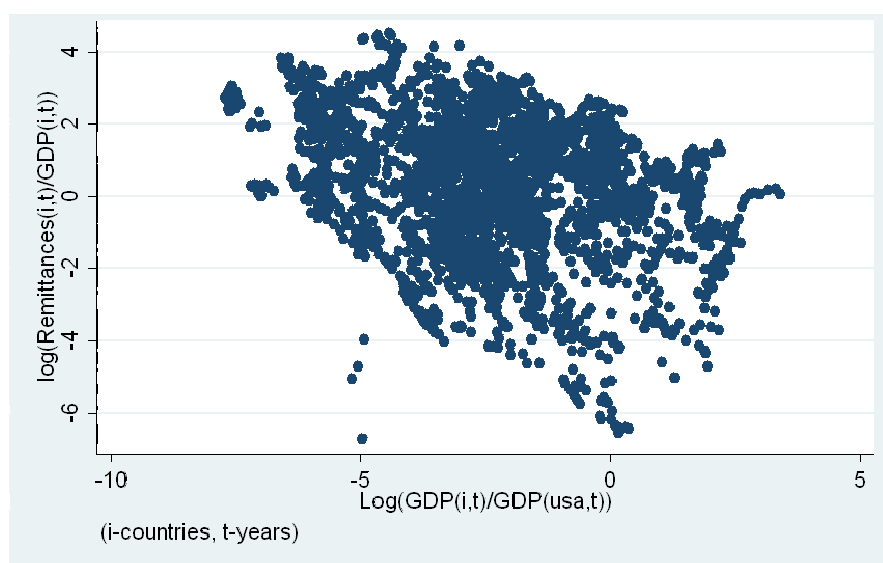
Source: Docquier and Marfouk (2005).

Figure A.2: Remittances as % of GDP



Source: IMF(2008).

Figure A.3: **The Insurance Component of Remittances Worldwide: De-**
veloping economies from 1980 to 2009



Source: Data from IMF (2008) and Docquier and Marfouk (2005).

A.2 Computing the Optimal Solution

I describe the procedure to compute the optimal solution of the problem of a household with a migrant abroad who sends remittances. 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,

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

The first-order conditions of this problem are:

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

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

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

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

$$\tilde{c} = c$$

$$Re = \bar{w}_{ik} - c$$

Steps to compute solution

I 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 $\hat{c}(a, a')$.
- Plug $\hat{c}()$ into 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 I follow the two-step comparative advantage mechanism.

- Use the calculated value functions as a new initial guess and repeat the procedure until convergence.

A.2.1 Computing the general equilibrium solution

I solve for prices (wages and the 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 the 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 productivity of each factor delivered by the model. Compute the average years of education and the aggregate tax revenues delivered by the model.
- Compare each factor's marginal productivity, 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.2.2 Computing the stationary distribution

I 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: $|\mu_i^{(0)} - \mu_i^{(1)}| < \varepsilon$.
- Repeat the procedure for each household type.

A.3 Computing the Competitive Transition

I 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} .
- I 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 productivity of each factor, lump-sum transfer and years of education; call them: $r^{new}, w_S^{new}, w_U^{new}, \Lambda_1^{new}, s^{new}$.
- Verify convergence criterion; stop if

$$\max \{ |r^{old} - r^{new}|, |w_S^{old} - w_S^{new}|, |w_U^{old} - w_U^{new}|, |s^{old} - s^{new}|, |\Lambda_1^{old} - \Lambda_1^{new}| \}$$

is small enough.

- Iterate until convergence; update the initial guess by using the average between the old and new values.

Table A.1: Moments

Moments	Data	Model
Capital/Output	2.2	2.09
Skilled migration rate	17.0%	19.8%
Unskilled migration rate	6.0%	5.5%
Migration cost/Labor income	0.5	0.50
Skill Premium	5.5	4.71
Aggregate labor income share	0.7	0.72
Income standard deviation (log)	1.1	0.97
$Income^{USA}/Income^{Source}$	~ 8.0	7.30

A.4 Parameters of the Model with Migration

Table A.2: 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
<u>Technology</u>		
	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%
<u>Productivity process</u>		
	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	\bar{w}_S	1.750
Unskilled wage abroad	\bar{w}_U	0.625
Tax rate	τ	0.10
<u>Human capital</u>		
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 Tables of Results

