The Demand-Supply-Demand Twist: 
How the Wage-Education Profile Got More Convex*

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Abstract

In the 1990s, in many countries, log wages became a more convex function of education: returns to college increased and returns to intermediate education declined. This paper argues that an important cause of this convexification was a two-stage demand-supply interaction: an increased demand for both sorts of educated workers stimulated a supply response; the increased supply of intermediate-educated further increased the demand for college-educated workers, because these two types of labour are complementary. This argument is supported by an empirical equilibrium model of savings and educational choices for Mexico, where the degree of convexification was amplified by loosening credit constraints.

Key Words: Wage Inequality, Human Capital, Empirical Equilibrium Model, Latin America.

JEL Codes: J24, J23, J31, C68.

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1 Introduction

In the 1990s in many countries the wage gap between education groups has changed differentially in the top and in the bottom half of the wage distribution: the wage-education profile convexified with the returns to college rising sharply and the returns to intermediate levels of education decreasing or remaining unchanged.\(^1\) This pattern has been documented both for the US and for a number of developing countries.\(^2\) Efforts to explain the convex wage-education profile have focused on the US. One of the leading explanations has been increasing returns to college in a model where the supply of education is taken as given and returns to schooling are heterogeneous (Deschenes 2002 and Lemieux 2006).\(^3\)

This paper suggests a different though not necessarily inconsistent explanation for the convex wage shift. The argument is based on a two-way interaction between the demand and the supply of education. An initial rise in the demand of workers with intermediate and college education increased the returns to both these two types of educated workers and thus gave incentives to invest in human capital. The increased supply of intermediate-educated workers - due to a reduction of financial constraints to invest in education - further increased the demand for college-educated workers (and therefore the returns to college) since intermediate and college-educated workers are complementary in production. As a result, the returns to college increased and the returns to intermediate education declined.

This paper studies the convexification in Mexico, a country where the convex wage shift was far more pronounced than the one observed in the US\(^4\): between 1987 and 2002 the higher

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\(^1\) Consistent with the convexification of the wage-education profile, changes in wage inequality have been characterized by divergent trends in upper- and lower-tail inequality: the 90th-50th percentile ratio of hourly wages increased, while the 50th-10th ratio declined or increased much less (Goos and Manning 2003 for the UK; Autor, Katz and Kearney 2006 and Goldin and Katz 2007 for the US; Spitz-Oener 2006 for West Germany, Binelli and Attanasio 2010 for Mexico).


\(^3\) The convexification of the education-wage profile has also been studied in the context of the long run theory of equilibrium wage functions. In an equilibrium model of savings and occupational choices, Mookherjee and Ray (2010) derive the theoretical prediction of a convex relationship between the skill-intensity of an occupation and its marginal rate of return so that "the return to human capital is endogenously nonconcave", which constitutes the central empirically testable proposition of the paper.

\(^4\) The changes in relative wages in the US were not very pronounced. Using data from the US Current Population Survey Lemieux (2007) show that between 1989 and 1999 the high school graduates-high school dropouts wage gap barely changed while the college-high school wage gap increased by around six per cent for
(college or more)-intermediate (high school) wage differential increased by more than forty-five per cent and the intermediate-basic (compulsory) education wage differential declined by over twenty-five per cent. Mean wages for those with intermediate education fell absolutely.

These changes in wages differentials were accompanied by significant changes in the supply of education: the proportion of people who completed high school increased from around 30 per cent in 1987 to 45 per cent in 2002 and the proportion of people who completed college or more increased from around 10 per cent in 1987 to 18 per cent in 2002. These supply changes could in theory have caused the convexification by altering the composition of workers. However, I show that this was not the case in Mexico, for either observable (such as birth cohort and age effects) or unobservable characteristics. Then, I develop a model to quantify the importance of the changes in the prices of education as the proximate cause of the convex shift.

The setting is an incomplete market, dynamic model of savings and educational choices where the interest rate is taken as given and the education prices are the marginal productivities of three human capital aggregates - basic, intermediate and higher education - that build up the economy human capital endowment. The production function is modelled as a flexible CES which allows for different elasticities of substitution between human capital pairs. Education and savings choices are taken by altruistic parents that face credit constraints. Individual wages are a function of the level of education and ability, and are subject to insurable idiosyncratic shocks.

Model’s simulations identify two main determinants of the convex wage shift: the extent of the credit constraints determines the size of the supply response to an increased demand for skill and thus the changes in the levels of wages; the production complementarities are responsible for the changes in relative wages: when workers with intermediate and higher education are complementary, in addition to the standard direct supply effect, the growth of workers with intermediate education increases the relative demand of workers with higher education and therefore their marginal product while it further decreases the relative return of those with intermediate education.

males and seven per cent for females. Consistently with these small changes in relative wages, the changes in the relative supply of workers with high school and college education have also been modest (Goldin and Katz 2007).
As in Heckman, Lochner and Taber (1998) (HLT - hereafter) and Lee and Wolpin (2006) (LW - hereafter) the results show that the interplay between changes in the demand and in the supply of skills is a key factor to explain the evolution of the returns to education. In addition, this paper uses the variation that comes from the convex wage shift to model the supply of education. In this regard, the inclusion of joint education and saving choices under credit constraints is a key model’s feature and the most relevant difference with respect to both HLT and LW.5

In addition to choices under credit constraints, the second important model’s feature and key ingredient of the explanation are the production complementarities between middle and high-skilled workers. This type of complementarities has also been pointed out as an important determinant of changes in wage differentials between workers with different skills by Autor, Katz and Kearney (2006) (AKK - hereafter). Assuming that middle-skilled workers are more complementary to high than to low-skilled workers and that computerization is a perfect substitute to middle-skilled workers, AKK show that a fall in computer prices displaces middle-skilled workers and leads to a polarization of employment and earnings. AKK take the supply of skills as exogenously given and use US data to provide some supporting empirical evidence to the qualitative predictions of their model. Differently, this paper models the supply of skills in structural details.

The remainder of the paper is organized as follows. Section 2 documents the wage convexification in Mexico. Section 3 presents the model and defines the equilibrium. Section 4 briefly discusses the estimation of the model. Section 5 presents the simulation results. Section 6 discusses the model’s fit and some robustness checks. Section 7 concludes. Appendix A describes the data and the Mexican education system. Appendix B gives details of the solution method. Appendix C and D discuss, respectively, model’s estimation and sensitivity analysis.
Figure 1: Convexification of the Mexican Wage Profile (Source: author’s calculations based on the Mexican employment survey. Adult population aged 25-60. Basic education is up to uncompleted secondary; intermediate education is up to uncompleted college; higher education is completed college or more.)

2 Wage convexification in Mexico

For the analysis of wage changes in Mexico I use micro data from the Encuesta Nacional de Empleo Urbano (ENEU) from 1987 to 2002. The ENEU is a quarterly household survey where households stay for five consecutive quarters in the sample. The measure of wages that I use is computed as real hourly earnings in the fourth quarter. A detailed description of the ENEU is presented in Appendix A.

Figure 1 presents mean log real hourly wages by years of education (Panel A) and by education category (Panel B) in 1987 and in 2002. In the decade of the 1990s mean wages up to completed college education (17 years of more) decreased (Panel A). If we group the years of education to construct three education categories (Panel B), the wage convexification is even more apparent: between the end of the 1980s and 2002 the college premium increased by over 70 per cent while relative wages of intermediate with respect to basic education decreased by around 15 per cent.\[^6\] The double change in relative wages was driven by a

\[^5\]Gallipoli, Meghir and Violante (2007) develop an equilibrium model of savings and educational choices with credit constraints. Their model has a much richer structure than the one developed here.

\[^6\]The difference of the mean real wages by education between the two years is highly statistically significant. A test of the increase of the relative wage at higher education and the decline of the relative wage at intermediate education also returns highly significant results.
drop in the level of the wages at intermediate education that decreased by as much as 5 percentage points.⁷

Somewhat surprisingly, the empirical literature on Mexico has focused on the increase in the college premium rather than on the convexification and has explained the rise in the college returns either with changes in the demand for skilled workers taking the supply as given or, viceversa, with changes in the supply of college taking the demand as given.⁸ On the contrary, Figure 1 shows that it was the combination of an increase in the returns to college and a decline in the returns to intermediate education that characterized the changes in wage inequality in the 1990s at a time of significant changes in both the supply of and the demand for labor. Explaining this double change in relative wages is the aim of this paper.

When did the wage convexification appear in Mexico? A vast empirical literature has documented two distinct episodes of changes in Mexican wage inequality: a period of rising wage inequality from the end of the 1980s to the mid 1990s and a period of stable or even decreasing wage inequality in the second half of the 1990s (for two recent papers see Binelli and Attanasio 2010 and Bosch and Manacorda 2010). Changes in wage differentials between education groups show a consistent pattern: they increased until the mid 1990s and decreased or remained stable afterwards (Figure 8 in Appendix A).⁹

It was in the mid 1990s that the wage differential between higher and intermediate and between intermediate and basic education started to diverge, the former keeping on increasing, the latter starting to decrease. Consistently, we would expect the wage-education

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⁷Interestingly, a similar convexification pattern is apparent in Brazil and Colombia in the 1990s: in both countries the college wage premium has been increasing by around 30 per cent while relative wages at intermediate with respect to basic education decreased by around 40 per cent in Brazil and 22 per cent in Colombia. In addition, as it is the case for Mexico, the mean wage at intermediate education decreased in real terms, respectively by 3 and 2 per cent in Brazil and Colombia.

⁸Goldberg and Pavcnik (2004) and Winters, McCulloch and McKay (2004) for two surveys of the "demand-change" literature; Jacoby and Skoufas (2002) and Binelli, Meghir, Menezes-Filho (2010) for two examples of the "supply-change" literature. One exception is Robbins (1996) who applies the approach developed by Katz and Murphy (1992) to analyze the changes in the relative wages and in the relative supply of education in a number of Latin American countries. However, Robbins (1996) only considers two education groups - skilled and unskilled workers - once more focusing exclusively on the changes in the wage premium to higher education rather than on the convexification.

⁹The decrease of the wage differential between intermediate and basic educated was much more pronounced than the decrease of the wage differential between higher and intermediate educated, so that over the 1987-2002 period the higher-intermediate wage differential increased while the intermediate-basic wage differential dropped.
profile to have started convexifying then. Panel A in Figure 2 presents mean log hourly wages for different years from the end of the 1980s throughout the decade of the 1990s; panel B presents mean wages by education averaged over the first and the second half of the 1987-2002 period. The main message from Figure 2 is that wages in Mexico started to convexity in the mid 1990s. This finding confirms the results reported by Bouillon, Legovini and Lustig (2005) that document a convexification of the Mexican wage-education profile in the first half of the 1990s.10

2.1 Changes in composition to explain the convexification

The changes in wages that characterize the convexification were accompanied by significant changes in the supply of education: the proportion of the Mexican adult population with, respectively, intermediate and higher education increased from around 30 and 10 per cent in 1987 to around 45 and 17 per cent in the year 2002.11

10Bouillon, Legovini and Lustig (2005) point at the Nafta trade liberalization reforms of 1994 as the proximate cause of the convex wage shift in Mexico. Brazil and Colombia were also characterized by a convexification of the education-wage profile following a process of significant trade liberalization. Colombia liberalized between 1985 and 1994, and Brazil between 1988 and 1995. In Brazil the wage profile started to convexify at the end of the 1990s; in Colombia, as it is the case in Mexico, wages started to convexify in the mid 1990s.

11Similar patterns characterize the changes in the supply of education in Brazil and Colombia: the proportion of the adult population with, respectively, intermediate and higher education increased from around
Given these significant supply changes, a first possible explanation of the convex wage shift is that the entrance in the labor market of the new cohorts of workers altered the wages significantly because of changes in the composition of observable and unobservable characteristics by level of education. Among observable characteristics, an important variable is individuals’ age. A vast empirical literature has documented how the age-earning profiles differ by skill and age with wage profiles being steeper for higher educated and younger workers (e.g. Gosling, Machin and Meghir 1999).

