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The Market for "Rough Diamonds": Information, Finance and Wage Inequality

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The Market for "Rough Diamonds": Information, Finance and Wage Inequality*

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Abstract

During the past four decades both between and within group wage inequality increased significantly in the US. I provide a microfounded justification for this pattern, by introducing private employer learning in a model of signaling with credit constraints. In particular, I show that when financial constraints relax, talented individuals can acquire education and leave the uneducated pool, this decreases unskilled-inexperienced wages and boosts wage inequality. This explanation is consistent with US data from 1970 to 1997, indicating that the rise of the skill and the experience premium coincides with a fall in unskilled-inexperienced wages, while at the same time skilled or experienced wages do not change much. The model accounts for: (i) the increase in the skill premium despite the growing supply of skills; (ii) the understudied aspect of rising inequality related to the increase in the experience premium; (iii) the sharp growth of the skill premium for inexperienced workers and its moderate expansion for the experienced ones; (iv) the puzzling coexistence of increasing experience premium within the group of unskilled workers and its stable pattern among the skilled ones. The results hold under various robustness checks and provide some interesting policy implications about the potential conflict between inequality of opportunity and substantial economic inequality, as well as the role of minimum wage policy in determining the equilibrium wage inequality.

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

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"There is all the difference in the world between treating people equally

and attempting to make them equal."

Friedrich August Hayek,

Individualism and Economic Order (1948).

1 Introduction

The sharp increase in US wage inequality seems to be a point of agreement among social scientists and policy makers. However, we still lack a rigorous understanding of its causes and consequences. Several studies, using a wide variety of data sources and indexes, suggest that after a period of stability, economic inequality has grown significantly since 1970's. Some patterns of increasing wage inequality, such as the rise in the education premium, are well-documented in the literature. However, some other aspects of widening inequality, such as the growing experience wage premium, are less well-reported, if not entirely absent from most existing studies. The rising inequality has coincided with the advancement of the American economy that offered more opportunities to historically less privileged groups. These opportunities relate to various dimensions of social life, from acquiring education to starting a business. Unambiguously, the improved functioning of markets over that period played an important role in generating more opportunities but also in boosting wage inequality.

As far as education is concerned, during the past forty years the average level of schooling increased sharply in the US, while wage inequality between different education groups has grown too. Most of the existing papers focus on technology to provide an explanation for the increasing education wage premium, despite the rising supply of educated workers.[1] In spite of its success and importance in understanding the effects of technical change on inequality, this approach fails to explain the consistently rising wage gap between groups with different levels of labor market experience, as well as the evolution of wage inequality within different education and experience groups.[2]

In this paper, I explore the importance of market failures, such as financial constraints and asymmetric information, in providing a unified explanation for several wage inequality facts. Using US data, I examine systematically the evidence on the evolution of wage inequality, both *between* different education or experience groups and *within* each of these groups. Then, I develop a microfounded theoretical model that is consistent with these stylized facts of increasing wage inequality. Ultimately, I test empirically the most important predictions of my theoretical explanation. I also build a unified framework to compare my model of sorting to the skill-biased technical change (SBTC) approach. The combination of the two theories is feasible, as my model focuses on labor supply and in this sense it is complementary to the SBTC, which emphasizes demand factors. The two theories together seem to provide a better understanding of labor income distribution, compared to each approach alone.

In particular, this study first documents some stylized patterns of wage inequality in relation to: the education and the experience wage premium, the education premium within different experience groups and the experience premium within different education groups.[3] Second, provides an explanation for these patterns by introducing private employer learning in a model of education signaling with credit constraints. My theory suggests that asymmetric information and credit constraints do not allow firms to distinguish the poor but able individuals from the less-able ones, resulting initially to a pooling wage for all uneducated workers. However, with working experience firms privately accumulate performance observations and learn the type of their own workers. Private learning implies that incumbent employers are better informed for the type of their own employees compared to

[1] Katz and Murphy (1992) is one of the earliest contributions on this branch of literature, while Acemoglu (2002), Hornstein et al. (2005) and Acemoglu and Autor (2011) review the literature on technology-skill complementarities.

[2] One of the first papers to criticize the technical change explanation was Card and DiNardo (2002a).

[3] The terms education, college and skill premium are used interchangeably throughout this paper to describe wage differentials between the relatively more and the relatively less educated workers. In the next section I provide a formal definition of the skill and the experience premium.

potential competitors. This allows firms to derive an information rent by sorting their workers more efficiently, which consequently leads to different wage paths for uneducated workers, depending on their revealed ability-type. Importantly, when financial frictions become less binding, a larger fraction of the talented individuals can acquire education and leave the uneducated pool. This implies that the eventual group of uneducated young workers becomes of lower average quality, as most of the *"rough diamonds"* have now been plucked out of this group. In response, firms offer lower wages to the remaining unskilled-inexperienced workers, which ultimately boosts wage inequality.

The model explains: the increase in the skill premium despite the growing supply of skills; the increase in the experience premium as a result of private employer learning; the sharp growth of the skill premium for inexperienced workers and its moderate expansion for the experienced ones; as well as, the puzzling coexistence of increasing experience premium within the group of unskilled workers and its flat pattern among the skilled ones. These results also hold when the purely informational model with signaling and employer learning, extends with the inclusion of returns to education due to human capital and returns to experience due to employee learning (learning-by-doing).

One of the most important predictions of the model is that unskilled-inexperienced wages decline and this in turn boosts wage inequality. Using the Current Population Survey, I find that US data from 1970 to 1997 confirm this prediction, as they indicate that the rise in the skill and the experience premium coincides with a fall in unskilled-inexperienced wages, while at the same time skilled or experienced wages remain constant. My theory suggests that on average, ability for uneducated workers is lower after the relaxation of credit constraints. I test empirically this hypothesis using the National Longitudinal Surveys of Youth. The empirical analysis provides further support to my sorting hypothesis, by showing that there is a robust decline on the ability of the average uneducated worker, compared to the past. I also exclude other potential explanations by showing that for the relatively more educated workers, there might be a decline in ability, however this decline over time is not always statistically significant and it is smaller in magnitude compared to low educated workers.

This paper contributes to a *microeconomic debate* on signaling and human capital, related to the field of the economics of information, which has grown rapidly since the 1970's and has been applied to different economic areas, including labor economics. Within the studies that focus on the economics of information in labor markets, this paper relates to three branches of the literature centering on signaling, employer learning and credit constraints. In this sense it links to earlier studies incorporating two of these; however, none of them builds on a unified framework of all these elements.[4] I strongly feel that it is crucial to include all three of them in evaluating the effects of education and experience on inequality in labor markets with informational and financial frictions.

Spence's (1973) seminal contribution centers on the idea that education serves as a signaling device and conveys information related to worker's ability to uninformed firms. That is why apart from the "return to education due to *human capital*", which captures Becker's (1964) idea that education increases productivity, there is also a "return to education due to *signaling*".[5]

However, employers can also derive information for the type of their workers through labor market experience. In this sense experience can also convey information and can generate a return, the

[4]Townsend (1979) was one of the first to combine two of these, credit market imperfections and information asymmetries in order to determine entrepreneur behavior and their contribution to aggregate output.

[5]Bedard (2001) examines credit constraints in eduction to find that the signaling explanation is empirically more plausible than the human capital one. However, using the minimum school age Chevalier et al. (2004) find that the human capital approach is more realistic. For an earlier literature review on this debate see Weiss (1995).

so called "return to experience due to *employer* learning". The non-informational counterpart for experience is the "return to experience due to *employee* learning" or learning-by-doing. So, for both education and experience there exists an informational and a non-informational return. Importantly, one must also notice that employer learning itself can be asymmetric in a dual way: first, current employers learn more about their workers' type compared to potential competitors, which I call "employer learning *asymmetric to the firm*"; second, a given employer learns more about a particular group of workers, say high school graduates, compared to other workers, for instance college graduates, which I call "employer learning *asymmetric to the worker*". Some of these ideas have been developed separately both theoretically and empirically but to my knowledge no study has examined all these informational aspects of the labor market in a unified framework, yet.

Only few studies focus on *asymmetric* employer learning. Schönberg (2007) supports that there is no evidence for asymmetric employer learning, apart from the case of college graduates, while Kahn (2009) employs different identification strategies and all cases favor asymmetric employer learning.[6] In a recent study, Arcidiacono et al. (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 tenure and employer learning seems to be important only for this group. Throughout this paper, employer learning is asymmetric, as incumbent firms learn better their workers' type compared to potential competitors.

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.[7] Farber and Gibbons (1996) develop a model with employer learning and among other they conclude that even though the influence of education declines as performance observations accumulate, the estimated effect of education on the level of wages is independent of labor-market experience, while ability measures unobserved by employers are increasingly correlated with wages as experience rises. 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 his talent. Bauer and Haisken-DeNew (2001) find no evidence of employer learning apart from the case of blue-collar workers at the lower end of the wage distribution. This result, which is in line with my paper, indicates that the absence of a college degree among unskilled workers increases the influence of employer learning on wages.

Card (1999) highlights the consistently higher IV estimates for the effect of education on wages, compared to the standard OLS. He stresses that this difference of 20-30% can be attributed to the existence of credit constraints. This hypothesis is also supported by Ellwood and Kane (2000), who find that the strong correlation between family income and college attainment, reveals the importance of credit constraints. Carneiro and Heckman (2002) provide an alternative view on this *policy debate* by showing that financial constraints are not important after controlling for long-run constraints related to family background and student ability. They also question the validity of IVs on education in the existing literature and they conclude that at the most an 8% of the US population is credit constrained.[8]

[6]Galindo-Rueda (2003) finds that this learning process, especially among blue-collar workers, favors incumbent employers relative to potential competitors (asymmetric employer learning). Pinkston (2009) employs a model of asymmetric employer learning to distinguish private employer learning from public learning and employee learning. However, in practice it is not easy to separate firm-specific learning-by-doing from employer learning.

[7]See Jovanovic (1979) for one of the earliest contributions on employer learning.

[8]Lochner and Monje-Naranjo (2011) focus on the different sources of student finance, as well as on the relationship

My approach links more to Hendel et al. (2005), which combines credit constraints as in Galor and Zeira (1993) with Spence's (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.[9] However, their framework is not appropriate for the study of the experience premium, as well as for within group wage inequality. Recent empirical studies, such as Lange (2007), have shown that the signaling value of education depends on employer learning, suggesting that also theoretical studies should combine employer learning and signaling, which is precisely what my paper does.[10] More importantly, the main finding in Hendel et al. (2005) is that unskilled wages decline and largely this accounts for the increase in the college premium, is not supported by empirical evidence. However, once we break down the skill premium to different experience groups, I can show that the decline of unkilled-inexperienced wages is the main determinant of rising wage inequality from 1970's till 2000. In particular, over the period 1970-1997 real unskilled wages declined only by 2.6%, while real wages for unskilled-inexperienced workers have fallen by 15.7% (see figure 21). To reconcile this fact with theory, apart from education I also analyze experience by introducing private employer learning in their model. This extension seems to explain some of the most important but yet puzzling facts of wage inequality and by doing so, it yields some realistic policy implications too.

My paper also contributes to a *macroeocnomic debate* related to technology and wage inequality. Numerous country-specific empirical studies, suggest that the contribution of education and experience on wages has increased since 1970's. Katz and Murphy (1992) attribute this to SBTC, while Juhn et al. (1993) find that education and experience explain about a quarter to a third of wage variation.[11] Bergman et al. (1998) provide international evidence for SBTC. Krueger et al. (2010), extend these findings to a cross-country comparison and support that two of the most important macroeconomic facts over the past three decades, are the sharp growth 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 does not change much and it even declines in some continental European countries - however the significant rise of the experience premium was uniform for their sample of countries and consists a macroeconomic regularity that is ignored in most of the existing macro-labor studies.

A very recent paper by Lagakos et al. (2012) suggests that the experience premium is flatter in poor compared to rich countries. In previous studies human capital includes mainly education and accounts for less than half of the variation in cross-country income differences. Their development accounting analysis proposes that human capital, which includes experience too, accounts for almost

between family income and schooling. They also provide evidence on the allocation of talent in different educational groups. In Lochner and Monje-Naranjo (2012) they survey the literature on credit constraints in education.

[9] Stiglitz (1975) and Krugman (2000) have also shown that better sorting in education rises inequality.

[10] Lange (2007) finds that employers learn quickly, since initial expectation errors decline by 50% within 3 years. For this reason he argues that the signaling value of education 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 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.

[11] 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 wage variance is between schooling level, and a 40% is across experience within schooling level.

two thirds of income variation across countries. However, they do not explain why the size of the experience premium is so different across countries. My paper focuses on how the experience premium increases in the US over time. However, if we consider that in several dimensions the US in the 1960's were similar to some less developed countries nowadays, then my theoretical model can also provide an explanation for the differences in the experience premium across countries. The goal of my study is to fill this gap in the macro-labor literature related to the experience premium by introducing private employer learning in a model of signaling with credit constraints. Ultimately, I show that a large part of increasing wage inequality that in the literature is attributed to SBTC, can be explained by a labor supply model of sorting, in which experience and market failures play an integral role.