Table A.3: 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	-14.4
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
Per capita 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 premium	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 deviation (log)	0.565	0.561	-0.8

Table A.4: 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
Per capita 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 premium	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 deviation (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 A.5: 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

Table A.6: **Measuring the Effects of Policies Against a Brain Drain** (% change with respect to the model with migration)

	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
Per capita 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 premium	-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 Additional Figures

Figure A.4: Competitive Transition Dynamics after Migration Shock

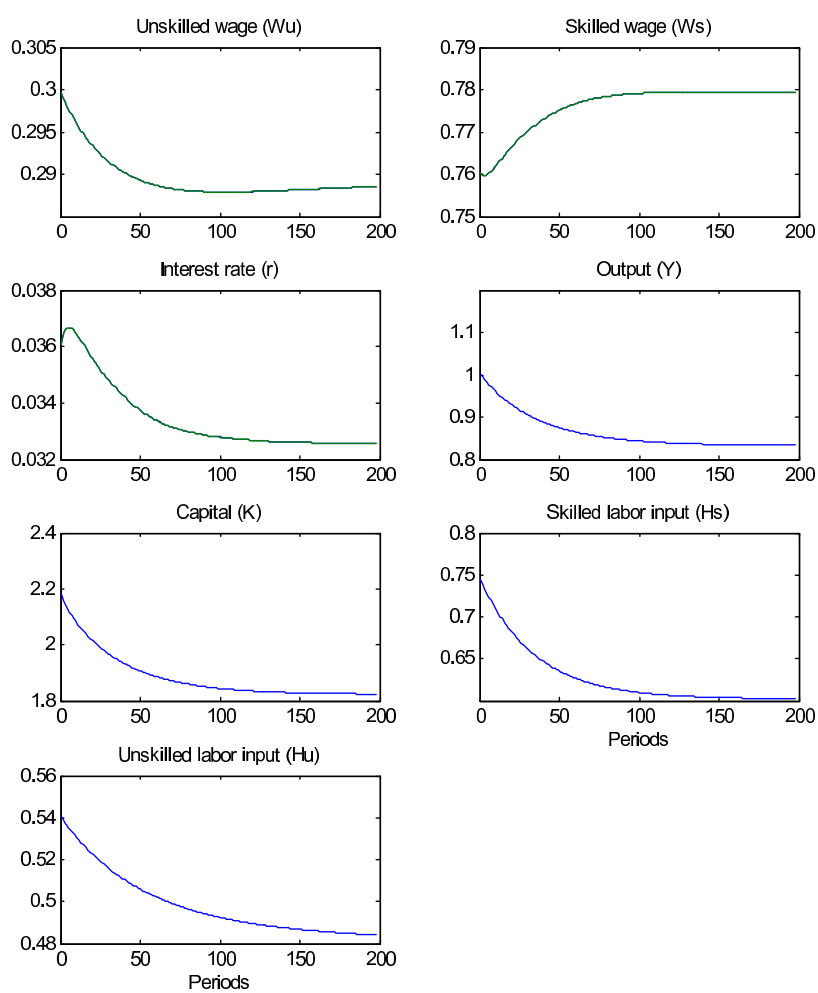
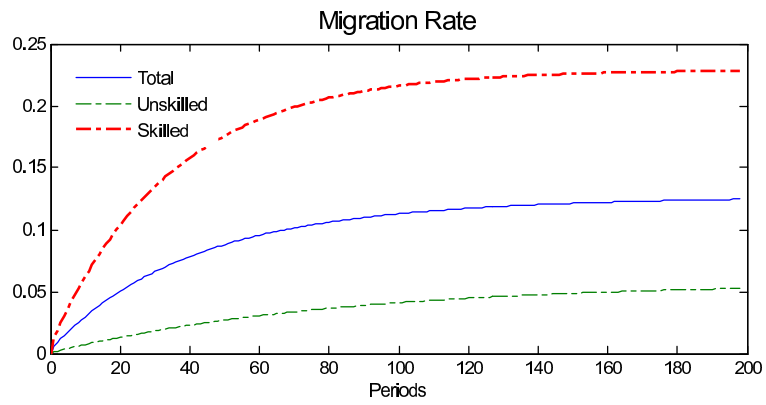
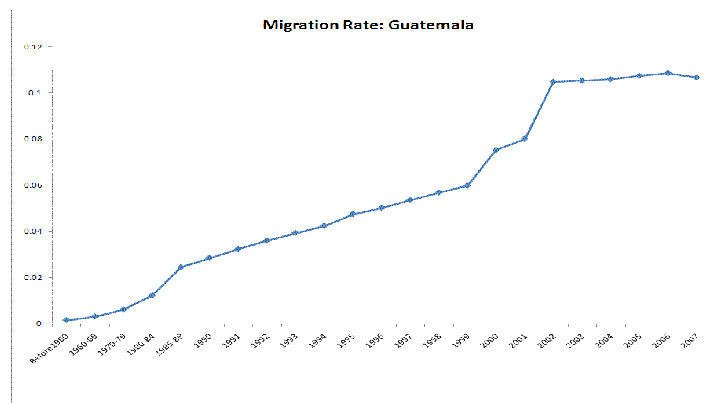


