Increasing Wage Inequality in Latin America in the 1990s: Credit Constraints or Growing Demand for Skill? Explorations with a Dynamic Equilibrium Model.*

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September 2007
PRELIMINARY AND INCOMPLETE
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Abstract

In the decade of the 1990s Latin American Countries have been characterized by a significant process of educational expansion towards Intermediate education and a sharp increase in the wage premium to Higher education. All the studies up to now have adopted a partial equilibrium approach focusing either on the supply or on the demand side of the economy and no definite conclusion has been reached on the determinants of the inequality increase. The correct answer can only be given within framework that accounts for the impact of both supply and demand-side factors. This paper provides such a framework. We develop and simulate a dynamic general equilibrium model of savings and investment in education under credit constraints that we use to evaluate the relative importance of exogenous changes in the production technology and in the level of credit constraints to explain the inequality increase. The model is estimated using micro data from Mexico between 1987 and 2002. The results of the simulations suggest that a skill-biased change in the production technology has been a fundamental factor behind the increase in the relative returns to Higher education observed in Mexico in the 1990s. Credit constraints alone, even at the maximum binding level of no possible borrowing, can not produce an equilibrium wage profile that is a convex function of the level of education. However, they affect the magnitude of the increase in the skill premium. The results show the existence a positive relationship between the level of credit constraints and the size of the wage premium: the more the individuals can borrow, the lower is the relative return to Higher education given the increased investment in human capital that becomes possible when the credit constraints are relaxed.

Key Words: Latin America, Wage Inequality, Investment in Education, General Equilibrium.
JEL Codes: J23, J24, J31,C68.

*Address: Institute for Fiscal Studies, 7 Ridgmount Street, London WC1E 7AE. Email: c.binelli@ucl.ac.uk. I thank Orazio Attanasio for many helpful comments and discussions. I also thank Lars Nesheim, Giovanni Gallipoli and Maria Casanova for useful comments. A previuos version of the paper circulated under the title "Wage Inequality and Schooling Investment in Latin America: a General Equilibrium Approach". All remaining errors are mine.

1 Introduction

In the decade of the 1990s Latin American Countries (LACs) have been characterized by a massive process of educational expansion. Primary education became almost universal and the share of individuals with completed Intermediate education increased from around 15 per cent at the beginning of the 1990s up to 25 per cent by the end of the decade. On the contrary, less progress was made at Higher education. The supply increase at Intermediate level did not translate into a proportional increase at Higher education and the share of College graduates remained below 15 per cent in all main LACs.[1]

At the same time, the distribution of income remained highly unequal and wage differentials between high and low educated significantly increased. Throughout the 1990s the Gini coefficient for Latin America was more than 20 per cent higher than the level that would have been proportional to the region per capita GDP: income inequality was "excessive" and highly persistent.[2] The main determinant of the excess inequality were widening gaps in the remuneration of labour at different levels of education. Between 1987 and 2002 relative wages at Higher education increased by around 21 per cent in Brazil and Colombia and up to 72 per cent in Mexico while relative wages at Intermediate education decreased by around 32 and 11 per cent in Brazil and Colombia and by 15 per cent in Mexico. As a consequence, returns to schooling become more convex, with proportional increases in education translating into higher than proportional increases in income for the more educated.

The increase in the relative returns to Higher education has been the subject of a vast empirical literature that has investigated the factors behind the increase in wage inequality. Two main explanations have been developed: "supply-side" explanations that focus on constraints on educational choices and self-selection on ability and "demand-side" explanations that relate the rise in wage inequality to changes in production technology and opening to trade that favoured skilled labour.

Disregarding which explanation has been favoured, all the studies up to now have adopted a partial equilibrium approach considering only one side of the economy and no attempt has been made to evaluate the relative importance of the supply and demand-side factors to explain the inequality increase. The results rely on the assumptions made on the side of the economy that is not explicitly modelled, so it maybe comes at no surprise that no definite conclusion has been reached on the determinants of the inequality increase. The correct answer can only be given in a framework that is able to account for the impact of both supply and demand-side factors. The aim of this paper is to provide such a framework.

We develop and simulate a dynamic model of saving and educational choices that we use to assess the impact of a skill-biased technological shift in aggregate production on the relative returns to schooling

[1] In the year 2000 the proportion of College graduates in Brazil and Colombia was around 11 per cent and around 7 per cent in Mexico. As a benchmark comparison, the corresponding figures for the UK and the US in the same year were, respectively, 27 and 37 per cent (see OECD Education at a Glance, 2002).

[2] See London and Szekely (2000).

under different levels of credit constraints. To this purpose, the model has two important features: it is a transitional dynamic model and it is of general equilibrium. The dynamic feature is essential given the very nature of wage inequality as the result of changes in the conditions and labour markets dynamics that characterize the economy. For a given set of model's parameters and initial distributions of financial resources and education, we compute the transitional dynamics towards the equilibrium steady state. The comparison between the transition path and the final steady state in the presence and in the absence of a skill-biased technological change for different levels of credit constraints will be used to evaluate the relative importance of exogenous changes in the production technology and in the tightness of the financial constraints to explain the increase in the skill premium.

The choice of modelling savings and education jointly is motivated by the extensive empirical evidence on the interactions between investment in human and physical capital as two alternative consumption-smoothing strategies.[3] The presence of credit constraints captures the role of financial constraints on educational choices. Finally, the model includes unobserved heterogeneity as an important component of earned wages, which produces self-selection on ability as an endogenous model's outcome.

Together with the dynamic nature of the model, the general equilibrium feature is of crucial importance. We assume that the economy is small and open to the international markets taking as given the world interest rate, while the returns to schooling are endogenously determined. They depend on the equilibrium price for each education level, which is affected by the supply changes at all levels and by the degrees of complementarity and substitutability between production inputs.

We assume that the aggregate output is produced using a Cobb-Douglas production function over physical and human capital that is modelled as a CES over three education levels. Consistently with the near-constancy of the share of physical capital in production in LACs in the 1990s,[4] we partial out physical capital and assume there are no complementarities between human and physical capital. Then, given the significant change in the supply of workers with Intermediate education and the steep increase in the relative return to Higher education, we choose a CES specification of the human capital aggregate that allows for complementarities between Intermediate and Higher education.

The production function is estimated using the equilibrium conditions for the skill prices and is used to assess the extent to which the three education levels are substitutable for each other. The degree of complementarity and substitutability between different human capital factors is a key factor determining the direction and the magnitude of the general equilibrium effects.

The parameters of the model are estimated using micro data from Mexico between 1987 and 2002.

[3] Jacoby and Skoufias (1997) develop a theoretical framework showing how in the presence of credit markets imperfections investments in education can be used as a form of self-insurance to smooth consumption and provide an empirical application using Indian data. Fitzismons (2007) finds evidence in the same direction using Indonesian data.

[4] See Bosworth (1998), Harrison (1994) and Hoffman (1993).

Mexico is one of the LACs that experienced the highest increase in wage inequality during the 1990s and underwent a significant process of trade opening and economic restructuring during the decade. Individual-level data from the Mexican Employment Survey are used to estimate the earnings process and the market rewards to each education level which are an input in the estimation of the aggregate production function.

The model is simulated under two counterfactual scenarios characterized by the presence and the absence of a skill-biased technological change (SBTC) for a given degree of credit markets imperfections. We model credit constraints as an exogenous limit on the maximum amount that individuals can borrow and we characterize the skill intensity of the production technology with the values of the shares of skilled human capital factors in production. Our benchmark is an economy with the maximum level of credit constraints (limit zero on net-indebtness) and the factor shares fixed at the estimated values at the end of the 1980s before any SBTC in production took place.

The results of the benchmark model without SBTC are compared with the SBTC scenario where the shares of skilled labour in aggregate production are increased by an amount that reflects the technological shift in production towards skilled labour derived from the estimation of the production function. We then compare the results obtained from the simulations in the presence and in the absence of SBTC for different levels of credit constraints. In each scenario the changes in composition are endogenously captured by changes in the ability distribution by education group.

The results of the simulations suggest that a skill-biased change in aggregate production has been a fundamental factor behind the increase in the relative returns to Higher education. The rise in wage inequality observed in Mexico in the 1990s appears to be the result of an excess demand for skill. In the absence of skill-biased technological change the model predicts a quasi-linear relationship between log wages and education. Credit constraints alone, even at the maximum binding level of no possible borrowing, can not produce an equilibrium wage profile that is a convex function of the level of education. However, they affect the *magnitude* of the increased return to Higher education and therefore the *extent* of the convexification. The results show a positive relationship between the level of credit constraints and the size of the skill premium: the more the individuals can borrow, the lower is the relative return to Higher education given the increased investment in human capital that becomes possible when the credit constraints are relaxed.

To the best of our knowledge, this paper is the first attempt to study the changes in wage inequality in Latin America with an estimable general equilibrium model of savings and educational choices. The model provides a comprehensive framework to evaluate the results of the partial equilibrium literature that has developed supply or demand-side explanations of the inequality increase.

On the one hand, the "supply-side" literature focuses on financial constraints that restrict access to

Higher education and on individuals' ability as a determinant of earnings. If credit constraints prevent free access to Higher education and ability is an important component of wages, at any point in time the convexity of the wage profile might simply reflect dynamic self-selection, a composition effect of higher ability into higher education. The increased convexification observed in the 1990s could then be explained by the shifts in the education distribution that reinforced the self-selection effect: higher graduation rates at Intermediate level decreased the mean ability at this level and increased the ability gap with respect to Higher education.

This first strand of literature is rather small mainly due to the limited availability of data for LACs. Among the main contributions are Binelli, Meghir and Menezes-Filho (2007) for Brazil and Jacoby and Skoufias (2002) for Mexico. Both papers find evidence of positive self-selection on ability into Higher education. However, changes in composition can not fully account for the observed increased in the return to skill and credit constraints seem to be the main determinants of educational choices. Binelli, Meghir and Menezes-Filho (2007) quantify the magnitude of the changes in composition due to the significant educational expansion at Intermediate level observed in Brazil in the 1990s. They find evidence of sizeable compositional changes but the changes in composition can not account for the big increase in the College premium. Their results show that financial and quality constraints play an important role: declining schooling quality at intermediate levels of education and binding liquidity constraints can explain both the inability of students to enter and to successfully complete College. Jacoby and Skoufias (2002) investigate the importance of self selection into Higher education in Mexico in the second half of the 1990s. They find evidence of credit constraints and weak evidence of selection bias.

On the other hand, the "demand-side" literature focuses on the impact of trade liberalization and a series of labor market reforms promoted in Latin America in the 1990s that produced an exogenous shift in aggregate production towards skilled labour, which resulted into an increase in the skill premium.

This second strand of literature is vast and counts on many different contributions for each Latin American country.[5] The results are generally suggesting the existence of a significant positive impact of skill-biased technological change and/or opening to trade on the skill premium.[6] Behrman, Birdsall and Szekely (2000) have performed an overall evaluation of the major market reforms that characterized LACs in the 1980s and 1990s. They construct six indexes for six main policy reforms and use a panel data set on eighteen LACs for the period between 1980 and 1998 to estimate the impact of the reforms on the relative wages to Higher versus Primary and to Higher versus Intermediate education.[7] The

[5] See, among the many others, Attanasio, Goldberg and Pavcnik (2002) for Colombia, Corseuil and Muendler (2003), Pavcnik, Blom and Goldberg (2002) and Giovannetti and Menezes-Filho (2006) for Brazil, Cragg and Epelbaum (1996) and Hanson and Harrison (1999) for Mexico.

[6] Goldberg and Pavcnik (2004) and Winters, McCullach and McKay (2004) provide two exhaustive surveys of the literature.

[7] The six reforms they consider are: privatization of former state enterprises, trade liberalization, capital account liber-

results indicate that domestic financial market reform, capital account liberalization and tax reform had a short-run disequalizing effect while privatization contributed to narrowing wage differentials and trade openness had no effect on wage differentials. Overall, the results suggest that technological progress, rather than trade flows, is the channel through which reforms are affecting wage inequality.

The remainder of the paper is organized as follows. Section 2 presents some empirical evidence on excess inequality and returns' convexification. Section 3 presents the economic model and section 4 defines and characterizes the equilibrium and its properties. Section 5 discusses the estimation and calibration of the model. Section 6 presents the results from the policy simulations and performs a sensitivity analysis. Section 7 gives some concluding remarks.

2 Excess Inequality and Returns' Convexification

In the decade of the 1990s Latin American Countries have been characterized by high and persistent levels of income inequality. Table 1 in Appendix 3 reports the value of the Gini coefficient for three main LACs at the beginning of the 1990s and ten years later together with the corresponding values for the EU-15 and the US.

Throughout the decade the Gini index for Latin America was at an average level of 0.53 without any significant tendency to decline. The index for each of the three main LACs is significantly higher up to double the size the value of the index for the European countries. It is also higher than the US index, even if with a decreasing margin given the sharp rise in inequality that characterized the US economy in the 1990s.

Changes in returns to schooling have been a major factor behind the increase in income inequality. In all LACs relative wages to Higher education significantly increased, while the relative premium to Intermediate education fell substantially. Returns to schooling have became more convex with proportional increases in education translating into higher than proportional increases in income for the more educated.[8]

Table 2 in Appendix 3 presents the value of the relative wage to Higher and Intermediate education at the end of the 1980s and at the beginning of the decade following the 1990s for three main LACs. The premium to Higher education is substantial: in 2002 it is around one hundred per cent in Brazil and Colombia and around sixty five per cent in Mexico. This value is much higher than the corresponding figure for developed countries. For example, Carneiro, Heckman and Vytlacil (2005) find a value for the College premium in the US of around 15-20 per cent. Together with a sharp increase in the relative return to Higher education the table shows a sharp decline in the relative premium to Intermediate education.

alization, domestic financial market liberalization, tax reforms and labor market reforms.

[8] The convexity of the wage function contrasts with the evidence on concave returns to schooling found in most developing countries including Latin America in the 1980s and 1970s and summarized by Patrinos and Psacharopoulos (2004).

In the rest of the paper we focus on Mexico, that is one of the LACs that experienced the highest increase in inequality in the 1990s. The data on wages come from the Mexican Employment Survey, ENEU (*Encuesta Nacional de Empleo Urbano*), collected by Mexican national statistical office. A description of the Survey together with details on the construction of the education groups is presented in Appendix 1. Figure 1 in Appendix 3 presents the logarithm of the real after-tax annual wage by education at the end of the 1980s and in 2002. Returns' convexification is apparent: from a quasi linear relationship in 1987, in 2002 wages have become a convex function of the level of schooling. An alternative way of looking at returns' convexification is considering changes in relative wages over time. Figure 2 in Appendix 3 presents the log relative wages between 1987 and 2002. As can be seen from the graph, relative wages to Higher education followed an upper sloping trend both with respect to Intermediate and to Basic education. On the contrary, relative wages to Intermediate versus Basic education declined.

