Microfoundations of Rising Experience Premia.*

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Abstract

During the past three decades both the skill and the experience premium increased significantly in English-speaking countries, leading to higher wage inequality. The skill premium seems to increase within any experience group. On the contrary, the experience premium rises significantly within the group of unskilled workers, while it remains flat among the skilled ones. Existing theoretical literature fails to provide a unified explanation of these facts. Using a model of asymmetric information, credit market imperfections and employer learning, I propose a microfounded justification for these recent patterns of wage inequality. I show that the relaxation of credit constraints decreased the minimum wage and this generated an increase in the experience premium within the group of unskilled workers. This suggests a mirror image between real minimum wages and economic inequality, a pattern that finds strong empirical support in many countries and especially in US, UK and Canada. This theory is also consistent with a rising skill premium within both the group of experienced and inexperienced workers.

Keywords: wage inequality, experience premium, skill premium, minimum wage, signaling, credit constraints, employer learning.

JEL Classification Numbers: D31, D82, E44, J31.

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1 Introduction

According to Hornstein, Krussel and Violante (2005) one of the most important challenges to the hypothesis that the recent changes in the wage structure are linked to technological progress, is to explain the combination of the rise in the returns to labor market experience for the low-educated workers and the flat pattern of the experience premium for college graduates. They highlight that the existing theoretical literature does not provide an answer to the experience premium puzzle. This study attempts to fill this gap in the literature by providing a microfounded explanation for the rising experience premium and ultimately for widening wage inequality.

Recent empirical evidence supports that wage inequality measured by the experience and the skill premium increased sharply since 1980's (see Krueger, Perri, Pistaferri and Violante (2010)). During the same period credit constraints relaxed significantly, generating more equal opportunities. This tendency has been observed in many developed countries. Additionally, the rise in residual wage inequality rekindled the scientific interest on labor income distribution[1]. Within this vast and growing literature on the sources of these recent labor market inequalities, most papers emphasize on the amplification of the skill premium and attribute this new pattern of wage inequality on the skill-biased technical change (SBTC)[2]. However, the increase of the experience premium still remains an understudied aspect of rising wage inequality. According to Card and DiNardo (2002), the evidence linking growing wage inequality to SBTC is surprisingly weak. Moreover, they conjecture that the emphatic focus on technology has diverted attention away from many other interesting developments in the wage structure that cannot be easily explained by SBTC. They suggest that the SBTC might have been responsible for expanding wage inequality during the 1970's; however, from early 1980's onwards other plausible factors, such as the fall of real minimum wage, might have attributed to this pattern of increasing wage inequality.

This paper presents a new theoretical channel, which is consistent with the pattern of rising wage inequality in the English-speaking countries. My approach focuses on the labor supply side and in this sense it is complementary to the SBTC that emphasizes on demand factors. I show that the combination of credit market imperfections (CMI), information asymmetries and employer learning, in an education signaling framework provides a new theoretical explanation for the rising experience premium within the group of unskilled workers and its flat pattern among the skilled ones. My theory is also consistent with a rising skill premium.

The paper proceeds as follows: the next section reviews previous related studies and locates the contribution of this paper into the existing literature, chapter 3 provides the theoretical framework, followed by a chapter with the comparative statics analysis, chapter five provides a discussion on the robustness of this paper results, while the last chapter contains some concluding remarks, policy implications and suggestions for future research. In appendices I, II, III and IV one can find proofs of propositions, variables explanation, tables and figures, respectively.

[1]For the rise of residual wage inequality see Violante (2002) and Lemieux (2006b).

[2]For a review of this literature see Acemoglu (2002), and Hornstein et al. (2005).

2 Related Literature and Stylized Facts

The Experience Premium.

Numerous country-specific empirical studies suggest that the contribution of education and experience on wages has increased since 1970's. Krueger et al. (2010), extend these microeconometric labor market findings, to a cross-comparison and support that two of the most important macroeconomic facts that occurred during the past three decades, are the sharp ascent on the experience premium for almost all countries and the heterogeneous pattern of skill premium. They propose that the direction and the size of the change in the skill premium differs across countries - in fact it increases in Anglo-Saxon counties, while it declines in continental Europe - however the significant rise of the experience premium was uniform for their sample of countries and consists a macroeconomic regularity of indisputable validity.

There are many explanations for the rise of the skill premium but surprisingly, only few for the increase of the experience premium. For the rise of the skill premium previous studies focus mainly on the SBTC justification. The existing theoretical literature on the experience premium is based on the following elements: 1) on-the-job training with SBTC, 2) General Purpose Technologies (GPT), 3) technology-experience complementarity in adoption, 4) vintage Human Capital and 5) demographic change.

In particular, Heckman, Lochner and Taber (1998) find that on-the-job training with SBTC justifies the increase of the experience premium, as well as the difference of the experience premium within educational groups. Aghion, Howitt and Violante (2002) propose that the generality of technological knowledge allows workers to accumulated skills and this augments the experience premium. Weinberg (2004) argues that senior workers have the privilege to combine their accumulated experience with technology and the high degree of complementarity between experience and technology amplifies the experience premium. Hornstein et al. (2005) point out that the experience premium can grow after a technological improvement if the loss of the vintage specific human capital comparing to the gain of the productivity improvement embodied in physical capital is larger for young workers. Jeong, Kim and Manovskii (2008) suggest that changes in the demographic composition can elevate the experience premium if the production function allows for complementarity between physical effort and accumulated working experience. Other possible justifications focus on the decline of minimum wages[3] generated by the increase in labor supply when the baby-boom generation entered the labor force[4].

Credit Constraints, Signaling and Employer Learning.

This paper relates to three branches of the literature focusing on credit market imperfections, signaling and employer learning. In this sense it links with earlier studies incorporating two of these; however, none of them builds on a unified framework of all three elements. For instance, Townsend (1979) was one of the earliest papers who combined credit market imperfections and information asymmetries, in order to determine

[3] Lee (1999), and Card and DiNardo (2002) provide empirical evidence on how the decrease of real minimum wage contributed to the increase of wage inequality.

[4] For the impact of the labor force growth see Dooley and Gottschalk (1984).

entrepreneur behavior and their contribution to aggregate output. However, he does not employ a signaling framework and he does not investigate the role of education. The signaling approach adopted in this study links more with Hendel, Shapiro and Willen (2005), which introduces à la Galor and Zeira (1993) credit constraints in the Spence (1973) model of job market signaling. They derive the important result that anything makes education more affordable, such as less severe credit constraints or lower tuition fees, increases the skill premium and wage inequality. However, their framework is not appropriate for the study of the experience premium.

Spence's (1973) seminal contribution initiated a debate on the role of education. On one hand, many economists adopt Becker's (1964) human capital approach, which suggests that education primarily increases productivity, while others are influenced by the spencian-signaling approach according to which education serves also as a message conveying information for worker's ability to firms[5]. Chevalier, Harmon, Walker and Zhu (2004) use the minimum school age to determine whether education increases ability or just reflects it. Their findings are supportive of the human capital approach. Lange (2007) supports that employers learn quickly, since initial expectation errors decline by 50% within 3 years. For this reason he argues that for a wide range of parameter values, the contribution of signaling to the gains from schooling is less than 25%, which highlights the limiting value of signaling. Kaymak's (2007) findings are on the same direction. Using OLS he estimates that the contribution of signaling to wages is a 22% of the return to education. For the higher ability workers, the return to signaling is much smaller. Habermalz's (2006) paper discusses the claim made in Altonji and Pierret (1996) that a high speed of employer learning indicates a low value of job market signaling. He deems that if employer learning is incomplete, a high speed of employer learning is not necessarily indicative of a low value of job market signaling. Bedard's (2001) study is supportive for signaling, as well. In particular, using a model with credit constraints she finds that the signaling explanation is empirically more plausible than the human capital one.

Even though there is a rich body of literature focusing on signaling and employer learning, none of the existing studies examines how credit constraints interact with these two elements and none compares how these financial frictions affect education and employer learning. Jovanovic (1979) was one of the earliest contributions on employer learning. Farber and Gibbons (1996) develop a dynamic model of learning about worker ability in a competitive labor market. Among other, they derive the following empirical result: although the influence of education on wages declines as performance observations accumulate, the estimated effect of education is independent of labor-market experience. Altonji and Pierret (1996) argue that the signaling value of education depends on how quickly firms learn and they show that even if employers learn relatively slowly about the productivity of new workers, the portion of the return to education that could reflect signaling of ability is limited. Altonji (2005) argues that the market might delay to learn that a worker is highly skilled if the worker's best early job opportunity is a low-skill-level job that reveals little about the worker's talent. While Bauer and Haisken-DeNew (2001) find no evidence of employer learning apart from the case of blue-collar workers at the

[5]For a review of this literature, on human capital and signaling explanations of wage determination see Weiss (1995).

lower end of the wage distribution. This probably indicates that the absence of degree among unskilled workers, increases the influence of employer learning on wages.

There are few studies focusing on asymmetric employer learning. Galindo-Rueda (2003) finds that British employers have limited information about their workers, so they make inferences based on their education levels, and progressively learn about their true ability. Moreover, this learning process particularly among blue-collar workers favors incumbent employers relative to potential competitors (asymmetric learning). However, in practice it is not easy to distinguish the firm-specific human capital (employee learning) from employer learning. Schönberg (2007) supports that there is no evidence for asymmetric employer learning, apart from the case of college graduates. Pinkston (2009) employs a model of asymmetric employer learning with testable implications in order to distinguish private employer learning from public learning and employee learning. In a recent study, Arcidiacono, Bayer and Hizmo (2010) derive the important result that education principally reveals ability, that is why ability is almost perfectly observed for college graduates, while the same is not true for high school graduates. For the latter, ability is gradually revealed with working experience and employer learning seems to be important only for this group of workers.

Education, Experience and Firm-Specific Tenure.
It is widely believed that among the observable characteristics education and experience explain a substantial part of wage differences and constitute two of the most fundamental determinants of wage variation across workers. According to Juhn, Murphy and Pierce (1993) education and experience can explain about a quarter to a third of the observed log weekly wage variation. Goldin and Katz (2007) support that during the period 1980-2005, in separate analyses by sex, rising education explains 62% of the growth of hourly wage variance for men and 37% for women. Similarly, Lemieux (2006a) finds that higher returns to post-secondary education explain 55% of the rise of male log hourly wage variance from 1973-5 to 2003-5. Murphy and Welch (1992), find that a 60% of variance in their baseline profile is between schooling level, and a 40% is across experience within schooling level. These evidence indicate that the influence of these two crucial determinants of wages (education and experience), is the principal candidate that shaped this recent trend in the pattern of wage inequality.