The increased supply of intermediate and higher educated in Mexico resulted into a change in the workers’ age composition towards higher skilled and relatively younger workers, thus age effects could have contributed to the convex wage shift. In order to account for changes in the age composition, I estimate Mincer-type wage regressions that control for education, age and its interaction with the level of education. Figure 3 presents the results. Panel A presents, for comparison, residual wages when controlling for education and age only; panel B presents residual wages when additionally controlling for the interaction of age and education. The wage-education profiles in panel A and B are qualitatively similar to the ones reported in Figure 1: in all cases the higher-intermediate wage differential increases and the intermediate-basic education wage differential decreases. The wage-education profiles for 2002 in Panel B Figure 1 was characterized by an increase in the higher-intermediate wage differential of around 73 per cent and a decrease of the intermediate–basic wage differential of around 15 per cent relative to 1987; the changes in the two wage differentials that characterized the wage-education profile for 2002 in panel A (B) Figure 3 were, respectively, an increased of around 70 (145) and a decrease of around 13 (44) per cent. Overall, the wage-education profile once age effects have been accounted for (Panel B Figure 3) is even more convex than the wage profile when the raw data are plotted (Panel B Figure 1).

The lack of a significant role of changes in the age composition to explain the convexification is perhaps a surprising result and one that deserves further investigation. An additional way to assess the contribution of the age effects is to compare the wage-education profile for different age groups. Mean wages in Figure 1 are constructed by considering all individuals 32 and 12 per cent in Brazil and 34 and 17 per cent in Colombia in 1987 to around 55 and 14 per cent in Brazil and 43 and 21 per cent in Colombia in 2002.
Figure 3: Convexification of the Mexican Wage Profile After Controlling for Age Effects (Source: author’s calculations based on the Mexican employment survey. Adult population aged 25-60.)

Figure 4: Convexification of the Mexican Wage Profile by Cohort After Controlling for Age Effects (Source: author’s calculations based on the Mexican employment survey.)

aged between 25 and 60. By constructing 5-years age cohorts, we can produce the same graph for each of 5-years seven age cohorts. Unreported results, all available upon request, show that, consistently with the findings in Figure 3, the wage-education profile convexified for each 5-years cohort, both when plotting the raw mean log wages, and when plotting residual wages after controlling for age.
Further insights on the determinants of the convexification can be drawn from the comparison of the wage-education profile by age cohorts. In particular, we can use comparisons of mean wages by age cohorts to assess the contribution of changes in the ability composition to the convex wage shift. Changes in ability could have played an important role: in particular, a decline in the average ability of intermediate-educated workers due to the expansion of the size of this group could have reduced wages at this level of education substantially and made the wage profile convexified.

We can compare the evolution of the relative returns to education for the cohorts of graduates that made their education choices before 1987 with the relative returns of those cohorts that invested in education during the 1990s. Assuming that investment in education ends at age 25 and that the individuals enter into the labor market at the end of the education period if not before, we can divide the 25-60 age sample in two groups. The first group consists of the individuals that made all their schooling decisions before 1987, that is by all individuals that are older than forty in 2002; the second group consists of those that are between 25 and 40 years old in 2002.

If changes in ability composition are driving the convexification, the wage-education profile of those that made all their schooling decisions before 1987 and were in the labor market by then should not have convexified during the 1990s. I estimate Mincer-type wage regressions that control for education, age and its interaction with the level of education. Panel A and B in Figure 4 report the results: in 2002 the wage-education profile convexified for both age groups. In particular, in 2002 relative to 1987 for the 25-40 age group the intermediate-basic wage differential increased by around 52 per cent but the higher-intermediate wage differential increased by over 1000 per cent; for the 41-60 age group the higher-intermediate wage differential increased by around 29 per cent and the intermediate-basic wage differential decreased by around 77 per cent.

All empirical evidence discussed so far suggests that the convexification was not primarily driven by changes in age and ability composition. A third candidate is changes in the prices or market value of education due to the interplay between changes in the demand and in the supply of workers with different skills - i.e. with basic, intermediate or higher education. The rest of the paper will develop a demand-supply equilibrium model that will allow to quantify
the contribution of changes in the education prices to explain the convex wage shift.

3 The model

At each time $t$ the economy consists of overlapping generations of parents and children that live together for four periods: a pre-school period and three periods necessary to complete three education levels - basic, intermediate and higher education.\footnote{A description of the Mexican schooling system and the construction of the education groups is presented in Appendix A.} 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 parental maximizing behavior.

3.1 Supply side: household decision problem

A continuum of individuals is born at each time $t$. Each individual lives for eight periods, four as a child and four as a parent. As a child the individual lives with the parent that works full time and maximizes utility which is a function of joint household consumption. In the first two periods consumption is the only choice variable. In the first period the child is in pre-school, in the second period is sent to compulsory basic education. In the third and fourth period the child can be sent either to school or to work. If the child is sent to school, the parent has to pay a fixed cost that is education-specific. If sent to work, the child works full time and gives her earnings to the parent. At the end of the fourth period the parent retires and leaves a bequest of financial assets to the child. The child starts the adult life with the level of education completed during childhood and an amount of assets given by parental bequest.

Labor supply is perfectly inelastic and wages clear the labor markets. The wage of an individual $i$ with education level $j$ and age $a$ in period $t$ is given by:

$$w^{i}_{j,a,t} = p_{j,t} \exp(e^{i}_{j,a,t}) \quad j = 1, 2, 3$$

(1)

with

$$e^{i}_{j,a,t} = \eta^{i} + g_{j}(ae^{i}) + z^{i}_{j,a,t}$$

(2)
where \( j = 1, 2, 3 \) denotes the education level from basic up to higher education. \( p_{j,t} \) is the price of a unit of human capital of type \( j \) at time \( t \); it is determined as the marginal product of the aggregate supply of education level \( j \) in period \( t \). \( e^i_{j,a,t} \) denotes labor efficiency of individual \( i \), which is a function of \( \eta^i \), the individual’s ability endowment, \( g_j(\text{age}^i_t) \), an education-specific polynomial in age which reflects the growth of wages with experience, and \( z^i_{j,a,t} \), an education-specific i.i.d. uninsurable shock that is assumed to be normally distributed with mean \( \mu_{z^i_{j,a,t}} \) and variance \( \sigma^2_{z^i_{j,a,t}} \). The uninsurable shock is received in each period and is a proxy of earnings’ volatility and uncertainty.

Individuals’ ability endowment, \( \eta^i \), 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. It is assumed to be perfectly transmitted between successive generations: each individual inherits at birth the ability endowment of her parent and passes it over to her own child.\(^{13}\)

In order to solve the household maximization problem the adults (parents) need to form expectations on current and future skill prices, which determine wages. Let us define as \( p_t(a) \) the vector of current and future skill prices forecasted from age \( a \) onwards. Omitting for simplicity the \( t \) time index, parental maximization problem is given by:

\[
V_a(X_a) = \max_{(c_a,J_a)_{a=\bar{a}}} \mathbb{E} \left\{ \sum_{a=\alpha}^{\bar{a}} \beta^{a-\alpha} U(c_a) + \beta^2 \lambda V_{\bar{a}}(X_{\bar{a}}) \right\} \\
\text{s.t. } \\
A_{a+1} = A_a (1 + r) + w_j p_j a + [(1-I_a) w_j c_j - I_a F_j c] - c_a
\]

\[
J_{a+1}^C = \left\{ \begin{array}{ll}
  j^C_a + 1 & \text{if } I_a = 1 \\
  j^C_a & \text{if } I_a = 0
\end{array} \right. \\
\forall \ a = \bar{a} - 1, \bar{a}
\]

\[
A_a \geq -B_a \quad \forall \ a = a_0, \ldots, \bar{a} - 1
\]

\(^{13}\)The assumption of perfect transmissibility of ability from parents to children is motivated by the empirical evidence from Latin America. The correlation between proxies for the ability level of parents and children is high. As an example, data from the Mexican Family Life Survey in 2002 shows that the correlation between the Raven test of the mother (or father) and their children is above eighty per cent.
where $X_a$ denotes the vector of state variables at age $a$, which includes the level of adult education, $j^P$, that is fixed throughout adulthood, the level of child education, $j^C_a$, the amount of assets at age $a$, $A_a$, the vector of current and future skill prices forecasted from age $a$ onwards, $p(a)$, the ability endowment, $\eta$, and the idiosyncratic shock to wages, $z_a$. Then $X_a = (j^P, j^C_a, A_a, p(a), \eta, z_a)$, with $j^C_a$ normalized to zero when consumption is the only choice variable. $\lambda$ is the degree of parental altruism, $a$ ($\bar{a}$) denotes the age of the parent at start (end) of the adult life and $V_{\bar{a}}(.)$ is the child’s lifetime utility once adult.

c_a and $A_a$ denote, respectively, joint household consumption and financial assets at age $a$. $w_{jP,a}$ is parental wage at age $a$ given parental education level $j^P$. $I_a$ is an indicator function taking the value of one when the child is sent to school and zero otherwise. If the child is sent to work, the parent receives the child’s wage, $w_{jC,a}$. If the child is sent to school, the parent pays the fixed costs, $F_{jC}$, for the $j^C$ schooling level attended by the child. $E$ denotes expectations that reflect uncertainty due to the presence of the uninsurable idiosyncratic shocks to earnings, $z$. $\beta$ 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.\(^{14}\)

The optimization problem described in (3) is solved under four main constraints. The first constraint (equation (4)) is a standard period budget constraint with the term in square brackets switching on when child education becomes a choice variable. The second constraint (equation (5)) defines the law of motion of child’s education. The third constraint (equation (6)) is a borrowing restriction imposing a limit $B_a$ on the amount of net indebtedness at age $a$. The fourth constraint (equation (7)) is a terminal condition that prevents parents from dying in debt: they can not leave debts to their children.

The borrowing limit, $B_a$, can take any value between zero, which corresponds to the maximum level of credit constraints of no possible borrowing, and an upper bound that is

\(^{14}\)We assume that the utility function takes a simple CRRA formulation:

$$U(c) = \frac{(c)^{1-\gamma}}{1-\gamma}$$

where $\gamma$ is the reciprocal of the intertemporal elasticity of substitution.
given by the present discounted value of lifetime earnings at age \( a \) under the lowest possible realization of individual labor efficiency, that is under the lowest possible realization of the idiosyncratic shock \( z \).\(^{15}\) The upper bound represents the maximum amount that an individual will always be able to repay without violating the no-debt condition specified in equation (7).\(^{16}\)

### 3.2 Demand side: aggregate production function

The representative firm operates a constant returns to scale technology production function over physical and human capital. I assume that there are no adjustment costs for physical and human capital and no shocks to the aggregate production. The production function in year \( t \) is given by:

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

where \( Y_t \) denotes aggregate output, \( K_t \) is aggregate physical capital and \( H H_t \) is aggregate human capital.\(^{17}\) \( \alpha \) 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.\(^{18}\) I assume that the economy is small and open to the world financial markets.\(^{19}\) Capital flows in or out of the country so that the marginal product of physical capital equals the world interest rate, \( r \).\(^{20}\)

\(^{15}\)The empirical distribution of \( z_j \) is defined over a finite support with a minimum value, \( z_j \), and a maximum value, \( z_j \). Therefore, wages are assumed to be always positive and different from zero.

\(^{16}\)The value of the upper bound arises naturally from the assumption that the utility function satisfies the Inada condition \( \lim_{c \to 0} U'(c) = -\infty \) and that parents have to repay all debts before retiring.

\(^{17}\)This specification of the production function assumes that there are no complementarities between physical and human capital. This assumption is motivated by the near-constancy of the share of physical capital in production estimated for LACs in the 1990s (Bosworth, 1998, Harrison, 1996 and Hoffman, 1993).

\(^{18}\)Given the assumption of no population growth and the normalization of \( Z \), there is no growth in steady state. Growth in the model will only occur during the transition towards a steady state as a result of the reallocation of efficiency units of labor from less to more productive combinations of the different types of human capital.

\(^{19}\)This is a reasonable assumption given that the model will be estimated for Mexico, which is a small economy open to financial trade particularly with the US. The interest rate, accordingly, will be set to the US level.

\(^{20}\)In the absence of aggregate shocks, the constancy of the world interest rate implies that the economy’s physical to human capital ratio is fixed over time. Also, this assumption implies that firms face no credit constraints. Differently from individual households, they can freely borrow in the international capital markets at the fixed rate \( r \). There are no financial intermediaries that can borrow money from firms and lend it to households.
I consider three types of human capital corresponding to the three education levels that the individuals can complete and I specify the aggregate human capital in year $t$, $HH_t$, as a nested CES function over the three types of human capital, $H_1, H_2, H_3$, which represent, respectively, the human capital of those completing basic, intermediate and higher education.