Variations in relative wages reflect changes in relative supply and demand of different production factors. Figure 3 in Appendix 3 shows the evolution of relative supply by skill pairs. Although in 2002 a high share of the population still belong to the low-education group, the figure shows a significant progress towards skill upgrading with a steadily increasing trend in the relative supply both at Intermediate and at Higher education.[9] The upward-sloping trend at Intermediate level is consistent with decreasing relative wages for this education group. On the contrary, the increase in relative wages at Higher education is evidence of a demand for high skilled workers that more than outweighed the supply increase for this group.

3 The model

The economy starts at some initial year t. In each year it consists of overlapping generations of parents and children that live together for a fixed number of periods corresponding to the number of years necessary to complete all educational levels from Basic to Higher education. At $t = 1$ each cohort schooling and wealth distribution are taken as exogenous initial conditions. From $t = 2$ these distributions evolve endogenously as a result of individuals' maximizing behavior.

Educational investments build up the economy skill endowment. We consider three skill categories according to the completed level of education. The first category corresponds to Basic, the second to Intermediate and the third to Higher education. The three types of skills define different production factors and are denoted, respectively, by S_{be}, S_{ie}, S_{he}, for Basic, Intermediate and Higher education.

[9] According to the ENEU, in 1987 77, 14 and 9 per cent of the working population aged 26-60 belong, respectively, to the first to the third education group. In 2002 these proportions changed to, respectively, 61, 21 and 18 per cent.

3.1 Supply Side: Household Decision Problem

Each individual lives for nine periods, four as a child and five as an adult. As a child, the individual lives with a parent that works full time and maximizes utility which is a function of joint household consumption. In the first period of life the child is in pre-school age and can not be sent to work. In the second period the child attends compulsory Basic education. In the third and fourth periods education becomes a choice variable and the parent chooses each period whether to send the child to school or to work. The child can always return to school after a period spent working. If sent to work, the child works full time and gives her earnings to the parent. At the end of the last period of coresidence the parent retires and leaves a bequest of financial assets to the child.

The young adult starts the adult life with an amount of cash-in-hand that is a function of the level of education and the amount of assets given by the parental bequest. We assume that investment in human capital is done during childhood and individuals can not return to school once adults, so that the educational endowment of an individual is entirely determined by parental investment decisions. The young adult lives alone for one period and then becomes a parent living with the child until retirement.

We assume that there is no unemployment and everybody can find a job at the market wage corresponding to the level of education she completed. Wages are given by the product of $p_{j,t}$, the equilibrium price for education level j in year t, and $e^i_{j,t}$, which denotes labor efficiency of individual i, with schooling level j, in year t. $e^i_{j,t}$ is a function of η^i, unobserved ability of individual i, $g_j(age)$, a polynomial in age specific to the jth skill group which reflects the growth of wages with experience and $z_{j,t}$, an uninsurable skill-specific shock received in year t.

Let us denote with $w^i_{j,t}$ the wage for an individual i with schooling level j in year t. It takes the following expression:

$$w^i_{j,t} = p_{j,t} * \exp(e^i_{j,t}) \qquad j = be, ie, he \tag{1}$$

with

$$e^i_{j,t} = \eta^i + g_j(age_{it}) + z^i_{j,t} \tag{2}$$

where z is assumed to be normally distributed with mean zero and variance $\sigma^2_{z_{j,t}}$. The individual fixed effect, η, represents the permanent component of human capital. It is a measure of ability and all unobservable family background factors that have a permanent impact on human capital formation and are transmitted from one generation to the next. We assume that it is perfectly transmitted between generations so that children's ability is the same as parental one.[10]

[10] An interesting development of the model could introduce grade progression probabilities between successive education levels that are a function of individuals' ability level.

We assume that individuals have rational expectations and perfect foresight: when making decisions they base their choices on the correct expectations of all future changes in economic conditions. Given the level of ability, own and child education, the amount of cash-in-hand and the sequence of skill prices foreseen over the life cycle, each period the adult maximizes the expected present value of lifetime utility by choosing how much to save and whether to send the child to school or to work after completion of Basic (compulsory) education. There is an altruistic motive for educational investments: the parent positively values child lifetime utility that enters directly into parental optimization problem and is a positive function of the level of ability, education and the amount of assets inherited from the parent.

Denoting with $\underline{a}$ and $\overline{a}$, respectively, the age in the first and last period of adult life before retirement, with k the number of periods the child and the adult live together and assuming preferences are intertemporally additive, adult maximization problem at age $\underline{a}$ in year t reads:

$$\max_{\{c_a, I_a\}_{a=\underline{a}}^{a=\overline{a}}} E\left\{\sum_{a=\underline{a}}^{\overline{a}} \beta^{a-\underline{a}} * n_a * U_t(\frac{c_a}{n_a}) + \beta^{\underline{a}} * \lambda * V_{\underline{a},t+k}\right\} \tag{3}$$

where c_a is joint household consumption at age a in year t and n_a is the equivalence scale that adjusts for the consumption needs of the household members present at age a. λ denotes the degree of parental altruism and $V_{\underline{a},t+k}$ is child value function in the first period of adult life. Each period utility is maximized over consumption. After completion of compulsory schooling education becomes a second choice variable. I is an indicator function taking the value one when the child is sent to school and zero otherwise.

Note that $U(.)$ and $V(.)$ are a function of calendar time since the skill prices, $p_{j,t}$, change over time. E denotes expectations that reflect uncertainty due to the presence of the idiosyncratic shocks to earnings and β is the discount factor. The utility function is assumed to be strictly increasing and concave in consumption, so that absolute risk aversion is decreasing in individual's wealth, the impact of risk on investment decisions being higher for poorer than for wealthier households.[11]

In the first year of adult life conditions are as follow:

$$A_{\underline{a}} = A^P_{\underline{a}} \tag{4}$$

$$s_{\underline{a}} = \overline{s} \tag{5}$$

where $A_{\underline{a}}$ and $s_{\underline{a}}$ denote, respectively, the level of assets and the number of years of education in the first period of adult life, and $A^P_{\underline{a}}$ and $\overline{s}$ are the endowment of assets and education left by the parent at

[11] We assume that the utility function takes a simple CRRA formulation:
$U(c) = \frac{(c)^{1-\gamma}}{(1-\gamma)}$
where γ is the reciprocal of the intertemporal elasticity of substitution.

the end of the last period of coresidence. Since investment in education is only allowed during childhood, education remains fixed at level $\overline{s}$ from the first year of adult life until retirement.

Finally, for all cohorts, two conditions are required to hold:

$$A^P_{\overline{a}} \geq 0 \quad (6)$$

$$A_a \geq B \qquad \forall \quad a = \underline{a}, ..., \overline{a} \quad (7)$$

The first equation states a terminal condition that prevents parents from dying in debt: they can not leave debts to their children. The second equation defines a borrowing constraint imposing a limit B on net indebtedness. The liquidity constraint in this model is a simple quantity restriction to the maximum amount an individual can borrow. The return that the parent faces when considering whether to send the child to school is given by the wage differential between two consecutive schooling levels. The parent will prefer schooling to the alternative investment into assets if the return to schooling is bigger than the interest rate on financial assets. If this is the case and the parent does not have enough cash in hand to send the child to school, then there is a liquidity constraint.

3.2 Demand Side: Aggregate Production Function

We assume that the economy is small and open to the world financial markets. As a result, capital will flow into or out of the country so that the marginal product of physical capital will be equal to the world interest rate, $\overline{r}$. Capital mobility between international markets guarantee that if there is "too much saving" relative to the amount that would generate $\overline{r}$ the excess saving is invested abroad and if there is "too little saving" capital comes from abroad.[12]

We assume that aggregate output is produced with a Cobb-Douglas constant returns to scale production function over physical and human capital. Complementarities between physical and human capital are ruled out and K is assumed to be separable over time. This assumption is motivated by the near-constancy of the share of physical capital in production estimated for LACs.[13] We assume there are no adjustment costs for physical and human capital and that there are no shocks to the aggregate production, that is that there is no aggregate uncertainty. The production function in year t is given by:

$$Y_t = Z_t K_t^{\alpha} H_t^{1-\alpha} \quad (8)$$

[12] The constancy of the world interest rate implies that the economy's capital to labor ratio is fixed over time. Specifically, let $\frac{Y_t}{H_t} = f(k_t)$ with $k_t = \frac{K_t}{H_t}$. Then, given the mobility of physical capital, the economy's capital to labor ratio, k, is constant over time: $r_t = f'(k_t) = \overline{r}$, $k_t = f'^{-1}(\overline{r}) = \overline{k}$.

[13] See Bosworth (1998), Harrison (1994) and Hoffman (1993).

where Y_t denotes aggregate output, K_t is aggregate physical capital and H_t is a constant return to scale CES aggregate of the three human capital inputs. α denotes the share of physical capital in production which is assumed to be constant over time and Z_t is the technology factor that is normalized to one in all years.

The aggregate stock of physical capital in year t, K_t, is given by the sum of total asset holdings within the economy, S_t, and the in or out flow of savings from abroad, NI_t, that is:

$$K_t = S_t + NI_t \tag{9}$$

$$S_t = \sum_a \sum_i A_i(a) \tag{10}$$

where S_t is given by the sum of total asset holdings at home over each cohort a and adult individual i in year t and NI_t is the amount of net investment abroad.

The aggregate stock of human capital j in year t, $H_{j,t}$, is given by the sum of the efficiency weighted individual supplies of education level j, $h_{j,i}$, over each cohort a and individual i active in the labor market in year t:

$$H_{j,t} = \sum_a \sum_i h_{j,i}(a) \qquad\qquad j = be, ie, he \tag{11}$$

where $h_{j,i}(a)$ is the supply of education level j of individual i who is of age a in year t weigthed by the individual labor market efficiency index $e^i_{j,t}$ as defined in equation (2) above.

We consider three types of human capital corresponding to the three education levels the individuals can complete and we specify the aggregate human capital in year t, H_t, as a nested CES function over the three education levels. There are three different ways of combining three inputs within a CES production function, depending on the assumptions on the elasticity of substitution (ES) between couples of production factors. By the symmetry of the CES aggregator, each combination restricts an elasticity to be equal to one of the other two.

In the model Basic education is made compulsory in order to reflect the almost universal attainment rates at Primary education achieved in Mexico in the 1990s, which was the result of several programs and policy interventions that enforced compulsory enrollment at this level.[14] On the contrary, as we discussed in section 2, both the supply of workers with Intermediate and with Higher education changed significantly and have been driving the observed increase in the skill premium. Therefore, we choose a

[14] According to the Mexican National Population Census, the enrollment rate at Primary education was around 90 per cent in 1990 and around 93 per cent in the year 2000.

specification that allows for complementarities between Intermediate and Higher education and restricts the ES between Basic and Intermediate education to be equal to the ES between Basic and Higher education.

H_t is specified as it follows:

$$H_t = \left\{\delta_{sk,t} H^{\rho}_{sk,t} + \delta_{unsk,t} H^{\rho}_{unsk,t}\right\}^{\frac{1}{\rho}} \tag{12}$$

where $H_{sk,t}$ and $H_{unsk,t}$ are, respectively, the human capital aggregates for skilled and unskilled labour at time t.

$H_{unsk,t}$ correspond to $H_{be,t}$ while H_{sk} is given by:

$$H_{sk,t} = [\alpha_{he,t} H^{\theta}_{he,t} + \alpha_{ie,t} H^{\theta}_{ie,t}]^{\frac{1}{\theta}} \tag{13}$$

The time-varying and skill-specific parameters δ and α in equations (12) and (13) denote the shares of the human capital factors in the aggregate production. Changes in δ and α reflect variations in production patterns and input requirements over time. The parameter ρ determines the elasticity of substitution (ES) between skilled and unskilled labor, which is given by $ES_{be,ie} = ES_{be,he} = \frac{1}{1-\rho}$, while θ determines the ES between Higher and Intermediate education, which is given by $ES_{he,ie} = \frac{1}{1-\theta}$.

Under the assumption of perfectly competitive markets, the skill price for each skill level j in year t, p_{jt}, is given by the marginal product of the jth aggregate human capital:

$$p_{be,t} = G_t(\delta_{unsk,t}) H^{\rho-1}_{be,t} = \frac{\partial Y_t}{\partial H_{be,t}} \tag{14}$$

$$p_{ie,t} = G_t(\delta_{sk,t})[\alpha_{he,t} H^{\theta}_{he,t} + \alpha_{ie,t} H^{\theta}_{ie,t}]^{\frac{\rho-\theta}{\theta}} \alpha_{ie,t} H^{\theta-1}_{ie,t} = \frac{\partial Y_t}{\partial H_{ie,t}} \tag{15}$$

$$p_{he,t} = G_t(\delta_{sk,t})[\alpha_{he,t} H^{\theta}_{he,t} + \alpha_{ie,t} H^{\theta}_{ie,t}]^{\frac{\rho-\theta}{\theta}} \alpha_{he,t} H^{\theta-1}_{he,t} = \frac{\partial Y_t}{\partial H_{he,t}} \tag{16}$$

where $G_t \equiv Y_t(1-\alpha)\frac{1}{[\delta_{sk,t} H^{\rho}_{sk,t} + \delta_{usk,t} H^{\rho}_{unsk,t}]}$.

Activities of the government are not central to the analysis. The government neither collects taxes nor redistributes them.

4 Equilibrium

This section is divided in three parts. The first part defines the equilibrium of the economy. The second part presents the recursive representation of the equilibrium. The third part discusses the properties of the equilibrium.

4.1 Definition of the equilibrium

In any given period t the equilibrium of the economy is characterized by an exogenous interest rate $\overline{r}$ and a vector of skill prices, $p_t = [p_{be,t}, p_{ie,t}, p_{he,t}]$, such that:

1. for each adult cohort working in period t c_a and I_a optimally solve household's optimization problem subject to the conditions stated in (4) to (7);

2. individuals have rational expectations and make their decisions on the basis of the set of perfectly foreseen p_t;

3. the human capital aggregates are obtained by aggregating over adults' optimal choices according to equation (11);

4. the physical capital aggregate is given by equation (9). Total asset holdings at home are obtained by aggregating over adults' optimal choices according to equation (10). The amount of net investment abroad is given by $NI_t = K_t - S_t$, so that $\overline{r} = \frac{\partial Y_t}{\partial K_t}$;

5. the skill prices satisfy conditions (14) to (16) so that the labour markets clear.