Additionally, if employer learning is private, then the distinction between general experience and firm-tenure is of major importance, since previous experience yields some information but unambiguously tenure is more informative. Some recent papers focus on the separation of general experience, sector tenure and firm-specific tenure. For instance, the case study of Dustmann and Meghir (2005) for Germany suggests that skilled wages grow with experience and the profile is concave, with growth starting at 7% early on and falling to 1.2% each year beyond the four first years. The returns to staying in the same sector are about 1% a year but they decline after five years, while the returns to staying in the same firm are about 2.5% a year again declining after the fifth year. Wages of the unskilled workers only grow for the first two or three years of labor market experience. The return to experience falls to zero from then on. Sector tenure has a statistically insignificant impact on wages. However, unskilled workers seem to enjoy a return to firm tenure that is about 4% per year for the first five years but declines to an insignificant 1.1% thereafter. They conclude that while the acquisition of transferable skills seems to be important for the wage growth of skilled workers early on in their career, unskilled workers benefit primarily from being attached to a particular firm. This empirical evidence highlighted by Dustmann and Meghir (2005) indicates that the significant rise of the experience premium stressed by Krueger et al. (2010) might represent more firm-specific tenure rather than general experience. Additionally, it provides suggestive evidence that asymmetries of information are more important within the unskilled group of workers and it might be the increasing effect of this group that drives the rising pattern of the experience premium. This premise is also in harmony with the finding of Arcidiacono et al. (2010) that the return to education due to employer learning is important only for the unskilled workers. However, a much earlier study by Abraham and Farber (1987) sharply points out that the measured positive cross-sectional return to seniority is largely a statistical artifact due to the correlation of seniority with omitted variables representing the quality of the worker, job, or worker-employer match. They find that after controlling for these omitted factors, earnings do not rise much with tenure.

Wage Inequality Facts.
Several previous studies examine the issue of measurement of economic inequality[6]. Apart from the mainstream indexes of income inequality, such as the Gini coefficient or the variance of log wages, economists developed new ways to observe the evolution of wage inequality, such as the evolution of the top incomes[7] or the returns to education and experience[8]. However, due to data unavailability a growing body of research papers in economics measure wage inequality using the skill, the experience and the gender premium. There is strong empirical evidence that the contribution of education and experience on earnings increased during the past three decades, while gender inequality decreased significantly[9]. This study measures wage inequality using the skill and the experience premium. That is why it is crucial to distinguish the return to education and the return to experience from the skill premium and the experience premium. Think of the following wage equation:

$$logWAGE_{it} = \alpha + \beta * EDUC_i + \gamma * EXP_{it} + CONTROLS + u_{it}$$

Where the additional control variables may include gender, race, occupation and marital status, as well as, individual and year fixed effects, among others. The difference between the return to education and the skill premium is the following: the individual financial *return to education* is actually the parameter β in the equation above, while the *skill premium* is the following ratio:

$$SkillPremium = \frac{W_{College}}{W_{HighSchool}}$$

Namely, the hourly wage ratio of college graduates over the one of high school graduates. That is why they also refer to this as college premium. Respectively, the *return to*

[6]See Schutz (1954), Atkinson (1970) and Sen (1973).
[7]See Piketty and Saez (2003, 2006), Atkinson, Piketty and Saez (2010).
[8]Katz and Murphy (1992), Juhn, Murphy and Pierce (1993).
[9]See Krueger et al. (2010) for a cross country calculation of the skill and the experience premium.

experience is the parameter γ in the equation above and the *experience premium* is the following ratio:

$$ExperiencePremium = \frac{W_{experienced}}{W_{inexperienced}}$$

This is the hourly wage ratio of the relatively experienced to the relatively inexperienced worker. For instance, in an attempt to compare the experience premium across countries, Krueger et al. (2010) use the hourly wage ratio of workers aged 45 to 55 years old over the wage of workers aged 25 to 35 years old[10]. Krueger et al. (2010) report evidence for nine developed countries, for the pattern of the the skill, the experience and the gender premium over the past three decades. They find that for the skill premium there is a clear dichotomy, since it increased significantly in US, UK, Canada, Mexico and Sweden, while it has declined in Germany, Italy, Russia and Spain. That is why if all countries are pooled together, as Trostel, Walker and Wooley (2002) do for 28 countries for the period 1985 to 1995, the return to education does not seem to follow and increasing pattern. The experience premium evolved more homogeneously across countries, as it increased in all countries apart from Sweden[11] and the magnitude of the increase was more similar comparing to the skill premium. Furthermore the gender premium fell substantially in all countries. Some of their results are collected and presented at table 1.

Percentage change in Wage Premia

Country	Skill Premium	Experience Premium	Gender Premium	Variance LogW	Period
CAN	22	31	-11	17	1978-06
GER	-8	22	-15	5	1983-03
ITA	-8	11	-5	3	1987-06
MEX	40	22	-6	4	1989-02
RUS	-6	5*	-7	-13*	1998-05
SPA	-33	7	-21	-18	1985-96
SWE**	14	-2	-5	-9	1990-01
UK	12*	20*	-21	10*	1980-06
US	40*	28*	-25	21*	1980-06

Note: This table summarizes the evolution of wage premia, such as the skill premium (the ratio between the average hourly wage of college graduates and the average hourly wage of high-school graduates), the experience premium (the ratio of the average hourly wage of 45–55 years old over the average hourly wage of 25–35 years old), and the gender premium (the ratio of the average wages of men to the average wages of women), as well as the variance of log wages as a measure of overall wage dispersion and inequality, for nine developed countries for a period varying from 1978 to 2006. A more detailed version of the table can be found in Krueger, et. al. (2010).
* Indicates that the statistic is on males only.
** Data refer to after-tax annual earnings.

Table 1: Wage Inequality across countries

Additionally, it is of major importance to calculate the college premium within different groups of experience and the experience premium within different groups of education.

[10] They use the age of the individual and not labor market experience, due to data unavailability.

[11] Notice in table 1 that the data for Sweden refer to after-tax earnings.

By doing this we will be able to tackle unanswered questions such as the one posed by Hornstein et al. (2006): why the experience premium increased significantly within the group of high school graduates, while it has remained constant within the group of college graduates. According the Murphy and Welch (1992) the pattern of the skill premium is increasing for all experience groups (see Table 2, appendix III). On the other hand, according to Weinberg (2004) the profile of the experience premium for the US is increasing for high school graduates and flat for college graduates (see Figure 1, appendix IV).

One other crucial aspect of the evolution of wage inequality, is the fall in real minimum wage (see figure 2 (appendix IV) for the pattern of real minimum wages as presented in Card and DiNardo (2002)). Many studies propose a pattern of movements to the opposite direction between real minimum wages and wage inequality. Lee (1999), Card and DiNardo (2002), and Teulings (2003) propose that the fall in real minimum wage is responsible for the rising wage inequality in the US and find that the real minimum wage explains approximately a 90% of variations on wage inequality. Figure 3 (appendix IV) illustrates the result by Card and DiNardo (2002) that there is a systematic relationship between real minimum wages and overall wage inequality. Additionally, comparing figure 1 with figure 2 and 3 (appendix IV) one can observe that the decline on the real minimum wage is closely linked with both the rise of the experience premium within the group of high school graduates and the rise on overall wage inequality in the US. Machin (1997), and Machin, Manning and Rahman (2003) find similar results for the UK. DiNardo and Lemieux (1997) suggest that in the US the minimum wage fell significantly inducing a rise on wage inequality, while in Canada the more moderate decrease in the minimum wage caused a smaller increase on wage inequality.

I summarize the above observation of labor market inequalities as follows:

- **Fact 1:** The experience premium increased significantly in almost all countries.
- **Fact 2:** The experience premium increased primarily within the group of high school graduates, while it has remained constant for college graduates.
- **Fact 3:** The skill premium increased significantly in Anglo-Saxon countries while it declined in continental European countries.
- **Fact 4:** Across time there is a systematic negative relationship between real minimum wages and the experience premium within the group of high school graduates, generating variations to overall wage inequality.

The Contribution of this Study.

The main contribution of this paper is the revelation of a theoretical channel between credit constraints and the experience premium. Many studies have examined why wage inequality has changed over time[12], some papers enlighten important aspects of the evolution of wage inequality over time; however, none of them provided a unified explanation of all four facts of wage inequality that I summarize above. In particular, I find that

[12]For a review of this literature see Aghion, Calori and Penãlosa (1999), Acemoglu (2002), Hornstein et al. (2004).

when credit constraints relax, minimum wages decrease for the unskilled and inexperienced workers, generating primarily an increase to the experience premium within the group of unskilled workers but also a rise to the skill premium. This theoretical result finds strong empirical support for the English-speaking countries and has some interesting policy implications.

3 The Economy

3.1 Preliminaries

In this economy people live for three periods, time is discrete, and the total population is comprised of heterogenous agents[13]. In the mass one of total population there are two types of workers, a proportion π of high ability workers and a proportion $1-\pi$ of low ability ones. Every potential worker has a private information on his productivity. Each worker produces q^j where $j=\{l,h\}$. In particular, the low ability worker produces q^l units of output and the high ability one produces q^h units ($q^h > q^l$). In addition to differing in ability, workers also differ in their initial wealth endowments. Therefore, there are two sources of heterogeneity stemming from innate ability and initial wealth differences.

The cost of education is dual. There is a direct fixed tuition cost T and an indirect differentiated effort cost depending on agent type. The effort cost is higher for the low ability worker $k^l > k^h$. This notion of indirect cost captures the idea of Spence (1973) that education is more challenging for the low ability students than for the high ability ones. Spence measures the added effort required for low ability students to graduate from college as an argument of the utility function. For simplicity, here this is modeled as a monetary cost[14]. Without loss of generality, it is also assumed that $k^h = 0$.