Figure A.5: Transition Path of Migration Rate



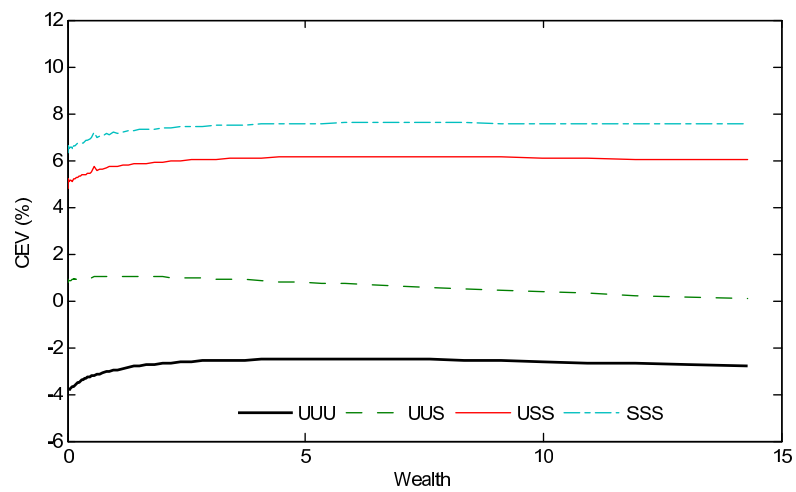
Source: Encuesta Sobre Remesas 2007.

Figure A.6: Migration Rate in Guatemala (%)



Source: Encuesta Sobre Remesas 2007.

Figure A.7: CEV by Household Wealth (% Change)



Appendix B

Additional Material for Chapter 2

B.1 Computing the Steady-State Solution and the Competitive Transition

Steps to compute the stationary competitive solution

- Choose an initial guess of the value function in period 30. Initialize parameters of the model: consider an initial set of prices (wage and interest rate), initial average years of education and an initial value of the lump-sum transfer.
- Solve the household's problem for the remaining periods by backward recursion. At period 29, for example, the value function of period 30 is given by the initial guess. In this step I use the first-order conditions of the household's problem to solve for hours of work. I use value function iteration with local search in order to solve for the household's optimal decision rules. The optimal policy rules are saving, consumption, parent hours of work, child hours of work and child's schooling decision.
- For the given set of prices, parameters and policy rules, solve for the stationary distribution. The stationary distribution is computed by the transition matrix method.

- Compute aggregate indicators (capital, labor), compute the marginal productivity conditions (marginal productivity of labor and capital) and the average years of education. Compare them with the initial prices and average years of education considered to solve the model (initial values).
- Iterate for a different set of prices, lump-sum transfers and average years of education until convergence, that is, when the competitive prices are equal to the corresponding marginal productivity conditions. I also iterate over the lump-sum transfer such that the government budget balances.

Steps to compute the competitive transition

- Compute both the baseline steady-state equilibrium (UCT model) and the final steady-state equilibrium (CCT model).
- Fix the length of the transition, say, $T = 200$.
- Guess an initial path or sequence of the following: prices, tax rate and average years of education; denote them by: $\Phi^{old} = [r^{old}, w^{old}, tax^{old}, S^{old}]$.
- Given the final steady-state solution and the sequence of prices, tax rate and years of education, solve for the whole sequence of value functions and policy rules along the transition path by backward recursion.
- At $t = 0$ the stationary distribution corresponds to the baseline solution. Compute (update) the distribution at $t = 1$ by using the previously estimated policy rules and the baseline distribution. Following a similar updating procedure, estimate the distribution for each of the 200 periods.
- Given the distribution and policy rules for each period I calculate aggregate variables and the model-generated path of prices, tax rate and the average years of education. Denote them by: $\Phi^{new} = [r^{new}, w^{new}, tax^{new}, S^{new}]$.
- Verify convergence criterion: stop if $|\Phi^{old} - \Phi^{new}| < \varepsilon$.
- If the convergence criterion does not hold, let $\Phi^{old} = 0.5(\Phi^{new} + \Phi^{old})$ and repeat the procedure from step 4 until the convergence criterion is reached.