Let us define with $t = 1$ and $t = T$, respectively, the first and the last year of a transition towards the steady state. Given the set of model's parameters and the distribution of ability, wealth and education in year 1, the transition to the steady state is characterized by an equilibrium skill price series $\left\{p^*_{j,t}\right\}_{t=1}^{T} = \left\{p^*_{be,t}, p^*_{ie,t}, p^*_{he,t}\right\}_{t=1}^{T}$ that satisfies conditions (1) to (5) for any t, $t = 1, ..., T$. This is the time path of skill prices that is correctly foreseen by the individuals and induces a path of education supplies that equals the path of demands for each education level forthcoming at these factor prices. When the skill prices and the human and physical capital aggregates are constant from some period t onwards, the economy has reached a steady state.

4.2 Recursive representation of the equilibrium

Let us denote with a adult's age, with $p(a)$ the vector of current and future skill prices up to the last period of life before retirement ($a = \overline{a}$), with $\overline{s}$ adult education that is fixed throughout the adult life, with s^c_a child education at age a, with ch_a the amount of cash-in-hand available at age a and with η individual ability.

In any given year t the vector of state variables at age a, $x\left(a\right)$, is given by $x(a) = (p(a), \overline{s}, s^c_a, ch_a, \eta)$, with s^c normalized to zero when consumption is the only choice variable. Given the maximization problem stated in (3) and the conditions set in (4) to (7), we can write the household maximization problem in the recursive formulation and solve it by value function iterations. In order to simplify the notation, in what follows we omit the subscipt t from the utility and value functions.

For a given vector of prices, the solution method can be summarized by the following steps.

Step 1. Solve the optimization problem in the last period of work life before retirement ($a = \overline{a}$).

Let us define with $V_{\overline{a}}^{Sch}(p(a), \overline{s}, s_{\overline{a}}^{c}, ch_{\overline{a}}, \eta)$ and with $V_{\overline{a}}^{Work}(p(a), \overline{s}, s_{\overline{a}}^{c}, ch_{\overline{a}}, \eta)$, respectively, the conditional value functions of sending the child to school and to work and let us denote with $W_{\underline{a}}^{Sch}(p(a), s_{\underline{a}}, ch_{\underline{a}}, \eta)$ and $W_{\underline{a}}^{Work}(p(a), s_{\underline{a}}, ch_{\underline{a}}, \eta)$ the initial guess for child lifetime utility conditional on having sent the child, respectively, to school and to work, with $\underline{a}$ denoting the age in the first period of adulthood.

Given $W_{\underline{a}}^{Sch}(.)$ and $W_{\underline{a}}^{Work}(.)$, $V_{\overline{a}}^{Sch}(.)$ and $V_{\overline{a}}^{Work}(.)$ take the following expressions:

$$\begin{aligned} V_{\overline{a}}^{Sch}(p(a), \overline{s}, s_{\overline{a}}^{c}, ch_{\overline{a}}, \eta) &= \max_{c_{\overline{a}}} \left\{ U(c_{\overline{a}}) + \lambda * \beta * E_{z_{\underline{a}}} W_{\underline{a}}^{Sch}(p(a), s_{\underline{a}}, ch_{\underline{a}}, \eta) \right\} && (17) \\ s.t. \quad c_{\overline{a}} &= ch_{\overline{a}} - A_{\overline{a}+1} && (18) \\ ch_{\overline{a}} &= A_{\overline{a}}(1 + \overline{r}) + w_{j,\overline{a}}^{Ad} - F_s && (19) \\ s_{\underline{a}} &= (s_{\overline{a}}^{c} + 1) && (20) \end{aligned}$$

$$\begin{aligned} V_{\overline{a}}^{Work}(p(a), \overline{s}, s_{\overline{a}}^{c}, ch_{\overline{a}}, \eta) &= \max_{c_{\overline{a}}} \left\{ U(c_{\overline{a}}) + \lambda * \beta * E_{z_{\underline{a}}} W_{\underline{a}}^{Work}(p(a), s_{\underline{a}}, ch_{\underline{a}}, \eta) \right\} && (21) \\ s.t. \quad c_{\overline{a}} &= ch_{\overline{a}} - A_{\overline{a}+1} && (22) \\ ch_{\overline{a}} &= A_{\overline{a}}(1 + \overline{r}) + w_{j,\overline{a}}^{Ad} + w_{jc,\overline{a}}^{Ch} && (23) \\ s_{\underline{a}} &= s_{\overline{a}}^{c} && (24) \end{aligned}$$

where $\overline{r}$ is the (world) real interest rate on financial assets A, F_s denotes the fixed costs of schooling for education level s and $w_{j,\overline{a}}^{Ad}$ and $w_{jc,\overline{a}}^{Ch}$ are, respectively, adult and child wages at age $\overline{a}$ given adult (child) skill level $j(jc)$. λ denotes the degree of parental altruism and expectations are taken over next period shock to earnings, z. Equations (20) and (24) describe the evolution of child education that increases by one unit if the child is sent to school. The level of child education at the end of the last period of coresidence defines the (fixed) education level throughout adulthood ($s_{\underline{a}}$).

Step 2. Proceed backwards and solve the conditional maximization problems in each period until the first period of adult life.

Before the child is born and in the pre-school period consumption is the only choice variable. The maximization problem is given by:

$$\begin{aligned} V_a(p(a), \overline{s}, ch_a, \eta) &= \max_{c_a} \left\{ U(c_a) + \beta * E_{z_{a+1}} V_{a+1}(p(a), \overline{s}, ch_{a+1}, \eta) \right\} && (25) \\ s.t. \quad c_a &= ch_a - A_{a+1} && (26) \\ ch_a &= A_a(1 + \overline{r}) + w_{j,a}^{Ad} && (27) \end{aligned}$$

In the third period the child is sent to compulsory Basic education. The maximization problem reads:

$$\begin{aligned} V_a(\overline{s}, ch_a, \eta) &= \max_{c_a} \{U(c_a) + \beta * E\max\} && (28) \\ s.t. \quad c_a &= ch_a - A_{a+1} \\ ch_a &= A_a(1+\overline{r}) + w^{Ad}_{j,a} - F_{pr} && (29) \end{aligned}$$

where F_{pr} denotes the fixed costs of Primary education and the $E\max$ operator is defined as the expected value over the maximum between the conditional value functions of the schooling and work alternative in the next period, which is the first period of choice between sending the child to school or to work. It takes the following expression:

$$E\max \equiv E_{z_{a+1}} \max[V^{Sch}_{a+1}(p(a), \overline{s}, s^c_a = be, ch_{a+1}, \eta), V^{Work}_{a+1}(p(a), \overline{s}, s^c_a = be, ch_{a+1}, \eta)]$$

where be denotes completed Basic education.

When child education becomes a choice variable, the conditional maximization problems read:

$$V^{Sch}_a(p(a), \overline{s}, s^c_a, ch_a, \eta) = \max_{c_a} \{U(c_a) + \beta * E\max\_Sch\} \quad (30)$$

$$s.t. \qquad c_a = ch_a - A_{a+1} \quad (31)$$

$$ch_a = A_a(1+\overline{r}) + w^{Ad}_{j,a} - F_s \quad (32)$$

$$s^c_{a+1} = (s^c_a + 1) \quad (33)$$

$$\begin{aligned} V^{Work}_a(p(a), \overline{s}, s^c_a, ch_a, \eta) &= \max_{c_a} \{U(c_a) + \beta * E\max\_Work\} && (34) \\ s.t. \quad c_a &= ch_a - A_{a+1} && (35) \\ ch_a &= A_a(1+\overline{r}) + w^{Ad}_{j,a} + w^{Ch}_{jc,a} && (36) \\ s^c_{a+1} &= s^c_a && (37) \end{aligned}$$

where F_s is the fixed cost of schooling level s and the $E\max\_Sch$ and the $E\max\_Work$ operators define the expected value over the maximum between the conditional value functions of schooling and working in the next period given the decision of sending the child, respectively, to school or to work in the current period.

They take the following expressions:

$$E\max\_Sch \equiv E_{z_{a+1}} \max[V^{Sch}_{a+1}(p(a), \overline{s}, s^c_{a+1} = (s^c_a+1), ch_{a+1}, \eta), V^{Work}_{a+1}(p(a), \overline{s}, s^c_{a+1} = (s^c_a+1), ch_{a+1}, \eta)]$$

$$E\max\_Work \equiv E_{z_{a+1}}\max[V_{a+1}^{Sch}(p(a),\overline{s},s_{a+1}^{c}=s_{a}^{c},ch_{a+1},\eta),V_{a+1}^{Work}(p(a),\overline{s},s_{a+1}^{c}=s_{a}^{c},ch_{a+1},\eta)]$$

Step 3. Compute new initial guesses for $W_{\underline{a}}^{Sch}(.)$ and $W_{\underline{a}}^{Work}(.)$.

The solution of the model in steps one and two provides the complete set of value functions and optimal saving rules for any combination of the state space variables.

We can use the optimal value function in the first period of adulthood, $V_{\underline{a}}$, as a new initial guess for child lifetime utility. Denoting with $s_{\overline{a}}^{c}$ the number of years of education of the child at the end of the last period of coresidence, $V_{\underline{a}}(p(a),s_{\underline{a}}=(s_{\overline{a}}^{c}+1),ch_{\underline{a}},\eta)$ will provide the new initial guess for $W_{\underline{a}}^{Sch}(.)$ and $V_{\underline{a}}(p(a),s_{\underline{a}}=s_{\overline{a}}^{c},ch_{\underline{a}},\eta)$ will provide the new initial guess for $W_{\underline{a}}^{Work}(.)$. Given the new initial guesses for $W_{\underline{a}}^{Sch}(.)$ and $W_{\underline{a}}^{Work}(.)$, we repeat steps one and two.

Given the conditional value functions for the work and schooling alternative, the child will be sent to school when the expected value of investing in schooling is at least as high as the expected value of sending the child to work, that is when the following condition holds:

$$V_{a}^{Sch}(p(a),\overline{s},s_{a}^{c},ch_{a},\eta)\geqslant V_{a}^{Work}(p(a),\overline{s},s_{a}^{c},ch_{a},\eta)\quad\forall\quad a=a\_ed,...\overline{a}\tag{38}$$

where a_ed denotes parental age when child education becomes a choice variable.

Step 4. Repeat steps one to three until the following two conditions are satisfied:

$$|V_{\underline{a}}^{Sch\_Iter}(p(a),s_{\underline{a}},ch_{\underline{a}},\eta)-V_{\underline{a}}^{Sch\_(Iter-1)}(p(a),s_{\underline{a}},ch_{\underline{a}},\eta)| \leq \varepsilon \tag{39}$$

$$|V_{\underline{a}}^{Work\_Iter}(p(a),s_{\underline{a}},ch_{\underline{a}},\eta)-V_{\underline{a}}^{Work\_(Iter-1)}(p(a),s_{\underline{a}},ch_{\underline{a}},\eta)| \leq \varepsilon \tag{40}$$

where ε is an arbitrarily small number and $|.|$ denotes the absolute value of the difference between the conditional value functions in the first period of adulthood in two consecutive iterations.

The solution method described in this section is used to solve the household's decision problem in each year t for a given vector of prices. The full solution in general equilibrium requires to iterate over the prices so that the market clearing conditions (14)-(16) are satisfied. Then, starting from some given initial conditions, the model will be solved in every period of the transition towards the steady state. The method for solving for the equilibrium price sequence that clears the market in every period of the transition is described in Appendix 2.

4.3 Properties of the equilibrium

Proposition 1 (Existence and Non-Uniqueness of the steady state). If the utility function $U(.)$ belongs to the space of bounded functions with the sup norm and is strictly concave and continuously differentiable, an equilibrium steady state exists. The equilibrium steady state depends on the initial conditions that characterize the model economy which are given by the distribution of education, wealth and ability and the set of model's parameters. Therefore, the steady state is history-dependent.

Proof. The existence of the steady state is guaranteed by the properties of the utility function. The solution to each of the functional equations that characterize the parental decision problem can be found by applying the Contraction Mapping Theorem and verifying that the Blackwell sufficient conditions are satisfied. It is straightforward to show that these conditions are satisfied if the utility function belongs to the class of bounded functions with the sup norm.[15]

The non-uniqueness result is due to the presence of a limited number of education levels that are available investment options under credit constraints. Each jth education level is characterized by a fixed cost F_j that the parent has to be able to pay to pursue the investment. Credit market imperfections do not allow free borrowing and restrict the number of feasible investment opportunities. Families can not optimally fine-tuning their educational investments that depend on the amount of resources they have and on the level of the credit constraints. Therefore, the steady state the economy will converge to will depend on the initial distribution of cash in hand and on the set of model's parameters, in particular on the level of the fixed costs of schooling and of credit constraints that characterize the economy. A formal proof of non-uniqueness for the case of two education groups is provided by Mookherjee and Ray (2003). The proof can be restated for any finite number of skill groups. It is the presence of the credit constraints that generate the non-uniqueness result when there is a limited number of education levels. Uniqueness is restored when there are perfect capital markets or a continuum of education levels with a corresponding continuum stream of fixed costs associated to them. In this situation, for any initial distribution of education and financial assets, families can always afford to pay a jth fixed cost and therefore invest into the corresponding jth education level. Mookherjee and Ray (2003, 2007) give a formal proof of how uniqueness is restored in a model with credit constraints and a continuum of occupation groups, provided that the interest rate is kept exogenous.

Proposition 2. For any given initial distribution of assets and education, the amount of financial wealth and optimal savings of individual households is low. In equilibrium, households that are constrained in the set of education investments they can afford tend to have higher savings.

Proof. Given the dynastic feature of the model, parental decisions on financial and human capital investments depend on the relative contribution of human capital and financial wealth to child lifetime utility. Since the model assumes full employment, human capital is the most effective way to increase child lifetime utility. Education represents an annuity that guarantees a sure lifetime income stream which is proportional to the maximum level of completed education. A marginal increase in education

[15] See Stokey and Lucas (1989).

corresponds to a permanent increase in lifetime utility given by the difference in the present discounted value of future earnings between two consecutive education levels. This increase will always be higher than the marginal increase of lifetime utility given by a marginal increase in the endowment of financial wealth. Therefore, the parent will invest in child education up to the level that is affordable given the cash in hand she holds and the level of credit market imperfections that characterize the economy. Then, given a degree of altruism that is common to all parents and independent of parental endowments, poor parents will compensate for the low amount of children's human capital by holding and bequeting more financial wealth.