Every period people can either work or go to school. Although, some find it profitable to acquire education when young or in the second period of their lives, no rational agent prefers to invest in education when old, since the next period, when she gets the return to school investment, she is dead with certainty. Agents can acquire costly education, at a fixed financial-tuition cost T, both when young and old. If they acquire education when young they work as skilled for the second and third period of their lives, for a wage w_2^s and w_3^s, respectively. If they do not acquire education they work for the unskilled wage w_1^u during the first period of their lives but during the second period of their lives some of them can acquire education using the unskilled wage they have accumulated during the first period. Notice that education is a mere signal, since it does not affect worker's productivity[15].

Timing. Timing is essential in this three-period model. In particular, during the first period of their lives some agents go to school, while others work after signing one-period

[13] In a dynamic framework this could be a standard three-period OLG model.

[14] One can think of this cost as paying additional tutors, purchasing supplemental materials or simply time costs.

[15] This paper examines only the signalling approach of wage determination. However, this approach can be combined with the human capital one and generate more realistic results.

contracts. At the end of this period they receive the wages agreed and they invest all their wealth in one-period bonds, for an interest rate r^l. Some borrow at a higher interest rate r^b in order to access education. All loans are payed back at the last period of agents lives. So, loans taken either in period one or in period two, are reimbursed at the end of period three.

During the second period of their lives firms privately observe workers' productivity. Uneducated workers decide whether to bargain or not, using as a threat the possibility of going to school at the second period. Notice that uneducated workers can still go to school when old. There is a cost for unsuccessful bargainers, while successful bargaining is not only costless but it also generates an increase in the second and third-period wage. Firms and workers sign wage-contracts for the remaining two periods. At the end of the second period they receive the payment agreed and they invest their wealth in bonds. For the third period everything is predetermined so workers repay their loans, gather all their lifetime earnings and they consume them.

Firms observe workers' productivity during the first period of employment and the second period they know the types of their employees. However, this is private information for each firm, so if workers want to be employed by other firms, they still have to acquire education in the second period of their lives. This leads to a wage bargaining process, which inherits some very interesting implications to our model. Furthermore, it is worth mentioning that the return to school investments is higher comparing to the return of bond investments[16]. Thus, agents first examine the possibility of investing in education and then in bonds.

Assumptions. The functioning of the economy is affected by three crucial assumptions: 1) *asymmetric information*, 2) *credit market imperfections* and 3) *employer learning*. Primarily in this setting agents have a private information about their ability type. Individuals of high ability try to signal their type to their potential employers. In fact, they invest in education to get their diplomas, and they use them to signal their type, which leads to a higher wage. Notice that education is a *costly signal* just as in Spence (1973) and the total cost differs depending on agents' type.

The second market failure is relates to the functioning of credit markets. I introduce credit market imperfections following Galor and Zeira (1993). So there is a lending interest rate r^l and a borrowing interest rate r^b and it is true that $r^b > r^l$. The difference between the two rates of interest stems from the possibility of defaulting, which requires the adoption of a costly screening technology by the lenders. In this partial equilibrium small-open-economy framework, r^l equals the world interest rate. That is why the relatively less wealthy agents cannot invest in education. This assumption combined with the asymmetries of information render firms incapable of distinguishing the low-type from the credit constrained high type, when there is no educational signal.

Employers privately observe worker performance and after a period of employment the ability-type of each worker is revealed. That is why after a period of employment only the incumbent firm knows the type of its workers. The potential competitors still

[16]As we shall see only high types choose to invest in education. So, putting it more precisely the return to school investments for the high types is higher than the return of bond investments.

face informational frictions about the type of potential new workers. All the above is common knowledge.

Additionally, the use of a set of mild assumptions facilitates the analysis, without harming the robustness of the theoretical framework. In particular, it is assumed that firms are *price takers* and the production function is subject to *constant returns to scale.* Price taking behavior is assumed in order to focus our analysis on imperfections related to information asymmetries and credit constraints. However, extending the present framework with the inclusion of strategic firms might generate some interesting implications. Constant returns guarantee that the marginal productivity does not depend on the number of workers, facilitating the analysis of wage determination.

Agents and Firms. All agents maximize their lifetime earnings, given their type and initial wealth. In this economy there are four classes of agents, differing on their type and initial wealth. Below I calculate the lifetime earnings for each class

Self-Funded Young Students: The first group is comprised by those who have enough initial wealth to acquire education when young without borrowing. Those with wealth $b^i \geq T + k^j$ get a lifetime income of:

$$y^A = (1 + r^l)^2(b^i - T - k^j) + (1 + r^l)w_2^s + w_3^s. \tag{1}$$

Young Borrowers: Workers with wealth $b^i \in [b^*, T + k^j)$ can access profitably the credit markets. However, since they cannot cover the total cost of education, seek for external funding, borrow and get lifetime income of:

$$y^B = (1 + r^b)^2(b^i - T - k^j) + (1 + r^l)w_2^s + w_3^s. \tag{2}$$

At the second period, workers who have worked as unskilled know that their employment firms have observed their productivity. So they can bargain with their employment firms, using the possibility of acquiring education when old and working for other firms. Notice that even workers with zero initial wealth can cover the tuition cost using their first-period labor income, provided that $w_1^u > T$. The crucial point is whether they are talented enough to cover the effort cost k^j.

Bargainers: Workers with $b^i \in [T + k^j - (1 + r^l)w_1^u, b^*)$ can acquire education using their own funds after a period of employment and get:

$$y^C = (1 + r^l)^2(w_1^u + b^i) + (1 + r^l)w_2^{u,j} + w_3^{u,j}. \tag{3}$$

Uneducated: Agents with initial wealth $b^i < T + k^j - (1 + r^l)w_1^u$ remain uneducated. These agents get a lifetime income of:

$$y^D = (1 + r^l)^2(w_1^u + b^i) + (1 + r^l)w_2^{u,j} + w_3^{u,j}. \tag{4}$$

Firms perfectly compete and their production function is linear that implies constant returns to scale in labor, which is the only input. Formally:

$$Y_t(Q_t) = AQ_t. \tag{5}$$

Where A is the productivity parameter and Q denotes efficient units of labor. In particular, the low ability agent is endowed with q^l units of efficient labor, while the high type is endowed with q^h, where $q^h > q^l$. Firms pick a mixture of wages that maximizes their profits.

The Game. Formally, the game can be defined as follows:

Definition 1 *The game is defined as $G = \langle N, B, \langle A_i, \tau_i, y_i, p_i \rangle_{i \in W} \rangle$, where:*

1. *N is the set of players, there exists a mass one of workers W and F firms, which perfectly compete.*

2. *A_i is the set of actions for worker i. $A = A_1 \times A_2 \times A_3$. Where $A_1 = \{school, not\}$, $A_2 = \{school, bargain, not\}$ and $A_3 = \emptyset$, since in period three everything is predetermined for agents by their previous actions.*

3. *B denotes the set of beliefs formed by the representative firm after observing the actions of senders.*

4. *τ_i is the types of player i. Ability type can be either low or high, while their initial wealth can be any non-negative value given by an unspecified cdf.*

5. *$y_i : A \to \mathbb{R}$ is the payoff function for player i.*

6. *p_i is the probability distribution over the types of workers for the entire society. In this game, $p_i = 1$, which means that all players have the same views for the probability distribution of types for the entire society but they cannot attach types to each agent i.*

3.2 Equilibrium

Wage contracts apply twice, once during the first and once during the second period of agents' lives. So there are two contracts for each agent, the first determines her wage when young and the second the wages of the two remaining periods. Firms follow different approach on the determination of wages, depending on whether the workers are young or not. For young potential workers, firms announce wage contracts by observing education choices only. So there is no bargaining between firms and young agents. Once an agent works for a firm, the firm observes the amount of output she produces and this reveals her type. The next period, firms use this private information, related to their employees' ability, in the determination of the second contract. However, the revelation of worker type cannot affect salaries during the first period, since the contracts are already signed for that period. Price taking firms equalize the wages of the workers to their expected marginal productivity conditional on their education. Formally, it is true that:

$$w_2^s = w_3^s = w^s = E(q|education) \tag{6}$$

$$w_1^u = E(q|no - education) \tag{7}$$

The determination of the wage of educated worker is trivial, since the productivity of each educated worker is known with certainty. Notice that $w_1^s = 0$, since they cannot work and invest in education at the same period. However, this is not the case for the uneducated ones. In order to study the role of financial market imperfections in an education signaling framework, we restrict attention to parameters that yield a separation of types in equilibrium. First, we assume that the differentiated cost of education for the low ability workers is sufficiently high that they never get an education. Specifically, we assume that even with the highest possible skilled wage w^s, a worker of low ability will still prefer to invest her wealth in bonds rather than in education:

$$\frac{w^s - w_2^u}{T + k^l + w_1^u} < \frac{(1+r^l)^2}{(2+r^l)}. \tag{8}$$

Intuitively inequality (8) means that for a low type, $y^A < y^D$, i.e. it is always more profitable to remain unskilled rather than acquiring education, since the effort cost is high. Notice that $w_2^u = w_3^u$, since everything is predetermined for the last period. For simplicity we denote the unskilled wage of the second and third period as w_2^u. Second, we assume that getting an education will be attractive for at least the richest high ability workers. If we define $w_1^P = q^P \equiv \pi w^s + (1-\pi)w^u$ as the average ability when both types are pooled together, our assumption implies that even with the lowest possible skilled wage w^s, a high ability person with a bequest above the cost of education will find it profitable to invest in education when young:

$$\frac{w^s - w^P}{T + w^P} > \frac{(1+r^l)^2}{(2+r^l)}. \tag{9}$$

Intuitively inequality (9) means that for a high type, $y^A > y^C$, i.e. it is always better to acquire education when young rather than bargain when old. Inequalities (8) and (9) ensure that an equilibrium exists where at least some high-ability agents get education when young and where no low ability agent gets education and that there are no pooling equilibria where all members of both types take the same educational choices.

The high types with bequests higher than the threshold b^*, find it profitable to borrow and invest education young rather than bargain when old. This threshold generates the following condition, which is important in explaining the behavior of the unskilled-labor supply. High ability agents find it profitable to get an education when young, if their initial wealth b^i is above the threshold b^*:

$$b^i \geq \frac{(1+r^b)^2 T + (1+r^l)^2 w_1^u - (2+r^l)(w^s - w_2^{u,h})}{(r^b - r^l)(2+r^b+r^l)} \equiv b^*. \tag{10}$$

Notice that the above condition means that for the high types with initial wealth higher than b^* it is true that $y^B > y^C$. Additionally, $b^* = C$ but I denote it as b^* to clarify that it is an initial wealth threshold.