Additionally, the rise in residual wage inequality rekindled the scientific interest on labor income distribution.[12] Within the vast literature on increasing inequalities, most of the papers center on SBTC to explain the rise of the skill premium.[13] However, the increase of the experience premium remains an understudied aspect of rising wage inequality. As Heathcote et al. (2010) put it "in the literature, the rise in the experience premium has received much less attention than the skill premium". Card and DiNardo (2002a), suggest that 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 other interesting developments in the wage structure that cannot be easily explained by SBTC. They conclude that technology 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.[14,15] Even though several authors highlight this gap in the literature, surprisingly enough only few studies focus on the increasing importance of experience on widening wage inequality. The existing studies on the experience premium are based on the following arguments:

1. *On-the-job training with SBTC*: Heckman et al. (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. A distinguishing feature of my paper is that I examine the evolution of this pattern across time, while they focus on wage profiles for different groups of workers.

2. *General Purpose Technologies*: Aghion et al. (2002) propose that the generality of technological knowledge allows workers to accumulate skills and this augments the experience premium. However, they do not examine the experience premium within different educational groups.

3. *Technology-Experience complementarity in adoption*: 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. However, it seems empirically more plausible young workers to adapt more easily to technological changes.

[12] Violante (2002) suggests an argument for the rise of residual wage inequality based on technological improvement that differentiates the quality of jobs even for workers of the same ability. In contrast, Lemieux (2006b) offers a line of reasoning against it, grounded on the quality of data and challenges the SBTC approach of rising demand for skills.

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

[14] For the effect of minimum wages on US inequality over the past 30 years, see Autor et al. (2010).

[15] Apart from technical change and minimum wages, the other sources of rising inequality include trade liberalization, immigration and the decline of labor unions. My analysis does not examine these channels. However, for literature reviews one can see Card et al. (2004), Card (2009), and Harrison et al. (2011), respectively.

4. *Vintage Human Capital*: 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 compared to the gain of the productivity improvement embodied in physical capital is larger for young workers. Again, this paper does not examine the experience premium within different education groups.

5. *Demographic change*: Jeong et al. (2010) 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.[16] However, they cannot explain why the experience premium rises only within the group of unskilled workers, despite the fact that the supply of experienced workers increases both within the skilled and the unskilled group.

All the abovementioned studies emphasize on the effects of technology on the experience premium and wage dispersion. My study approaches labor market experience from a different perspective, as it focuses mainly on informational and financial frictions.

The most important theoretical explanations on SBTC, relate to directed technical change (Acemoglu (1998) and Kiley (1999)) and technological revolutions (Caselli (1999)). Apart from SBTC some papers focus on the ability or the task -bias of technology.[17] Among the studies focusing on technology, the most relevant to my paper is the influential contribution by Galor and Moav (2000), according to which ability-biased technological transition captures both the increasing supply of skills and the rise on wage inequality between and within different skill groups. A common dimension in the two models is that both mine and their theory predicts the decline in unskilled wages. The two distinguishing features, relate to the fact that I also examine the experience premium and I provide an explanation based on market failures, while they mainly focus on education and technology. Another relevant paper centering on technology and education by Gould, Moav and Weinberg (2001), shows that technology depreciation increases wage inequality within the group of skilled and unskilled workers.

The discussion so far concerns education and general experience but the distinction between tenure and general experience can shed more light on whether employer learning is private or public. In particular, if employer learning is private, then previous experience might yield some information but unambiguously firm-specific 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 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 result highlights that the rise of the experience premium stressed by Krueger et al. (2010) might primarily represent firm-specific tenure rather than general experience. Additionally, it provides suggestive evidence that informational frictions are more important among unskilled workers and this asymmetric effect might drive the rising pattern of the experience premium when different skill groups are falsely pooled together. This premise is also in harmony with the major finding of Arcidiacono et al. (2010) that the return to education due to employer learning is important only for the unskilled workers.[18]

[16] For the impact of the labor force growth, which generated by the increase in labor supply when the baby-boom generation entered the labor market see Dooley and Gottschalk (1984).

[17] See Acemoglu and Autor (2011) for a review of the SBTC and the ability biased technical change explanations.

[18] However, an earlier but insightful study by Abraham and Farber (1987) sharply points out that the measured positive cross-sectional return to tenure is largely a statistical artifact due to the correlation of tenure with omitted

As far as the evolution of wage inequality is concerned, I employ mainly the skill and the experience premium to examine both the between group wage inequality but also its pattern within different education-experience groups. I use data for white males working full-time full-year from the March Current Population Survey (CPS), the major data source for wage representing the entire US labor market, to find some interesting patterns.[19] Figure 10a shows that both the skill and the experience premium increase significantly. Figure 11a highlights that the skill premium increases for both the experienced and the inexperienced workers but the rise is greater for the latter. Figure 12a shows the evolution of the experience premium within the group of skilled and unskilled workers. This graph indicates that a large part of the increase in the experience premium can be attributed to the influence of the group of unskilled workers. While figures 10b, 11b and 12b display the composition of workers for each education-experience group, indicating that this is not a mere composition effect. I summarize these wage inequality facts below:

- **Fact 1:** The skill premium increases despite the growing supply of skills.
- **Fact 2:** The experience premium rises significantly.
- **Fact 3:** The skill premium grows sharply for inexperienced workers and only moderately for the experienced ones.
- **Fact 4:** There is a puzzling coexistence of rising experience premium for unskilled workers and a flat pattern for the skilled ones.

The Contribution of this Study

The main contribution of this paper is the revelation of a new theoretical channel between market failures and the experience premium. Many studies have examined why wage inequality has changed over time,[20] some papers enlighten important aspects of the evolution of labor income dispersion; however, none of them provides a unified explanation of all four facts of wage inequality that I summarize above. In particular, I show that when credit constraints relax, the average unskilled worker becomes less productive, as the relative able individuals can abandon the uneducated pool. This decreases initial wages for unskilled-inexperienced labor and generates an increase in the experience premium *only* within the group of unskilled workers but also a sharp rise of the skill premium for inexperienced workers and a moderate increase for the experienced ones. This theoretical result finds strong empirical support in the US and yields some interesting policy implications.

Chapters 2, 3 and 4 provide the static model, comparative statics analysis and a dynamic framework. Chapter 5 connects the theoretical model with empirical evidence. Chapter 6 explores empirically whether ability is sorted better in education nowadays compared to the past using the National Longitudinal Surveys of Youth. Chapter 7 analyzes quantitatively my theoretical framework of sorting, calibrates it and incorporates it to the SBTC approach. Chapter 8 provides robustness checks, while the last chapter concludes.

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.

[19] For a more detailed description of my data see section 6.

[20] For a review of this literature see Aghion et al. (1999), Acemoglu (2002), Hornstein et al. (2005).

2 A Static Model of Sorting

2.1 Preliminaries

Agents. In this economy people live for three periods, time is discrete, and the total population is comprised of heterogenous agents. 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 vary 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 Spence's (1973) idea that education is more challenging for less able students. 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.[21] 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 at the final period of her life, as there is no period to get the return of her investment in schooling. 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.[22]

Firms. Firms compete over workers and set wage prices (Bertrand competition). Firms are interested in productivity, which is unobservable in the first period. That is why they observe workers' actions, they form beliefs and they set the first period wages accordingly. In the second period, firms privately learn the productivity of their employees. We require to have at least two firms in order wages to equal the perfectly competitive ones. The production function is linear that implies constant returns to scale in labor, which is the only input. Formally:

$$Y_t(Q_t) = AQ_t. \tag{1}$$

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.

Timing. Timing is essential in this three-period model. In particular, during the first period of their

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

[22] 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.

lives some agents go to school, while others work after signing one-period 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 go to school when old or not, using the unskilled wage w_1^u that they earned. At the end of the second period they receive the payment agreed and they invest their wealth in bonds. For the third period employees provide their labor, receive the corresponding wages, repay their loans, gather all their lifetime earnings and they consume them.

Firms privately observe workers' productivity during the first period of employment and at 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 as skilled, they still have to acquire education in the second period of their lives. Furthermore, it is worth mentioning that the return to school investments can be higher compared to the return of bond investments. Thus, agents first examine the possibility of investing in education and then in bonds.

Market Failures. The functioning of the economy is affected by three market failures: 1) *asymmetric information*, 2) *credit market imperfections* and 3) *private 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 relates to the functioning of financial 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 workers, as in Hendel et al. (2005).

The new element of my model is that employers privately observe worker performance and after a period of employment the 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 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 and firm homogeneity 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 heterogenous firms and differentiated jobs / tasks 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. A further assumption relates to the *indivisible* nature of educational

investments, which implies that education is a discrete binary choice taking either the value 0 or 1.

The Game. More 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* $A_1 = \{school, not\}$*,* $A_2 = \{school, not\}$ *and* $A_3 =$ *, 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.*

Lifetime Earnings. 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 social 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:

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

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:

$$y^B = (1 + r^b)^2(b^i - T - k^j) + (1 + r^l)w_2^s + w_3^s. \tag{3}$$

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.

Self-funded Old Students: 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:

$$y^C = (1 + r^l)^2(w_1^u + b^i) - (1 + r^l)(T + k^j) + w_3^s. \tag{4}$$

There can also be *old borrowers* but as you will see later on, we exclude this case.

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:

$$y^D = (1 + r^l)^2(w_1^u + b^i) + (1 + r^l)w_2^{u,j} + w_3^{u,j}. \tag{5}$$

Assumptions. I propose the following four assumptions that affect the actions of the agents. At this stage these assumptions depend also on the endogenous variables but once I solve the game (under these assumptions), I will be able to substitute out the endogenous variables and check whether the equilibrium that I guessed can be verified. In particular, I make the following assumptions:

Assumption 1: The effort cost for the low type is sufficiently high.

$$k^l > \frac{(1 + r^l)(w_2^s - w_2^{u,l}) + w_3^s - w_3^{u,l} - (1 + r^l)^2(w_1^u + T)}{(1 + r^l)^2} \tag{6}$$

The intuition is simple: for low types the effort cost k^l is high enough that no low type (not even the richest) finds it profitable to invest in education. Assumption 1 comes from the following comparison of lifetime earnings $y^D > y^A$.

Assumption 2: Even the lowest possible unskilled wage can cover the tuition cost.

$$T \leq (1 + r^l)q^l \tag{7}$$

The logic is straightforward: all the initially constrained high types can go to school when old, since even the minimum unskilled wage ($w_1^u(min) = q^l$) is enough to cover the tuition cost (which is the only cost for high types; recall $k^h = 0$). No agent borrows when old.

Assumption 3: Credit constraints make it profitable only for some high types to borrow and go to school when young.

$$b^i \geq \frac{(1 + r^b)^2 T + (1 + r^l)w_1^u - (1 + r^l)(w_2^s + T)}{(1 + r^b)^2 - (1 + r^l)^2} \equiv b^* \tag{8}$$

The above inequality is an incentive compatibility constraint, stating that only some relatively wealthy agents find it profitable to borrow and go to school when young. Assumption 3 comes from the following comparison of lifetime earnings $y^B \geq y^C$, which implies that high types with wealth $b^i \geq b^*$ prefer to go to school when young rather than when old. Notice that this assumption $y^B \geq y^C$ covers also the case $y^A \geq y^C$, which means that high types prefer to go early to school rather than late. This is true since CMI imply that it is always better to be self-funded rather than borrow $y^A > y^B$.

Assumption 4: High types prefer to separate themselves from the pool of uneducated workers even when old.

$$T < \frac{w_3^s - w_3^{u,P} + (1 + r^l)w_2^{u,P}}{1 + r^l} \tag{9}$$

Intuitively, for the high types who do not go to school when young (those with initial wealth $b^i < b^*$), it is always better to separate themselves from the pool of uneducated workers, by going to school when old. Assumption 4 comes from $y^C > y^D_{pooling}$. Where $y^D_{pooling}$ is:

$$y^D = (1+r^l)^2(w^u_1 + b^i) + (1+r^l)w^{u,P}_2 + w^{u,P}_3 \text{ and } w^u_1 = w^{u,P}_2 = w^{u,P}_3.$$

Discussion of the Assumptions. What do these assumptions imply for firm's beliefs? Assumption 1 implies that all educated workers are high types. So, firms know that a signal of schooling can be sent only by high types. This implies in turn that the skilled wage equals the productivity of the high type $w^s_2 = w^s_3 = w^{s'}_3 = q^h$. Assumption 4 implies that those who do not go to school even at period $t = 2$ are low types. So, the unskilled wages of the second and the third period equal the productivity of the low type $w^u_2 = w^u_3 = q^l$. Also notice that no agent goes to school at the third period of his life, as he will not be able get the return of educational investments. That is why the only wage that we have to determine is w^u_1.