Instead of assuming perfect substitutability between the three aggregate human capitals, I choose a flexible specification that allows for different elasticities of substitution (ES) between human capitals’ pairs. A convenient way to allow for a different ES between pairs of human capital is to combine them within a CES specification. I use the CES specification because it is simple, has few parameters and restricts the substitution elasticities to be constant.\footnote{An alternative to the CES is the translog function. However, the translog has many more parameters to estimate, which would significantly reduce the degrees of freedom in an already small sample.}

I specify $HH_t$ as follows:\footnote{Given three human capital inputs, there are three ways of nesting them within a CES aggregate: $\tilde{HH}_1 = \Gamma_1(H_3, \Gamma_2(H_2, H_1)), \tilde{HH}_2 = \Gamma_2(H_2, \Gamma_2(H_3, H_1))$ and $\tilde{HH}_3 = \Gamma_3(H_1, \Gamma_2(H_2, H_3))$, where $\Gamma_1$, $\Gamma_2$ and $\Gamma_3$ are CES aggregators. The CES functional form imposes symmetry restrictions on substitution elasticities. For $\tilde{HH}_1$, the ES between $H_3$ and $H_1$ is restricted to be the same as the one between $H_3$ and $H_2$. For $\tilde{HH}_2$, the ES between $H_2$ and $H_3$ is restricted to be the same as the one between $H_2$ and $H_1$. These restrictions contrast with factor elasticities previously estimated for LACs which show that the ES between higher and intermediate education differs from the one between either higher or intermediate and basic education (Manacorda, Sanchez-Paramo and Schady, 2010).}

$$HH_t = \left[ (1 - \delta_{s,t})H_{u,t}^\rho + \delta_{s,t}H_{s,t}^\rho \right]^{\frac{1}{\rho}} \quad (9)$$

where $H_{u,t}$ and $H_{s,t}$ are, respectively, the human capital aggregate for unskilled and skilled labor at time $t$.

$H_{u,t}$ corresponds to $H_{1,t}$ and $H_{s}$ is given by:

$$H_{s,t} = \left[ (1 - \alpha_{3,t})H_{2,t}^\theta + \alpha_{3,t}H_{3,t}^\theta \right]^{\frac{1}{\theta}} \quad (10)$$

The time-varying and skill-specific parameters $\delta$ and $\alpha$ in equation (9) and (10) denote the shares of the human capital factors in production. Changes in $\delta$ and $\alpha$ reflect variations in the productivity and in the demand of the different inputs. The parameter $\rho$ determines the ES between unskilled and skilled labor, which is given by $ES_{u,s} = ES_{1,2} = ES_{1,3} = \frac{1}{1 - \rho}$, while $\theta$ determines the ES between intermediate and higher education, which is given by
If either $\rho$ or $\theta$ is zero, the corresponding nesting is Cobb-Douglas. If $\rho > \theta$, the elasticity of substitution between higher and intermediate is lower than the one between either higher or intermediate and basic education, which means that there are complementarities in production between intermediate and higher education.

The labor input is measured in efficiency units: each input type is the product of the raw number of labor units of that type and the efficiency index defined in equation (2).

The aggregate stock of human capital $j$ in year $t$, $H_{j,t}$, is given by the sum of the efficiency weighted individual supply of education level $j$, at time $t$:

$$H_{j,t} = \sum_i h_{i,t}^j$$

where $h_{i,t}^j$ is the supply of education level $j$ of individual $i$ in year $t$ expressed in efficiency units.

Differently from physical capital, labor is not internationally mobile and its remuneration is set domestically. Under the assumption of perfectly competitive markets and profit maximization by firms, the price for education level $j$ in year $t$, $p_{j,t}$, is given by the marginal product of the $jth$ aggregate human capital. By taking the ratios of the marginal products, I can derive the expressions for the relative returns to schooling:

$$\frac{p_{2,t}}{p_{1,t}} = \frac{\delta_{s,t}}{(1 - \delta_{s,t})(1 - \alpha_{3,t})} \left( \frac{H_{1,t}}{H_{2,t}} \right)^{1-\rho} \left\{ (1 - \alpha_{3,t}) + \alpha_{3,t} \left[ \frac{H_{3,t}}{H_{2,t}} \right]^\theta \right\}^{\frac{\rho-\theta}{\theta}}$$

(12)

$$\frac{p_{3,t}}{p_{2,t}} = \frac{\alpha_{3,t}}{(1 - \alpha_{3,t})} \left( \frac{H_{3,t}}{H_{2,t}} \right)^{\theta - 1}$$

(13)

$$\frac{p_{3,t}}{p_{1,t}} = \frac{\delta_{s,t}}{(1 - \delta_{s,t})} \left( \frac{H_{1,t}}{H_{3,t}} \right)^{1-\rho} \left\{ \alpha_{3,t} + (1 - \alpha_{3,t}) \left[ \frac{H_{2,t}}{H_{3,t}} \right]^\theta \right\}^{\frac{\rho-\theta}{\theta}}$$

(14)

---

23There are different ways of measuring the ES when the aggregate output is produced with more than two inputs. We use the definition of the direct ES. One alternative commonly used definition is the Allen elasticity of substitution. The direct elasticity of substitution between Intermediate and Higher Education is solely a function of the curvature parameter, $\theta$, while the Allen definition involves both the curvature parameter and the factor shares.
where equations (12), (13) and (14) define, respectively, the relative returns to intermediate versus basic, higher versus intermediate and higher versus basic education.

The degree of complementarity between intermediate and higher education is an important determinant of the changes in relative returns. An increase in the amount of human capital at intermediate level has two different effects: a standard supply effect (SE) and a complementarity effect (CE). The standard SE is clear from the human capitals’ ratio in round brackets in equation (12) and (13). For a given supply of basic and higher human capital, an increase in $H_2$ decreases the relative return to intermediate with respect to basic education and increases the relative return to higher with respect to intermediate education. The CE is given by the term in curly brackets in equation (12) and (14). If $\rho > \theta$, that is if higher and intermediate education are more complementary than higher and basic (or intermediate and basic), an increase in $H_2$ further decreases the relative return to intermediate with respect to basic education and increases the relative return to higher with respect to basic education.

### 3.3 Equilibrium

Given an initial distribution of ability, financial assets and education and the world interest rate, $r$, a competitive equilibrium is given by a sequence of vectors of skill prices, $p_t = [p_{1,t}, p_{2,t}, p_{3,t}]$, aggregate labor inputs, $H_t = [H_{1,t}, H_{2,t}, H_{3,t}]$, parental decision rules for consumption and education choices, $[c_{a,t}, I_{a,t}]$, individual labor supply of education $j$, $j_{a,t}$, individual labor efficiency, $e_{j,a,t}$, age, time and education specific measures, $\varphi_{j,a,t}$, for $t = 0, 1, 2, ..., \bar{a}$ such that:

1. Given the prices $[p_{1,t}, p_{2,t}, p_{3,t}]$, the contingent plans $c_{a,t}$ and $I_{a,t}$ solve the household maximization problem (3) subject to (4) to (7).

2. Given the prices $[p_{1,t}, p_{2,t}, p_{3,t}]$, firms choose optimally the production factors and prices are marginal productivities:

$$p_{j,t} = \frac{\partial Y_t}{\partial H_{j,t}} \quad \forall j$$
3. The labor markets clear:

\[ H_{j,t} = \sum_{a=0}^{\pi} \int_{S} (j_{a,t}(s) * \exp(e_{j,a,t})) d\varphi_{j,a,t}(s) \quad \forall j \]

where \( S \) defines the state vector at age \( a \), time \( t \), minus the education states, i.e. \( S \equiv (A_{a,t}, p_t(a), \eta, z_{a,t}) \).

An equilibrium steady state is a competitive equilibrium with stationary prices and distributions, that is an equilibrium such that \([p_t, H_t] = [p, H]\) for all \( t \).

Starting from a set of initial conditions defined by the vector of model’s parameters and the distribution of education, wealth, ability and of the idiosyncratic shocks to earnings, the model is solved in each year of the transition towards a steady state with a standard solution method based on backward recursion and value function iterations. The full solution method for the steady state and the transitional dynamics is described in Appendix B.

4 Determining the parameters of the model

The ideal data set to estimate the model would combine micro data on the earnings of workers, their life-cycle consumption and wealth holdings, and macro data on prices and aggregates. Using the micro data joined with aggregate prices, I could estimate the parameters of the household decision problem and construct aggregates of human capital that can be used in determining the output technology. Two obstacles prevent implementing this approach. First, I lack information on individual consumption linked to labor earnings over many years. Second, the data on market wages do not reveal skill prices, as is evident from the distinction between \( w \) and \( p \) in equation (1), so it is not possible to estimate aggregate stocks of human capital using wage data directly.

To circumvent the first limitation, I follow practices widely used in the literature on empirical equilibrium models, and I choose discount and intertemporal substitution parameters in consumption to be consistent with those reported in the empirical literature and that enabled the model to reproduce key features of the macro data like the capital-output ratio. I calibrate these parameters after having estimated the wage equations and the production
function and I explore the sensitivity of the simulations to alternative choices of these parameters. The complete list of the calibrated parameters together with their value and the target used in the calibration is reported in Figure 13 in Appendix C.

To circumvent the second problem, I follow the method of using wage data to infer prices and to estimate skill-specific human capital aggregates developed by Heckman, Lochner and Taber (1998). By having a measure of the human capital series, it is then possible to estimate the production function. All estimation and calibration results are presented and discussed in Appendix C.

5 Simulations

I use model’s simulation to quantify the role of changes in the prices of education to explain the convexification. I do so by computing the equilibrium education prices \( p_{j,t} \) in equation (1) in different scenarios.

The 1990s in Mexico, as well as in all Latin America, were characterized by an increased demand for skilled labor largely due to the significant trade liberalization and labor market reforms that characterized this decade (Goldberg and Pavcnik 2004; Winters, McCulloch and McKay 2004). Interestingly, in Mexico the wage-education profile started to convexify in the mid 1990s after the market reforms took place (see discussion in Section 2 and Bouillon, Legovini and Lustig 2005).

The increased demand for skilled workers that these reforms induced and the related supply responses they generated could have been an important determinant of the wage convexification. In order to test this hypothesis, I define a baseline economy that matches the linear wage-education relationship observed in Mexico at the end of the 1980s and I assess the impact of an increase in the demand for skilled labor, \( \delta_s \), which I find to have increased in the 1990s by 1.35 per cent a year (see Table 6 and the discussion in Appendix C). I refer to this increased demand for skilled labor as "skill-biased technological change" (SBTC hereafter).
5.1 Increased demand for skilled labor

I assess the impact of the increased demand for skilled workers (SBTC) in two steps. First, I reduce the model to a partial equilibrium one where the supply of labor is kept fixed at the level observed in Mexico in 1987 and thus the wage changes are explained entirely by changes in the demand for the three different types of labor (Scenario I). Then, I define a second counterfactual where the supply of labor is allowed to react to the demand increase (Scenario II).

Figure 5: Steady state with skill-biased technological change and exogenously fixed (I) versus endogenous (II) supply of education.

Figure 5 presents the equilibrium (log) skill prices in the baseline model and in Scenario I and II. At baseline the model matches the education shares in 1987 and produces a linear relationship between the log prices and the level of education. Once the share of skilled labor increases, Scenario I produces a steeper prices' schedule. As clear from the equilibrium conditions and the fact that \( \delta_u = (1 - \delta_s) \), an increase in \( \delta_s \) decreases the equilibrium price at basic and increases the prices at both intermediate and higher education. With respect to the baseline, both the relative returns to higher with respect to intermediate and to intermediate with respect to basic education increase.

Scenario II allows the supply of labor to react to the changes in the prices due to the SBTC. The increased prices at intermediate and at higher education give incentives to invest after compulsory schooling. As expected and consistently with the fixed costs of education
being lower at intermediate than at higher education ($F_2 < F_3$), the supply of workers with intermediate education increases more than the one of workers with higher education, so with respect to the baseline the price at intermediate increases less than at the higher level. With respect to the baseline model the returns to higher education increase while the returns to intermediate education declined.

Figure 6: Steady state with skill-biased technological change, endogenous supply of education and isoelastic production function (III) versus production complementarities (II).

The comparison between Scenario II and I shows the role of the endogenous supply of education: the differential responses of the supply of intermediate and higher education to the demand increase are the key determinants of the divergent changes in the returns to schooling.