Firms determine wages for young agents and for old agents. First, I examine the first-period contracts. For young agents firms know that all the educated are high types. For the non-educated workers the determination of wage is more complicated, since firms are not sure whether they are of low ability or credit constrained high ability agents. The supply for unskilled labor is:

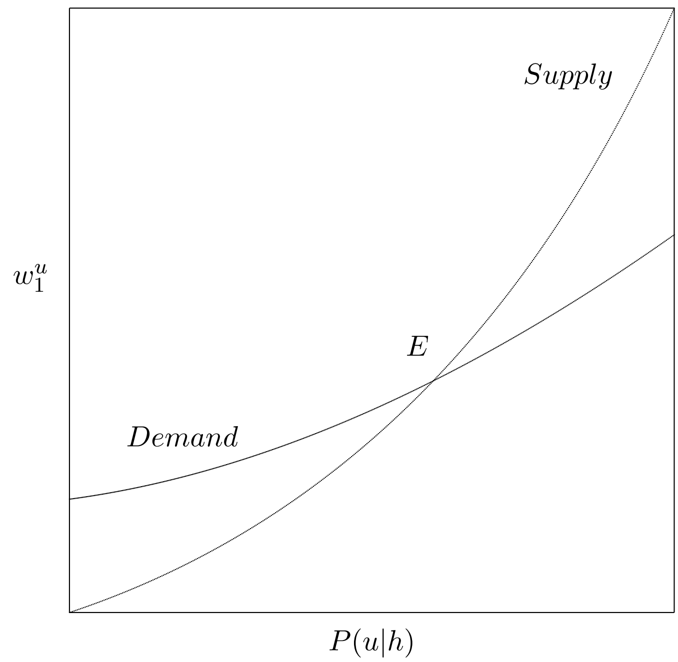
$$P(u|h) = P(b^i < b^*). \tag{11}$$

Where $P(\cdot)$ represents the cumulative density function of the initial wealth distribution for high ability workers. In figure 4 we can examine how the parameters of the model affect the supply curve. $P(u|h)$ represents the probability that the uneducated worker is of high ability. Generally, the higher b^* is, the greater is the number of high ability agents who do not get an education: $b^* \uparrow \;\Rightarrow P(u|h) \uparrow$. On the supply curve, an increase in the first period unskilled wage raises the wealth cutoff b^* by reducing the payoff to education, which raises $P(u|h)$ (see equation (10)). Hence, the supply curve is upward sloping. An increase in tuition level T increases b^* by driving down the return to education. So, for any given unskilled wage, more workers can not get an education, shifting the supply curve to the right. More severe credit market imperfections, which algebraically translates to an increase in the wedge $r^b - r^l$, the difference between the borrowing rate of interest and the lending rate of interest, both shifts the supply curve to the right and reduces its slope. Notice that r^l is constant and equal to the exogenous world interest rate, that is why an increase of r^b makes less credit frictions more severe. So, varying only the borrowing rate r^b for a given world interest rate r^l, will affect the degree of financial development, which is extremely important for the comparative statics analysis. To see why, re-write b^* from equation (10) as:

$$b^* = T - \frac{(2+r^l)(w^s - w_2^{u,h}) - (1+r^l)w_1^u - (1+r^l)^2 T}{(1+r^b)^2 - (1+r^l)^2}. \qquad (12)$$

From the above equation it is clear that an increase in the wedge $r^b - r^l$ leads to a higher b^* and thus a higher supply of unskilled labor. The wedge $r^b - r^l$, depends only on r^b, since r^l is fixed and equals the world interest rate. Furthermore, a larger wedge raises the slope of the supply curve. Intuitively, an increase in the wedge means that workers are more sensitive to changes in the return to education.

Figure 4: Unskilled-Labor Market



Overall, given the levels of w^s and r^l, for the supply curve it is true that:

- **Changes on the Supply curve:** $P(b^i < b^*)(w_1^u(+); T; r^b)$.
  An increase (decrease) in the first period unskilled wage w_1^u, increases (decreases) the probability that the high type is uneducated $P(u|h)$.

- **Shifts of the Supply curve:** $P(b^i < b^*)(w_1^u(+); T; r^b)$.
  An increase (decrease) on the tuition cost T or the borrowing interest rate r^b, shifts the supply curve outwards (inwards).

- **Changes on the Slope of the Supply curve:** $P(b^i < b^*)(w_1^u(+); T; r^b)$.
  An increase (decrease) on the borrowing interest rate r^b, decreases (increases) the slope of the supply curve.

The demand curve is in fact, the firms willingness to pay for a given mix of high and low-ability workers. Since firms compete for workers, their willingness to pay is uniquely defined by the break-even point of offering a wage equal to expected productivity. To compute the demand curve, I use equations (6) and (7) to determine the unskilled wage:

$$w_1^u = q^l \left(\frac{1-\pi}{1-\pi+\pi P(u|h)} \right) + q^h \left(\frac{\pi P(u|h)}{1-\pi+\pi P(u|h)} \right). \tag{13}$$

Solving for $P(u|h)$ gives the following demand function:

$$P(u|h) = \frac{1-\pi}{\pi} \left(\frac{w_1^u - q^l}{q^h - w_1^u} \right). \tag{14}$$

The demand curve for unskilled workers is upward sloping and this feature of our model drives many of our findings. Intuitively, as fewer workers get an education, firms realize that the average uneducated worker is more likely to be of high ability. Thus, they are willing to pay more for unskilled workers.

If the slope of the supply curve exceeds the slope of the demand curve and under the initial condition for $P(u|h) = 0$ of excess demand and the terminal condition for $P(u|h) = 1$ of excess supply, there exists at least one tâtonnement *stable* equilibrium. Generally, an equilibrium exist when the high ability workers who can not get an education coincides with the mass of high-ability uneducated population that the firms wish to employ in order to unskilled wage to maximize their profits.

Bargaining. The discussion so far concerns only the determination of the wages for young workers, which are given by the first period contracts. In fact, high ability agents with adequate bequests to acquire education when young, $b^i \geq b^*$, work for the skilled wage during the second and the third period of their lives $w^s = q^h$. Similarly, low ability agents do never invest in education, so they work as unskilled for the rest of their lives. However, the determination of the employment path of high ability agents with wealth $b^i < b^*$ is not so simple.

Firms know that high ability agents with $b^i < b^*$, produce q^h. However during the first period of their employment they offer them w_1^u, since they cannot afford signaling their type. During the second period of their lives, their type is known only by their employment firms. When old, these workers bargain over their wage and threaten firms that if they do not pay them the high wage that they deserve, they will find a job to other firms and get the skilled wage. Their employers argue that the other firms do not know their type so in the absence of a degree they will not receive the skilled wage. Workers reply that they will acquire education in order to signal their type to the other firms and get a higher wage. Firms know that this threat is *credible* for all the credit constrained high types, who are uneducated, only if the first period unskilled wage is higher than the tuition cost, $w_1^u > T$. That is why firms agree with bargainers to offer them the wage $w_2^{u,h} = w_3^{u,h} = [q^h - (1 + r^l)T]/(2 + r^l)$ that makes them indifferent between remaining to the same firm and going to school when old in order to work as skilled for other firms during the last period of their lives. High types find it profitable to separate themselves from the unskilled pool when old, even for the lowest possible wage for bargainers. Formally, it must hold that $E(q|u) = w_1^u < w_2^{u,h}$. Additionally, under a time-cost for changing jobs, workers are better of by accepting their employment firms offer. Respectively, low types face a time-cost when they bargain with their employment firms unsuccessfully. That is why all low types prefer not to bargain. Notice that nobody invests in education when old!

This process of bargaining generates a return to experience not as a result of a standard learning-by-doing process but as an informational benefit of employer learning, due to the combination of credit market imperfections, asymmetric information and bargaining. Successful bargainers receive the wage they would got if they had invested in school when old and so if they had worked only in the last period of their lives. So, they get $w_2^{u,h} = w_3^{u,h} = [q^h - (1 + r^l)T]/(2 + r^l)$ for the second and third period of their lives.

High types always find it profitable to bargain[17]. That is why an uneducated agent who seeks for employment when old is perceived as a bad type and so she will get the lowest possible wage $w_2^{u,l} = w_3^{u,l} = q^l$.

Lemma 1 *In the model described above there is a return to experience due to employer learning. This return is generated as a result of individual bargaining, and it is positive for high types, while it is negative for the low types.*

High ability workers, bargain based on the possibility of acquiring education and finding employment in other firms. This bargaining is successful for all the high ability workers, since they all have enough wealth cover the cost of education in the second period of their lives. In particular, the return to experience decreases for all low types, since after a period of employment their employers know that these are the low types.

Observe that profit-maximizing firms wish to keep the uneducated high ability employees, since they are paid less can their marginal productivity. By doing this firms derive an informational rent. More formally the proposition below holds.

Proposition 1 *If after a period of employment firms privately observe labor productivity, then this private information generates a profit for employers. This profit equals the difference between marginal productivity and the wages offered to the credit constrained high types.*

[17]High types find it profitable to separate themselves from the unskilled pool when old, even for the lowest possible wage for bargainers. Formally, it must hold that $E(q|u) = w_1^u < w_2^{u,h}$.

Proof. See Appendix I. ∎

The intuition is simple. Initially, firms employ workers without deriving significant profits. However, as they get familiar with their employees, they can sort them more efficiently and derive a surplus due to better sorting.