Unambiguously there are *off-the-equilibrium path beliefs*. However, I can eliminate them as unreasonable using the intuitive criterion by Cho and Kreps (1987). In particular, firm's belief that "an educated worker can be of low type" is unreasonable, since assumption 1 guarantees that all low types are better off without education. Accordingly, the belief that "in period two, high types try to find a job to other firms for a higher wage" can be eliminated. The logic is simple, prior trying to work for other firms, high types consider the following two reactions, in a forward-looking sense: first, in the absence of education other firms still cannot separate low from high types (private employer learning); second, if uneducated high types try to find a job to other firms for a higher wage, then all low types have an incentive to mimic them, this generates the pooling wage for all the uneducated workers $w^{u,P}_2 = w^{u,P}_3 = w^u_1$. But from assumption 4 we know that high types prefer to separate themselves from low types by going to school when old rather than remaining to the pool of all uneducated workers and by assumption 2 we know that they can do this.

2.2 Equilibrium

I employ the following equilibrium concept

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

1. *choices of education in the first period and second period, based on skills and initial wealth bequests:* $A^*_1(q^j, b^i) \in \{school, not\}$, $A^*_2(q^j, b^i) \in \{school, not\}$;
2. *beliefs by firms about worker type in the first period of employment given their education level* $B_1(j|A_1)$, $\forall\, A_1\{school, not\}$ *and* $B_2(j|A_2)$, $\forall\, A_2\{school, not\}$;
3. *and equilibrium wages:* $w^u_1, w^{u,h}_2, w^{u,l}_2, w^s_2, w^{u,h}_3, w^{u,l}_3$ *and* w^s_3.

Such that:

1. *workers maximize their lifetime earnings,*
2. *firms maximize their profits,*
3. *labor markets clear.*

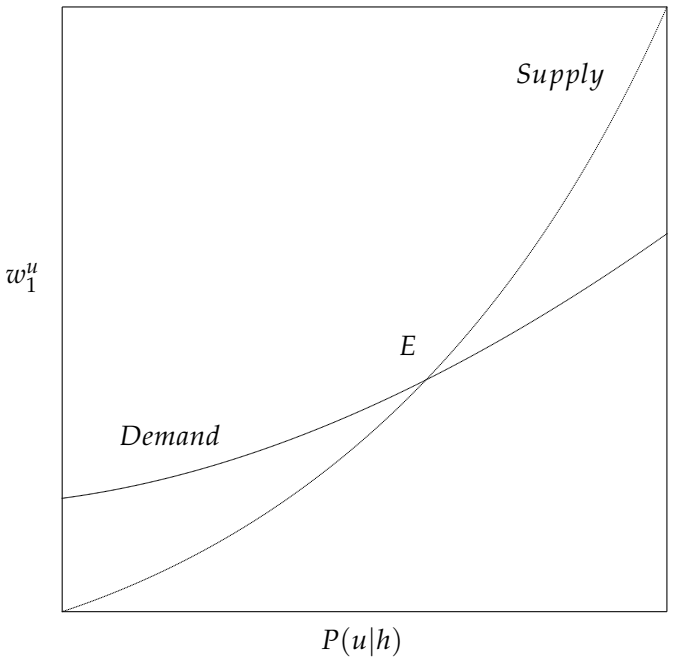
We can find all the wages above, apart from w_1^u. In order to have an equilibrium we have to determine the wage w_1^u.

Supply of Unskilled Labor in Period 1.
The supply for unskilled labor is:

$$P(u|h) = P(b^i < b^*). \tag{10}$$

Where $P(\cdot)$ represents the cumulative density function of the initial wealth distribution for high ability workers. In Figure 5 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 (8)). Hence, the supply curve is upward sloping. An increase in tuition level T increases b^* by driving down the return to education.

Figure 5: Unskilled-Labor Market



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 (8) as:

$$b^* = \frac{(1+r^b)^2 T + (1+r^l) w_1^u - (1+r^l)(w_2^s + T)}{(1+r^b)^2 - (1+r^l)^2} \tag{11}$$

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. 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.

Demand for Unskilled Labor in Period 1.
What I call demand is in fact, the firms willingness to pay for a given mix of high and low ability workers. Since firms compete over workers, their willingness to pay a wage equals the expected productivity. Under the assumption of constant returns to scale the marginal productivity and so the wages do not depend on the quantity of unskilled workers. Equation (12) below, determines the unskilled wage. Using (12) I derive (13), which is the demand curve:

$$w_1^u = q^l \left(\frac{1-\pi}{1-\pi+\pi P(u|h)} \right) + q^h \left(\frac{\pi P(u|h)}{1-\pi+\pi P(u|h)} \right). \tag{12}$$

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

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

The demand curve for unskilled workers is upward sloping and this feature of the model drives many of my 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.

Equilibrium Unskilled Wage in Period 1.
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. I use the following equation $f(\cdot)$ to formalize my argument:

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

$An equilibrium occurs when f(w_1^u) = w_1^u$. For locally tâtonnement stable equilibria, prices evolve according to $\partial w_1^u / \partial t = f(w_1^u) - w_1^u$. An equilibrium is *locally tâtonnement stable* if, whenever the initial price vector is sufficiently close to it, the dynamic trajectory causes relative prices to converge the equilibrium price. 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 existence and stability.

Proposition 1 (Existence, Stability) *Let $P(\cdot)$ be a continuously differentiable function. Then, there exists at least one stable equilibrium.*

Proof See Appendix I. ■

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.

The intuition of stability in this setting must be straightforward. Consider figure 5, where the horizontal axis measures the probability that the high type is uneducated $P(u|h)$ and the vertical the unskilled wage the first period w_1^u. The supply curve has a higher slope of the demand curve but both are upward sloping. Since the slope of the supply is higher than the slope of the demand curve this equilibrium is stable. Now consider a wage $\overline{w_1^u}$ above the equilibrium level. At this level we have excess demand.[23] This wage will decline in order to reach the equilibrium level, since for this wage $\overline{w_1^u}$, we have excess demand $P(u|h)^D > P(u|h)^S$ (recall that demand is the firm's willingness to pay). This means that firms are willing to pay this wage only when the probability that the high type is uneducated, is $P(u|h)^D$. But the supply of uneducated high-type workers is $P(u|h)^S$, which is lower than $P(u|h)^D$. This means that firms set the wages at a lower level compared to $\overline{w_1^u}$. This happens until we reach the locally stable equilibrium. In the same spirit when wages are lower compared to the equilibrium level, we have excess supply and wages increase until they reach the equilibrium level.

Verify the Solution. So far, the assumptions (1-4) depended on endogenous variables, as well. However, I have solved the game for these values and now I can verify the solution that I guessed. This transforms assumptions (1-4) into assumptions (1'-4'):

Assumption 1:

$$k^l > \frac{(1+r^l)(q^h - q^l) + q^h - q^l - (1+r^l)^2(w_1^{u*} + T)}{(1+r^l)^2} \tag{16}$$

[23]Generally, when the demand curve is downward sloping and the supply is upward sloping, for higher prices compared to the equilibrium prices we have excess supply. However, in this graph the demand curve is upward sloping, that is why we have excess demand. That is in our case (of upward-sloping demand curve), in the condition for local tâtonnement stability $\partial w_1^u / \partial t = f(w_1^u) - w_1^u$, the function $g(w) = f(w_1^u) - w_1^u$ represents the excess supply function and not the excess demand function, which is generally the case (when the demand curve is downward sloping and the supply is upward sloping).

Assumption 2:

$$T \leq (1 + r^l)q^l \tag{17}$$

Assumption 3:

$$b^* = \frac{(1 + r^b)^2 T + (1 + r^l)w_1^{u*} - (1 + r^l)(q^h + T)}{(1 + r^b)^2 - (1 + r^l)^2} \tag{18}$$

Assumption 4:

$$T < \frac{q^h + r^l w_1^{u*}}{1 + r^l} \tag{19}$$

Notice that all the assumptions above depend on parameters only, since I have proved that an equilibrium wage w_1^u exists and takes values from q^l to q^P.

Bargaining. Our analysis so far implies that high ability agents with adequate wealth 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. In particular, the discussion so far excludes the possibility of bargaining between firms and workers. However, we have reason to expect that after firms having privately observed the productivity of their workers, there can be mutually beneficial bargaining between firms and workers.

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 can bargain for a higher 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. 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; instead they will get $w_2^{u,P}$ and $w_2^{u,P}$ for the remaining two periods. Workers reply that they will acquire education in order to signal their type to the other firms and get the skilled wage. By assumption 2 firms know that this threat is *credible* for all the credit constrained high types, who are uneducated in period 1. 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 staying attached 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. By assumption 4 high types find it profitable to separate themselves from the unskilled pool, even when they are old. Additionally, under a time-cost for switching jobs, workers are better of by accepting their employment firms offers. Respectively, if low types face a time-cost when they bargain with their employment firms unsuccessfully, they will never choose to bargain. Notice that mutually beneficial bargaining implies 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 have obtained 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.

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 all of them have enough wealth to cover the cost of education in the second period of their lives.

Can employers offer a higher wage than $w_2^{u,h}$ and attract more uneducated high types? The answer is negative, since firms that try to employ workers from competitors, face asymmetries of information even during the second period. So they cannot distinguish the high from the low types. Additionally, when low types observe that constrained high types seek for employment, they always have an incentive to mimic them. However, from assumption 4, high types always find it profitable to bargain and separate themselves from pooling with the low types. Furthermore, employers always wish to keep the constrained high types in the firm, since they derive a profit by paying them less than their marginal productivity. That is why an uneducated agent who seeks for employment when old is perceived as a low type and so he will get the lowest possible wage $w_2^{u,l} = w_3^{u,l} = q^l$. Under the time-cost for switching jobs, low types also stay to the initial firm. Importantly, the proposition below states that in this setting firms derive an informational rent.

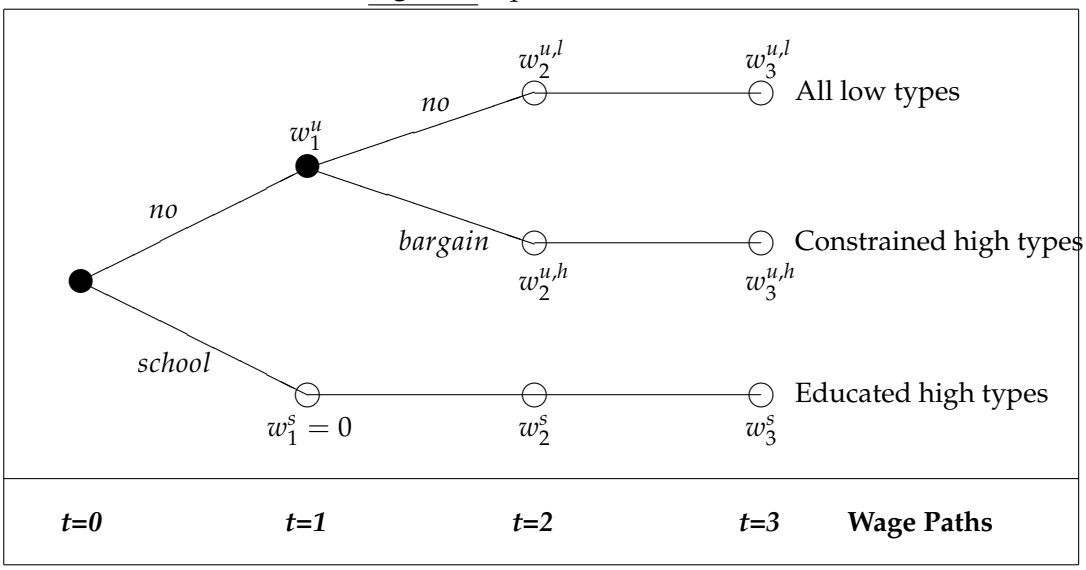
Proposition 2 *Firms derive an information rent as a result of better sorting. The corresponding surplus for firms is generated due to the combination of credit constraints, information asymmetries and privately observable productivity after the first period of employment (private employer learning).*

Proof See Appendix I. ■

The intuition is simple. Initially, firms employ workers without deriving profits. However, as they get familiar with their employees, they can sort them efficiently and obtain a surplus due to better sorting. Notice that firms derive a profit by offering the bargaining agents a lower wage compared to their productivity, since they subtract the tuition cost from the offered wage and they split it in the remaining two periods of employment. Bargaining is a mutually beneficial process, as both firms and bargainers become better off.

The functioning of the Economy. So far, I have presented the basic features of the model and now I can shortly review the functioning of this economy using the diagrammatic illustration of Figure 6. 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.