The size and the direction of the feedback effects of the changes in the supply of education on the education prices depend on the degree of substitutability between the aggregate human capitals (see Section 3.2). The estimation of the production function shows that there are complementarities between workers with intermediate and with higher education (see Appendix C). Figure 6 quantifies the importance of these production complementarities. I define a third counterfactual, Scenario III, which assumes that the production function is isoelastic, that is $\rho = \theta$ and therefore $ES_{u,s} = ES_{1,2} = ES_{1,3} = ES_{2,3} = \frac{1}{1-\rho}$. As it is clear from Figure 6, in the absence of complementarities between intermediate and higher education, the price at intermediate education increases and the equilibrium price schedule
is back to being a linear function of education.

5.2 Relaxation credit constraints

The simulations so far have shown that an endogenous supply response in the presence of production complementarities is key to produce the convexification. Among the main factors that determine the extent of the supply response to a given demand change is the degree of credit constraints: households will be better able to react to the increased demand for skills the easier it is to obtain resources to finance education.

I define a fourth counterfactual, Scenario IV, that is given by Scenario II with a relaxation of the credit constraints to the upper bound of the values that $B$ can take.\textsuperscript{24} Figure 7 reports the steady state price schedule at baseline, in Scenario II and in Scenario IV.

Figure 7: Steady state skill prices with skill-biased technological change and relaxation of the credit constraints.

With respect to Scenario II, the possibility of borrowing allows more people to complete

\textsuperscript{24}As I discussed in section 3.1, the internal consistency of the model allows to set an upper bound for the value that $B$ can take at any age, which is given by the present discounted value of the lifetime earnings at age $a$ under the lowest possible realization of the idiosyncratic education-specific shock $z_j$. Given the distribution of $z_j$ defined over a finite support with a minimum value, $\tilde{z}_j$, and a maximum value, $\bar{z}_j$, $\tilde{z}_j$ defines the lowest possible value that $z_j$ can take. I compute $\xi_{j,a} = (\eta^i + g_j(age^i) + \tilde{z}_j)$. At each age $a$, given parental education level $j$, $B_a = \sum_{i=0}^{\pi} \frac{w_{j,a}^i}{(1+r)^t} = \sum_{i=0}^{\pi} \frac{(1+r)^t}{(1+r)^i}$ where $r$ is the world interest rate.
intermediate and higher education, so investment in human capital at both levels increases and therefore the equilibrium prices at intermediate and higher education decrease. However, because of the bigger cost to acquire higher rather than intermediate education, the supply increase at intermediate does not translate into a proportional increase at higher education, so the price at intermediate decreases more than at the higher level.

As expected, there is a positive relationship between the borrowing limit and the size of the supply increase at intermediate: the more it is possible to borrow, the higher is the investment in education after compulsory schooling. Unreported results show that there is a borrowing threshold of around forty per cent of individuals’ lifetime earnings below which the size of the supply increase at intermediate is not enough to produce a sizeable decrease in the intermediate price below the value at baseline.

6 Model’s assessment

6.1 Model’s fit

For a quantitative assessment of the model’s performance we can compare the growth of the skill prices and relative returns computed from the simulations and from the data. The second column of Table 1 and 2 presents, respectively, the growth of the level and of the relative log education prices between 1987 and 2002 estimated from equation (20) in Appendix C, that is after controlling for age and individual fixed effects; columns three to six present, respectively, the growth of the level and of the relative log education prices computed at steady state in each of the four simulated scenarios with respect to the baseline model.

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<tbody>
<tr>
<td>Basic</td>
<td>−3%</td>
<td>−9%</td>
<td>−2%</td>
<td>−7%</td>
<td>−2%</td>
</tr>
<tr>
<td>Intermediate</td>
<td>−5%</td>
<td>13%</td>
<td>3%</td>
<td>7%</td>
<td>−6%</td>
</tr>
<tr>
<td>Higher</td>
<td>6%</td>
<td>20%</td>
<td>16%</td>
<td>17%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Table 1: Growth of the log education prices in the ENEU data between 1987 and 2002 having controlled for age effects and in the four simulations with respect to the baseline model

Both the changes in the level of the skill prices and in the relative returns in Scenario IV are close in magnitude to the ones computed from the data. Consistently, the proportions
Table 2: Growth of the relative log education prices in the ENEU data between 1987 and 2002 having controlled for age effects and in the four simulations with respect to the baseline model

<table>
<thead>
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</thead>
<tbody>
<tr>
<td>Higher versus Intermediate</td>
<td>72%</td>
<td>50%</td>
<td>69%</td>
<td>55%</td>
<td>75%</td>
</tr>
<tr>
<td>Higher versus Basic</td>
<td>25%</td>
<td>78%</td>
<td>52%</td>
<td>64%</td>
<td>34%</td>
</tr>
<tr>
<td>Intermediate versus Basic</td>
<td>-15%</td>
<td>119%</td>
<td>28%</td>
<td>78%</td>
<td>-26%</td>
</tr>
</tbody>
</table>

of workers aged 25-60 in the model and in the data match closely. In the data workers with basic, intermediate and higher education are, respectively, 77, 14 and 10 per cent of the workforce in 1987 and 61, 21 and 18 per cent of the workforce in 2002. The education proportions in the baseline model match by construction the data in 1987; in Scenario IV workers with basic, intermediate and higher education are, respectively, 61, 22 and 17 per cent of the workforce.

6.2 Discussion

There are three main aspects of the model that deserve further discussion: the role of changes in the composition of ability by level of education, the production function, and the credit constraints.

6.2.1 Changes in composition of unobservables

Section 2.1 discussed some preliminary evidence suggesting that the convexification was not driven by changes in the composition of unobservables, such as changes in ability composition by level of education. The results of the model’s simulations further confirm this result by showing that the proximate cause of the convex wage shift were changes in the prices of education.

However, the estimates of the ability distribution suffer from the incidental parameter problem (see Appendix C for details). In the absence of long series of panel data for Mexico, the robustness of the ability estimates is severely limited by the short length of the panel. More importantly, even if longer series on individual earnings were available, the quantitative importance of the changes in ability composition is sensitive to the specific ability distribution
estimated from the data: all estimates heavily depend on untestable assumptions on the
distribution of the unobservables.

In theory it is of course possible to think of a given initial ability distribution such that
a big enough drop in mean ability at intermediate and a big enough increase in mean ability
at higher education would produce a convexified wage-education profile so that the convex
wage shift would have been the result of pure compositional changes. I could simulate the
model for an arbitrary change of the moments of the initial ability distribution. However, in
the absence of a benchmark value for the changes in ability composition, it is not clear what
a meaningful or reasonable change in these moments is.

To the best of my knowledge, Binelli, Meghir and Menezes-Filho (2010) (BMM - here-
after) is the only paper that provides an estimate of the changes in the ability composition
by level of education in a Latin American country. BMM distinguish between four levels
of schooling and estimate the changes in ability composition by education and birth cohort
during the Brazilian educational expansion of the 1990s.

I use BMM's estimates as a benchmark for the magnitude of the changes in ability
composition and perform an indirect robustness test of the quantitative importance of these
changes to produce the convexification: I simulate the model at constant skill prices and
compute the changes in mean ability that would be necessary to produce the convexified
profile. Unreported results show that the mean ability level at intermediate education would
have had to decrease five times more than the relative decrease in ability at this level that
BMM estimate. Thus, in the absence of changes in the prices of education, the convex wage
shift could only have been produced by unrealistically big changes in the composition on
ability.

Therefore, even if the available data for Mexico do not allow to quantify the role of changes
in ability distribution, we can rule out the possibility that changes in the composition of
ability by themselves explained the convexification. The results of BMM obtained by using
a very different model in a different Latin American country point at the same conclusion.
6.2.2 Production function

Two important model’s features characterize the production function: first, the choice of modelling the SBTC as an exogenous increase in the demand for skilled labor; second production complementarities between workers with intermediate and higher education.

There is extensive evidence of a structural and exogenous increase in the demand for skilled labor in Latin America in the 1990s. This paper remains agnostic on the reason for this increase. In particular, I do not analyze whether it was driven by a skill-biased technological change, trade opening, FDI flows, or other factors. However, I note that an extensive literature exists for the region on the relationship between trade reforms of the 1990s and changes in the skill premium. The first Section of Appendix A briefly summarizes this evidence with a focus on Mexico.

In the simulations the increased demand for labor is modelled as an increase in $s$. However, the estimate of the linear trend for higher versus intermediate education in Table 1 shows that in the 1990s the share of workers with higher education, $\alpha_3$, also increased and did so by an average of 2.62 per cent a year. It is easy to show that an increase in $\alpha_3$ by itself without any change in the supply of education could have produced the relative wage changes that characterize the convexification: if $\alpha_3$ increases, everything equal, $\frac{p_3}{p_1}$ increases and, providing that $\left(\frac{H_3}{H_2}\right)^{\theta} < 1$, $\frac{p_2}{p_1}$ decreases (equations (12) and (13)). Also, $p_1$ would decrease and $p_3$ increase; therefore, $\frac{p_3}{p_1}$ would increase.

I assess the sensitivity of the simulations to the choice of modelling the increase in the demand for labor as an increase in $\alpha_3$ or as a combined increase in $\delta_s$ and $\alpha_3$. Rows three and four in Table 7 in Appendix D show the percentage changes in log education prices and in log relative prices from the initial steady state for the case of an increase in $\alpha_3$ by itself and in combination with an increase in $\delta_s$. Only when $\delta_s$ increases the model produces the drop in the level of the education prices at basic and intermediate that matches the data. An increase in labor demand by itself could not have produced the convexification: the endogenous supply reaction was a fundamental determinant of the convex wage shift. Then, the wage data are compatible with the demand for labor increasing equally for middle and highly educated workers ($\delta$ increases) or proportionally more for highly educated workers.
The second important feature of the aggregate technology is the presence of production complementarities between middle and highly skilled workers. These complementarities are consistent with an economy with two main sectors, a first one that employs low-skilled labor and a second one where production is carried out by the use of semi and high-skilled labor. This structure of production is a good description of the Mexican economy that can be characterized as comprising of two main sectors: a formal sector of semi and high-skilled workers and an informal sector of low-skilled workers. By defining a worker as "formal" if paying social security contributions in either the private or the public sector, evidence from the ENEU shows that in the 1990s almost eighty per cent of formal sector workers have at least completed high school education. The importance of this dual production structure is consistent with the findings of Binelli and Attanasio (2010) that show how the dynamics of wage inequality in Mexico in the 1990s are strongly correlated with changes in the size of the formal and informal sectors.

As discussed in the Introduction, production complementarities between middle and high-skilled workers have also been pointed out as an important determinant of changes in wage inequality by Autor, Katz and Kearney (2006). The model by Autor, Katz and Kerney (2006) (AKK) is an example of the "task-based technical change" (TBTC) or "polarization" models originating from the more nuanced view of skill-biased technological change that introduced the task dimension into the production function (Autor, Levy and Murnane 2003).

The key feature of the TBTC models is the assumption that labor production factors (typically three) differ with respect to the task content of their occupations, and that there are substitutabilities between tasks performed by workers with different skills. In other words, the production function is characterized by different degrees of complementarity/substitutability between occupations with different skill intensity so that an increased demand for skilled labour affects not only the supply of skilled labor itself but also the supply of unskilled labor (relative to middle-skilled labour).

TBTC models have been extensively used to explain the polarization of employment and wages (Autor and Dorn 2010 for the US; Goos, Manning and Solomons 2010 for Europe), and to quantify the contribution of changes in employment by occupations to changes in
the distribution of wages (Firpo, Fortin and Lemieux 2009 for the US). Even if for Mexico there are no publicly available data with information on the task intensity of occupations, Medina and Posso (2010) apply an AKK-type model to Mexico by assuming that low skilled workers perform manual intensive tasks, middle skilled workers perform routine intensive tasks, and highly skilled workers mostly perform abstract tasks. Using Census data they find some evidence of employment and wage polarization in the decade of the 1990s, which is consistent with the wage convexification that I document in this paper.

6.2.3 Credit constraints

Together with the increased demand for skilled labor, the second source of exogenous variation that in the model identifies the wage changes is the relaxation of the credit constraints.

The results show that a borrowing amount of around forty per cent of household earnings is needed to match the data in 2002 (see Section 5.2). It is possible to use the ENIGH to relate the change in the level of credit constraints to measurable changes in the credit market. The ENIGH contains detailed information on a number of variables that can be used to compute several measures of financial income and wealth assets (see Binelli and Attanasio 2010 for details). As a proxy for the proportion of borrowing in percentage of household income we can use the ratio of credit cards debts and consumer loans over household labor income. The ENIGH evidence is as follows: in 1992 median total household borrowing and labor income were, respectively, at around 551 and 8346 Pesos; in 2002 these amounts increased to, respectively, around 2073 and 5698 Pesos. Thus, the ratio increased from around 6 to around 36%, which is remarkably close to the 40% figure that the model predicts.