B.2 Parameters of the Baseline Solution: UCT

Table B.1: **Parameters of Baseline Solution**

Description	Parameter	Value
Preferences	β	0.916450
	σ	1.4
	B_p	30
	B_k	55
	ψ	0.30
Technology	z	1
Capital share	θ	0.33
Ph. capital depreciation	δ_k	0.065
Low skill labor share	χ_1	0.25513
Elasticity of substitution	$\frac{1}{1-\gamma}$	2.0
Productivity shock	$\rho_p = \rho_k$	0.65
	$\sigma_p = \sigma_k$	0.75
	ρ_{pk}	0.685
Human capital externality	ϕ_0^*	0.0037
	ϕ_{01}	$\log(0.9/4)$
	ϕ_{02}	$\log(1/4) - \log(0.9/4)$
	ϕ_{11}	0.074
	ϕ_{12}	0.0118
	ϕ_2	0.022
	ϕ_3	-0.00027
Tax rate	τ	0.07
Number of types	N	2
Education expenses	$cost_{pr}$	0.005
	$cost_{se}$	0.006
	$cost_{te}$	0.498
Poverty line	<u>line</u>	0.101

B.3 Estimation of Human Capital Production Equation

The human capital production function that we estimate is the standard Mincer¹ equation that relates the log of labor income per hour with schooling and experience $\text{Log}(H_t) = \phi_{01} + \phi_{02}Ab_t + \phi_{11}S_t + \phi_{12}S_tAb_t + \phi_2X_t + \phi_3X_t^2 + u_t$. I consider that this equation is different for high-ability and low-ability agents. Ab_t is a dummy variable that takes the value of one for high-ability agents and zero otherwise. Schooling denotes the years of education and experience denotes the individual's potential experience ($age - 6 - schooling$). I estimate the parameters of the Mincer equation by using the MxFLS household survey. This survey is a longitudinal survey with a panel structure available for 2002 and 2005. I use this survey since the panel structure allows estimating both the parameters of the Mincer equation and the parameters of the autoregressive process of the productivity shock. I proceed in two steps. First, I estimate the Mincer equation parameters by using standard OLS. Second, I use the estimated residuals of this first-step estimation in order to estimate the parameters of the autoregressive process. The first-step estimation is presented in Table B.2.

The available information does not allow us to directly estimate the parameters of the autoregressive $AR(1)$ process. However, since we have information for two periods (2002, 2005) we may be able to estimate an auxiliary process, $AR(3)$, that will later be used to recover the parameters of the $AR(1)$ process. Our autoregressive process is the following $\text{Log}(v_t) = \varphi\text{Log}(v_{t-1}) + \varepsilon_t$, and the available data allow us to estimate the following process $\text{Log}(v_t) = \tilde{\varphi}\text{Log}(v_{t-3}) + \tilde{\varepsilon}_t$. From the latter equation I may recover our underlying parameters by using the following relationship between the two processes: $\varphi = \tilde{\varphi}^{1/3}$ and $\sigma_\varepsilon^2 = \frac{\sigma_{\tilde{\varepsilon}}^2}{1 + \varphi^2 + \varphi^4}$. Note that v_t and v_{t-3} are the residuals that were estimated from the first-step estimation of the Mincer equation. Table B.3 shows the results of the second-step estimation (OLS).