Figure 6: Equilibrium Tree



3 Comparative Statics for less binding Credit Constraints

This chapter examines 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 Figure 1 (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 in the initial wage of the unskilled and inexperienced worker, which in turn leads to an increase in the experience premium. Notice that the rise in 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 2 (appendix III). 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 7.

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.

Figure 7: Comparative Statics in a Stable Equilibrium

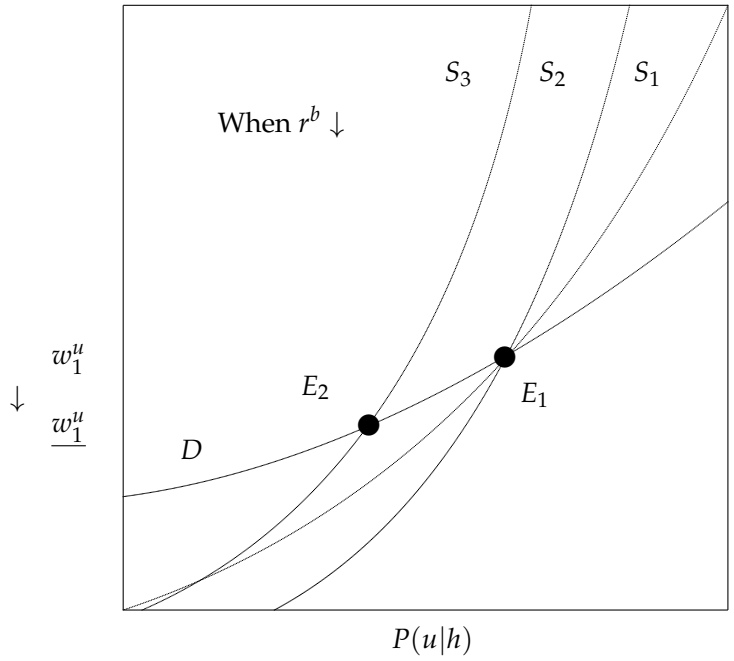


Table 2 illustrates the evolution of the skill premium within experience group and the experience premium within educational group, as credit constraints become less severe. The skill premium increases for both experience groups, which is in harmony with the empirical evidence for US, represented at Figure 1 (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 2 (appendix III). From propositions 3 and 4 the following corollary can be derived.

Corollary 1 *From propositions 3 and 4, we deduce that when credit frictions become less severe, the rise in the skill premium is larger in magnitude within the group of unskilled workers, compared to the group of skilled workers.*

Within Group Skill & Experience Premia

	Wage Premia	Credit Frictions Relax
Skill Wage Premium:		
Inexperienced	w^s_2 / w^u_1	Increases Sharply
Experienced	$w^s_3 / \underline{w}^u_2$	Increases Slightly
Experience Wage Premium:		
Young High School grads (t_2 / t_1)	$\underline{w}^u_2 / w^u_1$	Increases
Old High School grads (t_3 / t_2)	$\underline{w}^u_3 / \underline{w}^u_2$	Constant
College graduates	w^s_3 / w^s_2	Constant

Note: This table summarizes the results of propositions 3 and 4. When credit constraints become less severe both the skill and the experience wage premia increase. Where $\underline{w}^u_2$ indicates the average wage of all the unskilled workers at period 2. Accordingly $\underline{w}^u_3$ denotes the average wage 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. For more details on the derivation of these results see the proofs of propositions 3 and 4 at the appendix.

Table 2: Within Group Wage Premia

The validity of the above-mentioned result lies on the fact that a relaxation of credit constraints generates a larger decline in unskilled wages for inexperienced workers (w^u_1) compared to the average unskilled wage for experienced workers ($\underline{w}^u_2$). This result comes directly from the proof of proposition 4. Additionally, we know that the skilled wages for inexperienced and experienced workers are equal ($w^s_2 = w^s_3 = q^h$) and remain unaltered as credit frictions relax. Therefore, the increase in the skill premium for inexperienced workers (w^s_2 / w^u_1) is larger in magnitude compared to the increase in the skill premium for experienced workers ($w^s_3 / \underline{w}^u_2$), as the nominators do not change when credit frictions relax but the denominator of the former ratio declines by more compared to the latter. That is why the corollary holds.

This result provides an explanation to the puzzling observation by Card and DiNardo (2002b) which can be illustrated in figures 1 and 11 and is stated as follows in their own words:

> While the rise in the average wage gap between college and high-school workers has been extensively documented, the fact that the increases have been very different for different age groups is less well known. Specifically, the rise in the college/high-school wage gap for men is most pronounced among young workers entering the labor force after the late 1970s. Moreover, the pattern of this increase does not appear to be well explained by either the rising-skill-price or computer-use/skill complementarity versions of SBTC.

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 financial frictions relax both the experience and the skill premium increase. In the case of perfect financial markets, where everyone can borrow any amount, the skill and the experience premium is maximized. So, the following proposition holds.

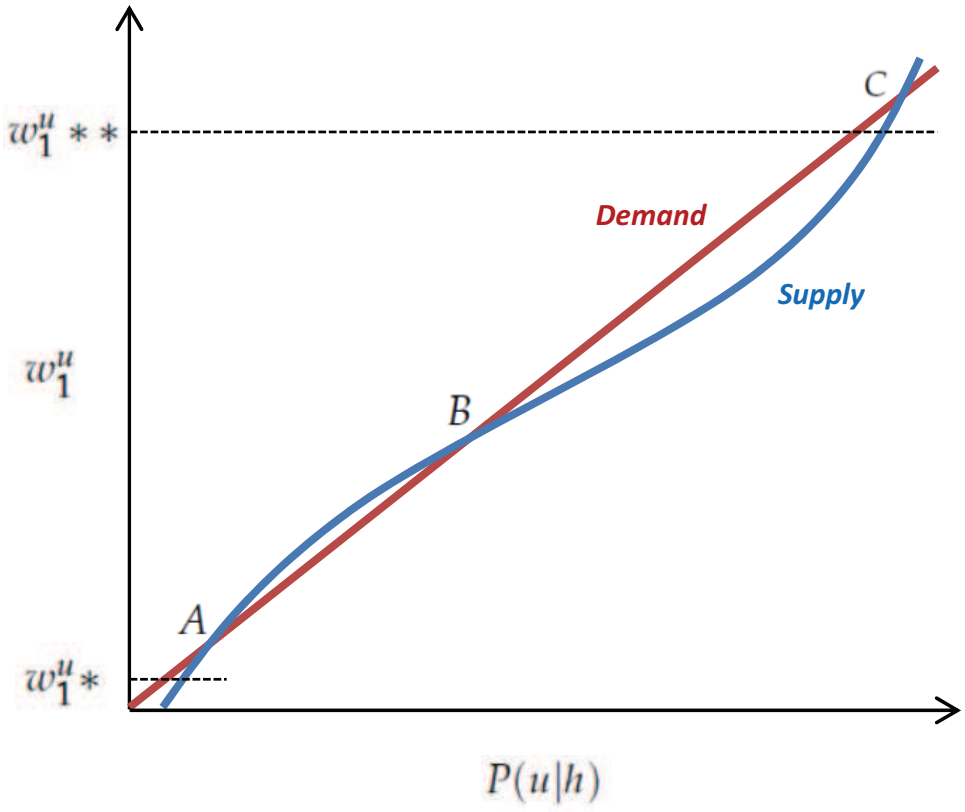
Proposition 5 *Both the skill and the experience premium increase monotonically as credit constraints relax.*

Proof See Appendix I. ■

3.1 Multiple Equilibria, Selection and Minimum Wage Policy

In our economy there can be multiple equilibria. Whenever the supply curve intersects the demand curve from below then the equilibrium is stable, otherwise it is an unstable equilibrium. For instance in the graph below we have three equilibria, denoted as A, B and C. Equilibria A and C are stable, while equilibrium B is an unstable one.

In turns out that labor market policies and in particular minimum wage policy can affect the equilibrium outcome and ultimately wage inequality. This can be illustrated in the graph below. Consider the three equilibria A, B and C. When policy-makers try to determine the level of the minimum wage in this economy they consider to set it either at a high level, say w_1^{u**} or at a low level, say w_1^{u*}. If they set the minimum wage at the high level w_1^{u**}, the economy would reach equilibrium C that corresponds at a relatively high wage for unskilled inexperienced workers, which in turn would keep wage inequality at a low level. Alternatively, if policy-makers set the minimum wage at the low rate w_1^{u*}, the economy would reach equilibrium A, which corresponds to a relatively low wage for unskilled inexperienced workers and therefore to higher wage inequality.



Notice that whenever the minimum wage is set above the wage that corresponds to the unstable equilibrium B, the economy reaches the stable equilibrium C, which leads to a low equilibrium wage inequality. When the minimum wage is set below or equal to the level that corresponds to equilibrium

A, then the economy converges to A and we have a high equilibrium wage inequality. The interesting rage of the minimum wage starts from wages above the level of equilibrium A and ends to the wage of the unstable equilibrium B. For this range of minimum wages the dynamic trajectory pushes the equilibrium to A but the minimum wage distorts the market mechanism and does not allow the economy to reach this level. So, in this case the equilibrium cannot be determined and only after a shock the economy can reach the stable equilibrium at point C.

This raises concerns related to unemployment, as policy-makers might decide to decrease minimum wages in order to increase employment. A discussion on this tradeoff is beyond the scope of this study. However, Card and Krueger (1994) show empirically that decreasing the minimum wage does not lead to an increase in employment.

4 The Dynamic three-period OLG Economy

The discussion so far concerns a static three-period economy. In this section I extend the static model to a dynamic one. For this purpose I employ the overlapping generations (OLG) model developed by Allais (1947), Samuelson (1958) and Diamond (1965). The only difference compared to their approach, is that I employ a three-period OLG model, instead the standard two-period OLG framework. So the demography of the dynamic economy can be described as follows: A mass one of agents, say generation t is born at period t and lives for three periods, at period t agents are young, at $t+1$ they are middle-aged and at $t+2$ they are old. When an agent reaches the second period of his/her life gives rise to one other agent.[24] This generates dynasties overtime. Generation $t+1$ is born at period $t+1$ and lives for three periods at period $t+1$ agents are young, at $t+2$ they are middle-aged and at $t+3$ they are old. Generation $t+2$ is born at period $t+2$ and lives for three periods at period $t+2$ agents are young, at $t+3$ they are middle-aged and at $t+4$ they are old. And so on. Notice that in period $t+3$ all three generations, grandchildren, children and parents overlap. This can be illustrated at the graph below.

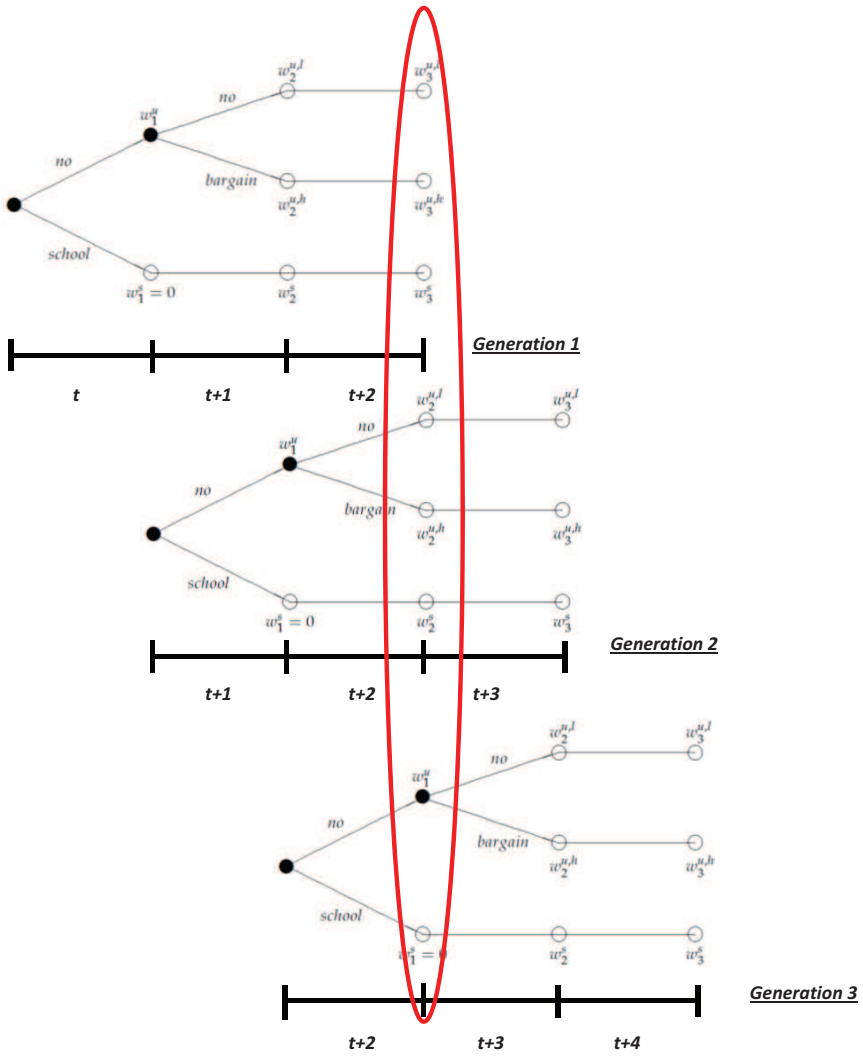
I extend the static setting to a dynamic three-period OLG model for consistency between my model and the demography of the Current Population Survey (CPS). The static version of the model refers to one cohort of workers, for instance individuals born at year t, while in fact in the CPS is a repeated cross section representing the US labor market, where different generations overlap over the years. Econometricians calculate the skill and the experience wage premia annually but at every given year young, middle-aged and old agents overlap. That is why, for the purpose of this study, I consider the three-period OLG model a satisfactory representation of the American labor market.