In addition to the micro-evidence provided by the ENIGH, there is additional macro-evidence that in the 1990s in Mexico borrowing constraints did become less stringent. The decade of the 1990s was characterized by a process of financial liberalization and deregulation of the securities markets, which resulted into an increased availability of consumer credit. Evidence from the Bank of Mexico shows that in 2002 the amount of credit to consumers was almost double the size of the amount in 1994.\textsuperscript{25}

\textsuperscript{25}The most recent available data from the Bank of Mexico show that the steep increase in consumer credit still continues: at the end of the year 2008 the total amount of credit to consumers was almost three times the size of the amount granted in 2002 (http://www.banxico.org.mx/estadisticas/statistics.html).
7 Conclusion

This paper studies a central feature that characterizes the changes in wage inequality in the decade of the 1990s: the relationship between log wages and the level of education convexified. The higher-intermediate wage differential increased and the intermediate-basic wage differential declined. These wage changes have important implications for the process of human capital accumulation. The non-linearity of the wage function changes the opportunity costs of investing in education that becomes profitable only if college is completed. This may induce the poor to drop out of school or even not to invest in human capital at all if they cannot afford financing education until the end of college.

This paper studies the convexification in Mexico where the wage changes were particularly pronounced. The results show that the convex wage shift can be explained by a two-way interaction between the demand and the supply of education with an initial increase in the demand for skilled workers and a supply response with feedback effects on relative wages in the presence of production complementaries and increased availability of credit to finance investment in education.

There are two main aspects that are not considered in the analysis and could have been important to explain the wage changes. First, the model abstracts from wage setting mechanisms and institutions such as the minimum wage. It could be that binding minimum wages prevented wages for low skilled workers to fall thus driving the decrease in the relative returns to intermediate education. However, the empirical evidence for Mexico suggests that in the 1990s minimum wages were not binding and rather decreased substantially (Bosch and Manacorda 2010). Second, the model abstracts from migration. In the 1990s there were vast migration flows from Mexico to the US. However, the Mexico-US migration was mainly an outflow of low-skilled workers with two thirds of the adult Mexican immigrants having not completed intermediate education. The low-skilled migration on its own could not explain the double change in the relative wages even if it could have contributed to

\[\text{26} \text{ The drop in mean wages at basic education was much smaller than the one of the minimum wages: between 1987 and 2002 minimum wages declined by around fifty per cent relative to median earnings (Bosch and Manacorda 2010), while wages at basic education decreased by less than four per cent.}\]

\[\text{27} \text{ See the Report of the US Center for Immigration Studies, 2001 that is available at www.cis.org}\]
reduce the fall in the wage at basic education.\textsuperscript{28}

Finally, one aspect that deserves further study is the production function. In particular, and to further stress a point made earlier, if data on task intensity by occupation became available, the model’s implications could be tested when using a TBTC-type production function that allows for substitutabilities between production tasks rather than between education levels. Likewise, the production complementaries-credit constraints’ explanation could be tested in different countries, such as the US where changes in labor market institutions\textsuperscript{29} and physical capital-skill complementarities\textsuperscript{30} could be two important model’s changes to introduce to explain the convexification.\textsuperscript{31} This is left for future research.

\textsuperscript{28}It could be interesting to disentangle the downward pressure on wages due to the demand decrease for low-skilled workers and the upper pressure due to the migration of this type of workers to the US.

\textsuperscript{29}Lemieux (2007) finds that changes in labor market institutions can account for around a third of the changes in low-end and top-end wage inequality in the US in the 1990s.

\textsuperscript{30}Beaudry and Green (2005) argue that capital-skill complementarities could be the main factor explaining the changes in the level of low-skilled wages and in the high-low skilled wage differential.

\textsuperscript{31}An other factor to include in the model could be international trade, which Wood (2002) and Anderson, Tang and Wood (2006) proposes as a main determinant of differential changes in wage inequality in the lower part and in the upper part of the wage distribution in the US.
References


Appendix A - The ENEU and the Mexican education system

The Mexican Employment Survey - ENEU

The ENEU (Encuesta Nacional de Empleo Urbano) is the Mexican national employment survey collected yearly by the Mexican national statistical office, INEGI. The ENEU has a structure similar to the US Consumer Expenditure Survey (CEX). It is a quarterly household survey that collects individual-level data and it has a rotating panel structure: households are interviewed for five consecutive quarters and in each quarter twenty 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 Mexican urban population: by the end of the 1990s it covered approximately sixty two per cent of the national urban population and ninety two per cent of the cities with population greater than one hundred thousand people. By the end of the 1990s, approximately seventy four per cent of the Mexican population lived in urban areas. Recent rounds of the ENEU have national coverage, but since the earlier ones survey urban areas only, I restrict the sample to urban areas in all years.

The main questionnaire is divided in three parts. The first part collects socio demographic information on all household members. The second part contains detailed employment information on individuals at least twelve years old. The third part reports information on the characteristics of the house of residence with additional questions on the characteristics of the building, number and type of rooms and ownership status from the 1994 wave onwards. 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 earnings, unemployment status and duration and social security taxes paid by the worker’s employer in the private and public sector.

The definition of earnings refers to monthly earnings from the main job net of all labor taxes and social security contributions paid in either public or private funds. For those paid by the week the survey transforms weekly earnings into monthly earnings by multiplying
the former by 4.3. Similar adjustments are used for workers paid by the day or every two
weeks. I compute hourly wages as the ratio between monthly earnings and hours worked in
the main occupation last month. All wage data are deflated using the Mexican national CPI
June 2002.

Figure 8 presents the relative wages by education for each year between 1987 and 2002.
In the decade of the 1990s the relative returns to higher education follow an upper sloping
trend with respect to both intermediate and basic education, while the relative returns to
intermediate versus basic education decline. This overall trend is comprised of two distinct
phases: an increase in the wage differentials until the mid 1990s and a decline afterwards,
especially for the relative wages to intermediate education.

Figure 9 presents the evolution of the relative supply by education. From the end of
the 1980s there has been a significant progress towards intermediate education, which is
consistent with the decreasing trend of the relative returns to intermediate education. The
relative supply of intermediate educated workers increased by over 130%. On the contrary,
the relative supply of higher with respect to intermediate education has only increased by
around 28%.

The increase in the relative returns to higher education is evidence of a demand for
skilled workers that more than outweighs the supply increase for this group.\textsuperscript{32} There is a
vast empirical literature that studies the impact of changes in the demand for labor in the
1990s on the returns to workers with college education. Most studies have found evidence
of a technological change that increased the demand for skilled labor, while a smaller set of
studies have estimated a positive impact of trade opening on the skill premium.\textsuperscript{33}

\textsuperscript{32}The ENEU data show that in 1987 the total number of individuals with intermediate education and higher
education was, respectively, 69284 and 21829; in 2002 these numbers increased to, respectively, 348091 and
140540, which means that by 278807 at intermediate education and by 118711 at the higher level.

\textsuperscript{33}On the impact of a skill-biased change in production, see, among the others, Attanasio, Goldberg and
for Brazil, Bustos (2010) for Argentina, Verhoogen (2008) for Mexico, and Avalos and Savvides (2003) for a
cross section of Latin American countries. On the impact of opening to trade, 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.

Behrman, Birdsall and Szekely (2007) perform an overall evaluation of the major market reforms that
characterized Latin America in the 1980s and 1990s and find that trade liberalization did not have any
significant impact on the changes in the wage differentials while the return to higher education significantly
increased when the economies became more technologically advanced and the exports of high-technology
products increased.
Figure 8: Relative wages by education (Source: author’s calculations based on ENEU data)

Figure 9: Relative supply by education (Source: author’s calculations based on ENEU data)

Mexico provides a very good example of the structural changes that characterized Latin America during the 1990s with a series of reforms that changed the structure of production and made the 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. In the same year Mexico was hit by a severe financial crisis, the "Peso crisis", which resulted into a massive devaluation of the national domestic currency. Between 1994 and 1996 Mexican GDP decreased by seven per cent a year. The recovery from the crisis was rather quick and by the end of 1995 Mexico had already reentered the international capital markets. The reform effort and the opening to foreign investment resulted into an increase in the use of skilled labor and in the production of skill-intensive goods. Several studies have found that NAFTA and the economic reforms of the 1994-1996 period increased the demand for skilled labor in production. More recently, Verhoogen (2008) find the Peso crisis more than the opening to trade being associated with an increase in the use of skilled labor and in the production of skill-intensive goods. Disregarding which explanation has been favoured, all studies agree that in the 1990s Mexico underwent a structural change towards the use of skilled labor in production. The share of skilled workers increased in all sectors and the exports of skill-intensive goods steeply rose.

The Mexican education system

The Mexican education system consists of four main cycles: pre-school, primary, secondary (lower and upper) and post-secondary (university/technical institutes or more) education.

Pre-school education is between age 3 and 6 and is provided free of charge. In December 2001, the Mexican Congress voted to make one year of pre-school education mandatory, a provision that went into effect in 2004. Primary education starts at age 6, it lasts six years and it has always been compulsory. Secondary education comprises two main levels: lower and upper secondary. Lower secondary lasts between three to four years, depending on the program. Upper secondary lasts three years. Both levels includes an "academic" and a "vocational" branch that paves the way, respectively, to university and non-university education. In 1993 lower secondary became compulsory. The policy change mainly affected rural areas with a large increase in the construction of schools and corresponding increasing attainment rates at lower secondary in these areas. Post-secondary education comprises universities, 4-years technical institutes and 2-years technical institutes. By far the majority
of students are enrolled in universities and a very small proportion is enrolled in 2-years technical institutes. University takes four to five years and graduate education lasts between two to four years (two years are necessary to obtain a Master degree and two additional years to obtain a PhD).

In order to construct the three education groups used in the paper, the schooling levels have been aggregated as it follows. The "basic education" group includes all individuals that have up to uncompleted upper secondary education, the "intermediate education" group includes all individuals that have up to uncompleted university education and the "higher education" group includes individuals who have completed university or more. As in Manacorda, Sanchez-Paramo and Schady (2010), I aggregated the academic and vocational branch of secondary education by considering in the "intermediate" group all individuals that have completed any of the two branches.

In the 1990s attainment rates were above 90 per cent at primary education in all Mexico; at lower secondary they were above 80 per cent in urban areas and below 40 per cent in rural areas. Focusing on urban areas motivates the choice of grouping primary and lower secondary into compulsory basic education.

The four model’s periods reproduce the four main stages of the education cycle. For simplicity, the length of each period is assumed to be the same and equal to seven years in order to match an average working life of adult Mexican workers of around thirty years.
Appendix B - Solution method

This appendix describes the method used to compute the equilibrium steady state and the transitional dynamics.

Steady state

The model is solved recursively by backwards induction from the last to the first period of adult life.

Step 1. Set an initial guess for the vector of skill prices \([p_1, p_2, p_3]\) and assume that future prices equal current prices.

Step 2. Solve the optimization problem in the last period of work life before retirement \((a = \pi)\).

Define with \(V^{Sch}_{\pi}(j^P, j^C, A_\pi, p(\pi), \eta, z_\pi)\) and with \(V^{Work}_{\pi}(j^P, j^C, A_\pi, p(\pi), \eta, z_\pi)\), respectively, the conditional value function of sending the child to school and to work and denote with \(W^{Sch}_{\pi}(j^P, A_\pi, p(\pi), \eta, z_\pi)\) and \(W^{Work}_{\pi}(j^P, A_\pi, p(\pi), \eta, z_\pi)\) the initial guess for child lifetime utility as an adult conditional on having sent the child, respectively, to school and to work in the last period of coresidence. \(\bar{\pi}\) denotes the age of the parent in the first period of adult life.