Equilibrium Concept. For this economy the following equilibrium definition applies:

Definition 2 *A Perfect Bayesian signaling equilibrium is defined as:*

1. *choices of education in the first period, based on skills and initial wealth bequests:* $A_1^*(q^j, b^i) \in \{school, not\}$*, choices in the second period, based on skills and initial wealth* $A_2^*(q^j, b^i) \in \{school, bargain, not\}$*;*
2. *beliefs by firms about worker type in the first period of employment given their education level* $B_1(j|A_1)$*,* $\forall\ A_1\{school, not\}$*;*
3. *and equilibrium wages:* $w_1^u, w_2^{u,l}, w_2^{u,h}, w_2^s, w_3^{u,l}, w_3^{u,h}$ *and* w_3^s*.*

Such that:

1. *workers' lifetime earnings are maximized,*
2. *firm's profits are maximized,*
3. *labor markets clear.*

We employ the solution concept of Perfect Bayesian equilibrium. Inequality (9) guarantees the existence of the separating equilibrium. Pooling in education is not possible, as inequality (9) shows that low ability individuals would like to deviate. Pooling in no education can exist if high ability agents do not want to deviate. Clearly there are off the equilibrium path beliefs by firms that would keep high ability agents from deviating (for example, if firms believe someone with an education is of low ability), but using the *intuitive criterion* of Cho and Kreps (1987), we can eliminate these beliefs as unreasonable. In particular, agents put zero probability on events that are dominated. Since inequality (9) guarantees that low ability agents would never choose to get an education, the beliefs of firms upon seeing education must be that the individual is of high ability. Lastly, inequality (10) ensures that a rich high ability person finds it profitable to deviate from the pool and signal her ability early through education. This means that high types prefer to go to school when young and signal their ability early rather than waiting for their type to be revealed to their employer and bargain later on. Two features are worth noticing. First, firms expectations that workers of different type wish to make different educational choices are *self-fulfilling* in this signaling equilibrium, since it is firms beliefs that those who acquire education are only high types that makes high types choosing to acquire education. Second, labor markets always clear, since this is a model of full employment and firms compete over workers.

From the definition above, we know that in equilibrium the following events occur with certainty: no low ability agent invest in education when young or old, so they work for w_1^u, when young and for $w_2^{u,l} = w_3^{u,l}$ for the remaining two periods; at $t = 1$ high ability agents with $b^i \geq C$ get an education when young and labor income of $w_2^s = w_3^s = q^h$ for the second and third period of their lives, the remaining high types work as unskilled for w_1^u; at $t = 2$ high ability agents who worked as unskilled the previous period bargain successfully and get a wage of $w_2^{u,h} = w_3^{u,s} = [q^h - (1 + r^l)T]/(2 + r^l)$. In the third period everything is predetermined by the previous period, so for all agents the second and third period wages coincide, $w_2^i = w_3^i$.

So the crucial variable we have to determine is w_1^u. An equilibrium occurs when the percentage of high ability workers who cannot get an education at an unskilled wage w_1^u is equal to the percentage of high ability workers that a firm needs to be in the unskilled pool of workers in order to break even by offering wage w_1^u. Formally, I use equation (14) to formalize this economy by means of an excess demand function. The demand function $f(\cdot)$ is defined as follows:

$$f : \mathbb{R}^3 \to \mathbb{R} : f(w_1^u; T, r^b) = \frac{(1-\pi)q^l + \pi q^h P(b^i < b^*(w_1^u; T, r^b))}{1 - \pi + \pi P(b^i < b^*(w_1^u; T, r^b))}.$$

For a given r^b and T, equilibrium occurs when $f(w_1^u) = w_1^u$. Since, I assume that prices evolve according to $\partial w_1^u / t = f(w_1^u) - w_1^u = g(w_1^u)$. Where $g(\cdot)$ is the excess demand function. An equilibrium is *locally tâtonnement stable*[18] if, whenever the initial price vector is sufficiently close to it, the dynamic trajectory causes relative prices to converge the equilibrium relative prices. The condition of tâtonnement stability is equivalent to the requirement that the slope of the supply curve must exceed the slope of the demand curve. The following proposition summarizes the existence result.

Proposition 2 (Existence) *Under the following assumptions:*
1) $P(\cdot)$ is continuously differentiable,
2) for $w_1^u = q^l$ it is true that $P(b^i < b^*)(q^h - q^l) < 0$, and
3) for $w_1^u = q^P$ it is true that $P(b^i < b^*)(q^h - q^P) > 0$,
there generically exists at least one stable equilibrium.

Proof. See Appendix I. ∎

Intuitively, for the existence of an equilibrium it is not enough the slope of the supply curve to be higher than the one of the demand curve (see figure 4). It is also necessary to have an initial and a terminal condition. In this model there can exist multiple equilibria. Generically, if the number of equilibria N is odd, the $(N-1)/2+1$ of them are stable. If the number of equilibria N is even, the $N/2$ of them are stable. The intuition for multiple equilibria is straightforward. Since increases in the unskilled wage lead to increases in both supply and demand, I can get equilibria with different levels of w_1^u. The highest w_1^u is, the less will get an education.

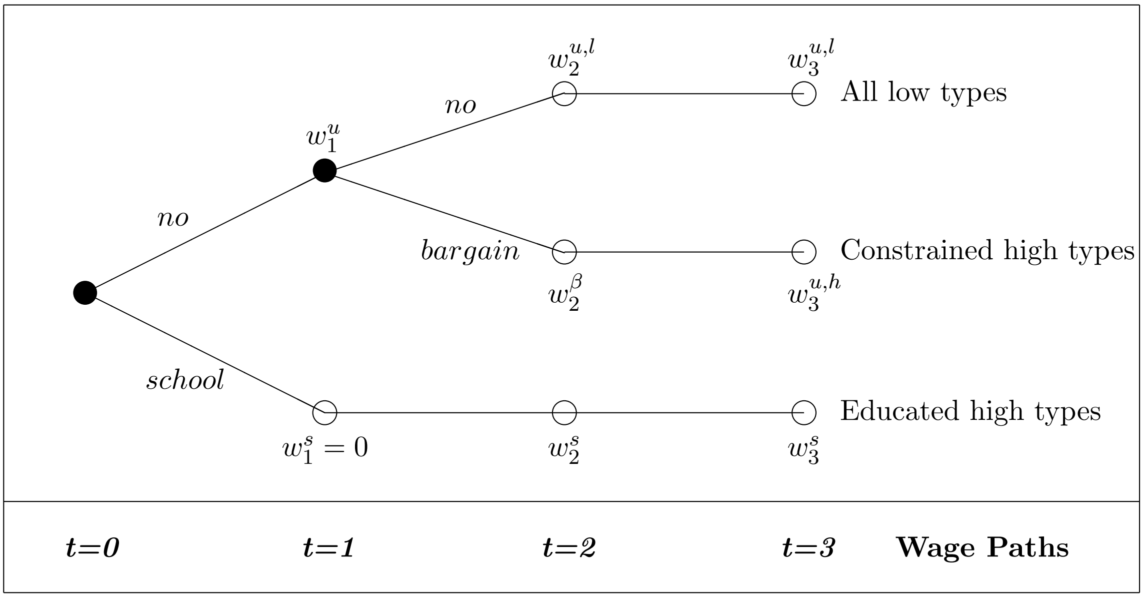
To see why stability is important, consider figure 4. In a stable equilibrium the slope of the supply curve is higher than the demand curve. If the supply of unskilled high ability labor is lower than the amount demanded by firms (excess demand) firms are willing to pay a lower wage, so the unskilled wage decreases to reach the equilibrium level, while

[18]From now on I refer to locally tâtonnement stable equilibria, as stable equilibria.

excess supply increases it. Less severe credit constraints, generated by a reduction of r^b, shift the whole supply curve inwards and increase its slope. In stable equilibria, such a shift leads to a reduction in the number of unskilled workers and a reduction in their wage. In unstable equilibria, the slope of the demand curve is higher comparing to the slope of the supply curve, so less credit frictions shift inwards the supply curve and increase its slope, leading to an increase in both the wage and the number of unskilled workers. Hence, in an unstable equilibrium, the comparative statics discussed in the propositions 2 and 3 would generate the opposite results.

The functioning of the Economy. So far, I have presented the basic features of the theoretical framework and at this point, I can shortly preview the functioning of this economy using the diagrammatic illustration of figure 5.

Figure 5: Equilibrium Tree



The black nodes denote that a decision is taken by the agent, while in the transparent nodes there is no option by the agent and the employment path is predetermined by previous choices. On the branches I display the choices and on the nodes the wages. The subscript on the wage always denotes the time. This graph is essential for the understanding of agent and firm behavior in this model.

4 Comparative Statics

At this point we examine the interaction between credit frictions, skill and experience premia. In a stable equilibrium, anything that makes it easier or more attractive for people to become educated raises the skill premium. The intuition is simple. Lowering the borrowing rate or tuition fees shifts the supply curve for unskilled labor to the left. With a normal downward-sloping demand curve, such a shift leads to a rise in the wage since demand would exceed supply. However, in our model the demand curve is upward-sloping, so the wage decreases to restore the equilibrium. Importantly, policies that equalize educational opportunity such as lowering r^b, actually increase wage inequality. I summarize this logic in the following proposition:

Proposition 3 *In any stable equilibrium, less severe credit constraints increase the skill premium. The rise in the skill premium occurs both within the group of experienced and inexperienced workers.*

Proof. See Appendix I. ■

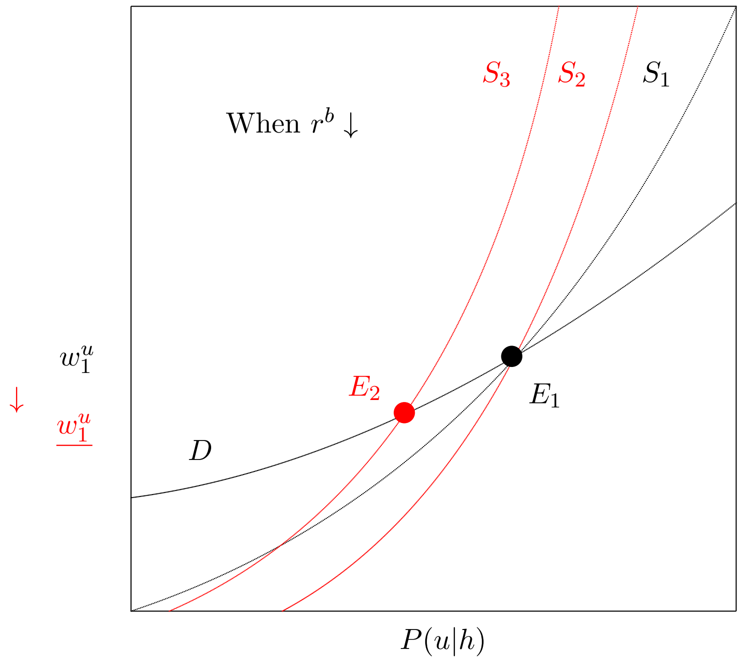
The proposition above is in harmony with Table 2 (appendix III) that shows a rise of the skill premium within any group of experience. This means that less severe credit constraints would increase skill premium and wage inequality. Additionally, if the borrowing interest rate decreases, fewer high ability workers will remain uneducated and by (9) we can see that b^* will fall, generating a decrease on the initial wage of the unskilled and inexperienced worker, which in turn leads to an increase on the experience premium. Notice that the rise on the experience premium is generated due to influence of the unskilled workers and not the skilled ones. More formally the proposition below holds:

Proposition 4 *In any stable equilibrium, less severe credit constraints increase the experience premium. The experience premium rises only within the group of unskilled workers, while it remains constant within the group of skilled workers.*

Proof. See Appendix I. ■

The findings summarized in Proposition 4 find strong empirical support by US evidence presented in Figure 1 (appendix IV). The important result of propositions 3 and 4 is that less severe credit market imperfections increase wage inequality in a dual way: by raising both the skill and the experience premium. This is the pattern that many developed countries experienced over the past three decades and especially US, UK and Canada. A diagrammatic exposition of propositions 3 and 4 can be seen in figure 6.