¹See Heckman et al. (2003) for an interesting review of the literature on the Mincer equation

Table B.2: **Estimated Parameters of the Mincer Equation**

Log of labor income per hour		
$Log(H_t) = \tilde{\phi}_{01} + \tilde{\phi}_{02}Ab_t + \tilde{\phi}_{11}S_t + \tilde{\phi}_{12}S_tAb_t + \tilde{\phi}_2X_t + \tilde{\phi}_3X_t^2 + v_t$		
<i>Constant</i>	$\tilde{\phi}_{01}$	2.0921 (0.0716)*
<i>Ability</i>	$\tilde{\phi}_{02}$	0.06179 (0.06307)
<i>Schooling</i>	$\tilde{\phi}_{11}$	0.06970 (0.00645)*
<i>Schooling * Ability</i>	$\tilde{\phi}_{12}$	0.01457 (0.00727)*
<i>Experience</i>	$\tilde{\phi}_2$	0.01602 (0.00406)*
<i>Experience²</i>	$\tilde{\phi}_3$	-0.00018 (0.00008)*
Sample Size		4492
R^2		0.13

*/ Standard deviation in parenthesis.

OLS estimation from MxFLS 2002,2005.

Table B.3: **Estimated Parameters of the Productivity Shock**

AR(3) Process	
$Log(v_t) = \tilde{\varphi}Log(v_{t-3}) + \tilde{\varepsilon}_t$	
$\tilde{\varphi}$	0.206 (0.031)**
$\sigma_{\tilde{\varepsilon}}^2$	0.91
R^2	0.06

*/ Standard deviation in parenthesis.

B.4 Comparison of Baseline Model and Data Moments

Table B.4: Summary of Moments

Moments	Data	Model
Capital / Output	3.00	3.14
Consumption / Output	0.80	0.80
Taxes / Output	5.0%	5.6%
Hours of work	0.40	0.39
Poverty rate	23%	24.1%
Gini (Consumption)	0.53	0.49
Education spending / Consumption	4.0%	3.1%
Correlation of parent-child income	0.50	0.485
Years of education	9.5	9.96
Education of adults		
Primary	27.0%	31.1%
Secondary	57.6%	53.9%
Tertiary	15.4%	15.1%

Table B.5: Parameters of the Hourly Labor Income Mincer Equation

Parameters	ϕ_{01}	ϕ_{02}	ϕ_{11}	ϕ_{12}	ϕ_2	ϕ_3
Model-generated values	-1.3630	0.0994	0.0693	0.0128	0.0150	-0.00016
Targeted values	-1.4917	0.0834	0.0697	0.0146	0.0162	-0.00018

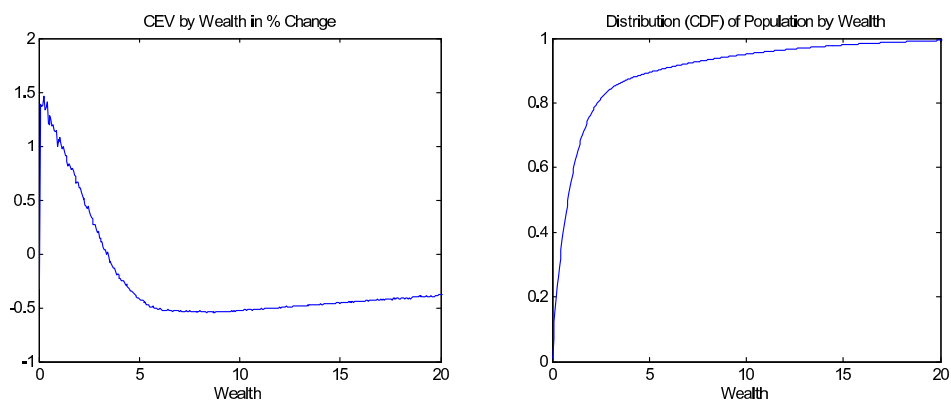
Table B.6: Long-term Effects of CCT

	UCT	CCT	% Change
Human capital	0.748	0.798	6.7
Consumption	0.520	0.552	6.2
Hours parents	0.386	0.386	-0.02
Hours child	0.192	0.178	-7.3
Secondary enrollment rate	0.69	0.89	29.4
College enrollment rate	0.22	0.20	-7.4
Years of education	9.96	11.1	10.9
<u>Education of adults</u>	<u>100.0%</u>	<u>100.0%</u>	
Primary	31.1%	10.8%	-65.1
Secondary	53.9%	71.1%	32.0
Tertiary	15.1 %	18.0%	19.8
Poverty rate	24.1%	18.9%	-21.6
Gini	0.485	0.470	-3.0
CEV			0.85
Output	0.65	0.70	6.5
Capital	2.05	2.18	6.0
Labor	0.37	0.40	6.8
<u>Prices</u>			
Interest rate	0.0400	0.0405	1.2
Wage (Unskilled)	0.2170	0.2174	0.2
Wage (Skilled)	1.0292	1.0235	-0.6
Aggregate transfers			
Lump-sum transfer	0.0354	0.0354	
Anti-poverty transfer	0.0010	0.0035	
Tax rate	7.00%	7.46%	
Tax revenues	0.0364	0.0388	

CCT: Conditional on both poverty and schooling attendance.