Given \(W^{Sch}_{\pi}(.)\) and \(W^{Work}_{\pi}(.)\), \(V^{Sch}_{\pi}(.)\) and \(V^{Work}_{\pi}(.)\) take the following expressions:

\[
V^{Sch}_{\pi}(j^P, j^C, A_\pi, p(\pi), \eta, z_\pi) = \max_{c_\pi} \left\{ U(c_\pi) + \lambda \beta E_{z_\pi} W^{Sch}_{\bar{\pi}}(j^P, A_{\bar{\pi}}, p(\bar{\pi}), \eta, z_{\bar{\pi}}) \right\} \\
\text{s.t.} \quad c_\pi = A_\pi(1 + r) + w_{j^P, \pi} - F_{j^C, \pi} - A_{\pi+1} \\
\quad j^C_{\bar{\pi}} = (j^C_{\pi} + 1) = j^P_{\bar{\pi}}
\] 

\[
V^{Work}_{\pi}(j^P, j^C, A_\pi, p(\pi), \eta, z_\pi) = \max_{c_\pi} \left\{ U(c_\pi) + \lambda \beta E_{z_\pi} W^{Work}_{\bar{\pi}}(j^P, A_{\bar{\pi}}, p(\bar{\pi}), \eta, z_{\bar{\pi}}) \right\} \\
\text{s.t.} \quad c_\pi = A_\pi(1 + r) + w_{j^P, \pi} + w_{j^C, \pi} - A_{\pi+1} \\
\quad j^C_{\bar{\pi}} = j^C_{\bar{\pi}} = j^P_{\bar{\pi}}
\]
where \( r \) is the fixed real interest rate on financial assets, \( F_{jC} \) denotes the fixed costs of schooling for child education level \( j^C \) and \( w_{jP,a} \) and \( w_{jC,a} \) are, respectively, parental and child wage at age \( a \) given parental (child) education level \( j^P(j^C) \). \( \lambda \) denotes the degree of parental altruism and expectations are taken over next period shock to earnings, \( z \). Equations (15) and (16) 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 \( (j^C_a = j^P_a = j^P) \). For simplicity I do not report the credit constraints (equation (6)) and the terminal condition (equation (7)).

**Step 3.** Solve the conditional maximization problems in the third, second and first period of adult life.

In the third period child education is a choice variable. The conditional maximization problems read:

\[
V_{a}^{Sch}(j^P, j^C_a, A_a, p(a), \eta, z_a) = \max_{c_a} \left\{ U(c_a) + \beta V_{a+1}(j^P, j^C_{a+1} + 1, A_{a+1}, p(a + 1), \eta, z_{a+1}) \right\}
\]

s.t. \( c_a = A_a(1 + r) + w_{jP,a} - F_{jC} - A_{a+1} \)
\[
\hat{j}^C_{a+1} = (j^C_a + 1)
\]

\[
V_{a}^{Work}(j^P, j^C_a, A_a, p(a), \eta, z_a) = \max_{c_a} \left\{ U(c_a) + \beta V_{a+1}(j^P, j^C_a, A_{a+1}, p(a + 1), \eta, z_{a+1}) \right\}
\]

s.t. \( c_a = A_a(1 + r) + w_{jP,a} + w_{jC,a} - A_{a+1} \)
\[
\hat{j}^C_{a+1} = j^C_a
\]

where \( F_{jC} \) is the fixed cost of child schooling level \( j^C \) and \( V_{a+1}(\hat{j}^C_{a+1}, \ldots) \) and \( V_{a+1}(j^C_a, \ldots) \) define, respectively, the expected value over the maximum between the conditional value functions of the schooling and work alternative 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:
In the second period the child is sent to compulsory basic education. The maximization problem is given by:

\[
V_{a+1}(j^P, j_a^C + 1, A_{a+1}, p(a + 1), \eta, z_{a+1})
\]

\[
\equiv E_{z_{a+1}} \max \{V_{a+1}^{Sch}(j^P, j_a^C + 1, A_{a+1}, p(a + 1), \eta, z_{a+1}), V_{a+1}^{Work}(j^P, j_a^C + 1, A_{a+1}, p(a + 1), \eta, z_{a+1})\}
\]

where \( j_a^C = 1 \) denotes completed basic education.

In the first period of adult life the child is in pre-school. Child education is normalized to zero. The parent solves the following maximization problem:

\[
V_a(j^P, A_a, p(a), \eta, z_a) = \max_{c_a} \left\{ U(c_a) + \beta V_{a+1}(j^P, 1, A_{a+1}, p(a + 1), \eta, z_{a+1}) \right\}
\]

\[
s.t. \quad c_a = A_a(1 + r) + w_{jP,a} - F_1 - A_{a+1}
\]

where \( F_1 \) denotes the fixed costs of basic education and \( V_{a+1}(1, \cdot) \) defines the expected value over the maximum between the conditional value functions of the schooling and work alternative in the next period given that the child has completed compulsory basic education in the current period:

\[
V_{a+1}(j^P, 1, A_{a+1}, p(a + 1), \eta, z_{a+1})
\]

\[
\equiv E_{z_{a+1}} \max \{V_{a+1}^{Sch}(j^P, 1, A_{a+1}, p(a + 1), \eta, z_{a+1}), V_{a+1}^{Work}(j^P, 1, A_{a+1}, p(a + 1), \eta, z_{a+1})\}
\]
**Step 4.** Compute the new initial guesses for $W^\text{Sch}(.)$ and $W^\text{Work}(.)$.

The solution of the model in steps two and three provides the complete set of value functions and optimal saving rules for any combination of the state space variables. The optimal value function in the first period of adulthood, $V_a$, provides a new initial guess for child lifetime utility. Denoting with $j_a^C$ the level of education of the child at the end of the last period of coresidence, $V_a(j^P = (j_a^C + 1), A_a, p(a))$ provides the new initial guess for $W^\text{Sch}(.)$ and $V_a(j^P = j_a^C, A_a, p(a))$ provides the new initial guess for $W^\text{Work}(.)$. Given the new initial guesses for $W^\text{Sch}(.)$ and $W^\text{Work}(.)$, I repeat steps two and three above.

Given the conditional value functions for the work and schooling alternative, the child is 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:

$$V^\text{Sch}_a(j^P, j_a^C, A_a, p(a), \eta, z_a) \geq V^\text{Work}_a(j^P, j_a^C, A_a, p(a), \eta, z_a) \quad \forall \ a = a_{\text{ed}}, \ldots, \bar{a}$$

where $a_{\text{ed}}$ denotes parental age when child education becomes a choice variable.

**Step 5.** Repeat steps two to four until the following two conditions are satisfied:

$$||V^\text{Sch}_a(Iter^1) - V^\text{Sch}_a(Iter^{(1)})|| \leq \varepsilon$$

$$||V^\text{Work}_a(Iter^1) - V^\text{Work}_a(Iter^{(1)})|| \leq \varepsilon$$

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

**Step 6.** Compute the equilibrium skill prices as marginal productivities of the human capital factors using the equilibrium price conditions.

Compute a new guess for the vector of the skill prices as a linear combination of the guess used to solve the model and the equilibrium prices computed in this iteration.

**Step 7.** Repeat steps two to six with the new guess for the vector of the skill prices.

Stop when the difference between each element of the vector of the equilibrium skill prices
and the initial guess for this price is arbitrarily small.

**Transitional dynamics**

Let us assume that the length of the transition is $T$ years.

**First iteration**

1. Start with year one. Make an initial guess on the vector of skill prices, $p_t \equiv [p_{1,t}, p_{2,t}, p_{3,t}]$, and assume that the prices from year one to the final year $T$ are the same, that is future prices equal current ones. The demand for skilled labor increases, which results into an increase in $p_2$ and $p_3$. Assume that individuals have perfect knowledge of the future: they take the vector of the skill prices $p_t$ as given and constant in each year of their life-cycle.

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 behavior of samples of 10000 individuals per cohort by drawing from the distribution of the idiosyncratic shocks to wages.

4. For each cohort, compute aggregate skill supplies summing over individual education supply.

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 from \( t = 1 \) to \( t = T \): this results into a \((T \times 3)\) 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 \((T \times 3)\) 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 \( t = 1 \) to \( t = T \) is close enough to the sequence of equilibrium prices for this iteration.

\( T \) is set to 50. The model always converges in less than 50 periods, so increasing the length of the transition does not affect the results.
Appendix C - Estimation and calibration

This Appendix discusses the estimation of the wage equations, the production function and the model’s calibration.

Wage equations

In order to estimate the parameters characterizing the wage equations and the structure of the error term as specified in equation (1) and (2), I would need a panel data set with individual information on wages, a measure of permanent heterogeneity with a measurable impact on wages, such as individual test scores, and age, spanning over many years. However, for Mexico there are no available data sets that follow individuals over many years.\footnote{The first survey that collects individual information on wages in Mexico over many years is the Mexican Family Life Survey (MxFLS). The first wave of the MxFLS was collected in 2002 and it was followed by a second wave in 2005; two additional waves are scheduled for 2009 and 2012. At present only the first two waves are available.} Also, until 2004 there were no standardized measures of test scores.\footnote{Non-standardized test scores were collected in Mexico since 1998 (Estandares Nacionales). In 2001 the ENLACE (ENgaging Latino Communities for Education) initiative was launched to support Latino students to progress from primary to secondary and college education. Standardized test scores started to be collected as part of ENLACE in 2004.} The only available data set with information on wages and a panel dimension following individuals over the 1990s is the Mexican Employment Survey, the ENEU (Encuesta Nacional de Empleo Urbano). A description of the ENEU is presented in Appendix A.

The ENEU collects wage information on the Mexican urban population of workers at least twelve years old over five consecutive quarters, the four quarters of a given year and the first of the following year. I consider the four quarters of a given year and I specify the following log wage equation for individual $i$ with education level $j$ in quarter $qr$:

$$\ln w_{i,j,qr} = \ln w_{j,qr} + g_j (age_i^j) + u_{i,j,qr}$$ \hspace{1cm} (17)

$$u_{i,j,qr} = \eta_i^j + z_{j,qr}^i$$ \hspace{1cm} (18)

$$z_{j,qr} \sim N(0, \sigma^2_{z_{j,qr}})$$ \hspace{1cm} (19)

where $\ln w_{i,j,qr}$ is the log hourly real wage of individual $i$ with education level $j$ in quarter $qr$, $\ln w_{j,qr}$ is the mean log wage among those with education level $j$ in quarter $qr$ and reflect
average productivity of workers with the \( j \) level of education, \( g_j(\cdot) \) is an education-specific quadratic polynomial in age that proxies for experience in the labor market, \( \eta^i \) is a permanent individual-specific effect and \( z_{j,qr}^i \) is an i.i.d. shock received by the individual \( i \) with education level \( j \) in quarter \( qr \).

I construct panels of individuals by matching workers by the position in an identified household, the number of years of education and age. I consider all wage workers between the age of 15 (minimum legal working age) and 60 (average retirement age) and I follow them over the four successive quarters in a given year. For each year of the sample between 1987 and 2002 I run the following fixed effects regression:

\[
(\ln w_{j,qr}^i - \ln \overline{w}_j^i) = (\ln w_{j,qr} - \ln \overline{w}_j) + g_j(\text{age}^i_{qr}) - g_j(\overline{\text{age}^i}) + (u_{j,qr}^i - \overline{u}_j)
\]  

(20)

where the upper-bar variables denote time averages over the four quarters in a given year. \( \ln \overline{w}_j^i \) is the average log wage over the four quarters for the \( i \)th individual with the \( j \)th education level, \( \ln \overline{w}_j \) is the mean log wage over the four quarters for education level \( j \). The term \( (\ln w_{j,qr} - \ln \overline{w}_j) \) is modelled as quarter-education dummies’ interactions. \( g_j(\text{age}^i_{qr}) \) is an education-specific quadratic polynomial in age.

For the purposes of the model’s simulations we require the unconditional distribution of ability as reflected by the fixed effect, \( \eta^i \). I use the estimate:

\[
\hat{\eta}_i = \frac{\sum_{n=1}^{N(i)} \ln w_{qr}^i - \ln \overline{w}_{qr} - g(\overline{\text{age}^i_{qr}})}{N(i)}
\]  

(21)

where \( N(i) \) is the total number of observations available on individual \( i \). In any given year the estimated fixed-effects give an estimate of the distribution of \( \eta \) for the population working in that year.\(^{36}\) I use the distribution of \( \hat{\eta} \) for 1987 as an estimate of the initial ability distribution before the convex wage shift took place. Figure 10 presents the results. Clearly the ability estimates suffer from the incidental parameters problem due to the short length of the panel (Heckman 1981).

\(^{36}\)The distribution of ability is taken to be time-invariant. I therefore abstract from any heterogeneity in ability endowments between successive cohorts active in the labour market in different years.
Given the estimation of the fixed effect regression (20), I can treat as observable the following:

\[ z_{j,qr}^i = \ln w_{j,qr}^i - g_j(\text{age}_{qr}^i) - \ln w_{j,qr} - \eta_i \]  

(22)

I use the residuals from the wage equation to obtain an estimate of the distribution of the idiosyncratic shock. I assume that \( z_{j,qr} \) is a normally distributed i.i.d. shock with mean zero and variance \( \sigma_{z_j}^2 \). I use the second moment of the distribution of \( z_{j,qr} \) for each education group to parametrize the distribution of \( z \) in the model. Table 3 presents the estimated variances for each education group and year between 1987 and 2002. The coefficients of the quadratic polynomials \( g_j(\text{age}_{qr}^i) \) provide the estimates of the education-specific experience effects in quarter \( qr \). Table 4 presents the (yearly rescaled) estimates of the age and age squared term for each education group and year between 1987 and 2002.