Proposition 6 *A modified version of Propositions 1 - 5, which are based on the three-period static model, holds also for the dynamic three-period OLG model.*

In the static model I have implicitly assumed that agents collect their wealth and consume only at the third period of their lives, the entire wealth they have accumulated. This is biologically unrealistic, as agents have to consume every period in order to survive. At the dynamic three-period OLG

[24] This assumption is not as unrealistic as it might seem, since it resembles modern societies were statistically each couple gives rise to approximately two children (a couple).

framework I can innocuously assume that every period the consumption of the entire dynasty (grandchildren, children and parents) comes from the lifetime earnings of the eldest altruistic parents. This develops further and improves the model.



Furthermore, I still assume that initial endowments are stochastic and there are no intergenerational bequests. Actually, there are intergenerational concerns, as parents feed both their children and their grandchildren; however, for simplicity I do not allow for intergenerational bequests. This is an assumption I can relax at a modified version of this model, which would be more appropriate for the examination of intergenerational justice.

Importantly, at the steady state the three-period OLG model inherits all the properties of the static model, including the propositions that are based on the comparative statics analysis. The cohort analysis that is based on the static model can be extended to this three-period OLG version that resembles more the demography of the dataset that I use, which is the Current Population Survey (CPS). Under the assumption that parents are altruistic with respect to consumption but not with respect to bequests the following proposition holds.

Notice that in period $t+2$ for instance, where all three generations overlap, we derive the following equilibrium wages for the steady state: $w_1^{u*}, w_2^{u,h*}, w_2^{u,l*}, w_2^{s*}, w_3^{u,h*}, w_3^{u,l*}$ and w_3^{s*}. Which are exactly

the same as in the static model. From propositions 2 and 3, for example, we can infer that at the steady state an economy with less severe credit constraints has higher wage inequality, generated by a higher skill and experience premium, compared to one other economy with more severe credit constraints. The reason why the above proposition holds is that my approach focuses on *within group* wage comparisons, for instance the skill premium within a group of a particular level of experience. This actually allows me to extend the results of the static model to the dynamic three-period OLG model. I consider this as an additional methodological contribution.

5 Evidence from the Current Population Survey

One of the most important result from the theoretical analysis is that when credit constraints relax, talented individuals can acquire education and leave the uneducated pool, the unskilled-inexperienced wages decline and this generates both an increase in the skill premium for inexperienced workers but also an increase in the experience premium only for unskilled workers. This occurs as in both wage ratios the denominator declines. This section, examines whether this theoretical prediction finds empirical support, using data from the March Current Population Survey (CPS), the major data source for wage representing the entire US labor market. I first show that the data I use are in perfect harmony with sources used from previous studies, then I examine in more detail the empirical facts that my study accounts for and ultimately I show why the fall of unskilled-inexperienced wages is so crucial.

5.1 Empirical Evidence from Previous Studies

Several studies examine the issue of measurement of economic inequality.[25] 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[26] or the returns to education and experience.[27] However, a growing body of research measure labor income inequality using the skill, the experience and the gender wage premium, mainly for convenience when theoretical models are calibrated or estimated using real data. Krueger et al. (2010) report evidence for nine developed countries, for the increasing pattern of the skill and the experience, as well as for the narrowing gender wage gap 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.[28] The experience premium evolved more homogeneously across countries, as it increased in all countries apart from Sweden[29] and the magnitude of the increase was more similar compared to the skill premium. Furthermore the gender premium fell substantially in all 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. By doing this we will

[25] See Schutz (1954), Atkinson (1970), Sen (1973), and Rothschild and Stiglitz (1973).

[26] See Piketty and Saez (2003, 2006), Atkinson et al. (2010).

[27] This branch of literature pioneered by the work of Jacob Mincer (1974) and revived during the 90's by Katz and Murphy (1992), Juhn et al. (1993) and others. Since then it has attracted numerous labor economists and macroeconomists focusing on labor income distribution.

[28] That is why if all countries are pooled together, as Trostel et al. (2002) do for 28 countries for the period 1985 to 1995, the return to education does not seem to follow and increasing pattern.

[29] Notice however that the data they use for Sweden refer to after-tax earnings.

be able to tackle unanswered questions such as the one posed by Hornstein et al. (2005): "why the experience premium increased significantly within the group of high school graduates, while it has remained constant within the group of college graduates". A study by Weinberg (2004) contrasts the difference between the increasing experience premium for unskilled workers and its flat pattern for the skilled ones (see Figure 2, appendix III). Or we can shed more light on the observation stressed by Card and DiNardo (2002b) that: "while the rise in the average wage gap between college and high-school workers has been extensively documented, the fact that the increases have been very different for different age groups is less well known". According to the latter the rise in the skill premium for men is much larger among young workers and this pattern does not appear to be well explained by either the rising-skill-price or computer-use/skill complementarity versions of SBTC." Existing literature, from Katz and Murphy (1992) to Acemoglu and Autor (2011) suggests that the pattern of the skill premium is increasing for all experience groups; however the increase is larger for inexperienced workers (see Figure 1, appendix III).

One other crucial aspect of the evolution of wage inequality, is the fall in minimum wages (see Figure 3 (appendix III) for the pattern of real minimum wages as presented in Card and DiNardo (2002a)). Many studies propose a pattern of movements to the opposite direction between minimum wages and wage inequality. Lee (1999), Card and DiNardo (2002a), 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 4 (appendix III) illustrates the result by Card and DiNardo (2002a) that there is a systematic relationship between real minimum wages and overall wage inequality. Additionally, comparing Figure 2 to Figures 3 and 4 one can observe that the decline in minimum wages is closely linked with both the rise of the experience premium within the group of high school graduates and the rise in overall wage inequality in the US.[30] Autor et al. (2010) show that a decline in minimum wages increases wage inequality not only at the lower tail of the wage distribution but also at wage percentiles where the minimum is non-binding, which implies spillovers.

5.2 My Empirical Approach: Data, Method and Results

For my own calculations I use the March Current Population Survey, which is constructed in order to be representative of the US labor market. I use individual data for real weekly earnings from 1963 to 2008. My sample is comprised of white males aged 16 to 64 that work full-time, full-year (FTFY), defined as 35-plus hours per week 40-plus weeks per year and who are not self employed. I also exclude those who have a real weekly wage below 67 US dollars (measured in 1982 US dollars). As in Acemoglu and Autor (2011), the real wage series are deflated using Personal Consumption Expenditure Deflator (PCE), which shows a lower rate of inflation compared to the more commonly used Consumer Price Index (CPI). However, before documenting the wage inequality patterns derived from my own calculations, I first highlight the most related findings from previous empirical studies.

Figure 10a shows that both the skill and the experience premium increase significantly. The skill premium increased significantly from 1980's onwards, climbing from 1.45 to almost 2 in the year 2008, which means that on average the wage of the skilled worker is almost twice as much as the wage

[30] Machin (1997), and Machin et al. (2003) find similar results for the UK. DiNardo and Lemieux (1997) suggest that in the US the minimum wage fell significantly inducing a rise in wage inequality, while in Canada the more moderate decrease in the minimum wage caused a smaller increase in wage inequality.

of the unskilled one. While the experience premium increased throughout the entire period of our study, from 1.3 in 1963 to 1.7 in 2008. Figure 11a highlights that the skill premium increases for both the experienced and the inexperienced workers but the rise is greater for the latter. Figure 12a shows the evolution of the experience premium within the group of skilled and unskilled workers. This graph indicates that a large part of the increase in the experience premium can be attributed to the influence of the group of unskilled workers. Figures 10b, 11b and 12b indicate the composition of workers for each education-experience group. Table 1 highlights the increase in the coefficients on education and experience from mincerian log-wage regressions in 1963 and 2008. Figure 13 shows the fall in the US federal real minimum wage that occurred during the period 1978-1989. However, the mere fall of the minimum wage cannot account for the rise in wage inequality, which extends to a longer period. Figure 14 shows that unskilled-inexperienced wages declined sharply during the period 1970-1997, when most of the increase in wage inequality occurred. Figure 15 shows that from 1970 to 1997 there was a mirror image between the real wage of unskilled-inexperienced workers and the experience premium only within unskilled, as well as the skill premium both within experienced and inexperienced workers.

5.3 The Falling Unskilled-Inexperienced Wages

Figure 14 indicates that indeed wages for unskilled-inexperienced workers declined significantly from 1970 to 1997. Over this period there was a decline of 20% in real wages for this group of workers. However, before examining this we should reconsider carefully the theoretical part and check whether it is appropriate to extend it empirically. In order to perform the comparative statics exercise, all other parameters must remain constant when credit constraints relax. The most relevant parameter in our case relates to the the tuition cost, which I treat as constant. Is this an empirically plausible assumption? Figure 20 indicates precisely this. In particular, Hoxby (2000) suggests that tuition fees for the average college have remained constant in real term between 1970 and 1996. Most of the rise in tuition fees on average, over this period has been driven mainly from increases at the very expensive colleges, while for most of the colleges there was actually no change in real terms. This means that during the period 1970-1996 we can perform the comparative statics analysis.

Figure 15 displays the inverse of this wage on the right vertical axis of each graph and the corresponding wage ratio on the right one. The inverse of the real wage for unskilled-inexperienced workers almost coincides with both the skill premium for experienced and inexperienced workers, as well as with the experience premium for unskilled workers (see the north-west, north-east and south-east graphs respectively). This happens during the period 1970-1997 (indicated by the two vertical lines on each graph), when that credit constraints have relaxed and college attendance have increased, as my study suggests (see figures 8 and 9). The north-west graph illustrates that the inverse of the real wage for unskilled inexperienced workers and the skill premium for experienced workers co-move but the rise in this wage premium is smaller compared to the skill premium for inexperienced ones. This fact is in line with my theoretical results. On the contrary, the south-west graph shows that the experience premium for skilled workers does not relate with the real wages for unskilled inexperienced workers and has a constant trend from 1970 to 1997. All these facts are in perfect harmony with the predictions of my theoretical model, since the increase in the three out of the four wage premia occurs due to the decline of the wage for unskilled inexperienced workers, while there is no increase in the experience

premium for skilled workers.

So far we have examined the evolution of the wage ratios in relation to the declining denominator (unskilled-inexperienced real wages). However, for a better understanding we also have to examine the nominators (skilled or experienced real wages). Figure 16 indicates that the increase in the skill premium for inexperienced workers coincides mainly with the decline in the denominator (unskilled-inexperienced wages), while the nominator (unskilled-inexperienced wages) remains constant. Figure 17 indicates that the increase in the experience premium for unskilled workers again coincides with the decline in the denominator (unskilled-inexperienced wages), while the nominator (unskilled-experienced wages) remains flat. In figure 18 the picture is not as clear as in the previous ones. However, even from this figure one can observe that if something, changes in the skill premium coincide with changes in the denominator (unskilled-experienced wages). While figure 19 clearly indicates that the experience premium for skill workers do not change as both the nominator (skilled-experienced wages) and the denominator (skilled-inexperienced wages) remain almost constant.

This evidence suggests that the explanation exposed in the theoretical part finds strong empirical support from the CPS and it is worthy examining some of its predictions more formally. In particular, the most important result of the theoretical model is the decline in ability for the average unskilled-inexperienced worker. I explore empirically precisely this prediction of the theoretical model.

6 An Empirical Test for the Allocation of Ability in Education

I argue that from 1970 till 1997 credit constraints have become less severe and this has sorted ability better in education groups. In particular, the credit constrained but able individual who could not acquire education in the past, can access the credit markets nowadays and go to school. In the model this leads to a decline in the ability of the average uneducated worker.[31]

The National Longitudinal Surveys of Youth (NLSY) for the years 1979 and 1997 include a measure of cognitive ability, the Arm Forces Qualification Test (AFQT). Using this I can find whether ability is better allocated in education groups nowadays or in the past. In particular, I am interested in examining whether the relatively uneducated group is comprised of less able individuals nowadays, as this is a crucial prediction of my theoretical model. However, AFQT is not comparable between the two surveys because individuals have taken this test at different ages and the test format has changed from a paper and pencil test in 1979 to a computer administered test format in 1997. Segall (1997) adjusts for the differences between the paper and pencil and the computer administered test, while Altonji, Bharadwaj and Lange (2012) control also for differences in ages and create an adjusted AFQT that is appropriate for comparisons between the two surveys. I am using this adjusted AFQT for my empirical analysis.