Proposition 3. The aggregate supply of human capital of skill j in period t, $H_{j,t}$, is a non-decreasing function of the jth skill premium but it may be non-monotonic with respect to the other skill premiums.

Proof. Consider the aggregate supply of human capital of skill level j, H_j. Consider first an increase of size $\varepsilon > 0$ in the jth skill premium p_j. Any parent that chooses to invest in child education at p_j, will do the same at $p_j + \varepsilon$. Therefore H_j will be a non-decreasing function of p_j.

Consider now an increase of size $\varepsilon > 0$ in p_j, $j = j+1, j+2$. In this case, the response of the aggregate supply H_j is ambiguous. As an example, let us consider the effect of an increase in p_{he}, the premium to Higher education, on the aggregate supply of Intermediate human capital, H_{ie}. The increase in p_{he} will give incentives to invest at all levels of schooling. In particular, both the supply of Intermediate and of Higher education are expected to increase. However, whether the proportion of Intermediate graduates increases or decreases will depend on the net difference between the "new comers", i.e. individuals going from Basic to Intermediate education, and the "leavers", i.e. individuals going from Intermediate to Higher education. Therefore, H_{ie} may be a non-monotonic function of p_{he}.

5 Estimation and Calibration

This section discusses the estimation of the model. The discussion will first focus on the estimation of the wage process. It will then turn to the aggregate technology.

5.1 Wage process

We specify an education-specific log wage equation for individual i with education level j in year t:

$$\ln w_{j,t}^i = p_{j,t} + g_j(age_t) + u_{j,t}^i \qquad j = be, ie, he \tag{41}$$

$$u_{j,t}^i = \eta^i + z_{j,t}^i \tag{42}$$

$$z_{j,t} \sim N(0, \sigma_{z_{j,t}}^2) \tag{43}$$

where $\ln w^i_{j,t}$ is the real log hourly wage of the head of household i with skill level j in year t. $p_{j,t}$ is the (log) price to education level j in year t, η^i is a permanent individual-specific effect, $g_j(.)$ is a skill-specific quadratic polynomial in age which proxies for labour market experience and $z_{j,t}$ is an education specific i.i.d. shock received by the individual in year t.

Identification of η_i is achieved by exploiting the panel data feature of the ENEU over four consecutive quarters. Following Cunningham and Maloney (2000), we construct the panels matching workers by position in an identified household, number of years of education, age and sex. As reported in Cunningham and Maloney (2000), using only the first three variables to concatenate and following changes in sex across the panels leads to mismatching (or mis-reporting) of under 0.5 per cent.

For each year and education group between 1987 and 2002 we run the following fixed effects regression:

$$(\ln w^i_{j,\widetilde{t}} - \ln \overline{w}_j) = (d_{\widetilde{t}} - \overline{d}) + g_j(age_{\widetilde{t}} - \overline{age}) + (u^i_{j,\widetilde{t}} - \overline{u}_j) \tag{44}$$

where $\ln w^i_{j,\widetilde{t}}$ is the real log hourly wage of the head of household i with education level j in trimester $\widetilde{t}$. Barred letters denote time averages over the four trimesters in year t and $d_{\widetilde{t}}$ is the time dummy for trimester $\widetilde{t}$ in a given year.

For each year and education group we obtain an estimate of the ability distribution from the distribution of the regression's fixed effect and an estimate of σ^2_z from the regression's residuals.[16] The mean of the first and second moment of the distribution of η and the estimated σ^2_z by year and education between 1987 and 2002 will be used to parametrize the distribution of ability and of the idiosyncratic shock by education group.[17]

In order to estimate the age effects we pool the ENEU waves between 1987 and 2002 and run an OLS regression of the real log hourly wage of the head of household over a quadratic education-specific polynomial in age and a set of education and year-specific dummy variables. The coefficients of the quadratic polynomials provide the estimates of the education-specific experience effects.

5.2 Aggregate production

The following paragraphs discuss the identification and estimation of the aggregate production function.

5.2.1 Identification

Consider the following production function:

[16] Given the short lenght of the panel, the estimates of the fixed effects are affected by the incidental parameters problem.

[17] The distribution of ability is taken to be time-invariant. We therefore ignore a possible heterogeneity between successive cohorts active in the labour market in different years in terms of ability endownments. Instead of using the estimated moments in 1987 to parametrize the ability distribution, we use the mean of the moments between 1987 and 2002 to reduce noise and imprecision of the estimates. The results of the simulations are not sensitive to this choice.

$$F(H, K) = Y = Z * H^{1-\alpha} * K^{\alpha} \tag{45}$$

where Y denotes aggregate output that is produced using aggregate physical (K) and human (H) capital that will be the sum of the different human capital inputs in the economy. Z is a technology parameter.

In order to estimate the production function it is necessary to identify the human capital aggregates, $H_{j,t}$, defined as the sum of the efficiency weighted labor supplies of all individuals with education level j in year t. The jth labor input is the product of the number of workers with the jth education level and an efficiency index, which reflects changes in the productivity of each jth type of labor over time.

We can identify the human capital aggregates $H_{j,t}$ by combining data on the wage bills paid in each year to the different education groups defined as the total earning payments received by the individuals of a given education group in each year with the time series of the skill prices estimated for each year between 1987 and 2002.

Define the wage bill $WB_{j,t}$ as:

$$WB_{j,t} = \widehat{p}_{j,t} * H_{j,t} \qquad j = be, ie, he \tag{46}$$

where $\widehat{p}_{j,t}$ is the estimated market price of workers with education level j in year t.

Therefore:

$$H_{j,t} = \frac{WB_{j,t}}{\widehat{p}_{j,t}} \qquad j = be, ie, he \tag{47}$$

In order to compute the wage bills we need a data set that is representative of the entire Mexican population. The ENEU collects information on urban areas only so it can not be used to this purpose. We use instead the Mexican nationally-representative expenditure Survey, ENIGH (*Encuesta Nacional de Ingresos y Gastos de los Hogares*), which is available in 1984, 1987 and every two years since then. It contains detailed information on assets and consumption together with earnings and a rich set of individual characteristics.

For each year and education group we compute the wage bill summing over the individual wages of all primary wage earners between the age of fifteen and sixty.[18] We linearly interpolate the available data for the missing years. The total number of workers and the wage bills by education for each year between 1987 and 2002 are reported in figures 4 and 5 in Appendix 3. The spikes in the wage bills in the

[18] We consider all wage earners that are heads of households and work either in the formal or in the informal sector. We consider individuals aged 15 to 60 since the minimum legal working age in Mexico is 15 and the average retirement age is 60.

mid 1990s reflect a period of high instability of Mexican economy that entered a severe financial crisis in 1995, which resulted into a massive devaluation of the national domestic currency.

We obtain an estimate of the skill prices by year and education group from the education and year-specific dummy variables in the pooled regression estimated on the ENEU data between 1987 and 2002 in section 5.1. The coefficients of the year and education specific dummy variables give an estimate of the average log hourly real wage for education level j in year t net of experience effects.[19] The choice of using the ENEU and not the ENIGH to estimate the skill prices is motivated by the higher quality data on labor income collected by the Mexican Employment Survey. Also, data quality on labor income is higher for urban than for rural areas and rural activities such as agricultural self-employment involve the use of own labour and capital simultaneously, which makes it difficult to obtain a measure of income from labour net of payments from physical capital.

Given the wage bills and the skill prices, we divide the wage bills by the exponentiated value of the skill prices to obtain the estimated time series of human capital aggregates for each year and education group.[20] The human capital series are reported in figure 6 in Appendix 3. The decrease (increase) in the value of the estimated H is due to an increase (decrease) in the level of the estimated prices of the corresponding H factor which grew proportionally more (less) than the total remuneration of the factor.

5.2.2 Estimation

The parameters of the production function can be estimated using the conditions for the equilibrium prices. Taking the ratio of equations (15) and (14), we derive the following condition:

$$\frac{p_{he,t}}{p_{ie,t}} = \frac{\alpha_{he,t}}{\alpha_{ie,t}} \left(\frac{H_{he,t}}{H_{ie,t}} \right)^{\theta-1} \tag{48}$$

Log linearizing the above equation, we obtain:

$$(\log p_{he,t} - \log p_{ie,t}) = [\log \alpha_{he,t} - \log \alpha_{ie,t}] + (\theta - 1) * (\log H_{he,t} - \log H_{ie,t}) \tag{49}$$

where $\log \alpha_{j,t}$ denotes the time series of relative demand shifts for skill level j measured in log quantity units.

Rewriting the above expression in terms of wage bills we obtain:

$$(\log WB_{he,t} - \log WB_{ie,t}) = [\log \alpha_{he,t} - \log \alpha_{ie,t}] + \theta * (\log H_{he,t} - \log H_{ie,t}) \tag{50}$$

[19] Since we do not have a panel data that allows us to run a fixed effect regression to jointly estimate the experience and the fixed effects, we can either use the skill prices from the pooled OLS regression or subtract from them a mean or median estimate of the fixed effects obtained from the yearly fixed effect regression by education group. Subtracting the estimated fixed effects adds substantial noise to the estimates without significantly changing the estimated values of the human capital aggregates, so we choose to simply use the skill prices in the pooled OLS.

[20] $H = \frac{WB}{\widehat{p}} \quad => \quad H = \frac{WB}{\exp(\ln(\widehat{p}))}$

Equation (50) will be used to estimate the values of the relative demand shifts and the elasticity of substitution between Higher and Intermediate education.

The time-varying factor shares $\alpha_{ie,t}$ and $\alpha_{he,t}$ reflect skill-biased technological change and the impact of exogenous shocks on aggregate production. A commonly used specification in the literature assumes that the logs of the factor shares follow a simple trend-stationary process:

$$\log \alpha_{s,t} = \phi_{0,s} + \phi_{1,s} * t + e_{s,t} \tag{51}$$

where $\phi_{0,s}$ is a skill-specific constant, t denotes a linear time trend and e_t is a normally distributed i.i.d. shock at time t for skill level s.

Combining equation (50) and (51), the value of the parameter determining the elasticity of substitution between Higher and Intermediate education, θ, and the logs of the factor share can be estimated from a regression of the ratio of log wage bills on the ratio of human capital aggregates, a linear trend and a constant. In order to correct for a possible endogeneity bias we apply an IV estimator using as instrument the first lag of the difference of the logs of the human capital factors. Then, given unskilled human capital corresponds to Basic education and skilled human capital is a composite of Higher and Intermediate human capital, we can estimate a regression of the ratio of log wage bills for skilled and unskilled on the ratio of skilled and unskilled human capital, a linear trend and a constant to obtain an estimate of ρ and of the logs of the factor share $\delta_{sk,t}$.

Tables 3 and 4 in Appendix 3 present the estimates obtained for Higher versus Intermediate education and for Skilled versus Unskilled. The estimates of θ and ρ imply a value for the ES between Higher and Intermediate (Skilled and Unskilled) of around 4.6 (5.5).[21] We estimate the skill bias parameters as of 0.026 for Higher versus Intermediate education and 0.018 for skilled versus unskilled. The estimate of the skill bias parameter for Higher education is close to the corresponding estimate of around 0.03 reported by Manacorda, Sanchez-Paramo and Schady (2006) using a cross-section of Latin American countries.[22]

5.3 Calibration and exogenous parameters

We calibrate or set exogenously the values of the parameters that can not be directly estimated with the available data. We set exogenously the values of r, β, α, λ, γ and the limit B on net indebtness, which defines the level of credit constraints. We set the values of the fixed costs of schooling, F_j, for each jth education level to the mean real costs including tuition fees, the costs of exams, books, school material,

[21] The estimates of the ES between different education groups do vary significantly depending on the definition of the education groups and the measure of labour supply that are used. Looking at Latin America, the most recent results obtained from a cross section analysis on a sample of LACs that includes Argentina, Brazil, Chile, Colombia and Mexico in the 1980s and 1990s suggest a value of around 4.5 for the ES between Higher and Intermediate education and a value of around 2.5 for the ES between Skilled and Unskilled (see Manacorda, Sanchez-Paramo and Schady, 2006).

[22] The same estimate has also been found by Heckam, Lochner and Taber (1998) and Katz and Murphy (1992) using US data.

uniforms and the maintenance costs for public education estimated using the nationally representative Mexican Family House Survey (MxFLS) that collects high quality data on a rich set of variables for a cross section of Mexican households in 2002. We use survey information on education costs instead of administrative data on fees available from educational institutions since the former provide an estimate of the *overall* costs of education, which are the relevant costs entering the households' budget constraint that F_j intend to measure.[23]

Given the open economy assumption, the value of the real interest rate, r, is fixed at 0.05, which is the U.S. steady state after-tax interest rate used in the calibration of the initial steady state by Heckman, Lochner and Taber (1998). Given an average working life of forty years and the five-period adult life in the model, the model period is seven years, which implies $r = 0.41$. The discount factor, β, is set to 0.71, which implies a subjective discount rate equal to the real interest rate (the objective market time discount rate).

The capital share, α, is set equal to 0.35, which is the average value between the lower and the upper bound that has been estimated in empirical studies that use data from LACs.[24]

The degree of parental altruism, λ, is set to 1. The coefficient of relative risk aversion, γ, is set to 0.9, which gives a value of around 1.1 for the elasticity of intertemporal substitution (EIS). The value is taken from Arrau and Wijnbergen (1991) that estimate for Mexico a value for the EIS between a lower bound of 0.8 and an upper bound of 1.4.

The limit on net indebtedness, B, is set to zero, which corresponds to the maximum level of credit constraints. The results of the model will be tested under alternative scenarios characterized by different degrees of credit markets imperfections.

We set the initial distribution of wealth and education using data from the ENIGH and the ENEU. The initial wealth distribution is given by a lognormal with mean and standard deviation from the distribution of financial assets of workers aged 26-60 between 1992 and 2002 in the ENIGH.[25] The initial education distribution is given by the mean proportions of workers aged 26-60 with completed Basic, Intermediate and Higher education for the adults, and by the mean proportions of workers aged 15-25 with completed Basic and Intermediate education for the young in 1987 in the ENEU.

For each education group the distribution of ability and of the idiosyncratic shock is drawn from a

[23]The Mexican Family Household Survey is collected in 2002 so the estimates refer to this year. In the model we assume that the costs do not change over time. Consistently with this assumption, we do not allow the values of the F_j to change over time.