<table>
<thead>
<tr>
<th>Year</th>
<th>Basic</th>
<th>Intermediate</th>
<th>Higher</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>0.085</td>
<td>0.073</td>
<td>0.079</td>
</tr>
<tr>
<td>1988</td>
<td>0.066</td>
<td>0.074</td>
<td>0.038</td>
</tr>
<tr>
<td>1989</td>
<td>0.070</td>
<td>0.077</td>
<td>0.117</td>
</tr>
<tr>
<td>1990</td>
<td>0.088</td>
<td>0.084</td>
<td>0.119</td>
</tr>
<tr>
<td>1991</td>
<td>0.089</td>
<td>0.087</td>
<td>0.119</td>
</tr>
<tr>
<td>1992</td>
<td>0.099</td>
<td>0.088</td>
<td>0.106</td>
</tr>
<tr>
<td>1993</td>
<td>0.065</td>
<td>0.088</td>
<td>0.113</td>
</tr>
<tr>
<td>1994</td>
<td>0.070</td>
<td>0.084</td>
<td>0.115</td>
</tr>
<tr>
<td>1995</td>
<td>0.073</td>
<td>0.085</td>
<td>0.110</td>
</tr>
<tr>
<td>1996</td>
<td>0.068</td>
<td>0.083</td>
<td>0.111</td>
</tr>
<tr>
<td>1997</td>
<td>0.084</td>
<td>0.078</td>
<td>0.099</td>
</tr>
<tr>
<td>1998</td>
<td>0.086</td>
<td>0.088</td>
<td>0.099</td>
</tr>
<tr>
<td>1999</td>
<td>0.078</td>
<td>0.094</td>
<td>0.121</td>
</tr>
<tr>
<td>2000</td>
<td>0.078</td>
<td>0.094</td>
<td>0.125</td>
</tr>
<tr>
<td>2001</td>
<td>0.083</td>
<td>0.075</td>
<td>0.099</td>
</tr>
<tr>
<td>2002</td>
<td>0.071</td>
<td>0.089</td>
<td>0.114</td>
</tr>
</tbody>
</table>

Table 3: Estimation wage equations: variance of the residuals (Source: ENEU)

Figure 10 presents the empirical frequencies of \( \eta \) obtained for 1987. The first and second moment of the distribution of \( \eta \) are used to parametrize the initial distribution of ability. I estimate a variance of 0.25 and a zero mean.
Production function

The identification of the parameters of the production function requires knowledge of the aggregate human capitals, which are the sum of the efficiency weighted labor supply of workers with a given level of education. The efficiency index defined in equation (2) is intrinsically unobserved. The method used to approximate the aggregate human capital series combines different information sources as in Heckman, Lochner and Taber (1998).

Let us define the wage bill $WB_{j,t}$ as the total earnings’ payments received by the individuals of a given education group in a given year. Then:

$$WB_{j,t} = \hat{p}_{j,t} \times \hat{H}_{j,t} \quad j = 1, 2, 3$$  (23)
where \( \hat{p}_{j,t} \) is the estimated market price of workers with education level \( j \) in year \( t \) and \( \hat{H}_{j,t} \) denotes the estimated value of human capital \( j \) at time \( t \).

Therefore:
\[
\hat{H}_{j,t} = \frac{W_B_{j,t}}{\hat{p}_{j,t}} \quad j = 1, 2, 3 \tag{24}
\]

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. I use instead the Mexican Expenditure Survey, the ENIGH (Encuesta Nacional de Ingresos y Gastos de los Hogares), that is nationally-representative and reports individual earnings together with detailed information on assets and consumption. It is available in 1984, 1987 and every two years since then. For each year and education group I compute the wage bill by summing over the individual earnings of all primary wage earners between the age of 15 and 60. I linearly interpolate the available data for missing years.

In order to obtain an estimate of the \( p_{j,t} \) I run the fixed effect regression described in equation (20) for each year between 1987 and 2002 and I compute the predicted mean log hourly real wage for each education level net of the fixed effects, which gives an estimate of the log skill prices by level of education in each year of the sample. Given the wage bills and the (log) skill prices, I divide the wage bills by the exponentiated value of the skill prices to obtain the time series of the human capital aggregates for each year and education group. The identification of the \( H \) factors is then consistent with the ability distribution estimated from the data and used to simulate the model.\(^ {37} \) The estimated log skill prices are presented in Figure 11.

Having a measure of the aggregate human capital series and of the education prices and having assumed that the aggregate inputs are paid their marginal product, the first order conditions of the firms’ maximization problem provide the structure to identify the parameters of the production function.\(^ {38} \) Log linearizing equation (13) and rewriting it in

\(^ {37} \)Heckman, Lochner and Taber (1998) assume that at older ages changes in wages are solely due to changes in education prices and do not depend any more on ability. Therefore, they use the average wages by year and level of education for the workers aged 45 or more to derive an estimate of the time series of education prices. By following the same procedure, I can estimate the skill price ratios by using the mean log wages by education for the workers aged 45 or more in each ENEU wave. The main results of the estimation of the production function remain unchanged.

\(^ {38} \)Essentially, I use the changes in the relative supply of education to identify the changes in relative demand (Katz and Murphy 1992).
terms of wage bills I obtain:

\[(\log W B_{3,t} - \log W B_{2,t}) = [\log \alpha_{3,t} - \log(1 - \alpha_{3,t})] + \theta(\log \tilde{H}_{3,t} - \log \tilde{H}_{2,t})\]  

(25)

where \(\tilde{H}_{3,t}\) and \(\tilde{H}_{2,t}\) denote the estimates of the human capital of workers with, respectively, higher and intermediate education at time \(t\).

Equation (25) can be used to obtain a direct estimate of the elasticity of substitution between higher and intermediate education. The time-varying factor shares \(\alpha_{2,t}\) and \(\alpha_{3,t}\) reflect changes in the productivity of and in the demand for workers with intermediate and higher education. I express the log of the share parameters as the sum of a constant and a time-varying component:

\[\log \alpha_{j,t} = \phi_{0,j} + \phi_{1,j} \cdot t + e_{j,t}\]  

(26)

where \(\phi_{0,j}\) is a skill-specific constant, \(t\) denotes a linear time trend and \(e_{j,t}\) is a normally distributed i.i.d. shock at time \(t\) for skill level \(j\).\(^{39}\)

Combining equation (25) and (26), the value of the parameter determining the elasticity of substitution between higher and intermediate education, \(\theta\), can be estimated from a regression of the ratio of log wage bills on the ratio of the human capital aggregates, a linear trend and a constant. Then, I use equation (10) above to construct a measure of skilled human capital as a weighted sum of workers with intermediate and higher education. To do so, I need an estimate of the log factor shares \(\alpha_{3,t}\). Given equation (25) and (26) and the fact that \(\alpha_{2,t} = (1 - \alpha_{3,t})\), I have that \(\log \left[ \frac{\alpha_{3,t}}{1 - \alpha_{3,t}} \right] = (\beta_0 + \beta_1 \cdot t)\), where \(\beta_0 = (\phi_{0,3} - \phi_{0,2})\) and \(\beta_1 = (\phi_{1,3} - \phi_{1,2})\). Therefore, \(\alpha_{3,t} = \frac{\exp(\beta_0 + \beta_1 \cdot t)}{1 + \exp(\beta_0 + \beta_1 \cdot t)}\). Finally, I can estimate a regression of the ratio of the 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 \(\rho\).

The endogeneity of the supply responses at intermediate and higher education to changes in relative wages is of key importance in the model and a central point of the paper. Thus, the difference of the log human capitals in equation (25) is endogenous. I use as instrument the lagged values of the human capital stocks themselves and the size of the cohorts of

\(^{39}\)Given the differential trends of the wage bills before and after 1994, I experimented with alternative specifications that allow the trend to vary for the pre and post 1994 period. However, the interaction term was never significant.
workers with basic education in each year of the ENEU measured as the proportion of those with primary education in a given year. The first instrument is a standard instrumental variable often used in macroeconomics to estimate production functions (Heckman, Lochner and Taber, 1998; Gallipoli, Meghir and Violante 2008). The assumption is that lagged relative supply impacts on relative wages only via current relative supply, the validity of which increases with longer time series. With sixteen years of data I can experiment with the use of different sets of lags. The second instrument is motivated by the very nature of the model: primary education is compulsory so it is not a margin of choice. At the same time, it clearly impacts on educational investments at both intermediate and higher education by determining the level of the price at basic education and therefore the relative returns to both successive education levels. Table 5 reports the estimates of the elasticity of substitution between skilled and unskilled labor: the first, second and third column report, respectively, the second-stage results and the first-stage estimate of the instrumental variable when using as instrumental variable the first lag of the log human capital difference (IVa), the size of the cohorts of workers with primary education (IVb), and both of them (IVc, where the first row reports the first-stage estimate of the lagged human capital difference, and the second row reports the first-stage estimates of the size of the primary educated cohorts). Table 6 reports the estimates of the elasticity of substitution between skilled and unskilled labor: the second-stage results and the first-stage estimate of the instrumental variable when using as instrument the first lag of the log human capital difference.40

All instruments in the first stage have a strong significant impact. The implied elasticity of substitution (one over one minus the coefficient of the difference of log $H$ in the corresponding column) between workers with higher and intermediate education is lower than the one between workers with either higher or intermediate and basic education. This is consistent with the presence of complementarities in production between workers with intermediate and higher education.

To the best of my knowledge Manacorda, Sanchez-Paramo and Schady (2010) is the only other study that has estimated a production function with three levels of human capitals for

40 The size of the primary educated cohorts is not valid in this case since it is a linear function of the denominator of the endogenous variable to be instrumented.
Table 5: Estimation of the elasticity of substitution between workers with higher and with intermediate education. IVa: instrument is the lagged difference of higher and intermediate human capital. IVb: instrument is the size of the primary educated cohorts. IVc: instruments are both the lagged difference human capital and size of the primary educated cohorts. Standard errors in parenthesis. Unskilled are workers with basic education. Skilled is the sum of workers with intermediate and higher education.

Latin America. They use a different CES nesting, they allow the elasticity of substitution within each level of education to differ between age groups and they use a cross section of Latin American countries rather than a time series for one country. Despite all these differences, they also estimate an elasticity of substitution between skilled and unskilled workers that is higher than the typical values estimated with US data (Katz and Murphy, 1992).

A joint estimation of the system of equations to test for the equality of the coefficients of the log relative supplies confirms that $\rho$ and $\theta$ are statistically significantly different. The test gives a value of chi-squared of 7.1 with a P-value of 0.0077. I also test for the assumption of equality between $ES_{3,1}$ and $ES_{2,1}$, which is a restriction imposed by the symmetry of the CES operator. The test gives a value of chi-squared of 0.35 with a P-value of 0.5525. Therefore, the test can not reject the null hypothesis of equal coefficients.

Using the wage bill equations for skilled and unskilled, the equivalent of equation (26) for log $\delta_{s,t}$ and the definition of the unskilled labor share as one minus the skilled share, I
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Skilled versus Unskilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference log $H$</td>
<td>0.8601</td>
</tr>
<tr>
<td></td>
<td>(0.1362)</td>
</tr>
<tr>
<td>Time trend</td>
<td>0.0135</td>
</tr>
<tr>
<td></td>
<td>(0.0065)</td>
</tr>
<tr>
<td>Constant</td>
<td>-26.0616</td>
</tr>
<tr>
<td></td>
<td>(13.0620)</td>
</tr>
<tr>
<td>Implied ES</td>
<td>7.1</td>
</tr>
<tr>
<td>Lagged difference log $H$</td>
<td>First Stage</td>
</tr>
<tr>
<td></td>
<td>0.8327</td>
</tr>
<tr>
<td></td>
<td>(0.1512)</td>
</tr>
</tbody>
</table>

Table 6: Estimation of the elasticity of substitution between skilled and unskilled workers. Instrument is the lagged difference of skilled and unskilled human capital. Standard errors in parenthesis.

can identify $\delta_{s,t}$ following the same steps used to identify $\alpha_{3,t}$. For the year 1987, I obtain a baseline estimate of 0.55 for $\alpha_3$ and of 0.69 for $\delta_s$. Given the estimated series of $\hat{\alpha}_{3,t}$ and $\hat{\delta}_{s,t}$, $\hat{\alpha}_{2,t} = (\hat{\delta}_{s,t} - \hat{\alpha}_{3,t})$ and $\hat{\delta}_{u,t} = (1 - \hat{\delta}_{s,t})$.