Initially, I am examining the correlation of AFQT with education for different groups. The results are displayed in Chart 1 (Appendix IV). All charts show a decline in ability for both the more and the less educated groups. However, the coefficients from regressions with years of education as the dependent variable and control variables that include ability measure with AFQT, among others give a better picture. In particular, I estimate the following regression:

$$Education_i = constant + \alpha_1 AFQT_i + \alpha_2 Female_i + \alpha_3 Black_i + \alpha_4 Hispanic_i + \alpha_5 YearOfBirth_i + \epsilon_i \quad (20)$$

[31] In this empirical section I use several education thresholds for the less educated groups and the results are robust.

Education is measured in years of schooling, for ability I use the adjusted AFQT, other control variables include dummies for gender and race. I estimate this regression for different education categories, such as for those who have at least high school complete to those who have not ($educ > 11$ vs $educ < 12$), those who have at least some college education to those who have not ($educ > 12$ vs $educ < 13$), as well as for those who have at least completed college to those who have not ($educ > 15$ vs $educ < 16$).

Chart 2 and Tables 2 and 3 indicate that the coefficient on AFQT declines much more for the less educated workers compared to the more educated ones. In particular, the difference between the more and the less educated workers is statistically significant and this is displayed in Chart 3. However, the most important result is depicted in Chart 3, which illustrates that ability declines significantly only for the less educated workers. The results are robust for all education groups. This analysis provides strong empirical support to my theoretical model. The main prediction of my model is that the average uneducated worker becomes less able, the wages for unskilled-inexperienced workers decline significantly and this boosts wage inequality. The analysis based on the NSLY tests precisely this hypothesis and provides further empirical support to the theoretical analysis.

6.1 An Alternative Test using Individual Fixed Effects

An alternative test for the same hypothesis could be based on the data from the Panel Study of Income Dynamics (PSID). The main advantage of this dataset compared to the NLSY is that it is a panel of data, which allows us to use individual fixed effects. The main idea is to use individual fixed effects and interpret them as ability. More formally, we take the following model:

$$\log wage_{it} = a_i + c_1 Exp_{it} + c_2 Exp_{it}^2 + c_3 Ten_{it} + c_4 Ten_{it}^2 + Controls + \epsilon_{it} \tag{21}$$

Then we can take the point estimates of the individual fixed effects, treat them as reflecting worker and use it as a control variable for the equaliton below:

$$Educ_i = c_0 + c_1 Ability_i + c_2 Income_i + Controls + \epsilon_i \tag{22}$$

However, this test has the following problems compared to the one I performed based on NLSY. First, the NLSY provide directly a measure of ability, while the PSID does not. Second, I find it problematic to take the individual fixed effect residuals from wage regressions, interpret them as ability and then find the effect of changes in this measure of ability (which is actually residuals from wages) on wages. Last but not least, Eeckhout and Kircher's (2011) recent insightful contribution in the sorting literature, suggests that such fixed effects are not appropriate for recovering information related to the type of economic agents.

7 Quantitative Analysis - Technology vs Sorting

7.1 The Model with Diminishing Returns to Labor

Consider the same economy with the only alteration that different education-experience combinations enter as imperfect substitutes in the production function, which exhibits diminishing returns to labor

inputs. There exist five such groups: unskilled-inexperienced, unskilled with some experience, unskilled experienced, skilled-inexperienced and skilled-experienced workers[32]. For each one of these groups labor exhibits diminishing returns, while production is linear (constant returns to scale) to composite labor, which is the only input. Formally:

$$Y = ZL \tag{23}$$

Labor is divided into the five groups as follows and takes the form of constant elasticity of substitution:

$$L = [(A_{U,I}L_{U,I})^{\sigma} + (A_{U,E}L_{U,E})^{\sigma} + (A_{U,EE}L_{U,EE})^{\sigma} + (A_{S,I}L_{S,I})^{\sigma} + (A_{S,E}L_{S,E})^{\sigma}]^{1/\sigma} \tag{24}$$

The marginal product of labor for each of these five groups is given below:

$$\frac{\partial Y}{\partial L_{U,I}} = ZA_{U,I}^{\sigma}L_{U,I}^{\sigma-1} \equiv w_1^u \tag{25}$$

$$\frac{\partial Y}{\partial L_{U,E}} = ZA_{U,E}^{\sigma}L_{U,E}^{\sigma-1} \equiv w_2^{u,P} \tag{26}$$

$$\frac{\partial Y}{\partial L_{U,EE}} = ZA_{U,EE}^{\sigma}L_{U,EE}^{\sigma-1} \equiv w_3^{u,P} \tag{27}$$

$$\frac{\partial Y}{\partial L_{S,I}} = ZA_{S,I}^{\sigma}L_{S,I}^{\sigma-1} \equiv w_2^s = q^h \tag{28}$$

$$\frac{\partial Y}{\partial L_{S,E}} = ZA_{S,E}^{\sigma}L_{S,E}^{\sigma-1} \equiv w_3^s (= q^h) \tag{29}$$

For unskilled workers Learning-By-Doing (LBD) implies that: $A_{U,EE} \geq A_{U,E} \geq A_{U,I}$; with equality if there is no LBD. The same holds for the skilled workers $A_{S,E} \geq A_{S,I}$.

Now by taking the log of the marginal rate of transformation (MRT) we can find the log of the wage premia, such as the skill and the experience premium. For instance the skill premium for inexperienced workers is the following:

$$\ln MRT_{SI,UI} = \ln \frac{w_2^s}{w_1^u} = \sigma \ln \frac{A_{S,I}}{A_{U,I}} + (1-\sigma) \ln \frac{L_{U,I}}{L_{S,I}} \tag{30}$$

According to the so called Skill-Biased Technical Change (SBTC) approach, the skill premium increased because technology favors the relatively more educated workers. More technically this requires that the fraction $A_{S,I}/A_{U,I}$ increases. This directed technical change increases the demand for skills and so the relative wages for this group of workers, despite the rise in the relative supply of skills $L_{S,I}/L_{U,I}$, which tends to decrease the relative wages for skilled workers. My signaling model with credit constraints and private employer learning suggests a complementary explanation based on the composition of unobservables, such as ability or productivity to groups of observables, such as education-experience categories. In particular, I show that the relaxation of financial constraints

[32]The average unskilled worker can acquire more experience as he enters the labor market earlier compared to the skilled-educated worker, who sacrifices some years of potential experience for schooling.

allowed talented individuals to acquire higher education and leave the uneducated pool, decreased unskilled-inexperienced wages and this in turn boosted wage inequality. This explanation is consistent with US data indicating that the rise in the skill and the experience premium coincides with the fall in unskilled-inexperienced wages, while at the same time skilled or experienced wages remain constant. This means that as the supply of skilled workers $L_{S,I}$ increases in equation (27), the productivity of the average unskilled worker $A_{U,I}$ falls, as the most talented among the previously credit constrained individuals are those who abandon the uneducated pool first.[33]

My model focuses on supply factors and provides an explanation of the pattern of rising wage inequality in the US, such as the increase in the skill premium despite the growing supply of skills, among other facts. However, this framework can be combined with the SBTC approach, which is based primarily on the demand side and in particular on the role of technology-skill complementarities.

7.2 Quantitative Analysis with Skill-Biased Technical Change Only

It is interesting to calculate how much of the rise in the skill premium for inexperienced workers can be attributed to the SBTC approach and how much to my theory. In order to do this I first calibrate equation (27) for the SBTC approach only, as in Katz and Murphy (1992).[34] According to data on wages from the CPS, during the period 1970-1997 the skill premium for inexperienced workers increased from 1.5 to 1.9, while the relative supply of skills increased from 0.3 to 0.5 (see figures 11a and 11b). Additionally, for an elasticity of substitution between skilled and unskilled inexperienced workers $1/(1-\sigma)$ of size 1.5, we can derive a value for σ equal to $1/3$. The value 1.5 of the elasticity of substitution comes from the level of the skill premium for inexperienced workers in 1970. Dividing both parts of the equation below, with equation (27), we can find the intensity of the SBTC between 1970 and 1997.

$$\ln \frac{1.9}{1.5}\frac{w_2^s}{w_1^u} = \frac{1}{3}\ln \gamma \frac{A_{S,I}}{A_{U,I}} + \frac{2}{3}\ln \frac{0.3}{0.5}\frac{L_{U,I}}{L_{S,I}} \tag{31}$$

The parameter γ captures the intensity of SBTC between 1970 and 1997. Solving for the above using (8) yields a γ equal to 5.65, which implies a skill-biased technical change in excess of 25% per year.

7.3 Quantitative Analysis with Skill-Biased Technical Change and Sorting

Now I incorporate my theory to the SBTC approach and equation (8) becomes:

$$\ln \frac{1.9}{1.5}\frac{w_2^s}{w_1^u} = \frac{1}{3}\left(\ln \delta \frac{\overline{A}_{S,I}}{A_{U,I}} + \ln \gamma' \frac{A_{S,I}}{\overline{A}_{U,I}}\right) + \frac{2}{3}\ln \frac{0.3}{0.5}\frac{L_{U,I}}{L_{S,I}} \tag{32}$$

δ captures the sorting effect, which leads to a decline in the productivity of the average unskilled-inexperienced worker. Notice that in the first term inside the parenthesis, the productivity of the skilled-inexperienced labor $A_{S,I}$ is held constant, while in the second term the productivity of unskilled-inexperienced workers is kept constant respectively. This allows us to separate the effect of sorting

[33] This does not mean that extended education finance can generate this process indefinitely. After a point more educational opportunities might also allow less able individuals to acquire education, which can happen only if schooling becomes less challenging. In the model this requires a decline in the effort cost of education.

[34] See also Violante (2008).

compared to other technological "improvements". In real 2008 dollars, unskilled-inexperienced wages have declined from 675 dollars per week in 1970 to 540 dollars in 1997, implying that δ equals 1.25.

$$\ln \frac{1.9}{1.5} \frac{w_2^s}{w_1^u} = \frac{1}{3} \left(\ln 1.25 \frac{\overline{A}_{S,I}}{A_{U,I}} + \ln \gamma^{'} \frac{A_{S,I}}{\overline{A}_{U,I}} \right) + \frac{2}{3} \ln \frac{0.3}{0.5} \frac{L_{U,I}}{L_{S,I}} \tag{33}$$

The parameter $\gamma^{'}$ captures the intensity of SBTC between 1970 and 1997 after controlling for the sorting effect. Solving for the above using (27) yields a $\gamma^{'}$ equal to 4.52, which implies a skill-biased technical change of less than 20% per year. This indicates that over the period 1970-1997, one fifth of the change on the demand (the difference between the 25% and the 20%), which in the literature is attributed to the skill-bias of technology, can be a supply effect based on the composition of ability to different education-experience groups. The data seem to support this explanation, as indeed wages for unskilled-inexperienced workers have declined significantly, while wages for skilled-inexperienced workers have remained flat. Additionally, technological change implies "improvements", which means an increase in $A_{S,I}$, which at the same time should have forced real wages for this group to increase. However, this is not what the data from the CPS suggest, if productivity is indeed in line with wages. On the contrary, there is strong evidence for falling wages for unskilled-inexperienced workers, which can be partially explained by a decline in the average productivity for this group $A_{U,I}$. Importantly, from 1970 to 1997 inequality measured by the skill and the experience premium seems to increase mainly due to the decline of unskilled-inexperienced wages. Figures 16 to 19 highlight precisely this observation. One can see the significant effect of the decline in unskilled-inexperienced wages, especially on figures 16 and 17. This suggests that we should be cautious in interpreting the residual change in productivity, denoted with $\gamma^{'}$ as driven by skill-biased technological change.

To illustrate the fit of my sorting theory with the data, I re-write the key equation, indicating with arrows the changes according to my model and the CPS.

$$\ln \frac{w_2^s}{w_1^u \downarrow} = \sigma \left(\ln \frac{\overline{A_{S,I}}}{A_{U,I} \downarrow} + \ln \gamma^{'} \frac{A_{S,I}}{\overline{A}_{U,I}} \right) + (1-\sigma) \ln \frac{L_{U,I}}{L_{S,I} \uparrow} \tag{34}$$

Similarly one can derive expressions and perform quantitative analysis for the other groups, such as the skill premium for experienced workers or the experience premium for skill and unskilled workers.