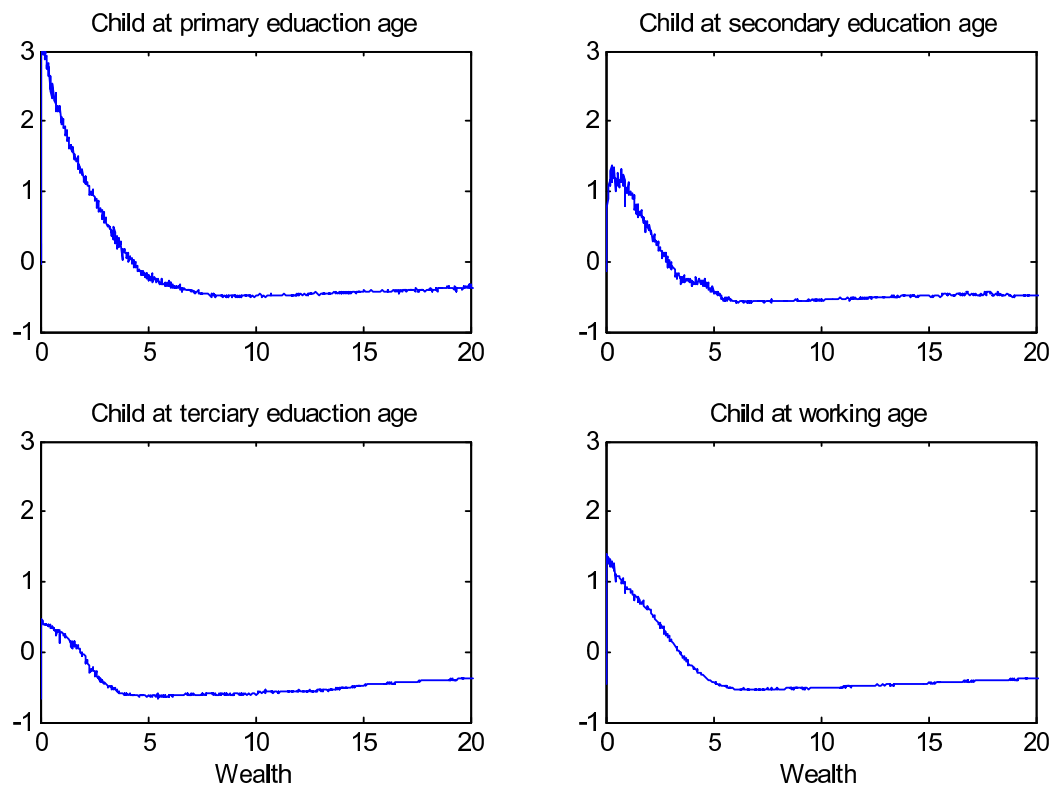
UCT: Conditional on poverty only.

Figure B.1: Consumption Equivalent Variation by Wealth (%)