Figure 6: Comparative Statics in a Stable Equilibrium



Notice that less severe credit constraints generated by a decrease in the borrowing interest rate r^b, increase the slope of the supply curve and shift the whole supply curve inwards. In a stable equilibrium - where the slope of the supply curve exceeds that of the demand curve - this decreases the unskilled wage of period one and so it increases the experience premium, since both $w_2^{u,h}/w_1^u$ and $w_2^{u,l}/w_1^u$ increase, as well as the skill premium w_2^s/w_1^u raises too. In an unstable equilibrium the results are reverted.

Table 3 below illustrates the evolution of the skill premium within experience group and the experience premium within educational group, as credit constraints become less severe. The skill premium increases for both experience groups, which is in harmony with the empirical evidence for US, represented at table 2 (appendix III). The experience premium increases significantly within the group of high school graduates, while it remains constant within the group of college graduates. This finding is also in accordance with the US labor market pattern presented in figure 1 (appendix IV).

Within Group Skill & Experience Premia

	Wage Premia	Credit Frictions Relax
Skill Wage Premium:		
Inexperienced	w^s_2 / w^u_1	Increases
Experienced	$w^s_3 / \underline{w}^u_2$	Increases
Experience Wage Premium:		
High School graduates (t_2 / t_1)	$\underline{w}^u_2 / w^u_1$	Increases
High School graduates (t_2 / t_1)	$\underline{w}^u_3 / \underline{w}^u_2$	Always Constant
College graduates	w^s_3 / w^s_2	Always Constant

Note: This table summarizes the results of propositions 3 and 4. When credit frictions relax, due to an exogenous decrease to the lending interest rate both the skill and the experience wage premia increase. Where $\underline{w}^u_2$ indicates the average of all the unskilled workers at period 2, regardless of whether they are bargainers or not. Accordingly $\underline{w}^u_3$ denotes the average of all unskilled workers for period 3. Also notice that both $\underline{w}^u_3 / \underline{w}^u_2$ and w^s_3 / w^s_2 are always constant and equal to unity. For more detail on the derivation of these results see the proofs of propositions 3 and 4 at the appendix.

Table 3: Within Group Wage Premia

However, one must also examine the behavior of wage premia in the extreme cases of financial development. In fact, in the case of extreme credit market imperfections, where the possibility of borrowing does not exist, the skill premium is minimized, while experience premium is low. As credit frictions relax both the experience and the skill premium increase. In the case of perfect credit markets, where everyone can borrow any amount, the skill and the experience premium is maximized. So, the following proposition holds.

Proposition 5 *Both the skill and the experience premium increase monotonically as credit constraints relax.*

Proof. See Appendix I. ■

Furthermore, recall that firms receive education levels as signals and make use of this information on the determination of first period wages. Once an agent works for a firm his type is revealed, since worker's productivity is privately observed by his employment firm. However, due to the fact that this information is private, firms can derive an information rent. The result is formally presented below:

Proposition 6 *Firms derive an information rent as a result of better sorting. The corresponding surplus for firms is generated due to the combination of credit constraints, information asymmetries and observable productivity after the first period of employment (employer learning).*

Proof. See Appendix I. ■

Notice that firms derive a profit by offering the bargaining agents a lower wage comparing to their productivity, since they subtract the tuition cost from the offered wage and they split it in the remaining two periods of employment. In particular, there is a mutually beneficial bargaining process, since both firms and bargainers are better off. These benefits principally because credit constrained high types are sorted properly within each firm after the first period of employment but also because the tuition cost - which is a pure waste - is not forgone.

5 Robustness

Human Capital. In general, education is not a mere signal. College attendance apart from indicating unobservable ability it also increases labor productivity. Even though this is a crucial point, I abstract from it in order to keep the framework simple and make clear the aspect of education that drives the results of this paper, which is nothing else but signaling. However, the inclusion of human capital not only leaves the qualitative results of propositions 3 and 4 unaffected but it also boosts further the magnitude of the increase in the skill premium. So, I examine the evolution of wage premia for the worst possible scenario for my theory, which means that even when one adopts a mere signaling approach without human capital, the results all the paper still hold.

Learning-by-Doing. It is also true that workers learn by doing and this increases their productivity. However, the model I presented above abstracts also from this element, since labor productivity is given for each agent for their entire life (q^l for the low types and q^h for the high types). I can easily extend the model and augment it with learning-by-doing by introducing a law of motion for labor productivity: $q^j_{t+1} = f(t)q^j_t$, where $t = 1, 2$, $j = \{l, h\}$ and $f(t) > 1$ and decreasing in time t. This would give a concave profile for wages over the life-cycle, affecting the level of wage premia but not the changes in response to a relaxation of credit constraints. This implies that propositions 3 and 4 are still valid.

Decomposition of Wage Dynamics

	Signaling Approach	Human Capital Approach
Return to Education due to:	**1) signaling**	**2) human capital**
High School graduates	**0**	**0**
College graduates	**+ (<25%)**	**+ + + (>75%)**
Return to Experience due to:	**1) employer learning**	**2) employee learning**
High School graduates	**+ or –**	**+**
College graduates	**0**	**+**

Note: The table above shows the evolution of wages depending on whether the individual possess education and / or experience. The wage growth is decomposed in four components. The return to education (here college education) is dual due to: 1) signaling and 2) human capital. According to Lange (2007) the signaling value of education represents at the most a 25% of the total value of education, while the remaining 75% is a human capital effect. Additionally he argues that the signaling value of education depends on the speed of employer learning and employers learn quickly – initial expectation errors decline by 50% within only 3 years. The return to experience is also twofold due to: 1) employer learning and 2) employee learning. According to Arcidiacono, et. al. (2010) the returns to 10 years of experience due employer learning are significant and approximately of the same size as the return to a college degree due to signaling. The return to employer learning is positive for the high types and negative for the low types. While employee learning or learning-by-doing increases for both college and high school graduates. Observe that both the signaling and the employer learning components of wage growth link with informational asymmetries (signaling approach), while the human capital and the employee learning ones link with the productivity increasing aspect of education (human capital approach).

Table 4: Wages over the life-cycle.

Minimum Wages. In the model presented above, without human capital, it seems that the minimum wage is not the initial wage of the unskilled worker with zero experience w_1^u but the wage of the low type unskilled worker with one year of experience, which is $w_2^{u,l}$. However, this is not empirically plausible. In reality my model does *not* argue that wages can also decrease with experience. On the contrary, it proposes that there can be a negative return to experience due to employer learning for workers with low ability. In general, economists observe that wages increase over the life-cycle generating a concave wage profile. However, this can be the total effect of two separate effects moving to opposite directions and differing in magnitude. Under asymmetric information competitive firms offer to the entire pool of unskilled workers a wage that equals their marginal productivity, say w_1^u. Then for the uneducated workers there is a dual influence on their wages. On one hand, there is a return to experience due to employee learning (learning-by-doing), which is always positive. While on the other hand, there is a return to experience due to employer learning, which is positive for the uneducated high types and negative for the uneducated low types. Now consider an unskilled low type. The first period competitive firms offer a wage w_1^u, even for the low types who produce only q^l that is lower than his wage $q^l < w_1^u$. Firms do this, since, if they offer a lower wage, other firms will attract low and high types but all firms wish to employ uneducated high types in the first period, since during the second period they derive a profit by those workers. During the second period there are two effects on the wage of a low type: a negative return to experience due to employer learning and a positive return to experience due to learning-by-doing. If the latter outweighs the former, then it is not clear to an economist whether the first effect even exists or not, since the observed pattern is just an increase in wages over the life-cycle. However, there are empirical papers addressing this issue and they find strong evidence for employer learning. In particular they find a causal effect of ability test scores and wages (see Arcidiacono et al. (2010)). My theory proposes that the concave profile of wages over the life-cycle conceals different effects moving potentially to opposite directions. Table 4 below illustrates these effects.

Therefore, the minimum wage is indeed the initial wage of the unskilled worker w_1^u and in fact the reduction of this minimum wage generates the increase in both the skill and the experience premium, generating higher wage inequality. This is a very important theoretical result that finds strong empirical support by evidence in the US, UK and Canada. According Card and DiNardo (2002) the early rise in inequality may have been due to rapid technological change, however they suspect that the increase in the early 1980's is primarily attributed to the fall in the real value of the minimum wage. They argue that there is a nearly mirror image of wage inequality and real minimum wages. Figure 3 (appendix IV) shows the co-movement between the predicted wage gap from regression on log of real minimum wage and the normalized $90-10$ wage gap. From this simple regression they find that a 90% of the variation of wage inequality can be explained by changes in real minimum wages.

6 Concluding Remarks

This paper provides an explanation for the growth of the experience premium that occurred in almost all countries during the past three decades. In particular, I show that the rise in the experience premium occurs primarily within the group of high school graduates and not within college graduates, a fact that the skill-biased technical change literature fails to explain. This is mainly a result of the decreasing the minimum wage that induces an increase in wage inequality, a pattern that finds strong empirical support in many countries and especially in the English-speaking ones. The theory presented here is also consistent with a rising skill premium within both experienced and inexperienced groups.