8 Robustness

Wage Decline for Unskilled Inexperienced Workers. This study attempts to explain the four facts I mentioned at the end of the second chapter. However, not only I managed to provide a microfounded explanation of these four facts but also I have shown that all these changes occur due the decline of the wage of unskilled and inexperienced labor. This last observation was a result of the theoretical model, which seems to find strong empirical support from US labor market evidence. In fact Figure 14 (Appendix III) shows that indeed the wages of unskilled inexperienced workers have declined significantly from 1970 to 1997. Exactly during the same period (1970-1997) we observe a large increase

at the skill premium for inexperienced workers, a more moderate increase at the skill premium for experienced workers and an increase at the experience premium *only* for unskilled workers, while the experience premium of skilled workers have remained constant (see figure 15). This is precisely what my theoretical model predicts. Importantly, in both my theory and the real data from the CPS the increase in the three out of the four wage premia that I examine, occurs when the wage of unskilled inexperienced labor falls.

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 of 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: $q^j_{t+1} = \lambda_t q^j_t$, where $t = 1, 2$, $j = \{l, h\}$ and $\lambda_1 > \lambda_2 > 1$. 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 would be valid even if we augment the model with learning-by-doing.

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^u_1 but the wage of the low type unskilled worker with one year of experience, which is $w^{u,l}_2$. However, this is neither empirically plausible nor my model argues that wages can also decrease with experience. On the contrary, I propose 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^u_1. 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^u_1, even for the low types who produce only q^l that is lower than his wage $q^l < w^u_1$. Firms do this, since, if they offer a lower wage, other firms will attract all the low and high types. But notice that 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, 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 3 illustrates these effects.

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 3: Wages over the life-cycle.

I propose that since 1970's credit constraints relaxed significantly (see Figure 8, appendix III) and rendered education more easily accessible. This in turn increased the college continuation rates (see Figure 9, appendix III) and left only few agents unskilled. Since educational opportunity increased, firms consider that the unskilled worker is less likely to be talented but credit constrained; while it is more likely to be less talented. That is why the initial wage for unskilled and inexperienced labor declined and generated an increase in the experience premium within unskilled workers; as well as, increased the skill premium within both the group of experienced and inexperienced employees.

Notice however, that this endogenously determined initial wage can decrease only if the legislation allows it, by setting the exogenous real minimum wage at a lower level, which is the case for the US labor market (see Figure 3, appendix III). During the period 1981 to 1989 US authorities allowed this decline in the federal minimum wage by being passive and keeping the nominal minimum wage at 3.35 dollars per hour despite the rising inflation. This generates a mirror image between the declining real minimum wage and the rising labor income inequality (see Figure 4, appendix III), a pattern that finds strong empirical support in many countries and especially in the US.

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 higher wage inequality. This is a very important theoretical

result that finds strong empirical support. My finding is in line with Card and DiNardo (2002a), who support that the early rise in inequality may have been due to rapid technological change, however they suggest that the increase in the early 1980's is primarily attributed to the fall in the real value of the minimum wage.

However, the mere fall of the minimum wage, which occurred from 1978-1989, cannot account for the rise in wage inequality, which extends to a longer period. Figure 14 shows that unskilled-inexperienced wages declined sharply during the period 1970-1997, when most of the increase in wage inequality occurred. The theoretical model suggests that the falling unskilled-inexperienced wages drive the four empirical facts that this study explains. Figure 15 shows that this is the case, since from 1970 to 1997 there was a mirror image between the real wage of unskilled-inexperienced workers and the experience premium only within unskilled, as well as the skill premium both within experienced and inexperienced workers.

Student Loans, Tuition Cost and College Expansion My theoretical model suggests that since 1970's credit constraints relaxed significantly. This is in harmony with US evidence on the increasing volume of loans as a percentage of GDP (see Figure 8). I argue that the easing of financial constraints, rendered education more easily accessible despite the rising tuition cost. According to Hoxby (2000) this is indeed the case, as increases in average tuition cost are driven by increases at the most expensive four-year private universities, while the majority of students attend colleges that have the lowest average price and where inflation adjusted tuition growth has been modest. She argues that for half of the US universities the tuition cost in real terms remained unchanged from 1970 to 1996, which is the period that I am primarily interested (see Figure 20). The relaxation of credit constraints increased educational opportunities and college continuation rates (see Figure 9) and left only few agents unskilled. Since educational opportunity increased, firms consider that the unskilled worker is less likely to be talented but credit constrained; while it is more likely to be less talented. That is why the initial wage for unskilled-inexperienced labor declined and generated an increase in the experience premium within unskilled workers; as well as, increased the skill premium within both the group of experienced and inexperienced employees.

9 Conclusion

This paper provides an explanation for the growing experience premium over the past four decades. In particular, it shows the reason why the experience premium rises only within the group of less-educated workers while it remains flat for the relatively more educated ones, a fact that the skill-biased technical change literature fails to explain. This is mainly a result of the declining unskilled-inexperienced wages that induce an increase in wage inequality, a pattern that finds strong empirical support in the US over the period 1970-1997. The theory presented here is also consistent with the sharp rise in skill premium for inexperienced workers and its moderate increase for the experienced ones. Notice that the skill premium increases despite the growing supply of skilled labor.

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. Forty years ago, it was more likely for the unskilled worker to be highly productive, since credit constraints were more severe and many able individuals could not

acquire education. However, credit frictions relaxed significantly since then and educational opportunities have become more equal. That is why being unskilled today is perceived by firms as an even worse signal for worker's ability compared to the past. This is the reason why during the 1970's firms used to offer higher initial wages to unskilled-inexperienced workers. From 1970 till 1997 initial real wages for unskilled-inexperienced labor have decline sharply. However, if after the relaxation of credit constraints an unskilled employee proves that he is highly productive but he just happened to be one of the few credit constrained workers, he receives a much higher return with experience, compared to what he would have got in 1970. 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 how the experience premium increased. In the same spirit, the skill premium has also widen, in response to the fall in wages for the unskilled-inexperienced worker.

An interesting policy implication relates to the potential conflict between *inequality of opportunity* and *wage inequality* and suggests that policy makers must clearly distinguish the one from the other. The fact that more equal opportunities can increase substantial economic inequality and lead to less equal opportunities for the future generations, highlights the vicious circle associated with the nature of inequality and the complexity of policy-making.

The other policy implication associates with the minimum wage policy. In the presence of multiple equilibria, selection is essential, as one of the candidate equilibria might lead to a high level of wage inequality, while one other can generate lower wage inequality. I show that through minimum wages governments can affect unskilled-inexperienced wages and therefore the equilibrium wage inequality.

My results are based on three realistic elements of the labor market: education signaling, credit constraints and private employer learning. The results are robust even when the pure signaling model augments with human capital and learning-by-doing. This paper provides a microfounded game-theoretical reasoning for significant macroeconomic facts related to rising wage inequality. My 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.

Lastly, both theoretical and empirical research is needed on the interaction among asymmetric information, credit constraints and employer learning, and their effects on the functioning of the macroeconomy and labor markets. Future theoretical studies should extend the current framework with the inclusion of parental bequests and derive useful implications about intergenerational justice and the distribution of income. In addition to this, further empirical studies are crucial for testing more formally the validity of the mechanism proposed here. In both cases, it seems that there is a promising avenue for research on the relationship between labor market inequalities and market failures, such as financial frictions and incomplete information. Unambiguously, this paper does not complete but just initiates an inquiry for the revelation of the laws that determine the experience premium and ultimately the evolution of labor income distribution.

Appendix I: Variables

Exogenous Variables

- π and $1-\pi$ the fraction of high and low types, respectively.
- q^h and q^l the productivity of high and low types, respectively.
- q^P the expected productivity of agents in the pooling equilibrium.
- k^h and k^l the effort cost of high and low types, respectively.
- r^b and r^l the borrowing and the lending interest rate, respectively.
- T the tuition cost.
- $P(\cdot)$ the cdf of the initial wealth for the high types.

Endogenous Variables

- w_1^u the wage of the uneducated worker in the first.
- $w_2^{u,P}, w_3^{u,P}$ the wage of the uneducated workers when low and high types are pooled, in the second and third period, respectively.
- $w_2^{u,h}, w_3^{u,h}$ the wage of the uneducated high type worker in the second and third period, when high types decide to separate themselves from the pool of uneducated workers and bargain successfully.
- $w_2^{u,l}, w_3^{u,l}$ the wage of the uneducated low type worker in the second and third period, when there is a separation of types within the pool of uneducated workers.
- w_2^s, w_3^s the wage of the educated worker in the second and the third period.
- $\underline{w}_2^u = \underline{w}_3^u$: The average wage of the uneducated worker at the second and third period.
- b^* the threshold of initial wealth above which the high types find it profitable to invest in education when young.

Appendix II: Proofs of Propositions.

Proof of PROPOSITION 1

For the proof of proposition 1, I proceed in two steps: first I prove existence and then stability. For existence, I apply *Brouwer's Fixed Point Theorem*, for continuous functions from a nonempty, convex, compact set to itself. Function $f(\cdot)$ is indeed continuous, since $P(\cdot)$ is continuous. The function maps from the set $[q^l, q^P]$ to $[q^l, q^P]$ and the set is convex and compact, since the unskilled wage w_1^u can take any value within this set. So, from Brouwer's Fixed Point Theorem an equilibrium exists.

Now I prove stability. For locally tâtonnement stable equilibria, prices evolve according to $\partial w_1^u / \partial t = f(w_1^u) - w_1^u$. If I set the derivative of function $f(\cdot)$ with respect to w_1^u larger than zero, I find that $q^h > q^l$, which is always true and means that $f(\cdot)$ is increasing in w_1^u. This implies that when we are in an

equilibrium, an increase in the wage must lead to $f(w_1^u) - w_1^u < 0$. Now let us take the maximum possible value for w_1^u, which is $q^P = q^l(1-\pi) + q^h\pi$ and occurs when $P(u|h) = 1$. Taking $f(w_1^u) - w_1^u < 0$ for this wage, leads to $q^h > q^l$, which is always true. Accordingly, a decrease from the equilibrium wage leads to $f(w_1^u) - w_1^u > 0$. If instead we take the minimum possible value for w_1^u, which is q^l and occurs when $P(u|h) = 0$, again we conclude that $q^h > q^l$, which is always true. Since, for the lowest price $w_1^u = q^l$ we have $f(w_1^u) - w_1^u > 0$ and for the highest price $w_1^u = q^P$ we have $f(w_1^u) - w_1^u < 0$, for a value of w_1^u in the set (q^l, q^P) we must have $f(w_1^u) - w_1^u = 0$, which means that there generically exists at least one locally tâtonnement stable equilibrium. Notice that the result holds generically, since we cannot exclude the possibility that the function $f(\cdot)$ is tangent to the diagonal. ■

Proof of PROPOSITION 2

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 credit constrained high types (bargainers) 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 $\pi_2 = N^B(q^h + T)(1+r^l)/(2+r^l)$, 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 of PROPOSITION 3

Recall that $b^* \downarrow \Rightarrow P(u|h) \downarrow \Rightarrow w_1^u \downarrow$. 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 of 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 compared their wages of the first and second period $\underline{w}_2^u/w_1^u$ and the other by compared 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.

$$ExpPremium_{before} \geq ExpPremium_{after} \tag{35}$$

$$\frac{\overline{w_2^u}}{w_{1\ before}^u} \geq \frac{\underline{w_2^u}}{w_{1\ after}^u} \tag{36}$$

$$\frac{\overline{N_2^h} w_2^{u,h} + N_2^l q^l / [\overline{N_2^h} + N_2^l]}{\overline{N_1^h} q^h + N_1^l q^l / [\overline{N_1^h} + N_1^l]} \geq \frac{\underline{N_2^h} w_2^{u,h} + N_2^l q^l / [\underline{N_2^h} + N_2 l]}{\underline{N_1^h} q^h + N_1^l q^l / [\underline{N_1^h} + N_1^l]} \tag{37}$$

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:

$$\frac{\overline{N^h} w_2^{u,h} + N^l q^l}{\overline{N^h} q^h + N^l q^l} \geq \frac{\underline{N^h} w_2^{u,h} + N^l q^l}{\underline{N^h} q^h + N^l q^l} \tag{38}$$