[24]See Bosworth (1998) for a discussion of the empirical issues involved in the estimation of the capital share in Mexico and Harrison (1994) and Hoffman (1993) for two cross-countries empirical studies that use a capital share that varies between the value of 0.3 and 0.4 for a group of LACs.

[25]The ENIGH is available for 1984, 1987 and every two years since then. The Survey reached its final structure only in 1992 with significant changes in the questionnaire and data collection in the years before. For this reason, we decided to parametrize the initial wealth distribution using the average of the first and second moments between 1992 and 2002 instead of the moments in 1987. The results of the simulations are not sensitive to this choice.

normal distribution with mean and variance estimated from the education-specific wage process.

The equivalence scale that adjusts for the consumption needs of the household members in a given year is set to 0.7 for a child reflecting the average calories intake of a child relative to an adult as reported by the Mexican National Nutritional Institute (see Hernández, Chávez and Bourges, 1987).

6 Policy Experiments

This section presents the results of the simulation of the model economy with and without skill-biased technological change (SBTC). The aim is to answer the following question: given the initial conditions that characterized the Mexican economy in 1987, following which path and to which level of aggregate output, physical and human capital and therefore skill premiums would the economy have converged in the presence and in the absence of SBTC? To this purpose, we first compare the transitional dynamics and the final steady steady in the two scenarios for a given set of initial conditions. Then, we discuss and assess the sensitivity of the results to changes in the initial conditions. In particular, we compare the results obtained with and without SBTC for different levels of credit constraints. The comparison is used to assess the interactions between changes in the production technology and in the tightness of the financial constraints and to evaluate their relative importance to explain the inequality increase.

6.1 Skill-biased technological change

Using the market clearing conditions for the equilibrium prices, we can derive the expressions for the relative returns to schooling:

$$\frac{p_{ie,t}}{p_{be,t}} = \frac{\delta_{sk,t}}{\delta_{unsk,t}} \alpha_{ie,t} \left(\frac{H_{be,t}}{H_{ie,t}} \right)^{1-\rho} \left[\alpha_{ie,t} + \alpha_{he,t} \left(\frac{H_{he,t}}{H_{ie,t}} \right)^{\theta} \right]^{\frac{\rho-\theta}{\theta}} \tag{52}$$

$$\frac{p_{he,t}}{p_{ie,t}} = \frac{\alpha_{he,t}}{\alpha_{ie,t}} \left(\frac{H_{he,t}}{H_{ie,t}} \right)^{\theta-1} \tag{53}$$

$$\frac{p_{he,t}}{p_{be,t}} = \frac{\delta_{sk,t}}{\delta_{unsk,t}} \alpha_{he,t} \left(\frac{H_{be,t}}{H_{he,t}} \right)^{1-\rho} \left[\alpha_{he,t} + \alpha_{ie,t} \left(\frac{H_{ie,t}}{H_{he,t}} \right)^{\theta} \right]^{\frac{\rho-\theta}{\theta}} \tag{54}$$

where equations (52), (53) and (54) define, respectively, relative returns to Intermediate versus Basic, Higher versus Intermediate and Higher versus Basic education.

Under the assumption of complementarities between Intermediate and Higher education, an increase in the number of individuals with completed Intermediate (Higher) education produces two different effects:

a standard supply or relative quantity effect that is a negative impact on the relative returns to Intermediate (Higher) education and a complementarity effect that depends on the degree of substitutability between the two production factors.

The standard supply effect is clear from equation (53): relative returns to Higher with respect to Intermediate education increase when the relative supply of Intermediate education increases.

The complementarity effect is jointly described by equation (52) and (54). When Higher education is more complementary with Intermediate than with Basic education, that is when $\rho > \theta$, an increase in the supply of workers with Intermediate education increases relative returns to Higher versus Basic education (equation (54)) and further decreases relative returns to Intermediate with respect to Basic education through the term in the square bracket in equation (52). Symmetrically, an increase in the number of workers with completed Higher education increases relative returns to Intermediate with respect to Basic education and further decreases relative returns to Higher versus Basic education.

The feedback impact of the general equilibrium effects on the skill prices could have been an important factor to explain the increase in the relative return to Higher education observed in Latin America in the 1990s. As we already discussed, in all main LACs there was a significant increase in the supply of Intermediate education that did not translate into a proportional increase at College level. If Higher education is more complementary with Intermediate than with Basic education, a combination of the supply and complementarity effects would increase relative returns to Higher with respect to both Basic and Intermediate education and decrease relative returns to Intermediate education.

The size of the general equilibrium effects will depend on the actual value of ρ and θ that determine the ES between the human capital factors and on the value of the factor shares that measure the contribution of the different production inputs to the aggregate output. The GE effects would be reinforced by a skill-biased change in the production technology resulting into an increase in the share of skilled human capital in the aggregate output.

The values of ρ and θ obtained from the estimation of the production function show the existence of a stronger complementarity between Higher and Intermediate than between Higher and Basic education. The estimate of ρ is higher than the one of θ indicating that Higher education is more complementary with Intermediate than with Basic education. The GE effects could then have played an important role to explain the rising premium to Higher education, a role that would have been reinforced by a skill-biased technological change (SBTC) in aggregate production.

Evidence of a SBTC in Latin America in the 1990s has been found by several empirical studies for all main Latin American countries.[26] At the same time, a related group of studies find evidence of a

[26] See, among the others, Attanasio, Goldberg and Pavcnik (2002) for Colombia and Corseuil and Muendler (2003), Pavcnik, Blom and Goldberg (2002) and Holm-Nielsen and Verner (2001) for Brazil.

positive impact of trade opening on the skill premium.[27] However, when the relative importance of the trade liberalization and of technology explanation has been compared, results suggest that the skill-biased technology transfer is the driving force behind the increase in the skill premium. Behrman, Birdsall and Szekely (2000) find that trade liberalization does not have any significant impact on wage differentials between successive education levels while wage gaps significantly rise when exports of high-technology products increase. Avalos and Savvides (2003) find that increased trade openness is related to reductions in wage differentials between high and low educated, while exposure to foreign direct investment, greater imports of machinery and equipment and R&D transfer from developed economies are associated with increases in wage differentials.[28]

We can use our model to simulate the impact of a skill-biased technological change (SBTC) in general equilibrium. The main episode of technological change in Mexico took place in the mid 1990s. After a series of currency devaluations and financial crisis from the mid 1970s to the late 1980s, Mexico undertook some major structural reforms designed to make its economy more open to foreign investment. The reform effort culminated in 1994 when Mexico became a member of the Organization for Economic Cooperation and Development (OECD) and entered the North American Free Trade Agreement (NAFTA) with the US and Canada, further opening to foreign investment and bolstering investors' confidence in long-term prospects of stable economic growth. However, partly due to the inexperience of the new independent Central Bank, in the same year Mexico entered a severe financial crisis that resulted into a massive devaluation of the national domestic currency. The international response to the crisis was immediate and assistance was promptly provided by the US and the IMF. As part of the rescue package, in March 1995 Mexican government released a new economic plan to address the economic requirements set by the US and the IMF. The recovery was rather quick and by the end of 1995 Mexico had reentered the international capital markets.[29]

The reforms of the mid 1990s turned Mexico into a more technologically advanced country with an increased demand of skilled-labour. We can simulate the effect of a skill-biased technological change by using the estimates obtained for the trend parameters in the estimation of the production function as the base case. Starting from the values of the factor shares for the year 1987, we assume that $\alpha_{he,t}$ and $\delta_{sk,t}$ increase linearly at 3 and 2 per cent per year starting in 1994 and continuing for five years. Shifts of longer and shorter duration produce qualitatively similar results.

Figure 7 and table 5 in Appendix 3 present the estimated skill prices and the associated relative returns to schooling in the final steady state. The "no-SBTC" has been obtained by fixing the factor

[27] See, among the others, Hanson and Harrison (1999) for Mexico and Lisboa, Menezes-Filho and Schor (2004), Gonzaga, Menezes-Filho and Terra (2006) and Giovannetti and Menezes-Filho (2006) for Brazil.

[28] In practice trade opening and skilled-biased technological change are very related since a change in production towards skilled labour could be the effect of increased exposure to international markets.

[29] For a detailed description of Mexican Peso Crisis, see Arner (1996).

shares at the values in 1987 and the "SBTC" by allowing them to increase linearly for five years starting in 1994. The comparison between the two scenarios suggests that skill-biased technological change has been an important factor behind the increase in the skill premium observed in Mexico in the 1990s.

While in the absence of skill-biased technological change the model predicts a quasi-linear relationship between log wages and education, the presence of a skill-biased change in technology produces an equilibrium wage profile that is a convex function of the level of education. This is an important result: it suggests that a change in production towards skilled labour was a fundamental determinant of the convexification of the returns that characterized the changes in wage inequality in the 1990s. Credit constraints alone, even at the maximum binding level of no possible borrowing, are not enough to produce the convex shape of the wage function with respect to the education level.

Figures 8 to 10 present the changes in the equilibrium log price for each education level during the transition towards the steady state for the first forty years of the transition.[30] As can be seen from the graphs, both in the presence and in the absence of SBTC wages are decreasing at Basic education and increasing at Intermediate and Higher education. However, the speed of the changes differs significantly in the two scenarios. In particular, in the presence of SBTC, wages at Basic education decrease much more fastly and increase much more steeply at Higher education. As a consequence, if we compute the changes in the relative returns between consecutive education levels, only the SBTC scenario is able to produce a path of increasing relative returns to Higher education, which is consistent with the observed empirical evidence.

Figures 11 to 13 present the transitional dynamics in the SBTC and no-SBTC case for each of the three types of human capital aggregates, H_{be}, H_{ie} and H_{he}. While in each year of the transition the amount of unskilled human capital is almost identical in the two scenarios, in the presence of SBTC both Intermediate and Higher human capital types are higher throughout the transition. Interestingly, while the Intermediate type converges to a lower steady state level, the amount of Higher human capital declines more fastly in the SBTC scenario and converges to the same steady state value in the two scenarios. The declining trends in Intermediate and Higher human capital are a result of the tight credit constraints that are set at the maximum level of no possible borrowing in the baseline model.

Figure 14 presents the transitional dynamics for the aggregate output, Y. As can be seen from the graph, the output is more fastly declining and significantly lower at steady state in the SBTC scenario. This result is due to a fast decline of physical capital during the transition when the economy experiences a SBTC. The reason for this decline lies in the trend of the net investment abroad (NI in equation (9)). Unreported graphs show that throughout the transition, despite a higher level of national savings, the SBTC economy is characterized by a much higher level of indebtness in the world financial markets with

[30] We only report the years of the transition before the economy reaches the steady state.

respect to the no-SBTC scenario.

6.2 Discussion and sensitivity analysis

Given the existence of multiple steady states stated in Proposition 1, the results of the simulations are sensitive to the distributions and the set of parameters that characterize the initial conditions of the model economy. In particular, the level of credit constraints and the value of the parameters governing the elasticities of substitution (ES) between production factors are of crucial importance. The former has a direct impact on the educational choices and in turn on the extent of the returns' convexification; the latter has an indirect impact on the supply of human capital since it determines the direction and the magnitude of the general equilibrium effects. In this section we discuss the consequences of the multiplicity of equilibriums and the robustness of the results to changes in the level of the credit constraints. We then discuss the validity and internal consistency of the estimated ES between production factors.

6.2.1 Multiple equilibriums and initial conditions

Given the non-uniqueness stated in Proposition 1, the results of the simulations are sensitive to changes in the initial conditions that characterize the model economy. The differences in the steady states results in the presence and in the absence of SBTC could be due to differences between the steady states the economy can converge to from a given set of initial conditions rather than to the exogenous change in the production technology.[31]

The initial conditions are given by the set of model's parameters, the ability distribution by education group and the distribution of wealth and education in 1987. The education distribution is taken from the data and is accurately measured in the ENEU. The ability distribution is estimated from fixed effects regressions that suffer from the incidental parameter problem but represent the best way to proxy for ability given data availability for Mexico. The wealth distribution is parametrized using the mean of the first and second moments of the distribution of financial assets observed in the ENIGH between 1992 and 2002. The data could suffer from severe imprecision and self-report bias, so it could be important to test the sensitivity of the simulations' results to changes in this distribution. However, given Proposition 2, investments in financial assets play only a marginal role and individual savings tend to be low for any given distribution of wealth. Therefore, the steady state results are not significantly affected by changes in the parameters that characterize the initial distribution of financial assets.

[31] Following Mookherjee and Ray (2003, 2007), we could overcome the multiplicity problem by making human capital a continuum variable using "units" of human capital or years of education instead of levels. However, there is extensive empirical evidence suggesting that education is fundamentally discrete, that is it is degrees and not the number of years of education that matters; in addition, the question of interest in this paper is to investigate the role of SBTC to explain the increase in the premium to the highest *level* of education. Given the very nature of education as a discrete outcome, a history-view of the market could be more appropriate to study changes in wage inequality with respect to a framework that assumes the existence of a unique steady state independently of the initial conditions.

The values taken by the model's parameters are the key feature that characterizes the initial conditions. In particular, investments in education depend crucially on the interplay between the level of the fixed costs of schooling F_j for any jth education level and the value of the limit B on net indebtness. The costs of schooling can be estimated from households surveys that have information on total education expenditures as the sum of direct and subsistence costs. We use the nationally representative MxFLS that collects data on both tuition and on maintenance costs.

On the contrary, there is no empirical benchmark to fix the value of B, which reflects the degree of credit market imperfections. If there is established evidence of binding credit constraints on educational choices in Mexico,[32] we are not aware of any estimate of the actual degree of credit market imperfections. We therefore test the sensitivity of our results for a grid of values that B can take given a lower and an upper bound, which define, respectively, the minimum and the maximum degree of credit constraints. We set the upper bound to zero, which implies that no borrowing is allowed, and the lower bound to (minus) the present discounted value of future earnings under the worst possible realization of the idiosyncratic shock to wages, which is the maximum amount the individual will always be able to repay at any age and therefore will be able to borrow without violating the transversality condition stated in equation (6).

Figures 15 and 16 present the log prices by education in the final steady state when B is given by the lower bound (figure 15) and the mid point (figure 16) of the grid. As can be seen from the graphs, the relaxation of the credit constraints does not change the result presented in figure 7 for the case of $B = 0$: in the absence of a skill-biased technological change, the model predicts a quasi-linear relationship between the log wage and the level of education.