The economic intuition behind most of the results of this paper is that without knowing the productivity of each person, competitive firms form beliefs for their potential employees and pay them according to their expected productivity. Thirty years ago, it was more likely for the unskilled worker to be highly productive, since credit constraints were more severe and educational opportunities fewer. However, credit frictions relaxed significantly since then, and so, educational opportunities increased. That is why being unskilled today is perceived by firms as a very bad signal for worker's ability. This is the reason why, some decades ago, firms used to offer higher initial wages to the unskilled-inexperienced workers. Nowadays initial real wages for unskilled-inexperienced labor are much lower; however, today if an unskilled employee proves that he is highly productive but he just happened to be one of the few credit constrained workers, he gets a much higher return with experience, comparing to what he would got during the 1970's. This means that not only formal signals, such as college degrees, generate wage benefits for workers; but also informal learning, such as private employer learning, is crucial for worker's wage growth. This is the underlying mechanism that boosted the experience premium over the past three decades. In the same spirit, the gap between the average skilled and the average unskilled wage has also widen, in response to the fall on the initial wage for the unskilled worker.

An interesting policy implication is that offering more opportunities might generate greater inequality, since people are born different in many aspects, including ability. Thus, policy makers must distinguish *equality of opportunity* from *substantial equality*, since policies favoring the one might harm the other. Hence, the nature of inequality looks more like a vicious circle, as offering more equal opportunities can in fact increase substantial economic inequality, leading to less equal opportunities for the future generations. Therefore, if the equality of opportunity is one of the targets of economic policy, redistribution of opportunity must be *permanent*, since a one-shot redistribution does not seem to generate the desirable results[19].

My results are based on three crucial and realistic elements of the labor market: asymmetric information, credit constraints and asymmetric employer learning. Although the model builds on a pure signaling approach its results are robust even after augmenting it with human capital and/or learning-by-doing. This paper provides a robust micro-founded game-theoretical reasoning for significant macroeconomic facts, such as the rise in wage inequality. This approach focuses mainly on the role of labor supply; however, there is a growing literature on the skill-biased technical change that focuses on the demand side. I feel that these two approaches must be seen as complementary rather than substitutionary.

Last but not least, both theoretical and empirical contributions are still needed on the interaction among asymmetric information, credit constraints and employer learning, and their effects on wage inequality and the functioning of the macroeconomy and the labor market. Future theoretical studies need to extend the current static framework into a dynamic and derive useful implications about inequality, intergenerational justice and redistribution of both income and opportunities. Additionally, upcoming studies should extend this partial equilibrium approach and provide a general equilibrium closed economy framework, which would be more appropriate for welfare comparisons. While further empirical studies are indispensable for testing formally the validity of the mechanism proposed here, as well as, for distinguishing employer from employee learning and the signaling from the general human capital or the firm-specific human capital effects. In both cases, there is a promising avenue for future research on the relationship between labor market inequalities and market failures, such as credit frictions and asymmetries of information. Unambiguously, this paper does not complete but just initiates an inquiry for the revelation of the laws that determine the evolution of the experience premium and ultimately of labor income distribution.

[19]This is harmony with Aghion and Bolton (1997). However, in Banerjee and Newman (1993) a one-shot redistribution can have permanent results.

A Appendix I: Proofs of Propositions.

Proof. PROPOSITION 1

Firms have zero profits at the first period; while, they have positive profits at the second and third period. If the profit for the representative firm at period two is π_2 and if N^B is the number of bargainers or credit constrained high types employed by the representative firm, then it is true that $\pi_2 = N^B(q^h - w_2^{u,h})$. This is always positive since $w_2^{u,h} = [q^h - (1+r^l)T]/(2+r^l)$. This implies that $\pi_2 = N^B(q^h + T)\frac{1+r^l}{2+r^l}$, which is always positive. Notice also that $w_2^{u,h} = w_3^{u,h}$ and therefore $\pi_2 = \pi_3$. That is why during the second and third period profits are positive for all firms. ∎

Proof. PROPOSITION 2

The supply curve given by equation (13) using (12), is continuous. By assumption 1 in the Proposition, $P(\cdot)$ is continuous, so the demand curve $f(\cdot)$ is continuous, as well. The unskilled wage must lie in a nonempty, convex, compact set. When all high-ability agents become educated, the unskilled wage is minimized, so $w_1^u = q^l$. When no high-ability agent becomes educated, the unskilled wage is maximized, so $w_1^u = w^P = q^P$. Additionally, assumptions 2 and 3 in the Proposition guarantee that the supply and demand curves intersect, since initially there is excess supply and terminally excess demand. Therefore, by the general form of *Brouwer's Fixed Point Theorem*, for continuous functions from a nonempty, convex, compact set to itself, an equilibrium exists. However, this equilibrium need not be regular. That is why the existence result holds *generically*.

Now, we show that if there exist regular equilibria, at least one is stable. Consider the highest possible equilibrium wage $w_1^u = q^P$, which occurs for $P(u|h) = 1$. Assumption 3 in the Proposition implies that at this wage we have excess demand. By continuity and assumption 3 we know that at this equilibrium, an increase in w_1^u leads to excess demand. By regularity we know that a decrease in w_1^u leads to excess supply. So, this regular equilibrium must also be stable equilibrium. ∎

Proof. PROPOSITION 3

Recall that $b^* \uparrow \Rightarrow P(u|h) \uparrow \Rightarrow w_1^u \uparrow$. There are two skill premia. The first one is the skill premium within the group of inexperienced workers, which is denoted as w_2^s/w_1^u. From (15) we can see that in a stable equilibrium a fall in r^b decreases b^* and w_1^u. So the first skill premium $w_2^s/w_1^u = q^h/w_1^u$ increases. The second skill premium is within the group of experienced workers denoted as $w_3^s/\underline{w}_2^u$. Notice that $\underline{w}_2^u$ stands for the average wage of the uneducated worker regardless of whether he is a bargainer or not. This wage depends on the number of low types getting wage $w_2^{u,l} = q^l$ and the number of credit constrained high types getting $w_2^{u,h}$, which is higher than q^l. Observe also that a fall in r^b decreases the number of bargainers who get the higher wage $w_2^{u,h}$ and therefore it decreases the average wage of the uneducated worker with one year of experience $\underline{w_2^u}$. Given that w_3^s is constant an equal to q^h, the second skill premium increases as well, when credit frictions relax. So the skill premium for both the inexperienced and the experienced workers increase as credit frictions relax. ■

Proof. PROPOSITION 4

There are three experience premia one for the skilled and two for the unskilled workers. For the skilled workers it is $w_3^s/w_2^s = q^h/q^h = 1$. For the unskilled workers the one is computed by comparing their wages of the first and second period $\underline{w_2^u}/w_1^u$ and the other by comparing the wages of the second and third period $\underline{w_3^u}/\underline{w_2^u} = 1$. Notice that the only experience premium that is not constant is the one of the unskilled workers for the first period of their experience and equals $\underline{w_2^u}/w_1^u$. In a stable equilibrium, less severe credit frictions caused by a decline in r^b decrease b^* and w_1^u. However, less severe credit frictions decrease $\underline{w_2^u}$ as well, since fewer high types will be credit constrained and fewer agents in the uneducated pool will get the higher wage ${w_2^u}^{,h}$. So both the nominator and the denominator decrease. Now we compare two experience premia. The one denotes the experience premium before the relaxation of credit frictions and the other after it. Proposition 4 will hold if $ExpPremium_{before} < ExpPremium_{after}$. I suppose that this inequality does not hold and if I derive a contradiction, then proposition 4 holds.

$$ExpPremium_{before} \geq ExpPremium_{after}$$

$$\frac{\underline{w_2^u}}{w_1^u}_{before} \geq \frac{\underline{w_2^u}}{w_1^u}_{after}$$

$$\frac{\overline{N_2^h} {w_2^u}^{,h} + N_2^l q^l / [\overline{N_2^h} + N_2^l]}{\overline{N_1^h} q^h + N_1^l q^l / [\overline{N_1^h} + N_1^l]} \geq \frac{\underline{N_2^h} {w_2^u}^{,h} + N_2^l q^l / [\underline{N_2^h} + N_2 l]}{\underline{N_1^h} q^h + N_1^l q^l / [\underline{N_1^h} + N_1^l]}$$

Where N denotes the number of agents, the subscript denote the time-period and the superscript the type of the group. Observe that when the credit frictions are severe there are more credit constrained high types in the uneducated pool, which I denote will upper-bar $\overline{N_1^h}$, accordingly after the relaxation of credit constraints there are fewer, which I denote with lower-bar $\underline{N_1^h}$. I use the same notation for period two as well, when the subscript at N^h is 2. Notice that: $\underline{N_1^h} = \underline{N_2^h}$, also $\overline{N_1^h} = \overline{N_2^h}$ and $N_1^l = N_2^l$. So the above inequality becomes:

$$\frac{\overline{N^h} {w_2^u}^{,h} + N^l q^l}{\overline{N^h} q^h + N^l q^l} \geq \frac{\underline{N^h} {w_2^u}^{,h} + N^l q^l}{\underline{N^h} q^h + N^l q^l}$$

After some algebra this leads to ${w_2^u}^{,h} \geq q^h$. But this cannot be true since it is always true that ${w_2^u}^{,h} < q^h$. This gives us the desirable contradiction. That is why the experience premium always increases as credit frictions relax. ■

Proof. PROPOSITION 5

Given the distribution of initial wealth and skills, for the skill premium we have the following three cases: (i) in the case of extreme credit market imperfections, where the possibility of borrowing does not exist, both the probability of being uneducated given that you are of high type $P(u|h)$ and the unskilled wage w_1^u are maximized, so for a given level of skilled wage $w^s = q^h$, the skill premium $w_2^s = w_1^u$ is minimized; (ii) for all the cases of moderate credit market imperfections (the cases between the extreme form of credit market imperfections and perfect credit markets), as credit constraints relax or as the wedge $r^b - r^l$ declines, the skill premium increases (see proposition 3); (iii) in the case of perfect credit market, where all agents can borrow any amount they wish, the probability of being uneducated given that you are of high type $P(u|h)$ is zero and the unskilled wage is minimized $w_1^u = q^l$, leading to the maximum level of the skill premium that is q^h/q^l. Therefore, the skill premium increases monotonically as credit constraints relax.