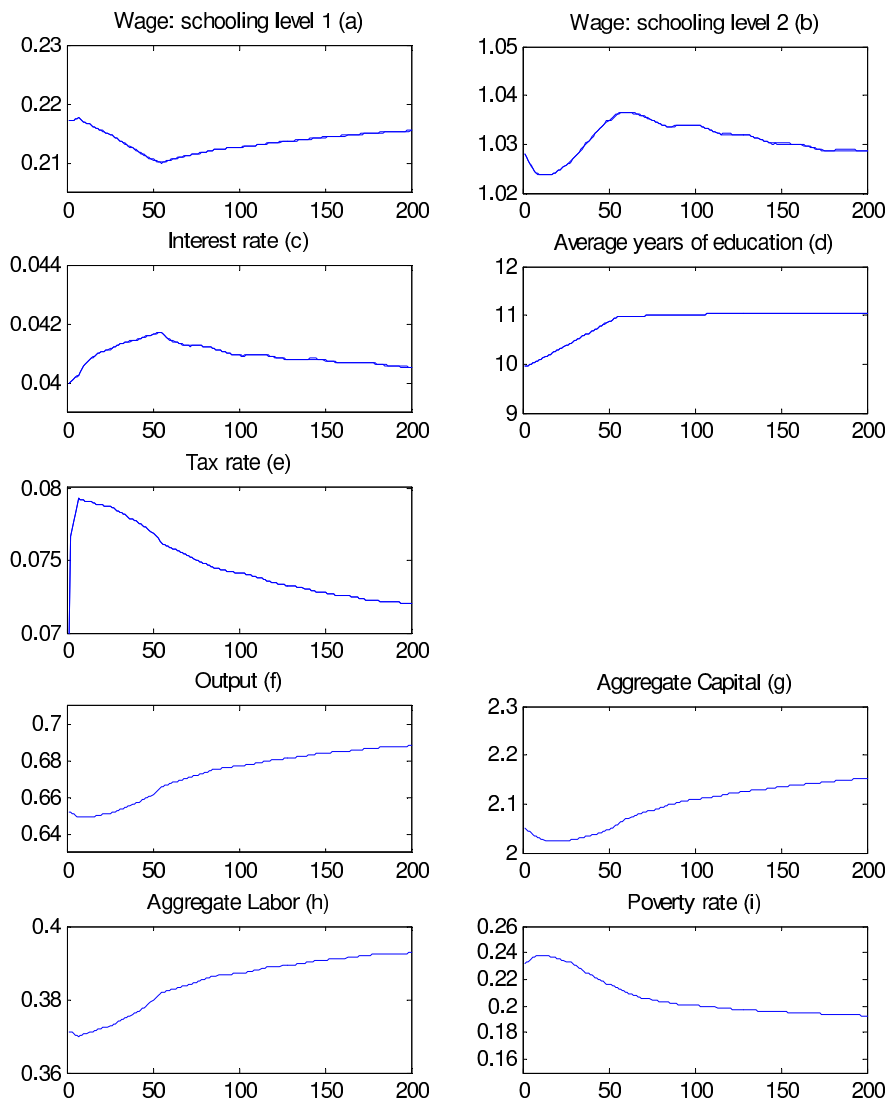
B.5 Welfare Effects of CCT: Consumption equivalence variation by wealth and age

Figure B.2: CEV in % Change by Child Age



B.6 The Competitive Transition Path

Figure B.3: Competitive Transition



B.7 Intergenerational Transmission of Poverty

Table B.7: Correlation of Parent and Child Labor Income

	UCT	CCT	% Change
$Corr[\log(Inco_p), \log(Inco_k)]$	0.485	0.470	-3.0%

Table B.8: **Distribution of Population According to Poverty Situation** (in % of Population)

	Baseline	2nd Generation		3th Generation		4th Generation	
	All	Poor	No-Poor	Poor	No-Poor	Poor	No-Poor
Poor	23.3	6.5	16.8	5.8	17.5	5.5	17.8
No-Poor	76.7	13.5	63.2	13.0	63.7	12.6	64.1
All	100.0	20.0	80.0	18.8	81.2	18.1	81.9

The baseline distribution represents the poverty status at period zero.

The 2nd generation represents the poverty status of the panel of individuals at period 60.

Similarly, the 3th and 4th generations correspond to periods 120 and 180, respectively.

/* Results correspond to a simulated panel of individuals along the competitive transition.

Table B.9: **Distribution of Parents' Education According to Generations** (in % of Population)

Education	Baseline	2nd Generation			3th Generation			4th Generation		
	All	P	S	T	P	S	T	P	S	T
P	31.1	5.2	25.1	0.8	4.3	24.8	2.0	4.0	24.2	2.8
S	51.6	6.3	39.9	5.4	5.9	37.9	7.7	5.7	37.0	8.9
T	17.3	0.1	5.5	11.7	0.4	7.0	9.9	0.6	7.8	8.9
All	100.0	11.6	70.3	18.1	10.7	69.7	19.6	10.4	69.0	20.6

P: Primary education. S: Secondary education. T: tertiary education

The baseline distribution represents the distribution of parents' education at period zero.

The 2nd generation represents the education distribution of the panel of individuals at period 60.

Similarly, the 3th and 4th generations correspond to periods 120 and 180, respectively.

/* Results correspond to a simulated panel of individuals along the competitive transition.