However, even if credit constraints do *not* determine the *existence* of the convex shape of the wage function, they determine the *extent* of the convexification. Intuitively, everything else equal, we would expect a positive relationship between the level of the credit constraints and the size of the skill premium: the lower the level of credit constraints, the lower the relative return to Higher education given the increased investment in human capital that becomes possible when the credit constraints are relaxed.

We can test this prediction by comparing the value of the relative return to Higher education in the presence of SBTC for different degrees of credit market imperfections. Tables 6 and 7 are the equivalent of table 5 for the cases of B equal to the lower bound and to the mid point of the grid. The results confirm the expected association between credit constraints and changes in the returns to skill: the more the individuals are allowed to borrow, the lower is the relative return to Higher education. From around 27 per cent when credit constraints are at the maximum level ($B = 0$), the relative return to Higher education decreases to around 13 per cent when B equals the mid point of the grid and of an other percentage point when B is equal to the lower bound.

[32] See, for example, Jacoby and Skoufias (2002) and Kaufmann (2007).

Both in the presence and in the absence of SBTC, the relaxation of the credit constraints allows more families to invest in human capital after completion of compulsory Basic education. Consistently, unreported results show that, when borrowing is allowed, the Basic human capital type converges to a lower value while both Intermediate and Higher types reach a steady state value that is higher than the one they take when the credit constraints are at the maximum level. During the transition towards the steady state Basic human capital decreases while both the Intermediate and Higher type increase, reversing the trends presented in figures 11 to 13 when the credit constraints are at the maximum level. As the aggregate human capital is increasing, so are the physical capital and in turn the aggregate output that both converge to a steady state value that is significantly higher than the value they reach when no borrowing is allowed.[33]

6.2.2 Estimation of the production function

With the exception of structural general equilibrium models[34], the estimation of the production function before the model is solved and simulated is common practice in GE models of savings and educational choices. Generally, the papers do not present any discussion of the sensitivity of the results to the estimated elasticities of substitution (ES) between aggregate factors.[35]

However, the value of the ES between different production inputs is a key parameter in models that account for the feedback impact of changes in supply on changes in returns to schooling and the results of the simulations depend crucially on the actual values assigned to it. Therefore, for the internal consistency and the robustness of the model's predictions, the ES should be structurally estimate while the model is solved in order to assure coherence between the values of the parameters of the production function and the simulated educational choices.

Despite of its shortcomings, for the purpose of the analysis developed in this paper, we decided to keep the reduced-form estimation of the production function for two main reasons. First, differently from the US literature, there are very few papers that estimate a production function using data from LACs and there is no a established consensus on the values of the estimated ES. Therefore, it is valuable on its own to use a consistent method to produce such estimates. As we already discussed in section 5.2, despite of the different methodology we use, the estimates we obtain are close to the values found in other papers, which offers an indirect test of their validity and adds empirical evidence towards a definitive answer on their values.

Second, and most importantly, in this paper we are interested in studying the impact of a SBTC on the returns to schooling in steady state rather than in explaining the changes in wage inequality during

[33] The results for the steady state and the transition when credit constraints are relaxed are available from the author upon request.

[34] For two recent examples, see Lee (2005) and Lee and Wolpin (2006, 2007).

[35] See, for example, Heckman, Lochner and Taber (1998) and Gallipoli, Meghir and Violante (2006).

the transition. To this purpose, the important choice is the one on the aggregation of the production inputs: the decision to allow or not for capital/skill complementarities and, in the case of multiple human capital factors, on how to aggregate them in pairs is in turn driving the actual value of the estimated ES. We exclude capital-skill complementarities given the empirical evidence on the quasi-constancy of the share of physical capital in production observed in Mexico in the 1990s and we motivate the choice on the aggregation of the human capital factors in the CES specification with the evidence on the changes in the supply for different education levels in the decade. Adding a structural estimation of the production function could be an interesting extension of the model that would make it more suitable to study the evolution of the economy through the transition.

7 Conclusion

In the decade of the 1990s Latin American Countries experienced a significant process of educational expansion towards Intermediate education together with a sharp increase in the wage premium to Higher education. As a consequence, returns to education have become more convex with proportional increases in education translating into higher than proportional increases in income for the more educated.

The increase in the relative return to Higher education has been the subject of a vast empirical literature that has developed supply and demand-side explanations of the inequality increase. The "supply-side" explanations emphasize the role of a wage premium to individuals' (unobserved) ability and the presence of quality and financial constraints that restrict access to Higher education. The "demand-side" explanations focus on the impact of changes in the production technology and of economic reforms that favoured skilled labour.

All the studies up to now have adopted a partial equilibrium approach explaining the rise in wage inequality by considering only one side of the economy. The results rely on the assumptions made on the side of the economy that is not explicitly modelled, so it maybe comes at no surprise that no definite conclusion has been reached on the determinants of the increase in the skill premium. The correct answer can only be given in a framework that is able to account for the impact of both supply and demand-side factors. This paper provides such a framework.

We develop and simulate a dynamic general equilibrium (GE) model of savings and investment in education under credit constraints that we use to evaluate the relative importance of the supply and the demand-side factors to explain the inequality increase. To our knowledge, this is the first attempt to model the determinants of changes in wage inequality in Latin America in a dynamic GE framework jointly modelling educational and saving choices.

The dynamic feature of the model is essential given the very nature of wage inequality as the result of changes in the economic conditions and labour markets dynamics that characterize the economy. For a given set of model's parameters and initial distributions that define the individuals' endowments of financial resources and education, we compute the transitional dynamics towards the equilibrium steady state. The comparison between the transition path and the final steady state in the presence and in the absence of a skill-biased technological change for different levels of credit constraints is used to evaluate the relative importance of exogenous changes in the production technology and in the tightness of the financial constraints to explain the increase in the relative rerturn to Higher education.

The parameters of the model are estimated using micro data from Mexico between 1987 and 2002. Mexico is one of the LACs that experienced the highest increase in wage inequality during the 1990s and underwent a significant process of trade opening and economic restructuring during the decade.

The model is simulated under two counterfactual scenarios characterized by the presence and the absence of skill-biased technological change (SBTC) for a given degree of credit markets imperfections. We model credit constraints as an exogenous limit on the maximum amount that individuals can borrow and we characterize the skill intensity of the production technology by the values of the shares of skilled human capital factors in production. Our benchmark is an economy with the maximum level of credit constraints (limit zero on net-indebtness) and the factor shares fixed at the estimated values at the end of the 1980s before any SBTC in production took place.

The results of the benchmark model are compared with the SBTC scenario where the values of the share of skilled labour in the aggregate production are increased by an amount that reflects the technological shift in production towards skilled labour estimated for Mexico in the 1990s. We then compare the results obtained from the simulations in the presence and absence of SBTC for different levels of credit constraints. These comparisons are used to assess the relative importance of exogenous changes in the production technology and in the tightness of the financial constraints to explain the inequality increase. In each scenario changes in composition are endogenously captured by changes in the ability distribution by education group.

The results of the simulations suggest that SBTC was a fundamental determinant of the convexification of the wage profile with respect to the level of education, which characterized the changes in wage inequality observed in Mexico in the 1990s. The increase in the premium to Higher education appears to be the result of an excess demand for skill. The degree of credit markets imperfections affects only the magnitude of the increased return to Higher education.

In the absence of skill-biased technological change the model predicts a quasi-linear relationship between log wages and education. Credit constraints alone, even at the maximum binding level of no possible borrowing, can not produce an equilibrium wage profile that is a convex function of the level of education. However, they affect the magnitude of the increased return to Higher education and therefore the extent of the convexification. The results show a positive relationship between the level of credit constraints and the size of the skill premium: the more the individuals can borrow, the lower is the relative return to Higher education given the increased investment in human capital that becomes possible when credit constraints are relaxed.

The steep increase in earnings' differentials between high and low educated has become a primary political concern in all LACs and in Mexico in particular. Excess inequality decreases the rate of poverty reduction since the growth elasticity of poverty reduction decreases as the income distribution worsens (see Ravallion, 1997). The link between poverty and inequality makes inequality reduction a very relevant policy issue.

The results of this paper have two main policy implications for an effective inequality reduction strategy. First, the role of the skill-biased change in production technology as the driving factor behind the increase in the skill premium suggests that a structural economic change is on going which is transforming Mexico in a more technologically advanced country with an increased need of highly educated labour. Therefore, more resources have to be devoted to the expansion of Higher education increasing the availability of places and the quality of education at this level. In addition, the positive relationship between the level of the credit constraints and the actual extent of the skill premium suggests that the increase in the resources spent on Higher education should be combined with higher monetary incentives and better ways of funding education to ease the constraints and effectively allow people to participate and to successfully complete post-secondary education. A persistent educational expansion will compress the returns and in turn reduce wage inequality. Of course, it will also reduce the incentives to invest at this level. However, given the very high returns at present, they will probably still remain high enough to mantain Higher education an attractive investment opportunity.

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APPENDIX 1

This appendix describes the data used to estimate the wage process and the construction of the education groups.

ENEU

The ENEU (*Encuesta Nacional de Empleo Urbano*) is the Mexican national employment survey collected yearly by Mexican national statistical office, INEGI. It is a quarterly household survey with a rotating panel structure: households are interviewed for five successive quarters and in each quarter 20 per cent of the households are replaced by new households that are interviewed for the first time. The Survey started in 1981 with progressive increase of the geographic coverage. The sample is selected to be geographically and socio economically representative of the national Mexican urban population: by the end of the 1990s the Survey covered approximately 62 per cent of the national urban population and 92 per cent of the cities with population greater than 100,000.

The main questionnaire is divided in three parts, the first with socio demographic and employment information on individuals at least 12 years old, the second with socio demographic data on individuals younger than 12 and the third with information on the characteristics of the house of residence. The employment information is very detailed with several questions on individuals' occupation status, type and characteristics of employment, sector of main and secondary job, contract type, number of working hours, monthly wages, unemployment status and duration and social security taxes paid by the worker's employer in the private and public sector.

In the empirical analysis we consider the labour income in the primary occupation of all head of households that are wage earners and are between 15 and 60 years old.

Construction of the education groups

The Mexican education system consists of three main cycles: Primary, Secondary (Lower and Higher) and Post-secondary (University/technical institutes or more). Primary education lasts 6 years, Lower and Higher Secondary 3 years each, University 4 to 5 years and graduate education 2 to 4 years (2 years are necessary to obtain a Master degree and other additional 2 years are necessary to obtain a PhD).

Primary education starts at age 6 and it has always been compulsory. In 1992 Lower Secondary has also became compulsory. At the end of the 1990s completion rates were almost 100 per cent at Primary and around 40 per cent at Lower Secondary. Secondary education includes an "academic" and a "vocational" branch that paves the way, respectively, to University versus non-University education. Post-secondary education comprises Universities, 4-years technical institutes and 2-years technical institutes. By far the majority of students are enrolled in University and a very small proportion is enrolled in 2-years technical institutes.

In order to construct the three education groups used in the model, the schooling levels have been aggregated as it follows. The "Basic education" group includes all individuals that have up to uncompleted Secondary education, the "Intermediate education" group includes all individuals that have up to uncompleted Post-secondary education and the "Higher education" group includes individuals who have completed University or more. As in Manacorda, Sanchez-Paramo and Schady (2006), we aggregate the Lower and Higher level and the academic and vocational branch into Secondary education considering in the "Intermediate" group all individuals that have completed any of the two levels and branches.

APPENDIX 2

This appendix discusses the method used to compute the equilibrium transitional dynamics to a final steady state starting from a given set of model parameters and an initial ability, wealth and education distribution characterizing the model economy.

First iteration

1) Start with year one. Make an initial guess on the vector of the skill prices p(t) and assume that the prices from year one to the final year T are the same, that is future prices equal current ones.
2) For all ages (cohorts) take an exogenous distribution of wealth and education.
3) Given p(t) and the distribution of wealth and education, simulate the behaviour of samples of 10000 individuals per cohort by drawing from the distribution of the idiosyncratic shocks.
4) For each cohort, compute aggregate skill supplies and physical capital summing over individual education supply and optimal asset choices.
5) Update p(t) with the market clearing prices and save the vector of equilibrium prices for this year.
6) Go to year two. The distribution of wealth and education is endogenously determined by individuals' optimal savings and education choices made in year one. Individuals in the final year of adult life retire. Individuals in the first year of adult life inherit wealth and education from retirees in year one. Individuals aged in between update the values of the state space variables according to the optimal asset and education choices made in year one. Given a new initial guess on prices, repeat steps from (3) to (5) above.
7) Go on until year T repeating for each year the steps from step (1) to (6) above.
8) Collect the vectors of equilibrium prices for all years. We obtain a (Tx3) matrix that contains the sequence of the skill prices for the three education levels that represents the first iteration equilibrium.

From the second iteration onwards

9) Start with year one. Compute a new initial guess for the skill prices as a function of the guess and the value of the equilibrium prices for this year from the previous iteration.
10) Repeat all the steps from (1) to (8) above and collect the (Tx3) matrix of the sequence of prices for this iteration.
11) Repeat steps (9) and (10) for successive iterations until the initial guess on the vector of prices for each year from 1 to T is close enough to the sequence of equilibrium prices for this iteration. This is the rational expectations equilibrium where skill markets clear and individuals' expectations about future prices are realized as the equilibrium price sequence.
If the skill prices and the human and physical capital aggregates are constant from some year t onwards, then the economy has reached an equilibrium steady state at year t.

T is set to 50. The model always converges in less than 50 periods, so increasing the number of periods does not affect the results.

APPENDIX 3

Table 1: Gini index.

Year	1990	2000
BRAZIL*	0.592	0.575
COLOMBIA*	0.492	0.482
MEXICO*	0.518	0.528
EU-15**	0.306	0.279
US***	0.428	0.462

*Author's calculations from household Surveys.
**Data refer to 1995 and 2000, source Eurostat.
***Source US Census Bureau.

Table 2*: Relative wages.