Figure 11 present the series of the estimated skill prices normalized to 1987. The two distinct phases that characterize the changes in wage inequality can be clearly seen: skill prices increased until the mid 1990s, dropped between 1994 and 1996, and started increasing again afterwards but only to reach a higher level in 2002 than it was in 1987 at higher education. Between 1994 and 1996 the log skill price decreased by around twelve per cent at basic and by around ten per cent at intermediate and higher education. This drop is the result of the Peso crisis that hit Mexico in 1994: the total wage bill declined in real terms by around 29 per cent at basic education and by around 35 and 48 per cent at intermediate and higher education.

Figure 12 presents the estimated CES shares of the three aggregate human capitals in production. The figure clearly shows the increased demand for highly educated workers that characterized the Mexican economy in the 1990s: the share of workers with higher education increased at the expense of the share of workers with intermediate and basic education.
Figure 11: Estimated log skill prices Mexico (Source: author’s calculations based on ENIGH and ENEU data)

Figure 12: Estimated shares of higher, intermediate and basic human capital in CES production function (Source: author’s calculations based on ENIGH and ENEU data)

Calibration
Initial distribution of wealth and education
I set the initial distribution of education using the 1987 wave of the ENEU. I consider
the population of workers and I divide it into two categories: the adult population that is made up by all working heads of households aged between 25 and 60 with basic, intermediate and higher education and the population of young living with their parents aged between 15 and 24 with completed basic and intermediate education. I use the mean proportions by education in the adult workers’ population to set the initial education distribution of the parents and the mean proportions of the young workers with basic and intermediate education for the education distribution of the children in the third and fourth periods. In the pre-school period all children have by definition zero education. In the second period they all complete compulsory basic education.

I set the initial wealth distribution to a lognormal with mean and standard deviation computed from the distribution of financial assets of the workers aged between 25 and 60 in the ENIGH 1992.41

Preferences, credit constraints and costs of schooling

The coefficient of relative risk aversion, $\gamma$, 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 van 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. Consumption is adjusted to account for the presence of the child. I use an equivalence scale equal 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 (Hernández, Chávez and Bourges, 1987). Assuming that parent-child dynasties are linked by fully altruistic preferences, the altruism parameter, $\lambda$, is set to one. The limit on net indebtedness, $B$, is set to zero, which corresponds to the maximum level of credit constraints.

I set the values of the fixed costs of schooling, $F_j$, for each $jth$ education level so that the model matches the education distribution of the workers aged between 25 and 60 in the ENEU in 1987.42 I find $F_1 = 0.035$, $F_2 = 0.26$ and $F_3 = 0.64$, which implies that the costs

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41 The ENIGH reached its final structure only in 1992 with significant changes in the questionnaire and data collection in the years before. For this reason, I parametrize the wealth distribution using the first and second moments of the 1992 instead of the 1987 wave. The results of the simulations are robust to matching additional moments of the wealth distribution and to relaxing the assumption of it being lognormal.

42 The model does not distinguish between pecuniary and non-pecuniary (or indirect) costs of education, both of which are effectively absorbed in the fixed costs of schooling. Despite being informative for policy inference, the distinction between direct and indirect costs of schooling is not key to the arguments developed in this paper. Also, and more importantly, to the best of my knowledge there are no available data in Mexico.
at intermediate level are around seven times the ones at primary and the costs at higher education are around eighteen times the ones at primary.

Interest rate and capital share

Under the assumption of a small open economy (see Section 3.2), the value of the real interest rate, \( r \), is set to a US benchmark value. I choose a value of five per cent, which is the average real interest rate on the US 6-months Treasury Bills published by the Federal Reserve Board for the period between the year 1990 and 2000. Given an average working life of the adult Mexican population of approximately thirty years, the model period is set to seven years. Therefore, the interest rate in the model is \( r = (1.057 - 1) \approx 0.41 \). Setting the yearly discount factor equal to the inverse of \( (1 + r) \), \( \beta = 1.05^{-7} \approx 0.71 \).

The capital share, \( \alpha \), is set equal to 0.35, which is the average value between the lower and the upper bound that has been estimated for LACs.

Figure 13 reports the complete list of the calibrated parameters in the baseline model together with their value, a brief description and the target used to calibrate the model.

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43 Education in Mexico is free in public schools while private education is expensive at all levels. The ENEU does not record information on the type of school attended, so it is not possible to distinguish between public and private schools. The \( F_j \) in the model measure the average total direct costs of education, which includes fees, costs of school material and maintenance. An empirical counterpart of these costs is provided by the first wave of the MxFLS, which collects high quality data on a rich set of variables for a cross section of Mexican households in 2002. The Survey contains a detailed set of questions on education costs and distinguishes between tuition fees, the costs of exams, books, school material, uniforms and the maintenance costs for public and private schools. Summing over the different categories and computing the mean for public and private education, the costs of intermediate education are around eight times the ones at primary while the ones at higher education are around nineteen times the ones at primary.

44 See Bosworth (1998) for a discussion of the empirical issues involved in the estimation of the capital share in Mexico and Harrison (1996) 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.
### Figure 13: Model’s calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>7 years</td>
<td>Model period</td>
<td>Average length working life of adult Mexican workers</td>
</tr>
<tr>
<td>r</td>
<td>0.41</td>
<td>Real interest rate</td>
<td>Average real interest rate US 6-months Treasury Bills 1990-2000</td>
</tr>
<tr>
<td>β</td>
<td>0.71</td>
<td>Discount factor</td>
<td>$1/(1+r)$</td>
</tr>
<tr>
<td>γ</td>
<td>0.9</td>
<td>Relative risk aversion</td>
<td>Elasticity of intertemporal substitution estimated for LACs (Arrau and Wijnbergen, 1991)</td>
</tr>
<tr>
<td>B</td>
<td>0</td>
<td>Limit on net indebtedness</td>
<td>Maximum level of credit constraints</td>
</tr>
<tr>
<td>λ</td>
<td>1</td>
<td>Parental altruism</td>
<td>Parent-child dynasties linked by fully altruistic preferences</td>
</tr>
<tr>
<td>α</td>
<td>0.35</td>
<td>Share physical capital in production</td>
<td>Share physical capital estimated for LACs in the 1990s (Harrison, 1996 and Hoffman, 1993)</td>
</tr>
<tr>
<td>F_1</td>
<td>0.035</td>
<td>Fixed cost basic education</td>
<td>Proportion workers aged 25-60 with basic education in ENEU 1987</td>
</tr>
<tr>
<td>F_2</td>
<td>0.26</td>
<td>Fixed cost intermediate education</td>
<td>Proportion workers aged 25-60 with intermediate education in ENEU 1987</td>
</tr>
<tr>
<td>F_3</td>
<td>0.64</td>
<td>Fixed cost higher education</td>
<td>Proportion workers aged 25-60 with higher education in ENEU 1987</td>
</tr>
</tbody>
</table>
Appendix D - Sensitivity analysis

This Appendix presents the results of the model’s simulations for changes in some important estimated and calibrated parameters.

<table>
<thead>
<tr>
<th>Simulated economy</th>
<th>Log education prices</th>
<th>Log relative education prices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Basic</td>
<td>Intermediate</td>
</tr>
<tr>
<td>1. Data</td>
<td>-3%</td>
<td>-5%</td>
</tr>
<tr>
<td>2. Scenario IV</td>
<td>-2%</td>
<td>-6%</td>
</tr>
<tr>
<td>3. Increase alpha</td>
<td>13%</td>
<td>6%</td>
</tr>
<tr>
<td>4. Increase alpha and delta</td>
<td>-10%</td>
<td>-6%</td>
</tr>
<tr>
<td>5. Reduced credit constraints</td>
<td>21%</td>
<td>-3%</td>
</tr>
<tr>
<td>6. Increase earnings risk</td>
<td>5%</td>
<td>31%</td>
</tr>
<tr>
<td>7. Decrease earnings risk</td>
<td>13%</td>
<td>0%</td>
</tr>
<tr>
<td>8. Higher risk aversion</td>
<td>5%</td>
<td>25%</td>
</tr>
<tr>
<td>9. Lower risk aversion</td>
<td>-10%</td>
<td>56%</td>
</tr>
<tr>
<td>10. Lower parental altruism</td>
<td>-10%</td>
<td>31%</td>
</tr>
</tbody>
</table>

Table 7: Percentage change log wages and log relative wages by education with respect to baseline model.

Notes:
1. Percentage difference in estimated log education prices and log relative education prices from 1987 to 2002 in ENEU data.
2. Increase demand for skilled labour and relaxation credit constraints to maximum possible borrowing. All details in Section 5.2.
3. Increase demand for higher educated labour and no borrowing. All other parameters as in Scenario IV.
4. Increase demand for skilled labour and for higher educated labour and no borrowing. All other parameters as in Scenario IV.
5. Reduced credit constraints: max borrowing equals fixed costs higher education. All other parameters as in Scenario IV.
6. Highest variance shocks to earnings by education from Table 5 and no borrowing. All other parameters as in Scenario IV.
7. Lowest variance shocks to earnings by education from Table 5 and no borrowing. All other parameters as in Scenario IV.
8. Higher degree relative risk aversion ($\gamma=1.25$) and no borrowing. All other parameters as in Scenario IV.
9. Lower degree relative risk aversion ($\gamma=0.7$) and no borrowing. All other parameters as in Scenario IV.
10. Lower degree of parental altruism ($\lambda=0.8$) and no borrowing. All other parameters as in Scenario IV.

Rows three and four of Table 7 report the simulation results of alternative ways of modelling the demand for skill (see Section 6.2.2). Rows five in Table 7 shows the percentage changes in log prices and in log education relative prices from the initial steady state for the case when the maximum amount that is possible to borrow equals the fixed costs of higher education.\footnote{In the model the credit constraint sets an unconditional limit to the maximum amount that it is possible to borrow disregarding the use of these monetary resources, which families can spend either on consumption or on education. In this way, the model abstracts from any social welfare program or government subsidy directly designed to promote investment in education. This assumption is motivated by the absence of any change in the provision of this type of programs in the decade of the 1990s. All major education interventions were introduced in Mexico at the end of the 1990s, the most famous one being Progresa (later on renamed Oportunidades) that started in rural areas of Mexico in 1997 (the website of the Mexican Ministry of Education - SEP- www.sep.gob.mx provides all detailed information on each of these programs). Progresa has been shown to be highly effective in increasing school attendance (Behrman, Sengupta and Todd 2005; Schultz 2004) and can surely be expected to have a large impact on wages through the increased supply of} Consistently with the increased availability of borrowing, investment in
basic education decreases, and the supply of both those with intermediate and with higher education increased. Interestingly, the supply increase at intermediate education is smaller in size than the one that characterizes scenario IV: the relaxation of the credit constraints is big enough to allow most individuals to invest up to higher education so that with respect to Scenario IV investment at intermediate education increased less at intermediate and more at the higher level.

Rows six to ten show the results of changes in the extent of earnings risk, the degree of risk aversion and the degree of parental altruism, which are all important determinants of how much parents invest in children’s education. The extent of earnings risk in the model depends on the variance of the idiosyncratic shocks to wages. The values of the estimated variance for each education group and year are reported in Table 5 in Appendix C. Rows six and seven in Table 7 report, respectively, the percentage changes in log education prices and in log relative prices from the initial steady state when the variance of earnings for each education level is fixed at the maximum and minimum level estimated from the data between 1987 and 2002 and reported in Table 5. Rows eight and nine show the simulation results when the degree of relative risk aversion is such that the elasticity of intertemporal substitution equals the lower and upper bound estimated for Mexico by Arrau and van Wijnbergen (1991). Row ten presents the results for a decrease in the degree of parental altruism from the value of one to 0.8. Overall, the results show that only a decrease in earnings risk produces a convexified wage-education profile. However, in the absence of a relaxation of the credit constraints, even in the presence of a decreased earnings risk investment at intermediate education increases too little to make the price at this level falling below the value at baseline.

education. However, it was implemented at the end of the 1990s when the convexification had already made its appearance, so, clearly, it can not be its root cause.