Accordingly, for the experience premium, given the distribution of initial wealth and skills, we have the following three cases: (i) in the case of extreme credit market imperfections, where the possibility of borrowing does not exist, both the probability of being uneducated given that you are of high type $P(u|h)$ and the unskilled wage w_1^u are at their higher level, so for a given level of skilled wage $w^s = q^h$ and tuition fees T the experience premium is at its minimum level; (ii) for all the cases of moderate credit market imperfections (the cases between the extreme form of credit market imperfections and perfect credit markets), as credit constraints relax or as the wedge $r^b - r^l$ declines, the experience premium increases (see proposition 4); (iii) in the case of perfect credit market, where all agents can borrow any amount they wish, the probability of being uneducated given that you are of high type $P(u|h)$ is zero so all high ability agents receive an education, that is why no agent bargains successfully and so the experience premium equals one, which is its higher possible level. Therefore, the experience premium increases in a monotonic fashion as credit constraints relax. ■

Proof. PROPOSITION 6

The information rent comes from the following source: Firms do not pay the high ability workers who bargain successfully, according to their expected productivity $w_2^s = q^h$ but they offer them $w_2^{u,h}$. Where $w_2^{u,h} < w_2^s$. In this sense bargaining is mutually beneficial and efficient, since the pure waste of acquiring the costly signal is not forgone. The size of the surplus equals $w_2^s - w_2^{u,h}$ times the number of credit constrained unskilled high types (bargainers). ■

B Appendix II: Variables

Exogenous Variables

- π: The proportion of high ability agents.
- q^h: The productivity of high ability agents.
- q^l: The productivity of low ability agents.
- q^P: The expected productivity of agents in the pooling equilibrium.
- $P(\cdot)$: The cumulative density function of the bequest distribution for high types.
- r^b: The borrowing interest rate.
- r^l: The lending interest rate.
- T: The fixed cost of tuition required for education.
- $k^h = 0$: The differentiated cost of education for the high type.
- k^l: The differentiated cost of education for the low type.

Endogenous Variables

- $w_1^u = E(q|n)$: The first period unskilled wage equals the expected productivity of the uneducated agent.
- $w_2^{u,l} = w_3^{u,l} = q^l$: The second and third period wage for both the low types, all of which are unducated.
- $w_2^{u,h} = w_3^{u,h} = [q^h - (1 + r^l)T]/(2 + r^l)$: The second and third period wage of the uneducated high types, who are the bargainers.
- $w_2^s = w_3^s = E(q|e) = q^h$: The skilled wage for the educated high types, for time period two and three.
- $\underline{w}_2^u = \underline{w}_3^u$: The average wage of the uneducated worker at the second and third period.
- b^*: The initial wealth threshold below which high ability agents do not find it profitable to borrow and invest in education when young.

C Appendix III: Tables

HOURLY WAGE OF COLLEGE GRADUATES/HOURLY WAGE OF HIGH SCHOOL GRADUATES: SELECTED YEARS AND LEVELS OF WORK EXPERIENCE

	Years of work experience			
Year	1–5	6–10	26–35	All levels
1964	1.59	1.42	1.40	1.43
1969	1.52	1.42	1.43	1.44
1974	1.39	1.37	1.43	1.41
1979	1.30	1.26	1.43	1.37
1984	1.63	1.42	1.40	1.44
1989	1.74	1.66	1.49	1.58
All years	1.52	1.43	1.42	1.44

Table 2: Skill premium within experience groups.

Table 2 shows that the skill premium increases within any level of experience. For more details see the original source: Murphy and Welch (1992).

D Appendix IV: Figures

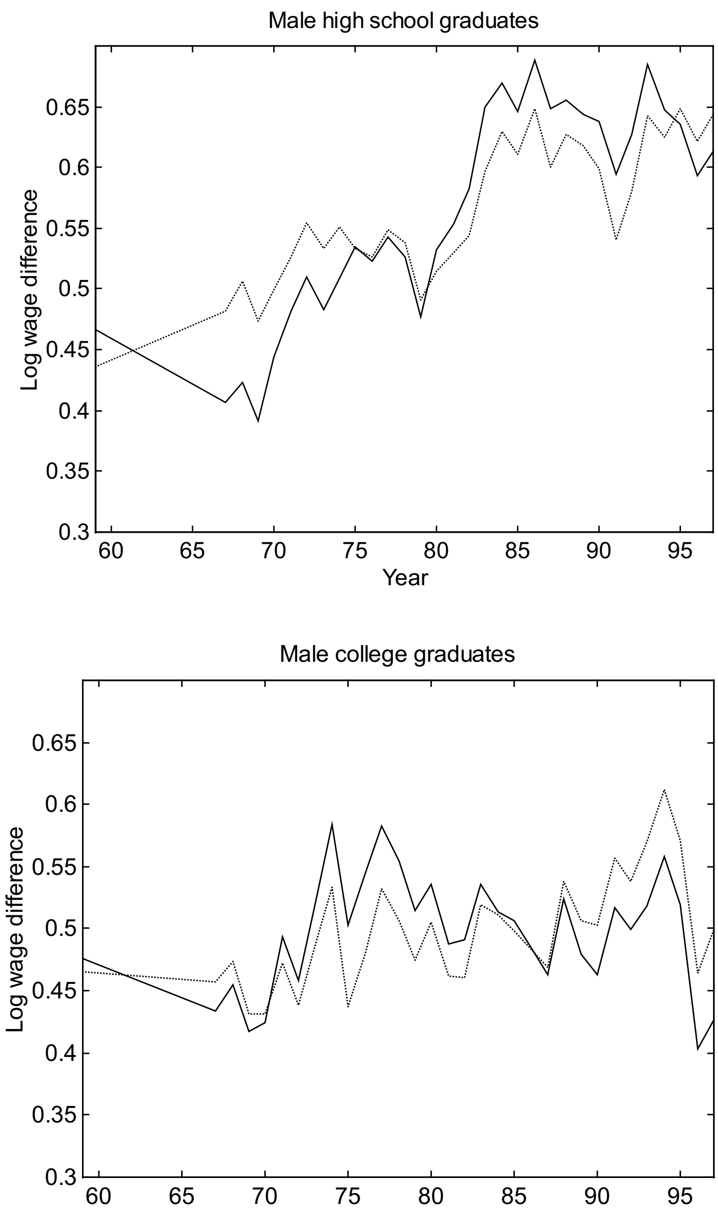


Figure 1: The experience premium within educational group.

The experience premium for high school male graduates, over the period 1959-1997. The solid lines give the log wage differential between workers with 25-34 and 0-4 years of experience. The dashed lines give the log wage differential between workers with 0-9 and 10-19 years of experience, in order to take into account cohort effects. The regressions on log wage differentials adjust for years of education (among college graduates), marital status, race, urban residence, and region. For more details see the original source: Weinberg (2004).

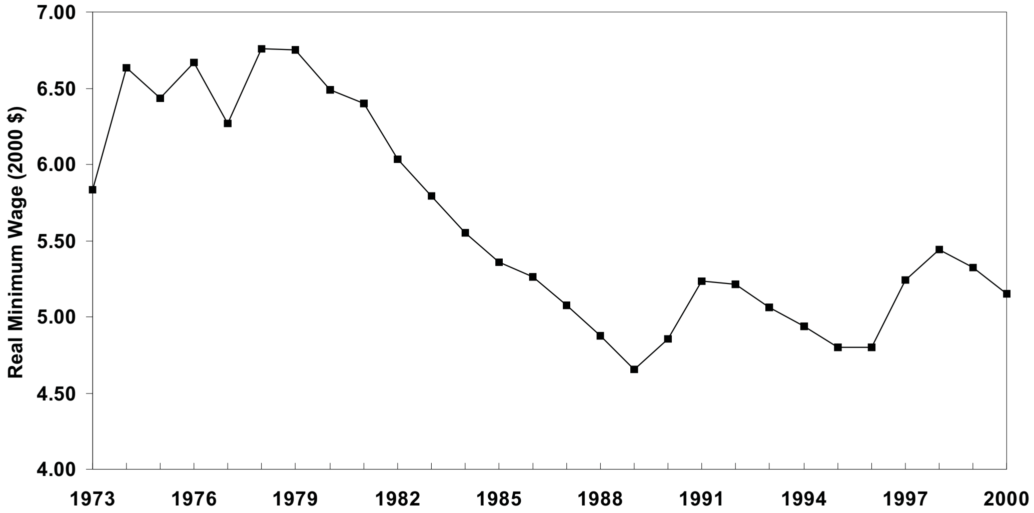


Figure 2: The falling real minimum wage in US (1973-2000). Source: Card and DiNardo (2002).

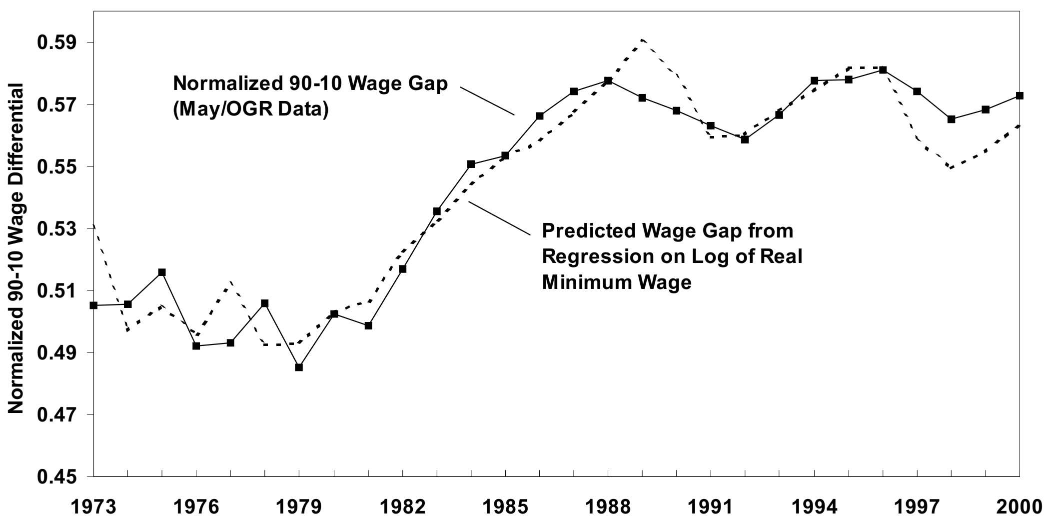


Figure 3: Wage inequality & real minimum wage in US (1973-2000). Source: Card and DiNardo (2002).

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