Year	1987	2002	Growth
BRAZIL			
Higher vs. Intermediate	0.828	1.002	**21%**
Intermediate vs. Basic	0.926	0.627	**-32%**
COLOMBIA**			
Higher vs. Intermediate	0.899	1.092	**21%**
Intermediate vs. Basic	0.484	0.429	**-11%**
MEXICO			
Higher vs. Intermediate	0.375	0.646	**72%**
Intermediate vs. Basic	0.451	0.384	**-15%**

*Mean real log hourly wages household head, age 25-60
**Data for Colombia refer to 1988 and 1998

Figure 1: **Mean log annual real wages by education, Mexico.**

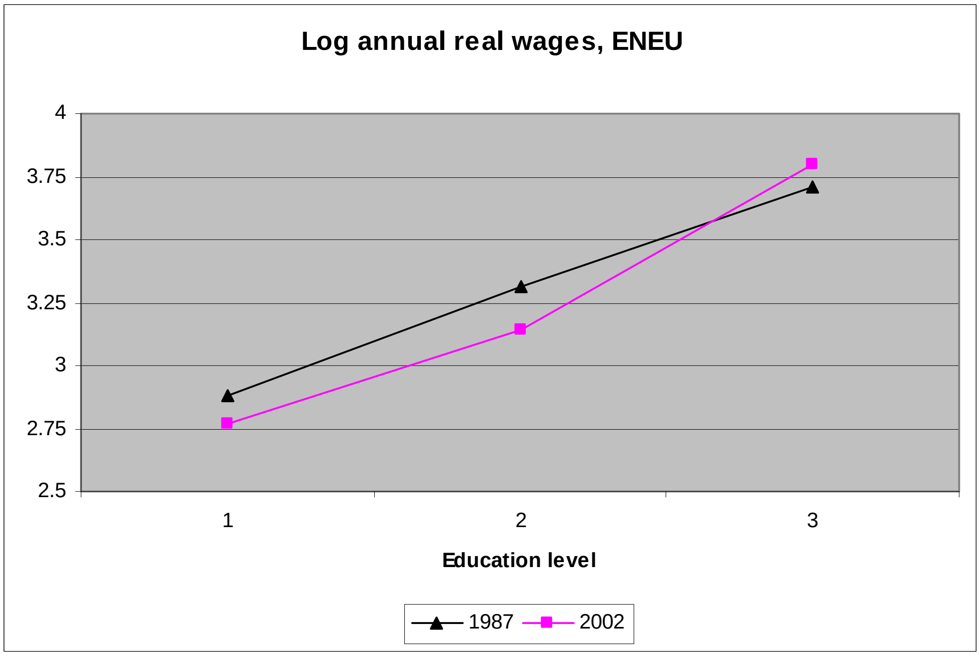

Figure 2: **Relative wages 1987-2002, Mexico.**

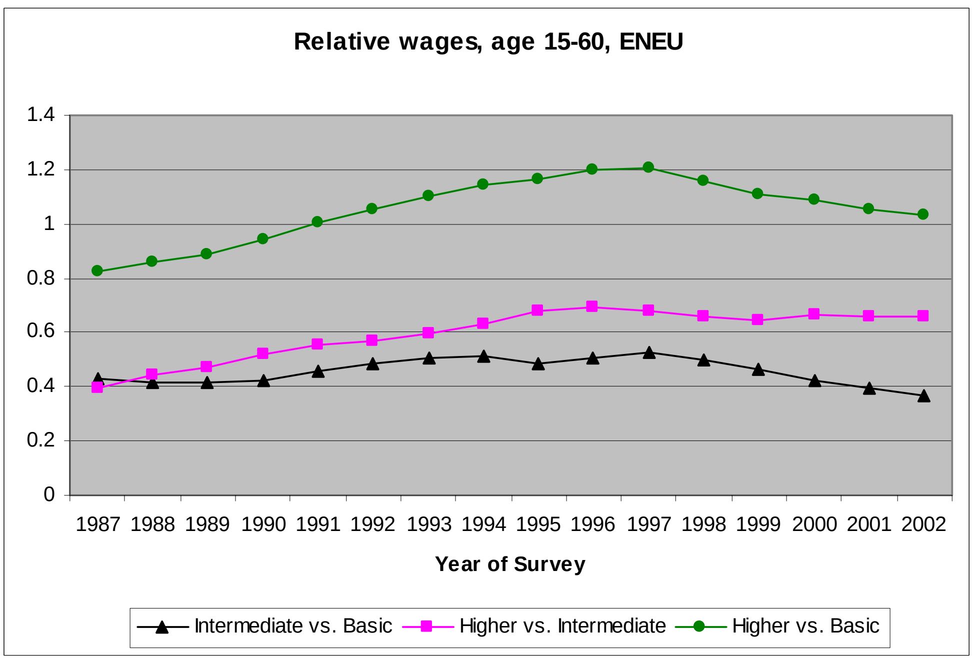

Figure 3: **Relative supply 1987-2002, Mexico.**

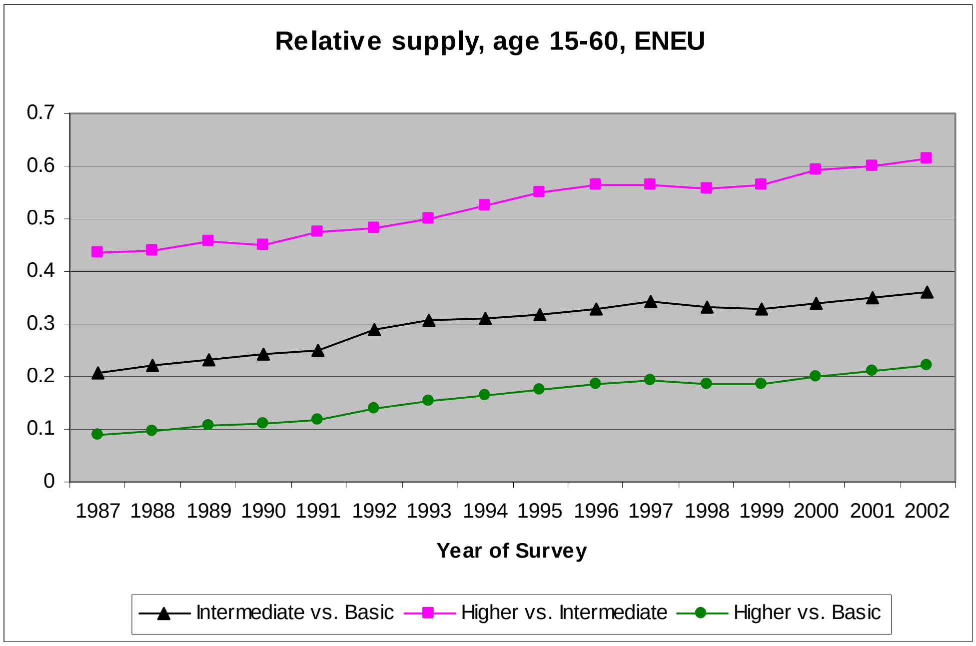

Figure 4: **Wage workers, 1987-2002, Mexico.**

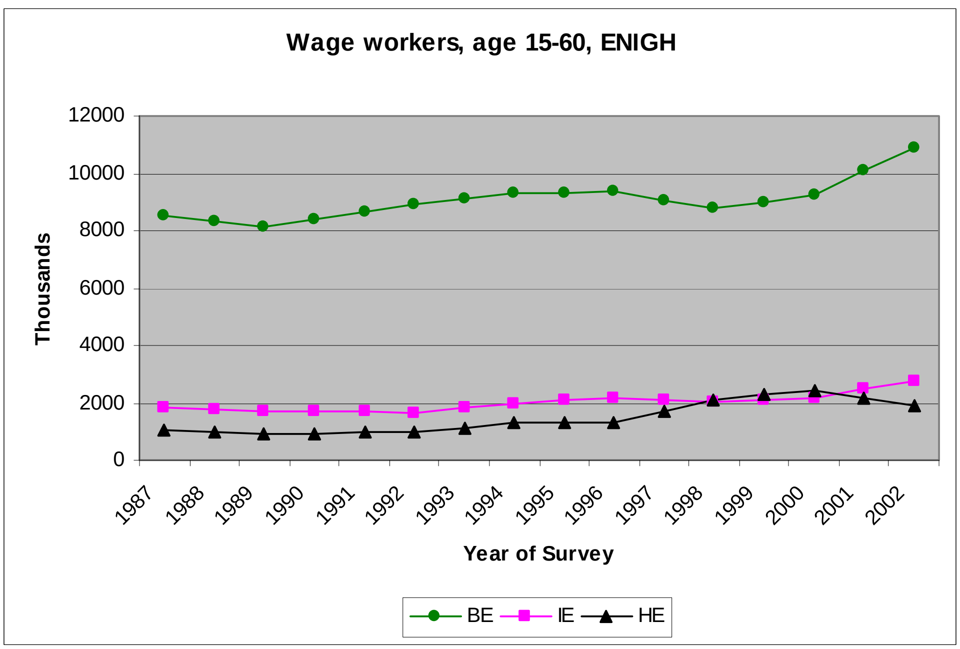

Figure 5: **Wage bills 1987-2002, Mexico.**

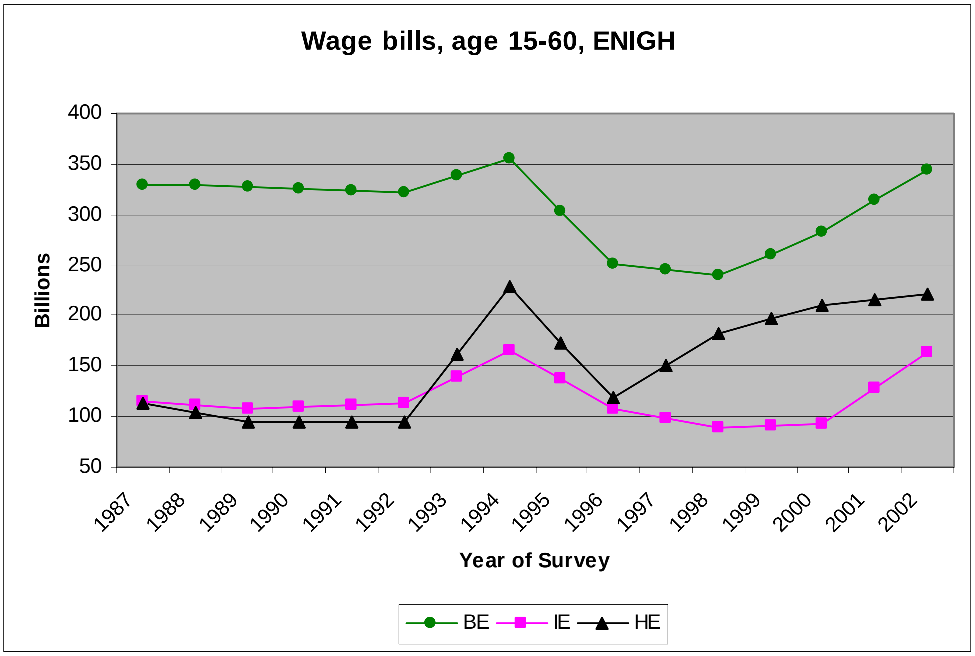

Figure 6: **Human capital aggregates, 1987-2002, Mexico.**

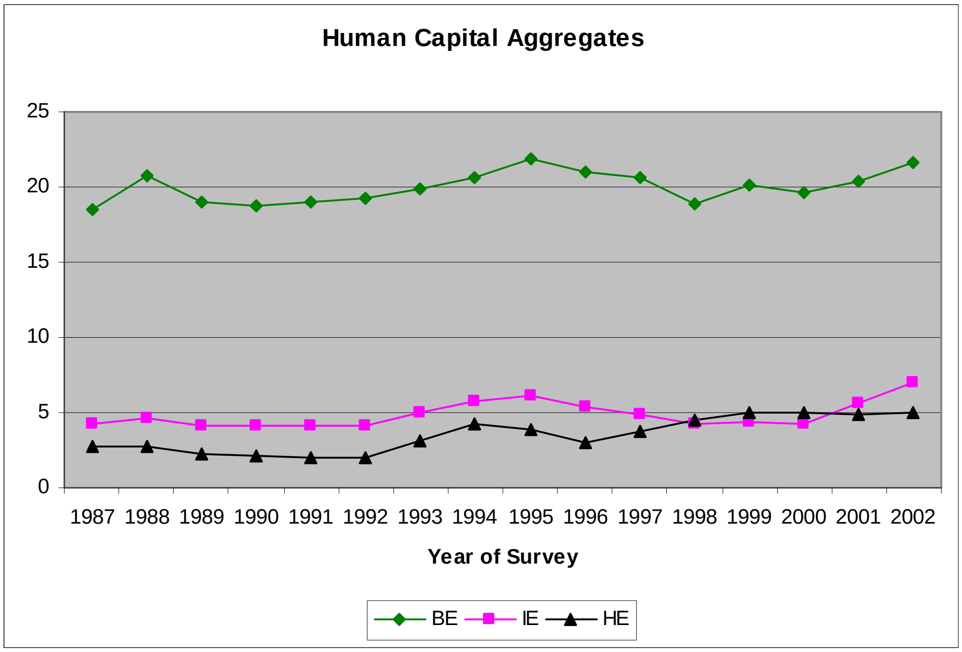

Table 3*: Estimation production function Higher vs. Intermediate

log(H32)	0.782
	(0.143)
Time trend	0.026
	(0.008)
Implied ES	4.6

* Standard errors in parentheses .

Table 4*: Estimation production function Skilled vs. Unskilled

log(HSkUnsk)	0.820
	(0.218)
Time trend	0.018
	(0.007)
Implied ES	5.5

* Standard errors in parentheses.

Figure 7. Log prices by education final s.s., B=0.

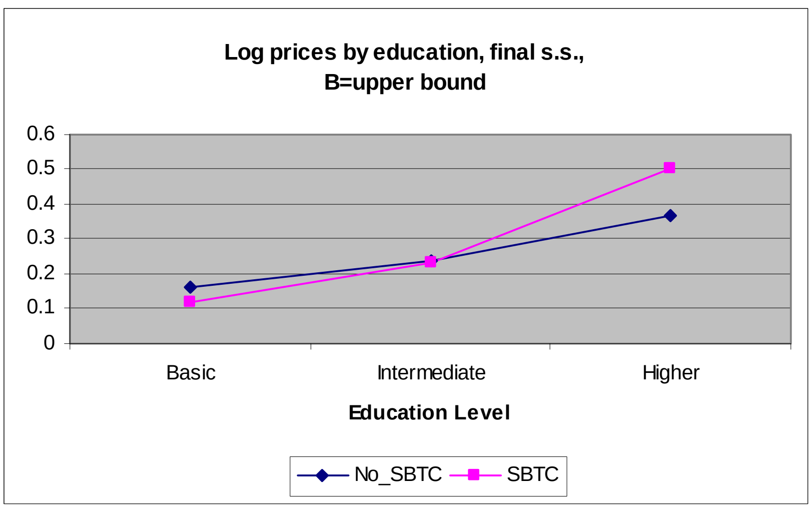

Table 5. Returns to schooling final s.s., B=0.

	No SBTC	SBTC
Higher vs. Intermediate	12.7%	26.9%
Intermediate vs. Basic	7.8%	11.1%

Figure 8. **Log price Basic education during the transition, B=0.**

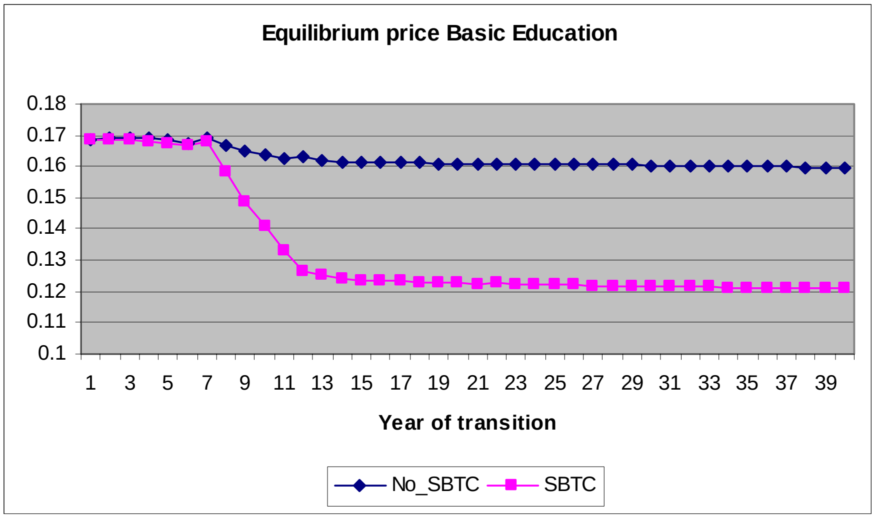

Figure 9. **Log price Intermediate education during the transition, B=0.**

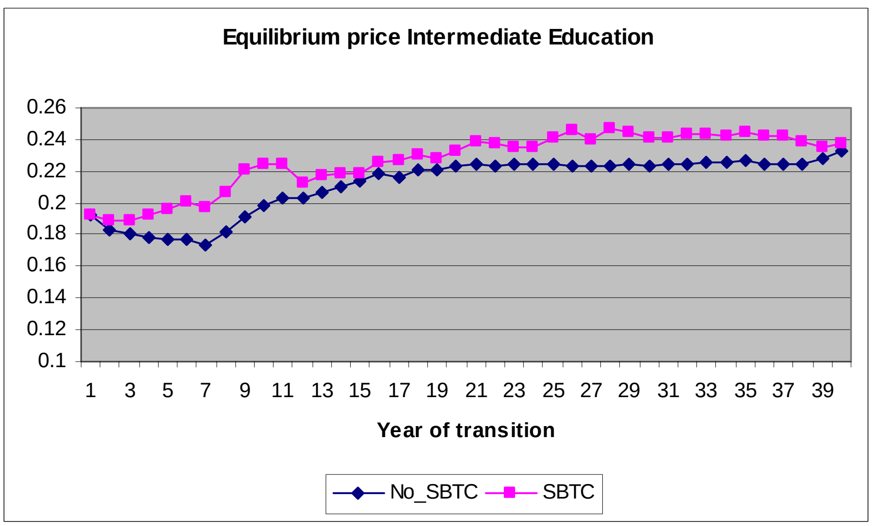

Figure 10. **Log price Higher education during the transition, B=0.**

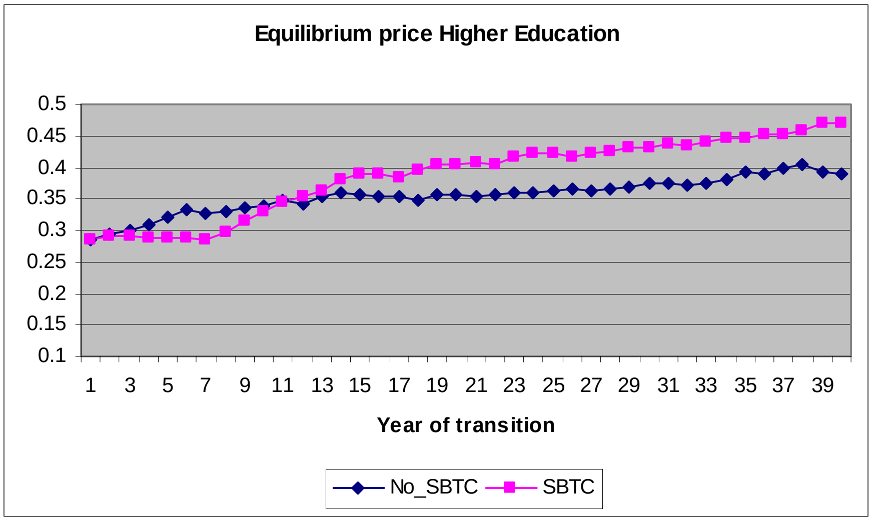

Figure 11. **Aggregate human capital Basic education during the transition, B=0.**

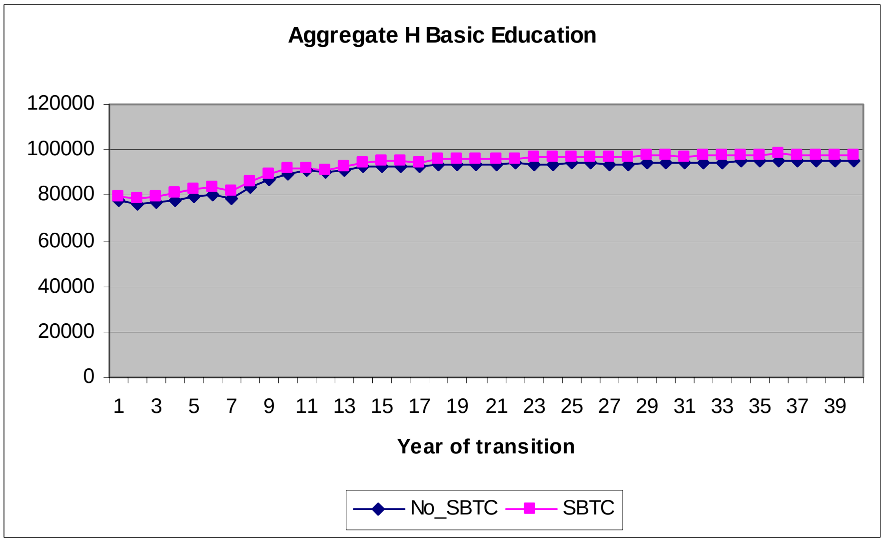

Figure 12. **Aggregate human capital Intermediate education during the transition, B=0.**

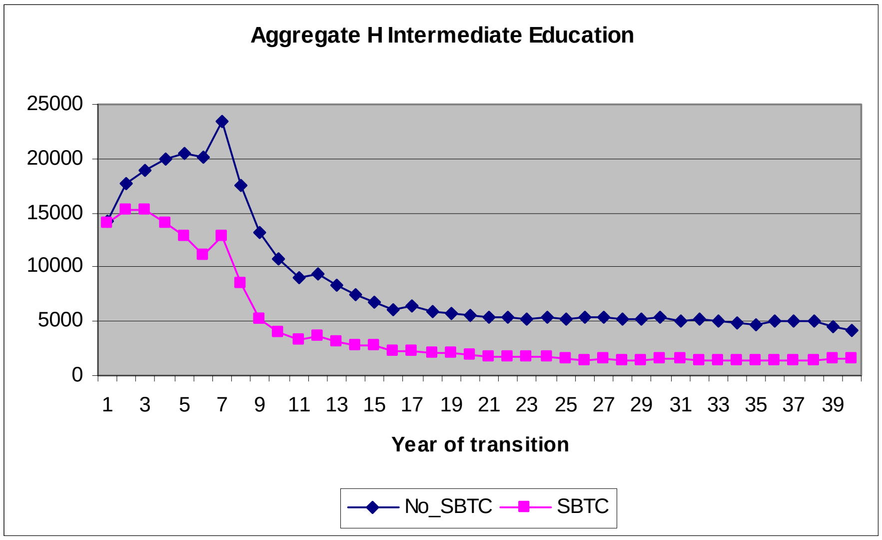

Figure 13. **Aggregate human capital Higher education during the transition, B=0.**

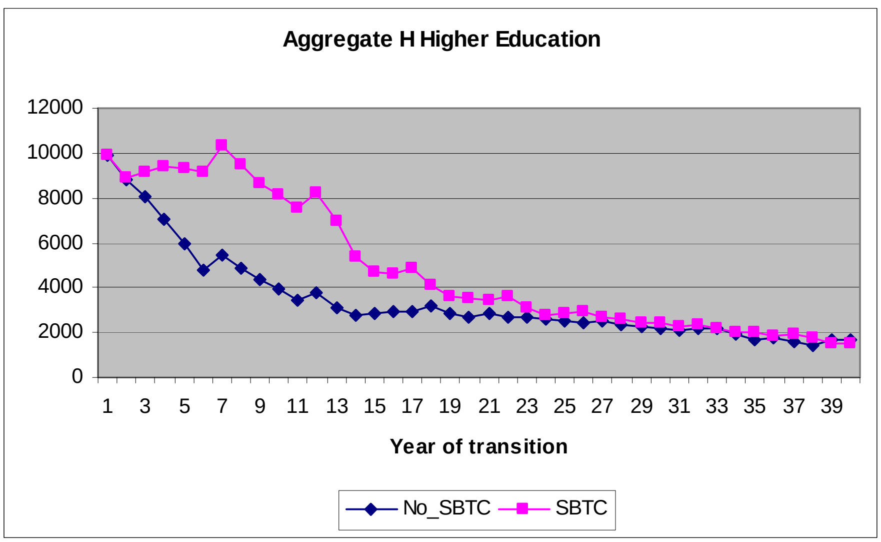

Figure 14. **Aggregate output during the transition, B=0.**

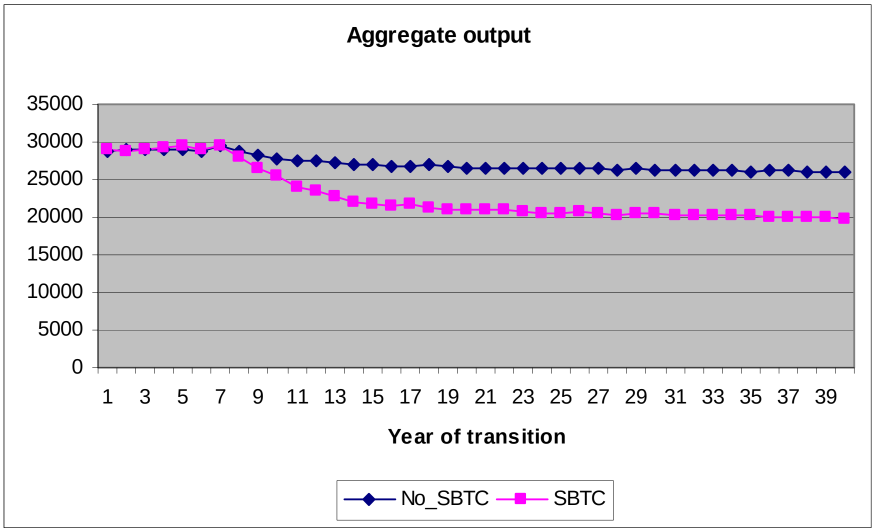

Figure 15. **Log prices by education final s.s., B=lower bound.**

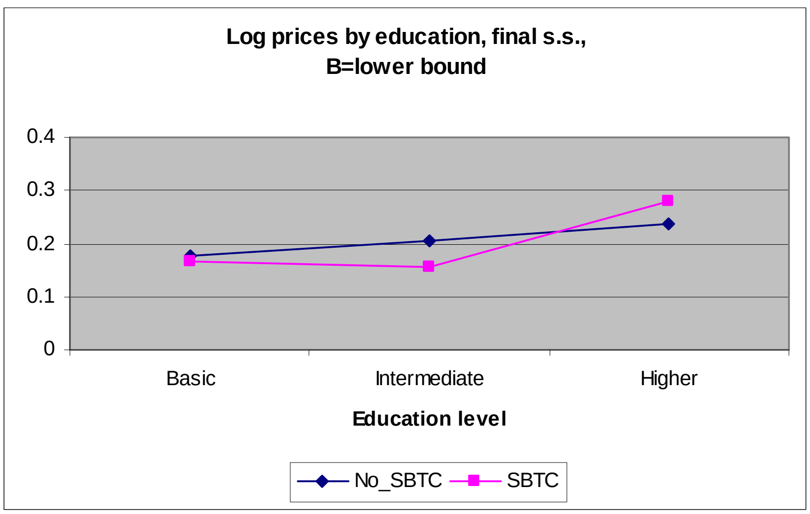

Figure 16. Log prices by education final s.s., B=mid point.

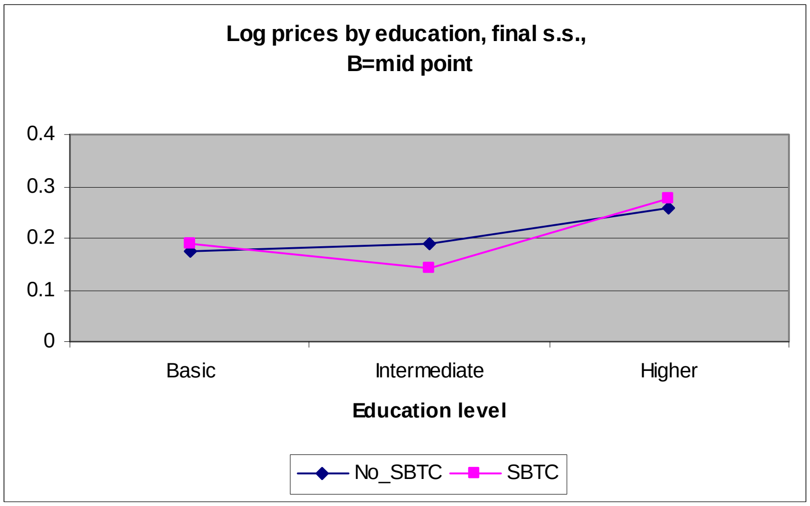

Table 6. Returns to schooling final s.s., B=lower bound.

	No SBTC	SBTC
Higher vs. Intermediate	3.4%	12.2%
Intermediate vs. Basic	2.6%	-0.96%

Table 7. Returns to schooling final s.s., B=mid point.

	No SBTC	SBTC
Higher vs. Intermediate	6.9%	13.4%
Intermediate vs. Basic	1.2%	-4.6%