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

Proof of 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. ■

Appendix III: Figures

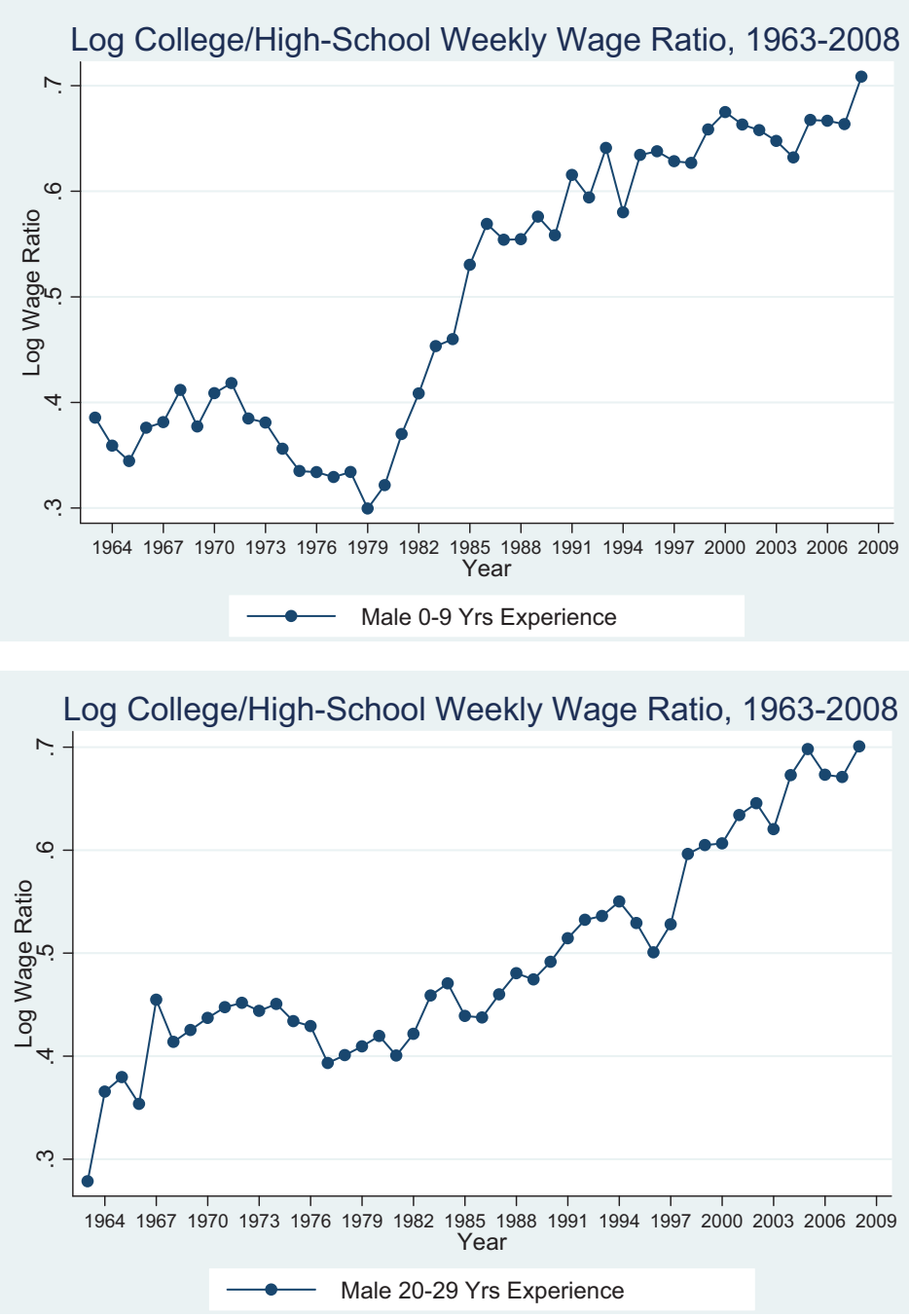


Figure 1: Skill premium within experience groups.

Figure 1 shows that the skill premium increases within both the group of experienced and inexperienced workers. Source: Acemoglu and Autor (2011).

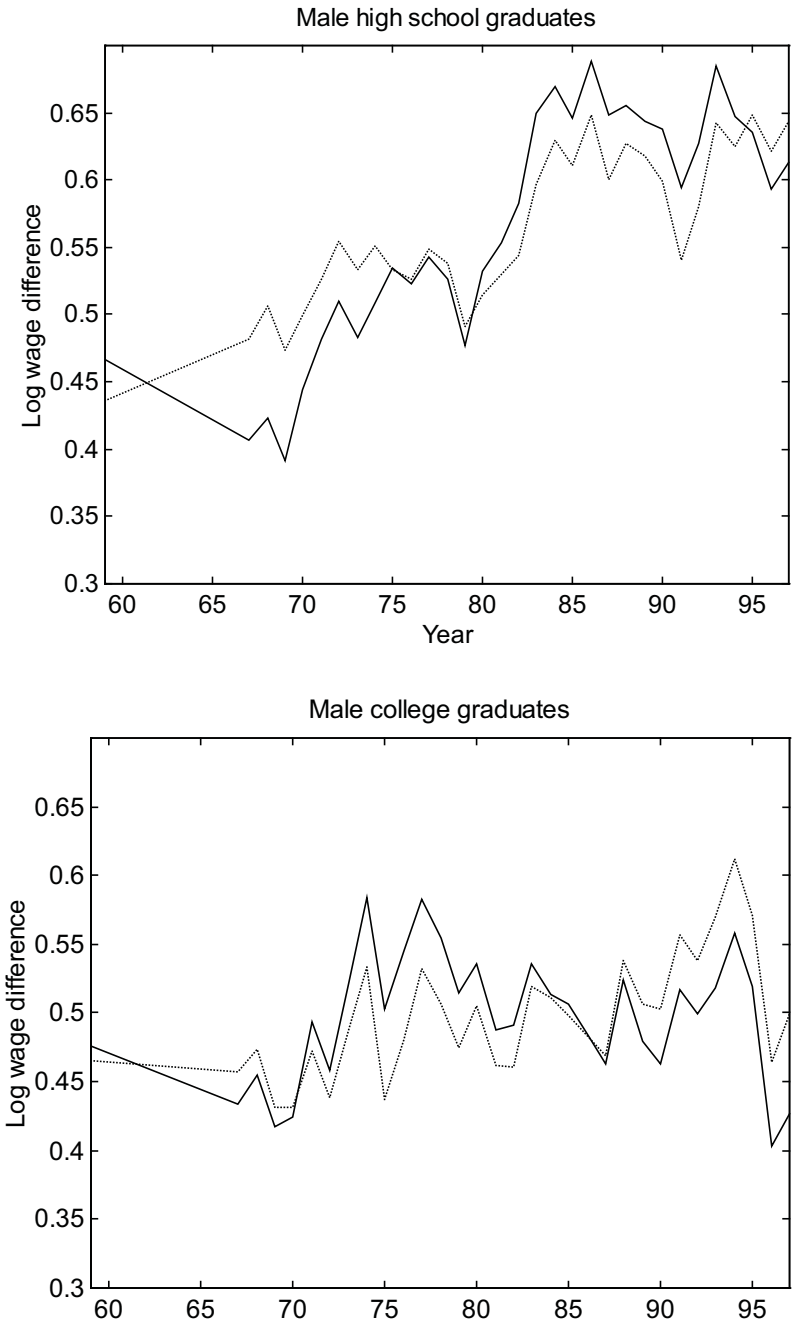


Figure 2: The experience premium within educational group.

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

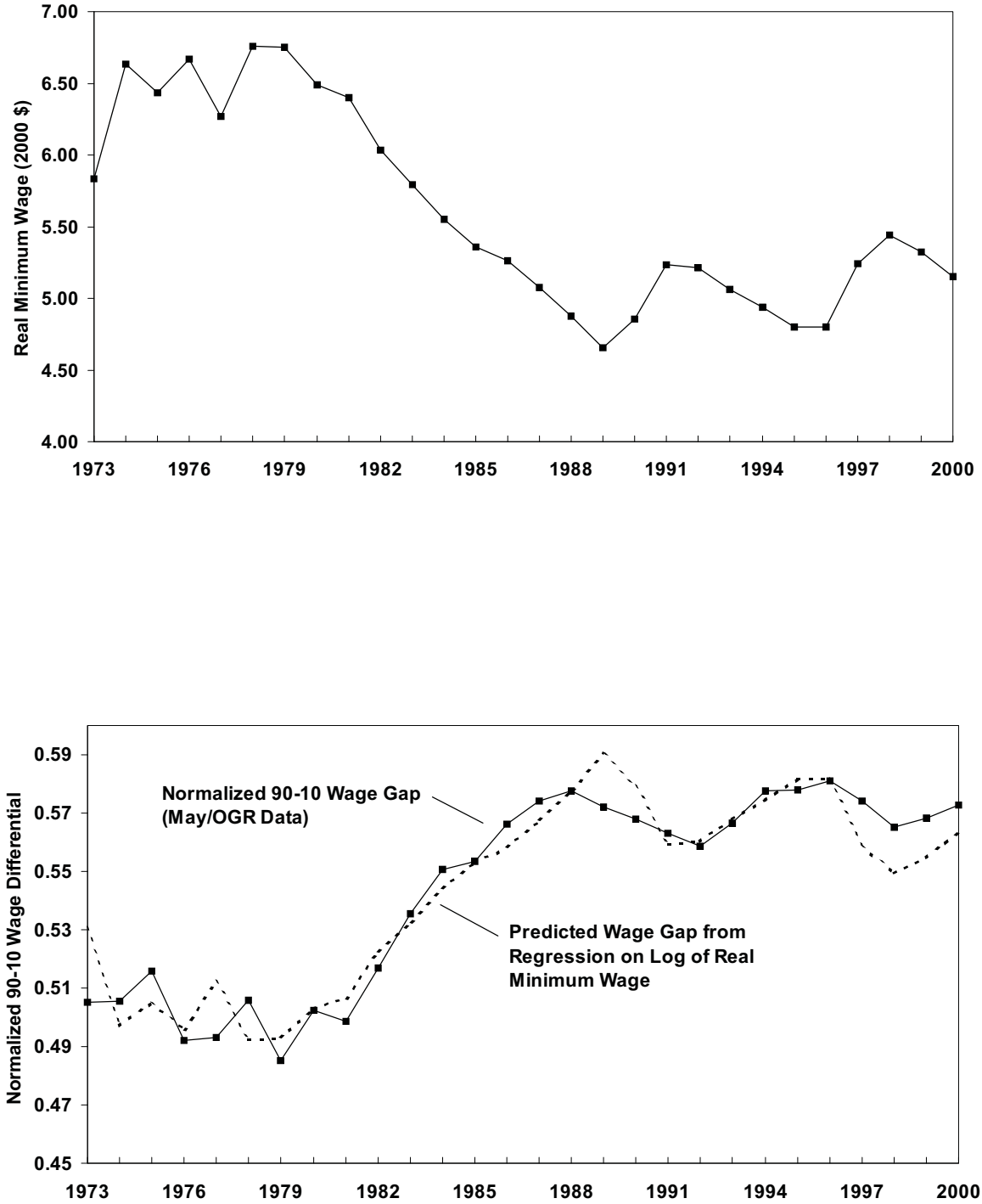


Figure 4: Wage inequality & real minimum wage in US (1973-2000). Source: Card and DiNardo (2002a).

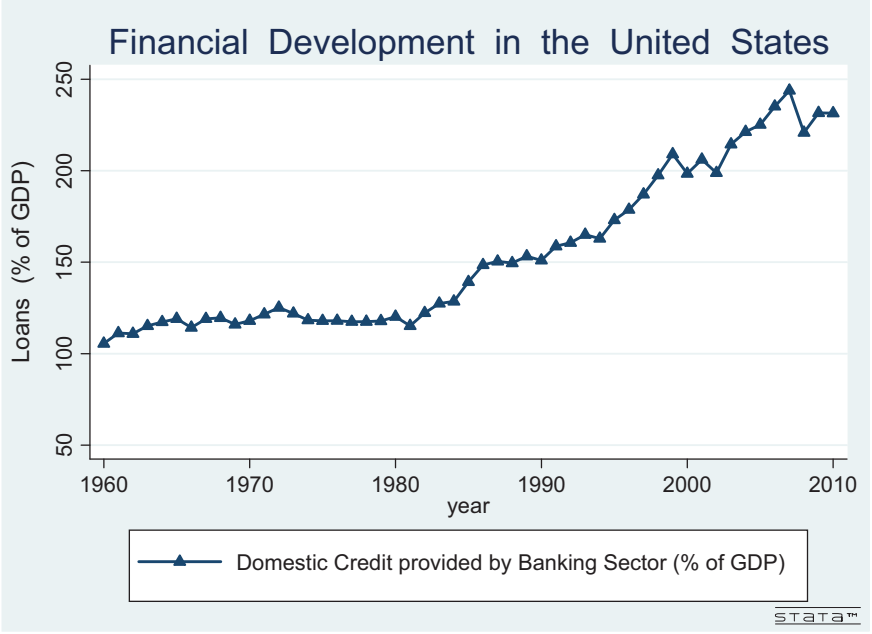


Figure 8: Financial Development (1960-2010). Financial Development is measured by the index Domestic Credit provide by the Banking Sector as a percentage of GDP. Source: World Development Indicators database, International Monetary Fund and World Bank.

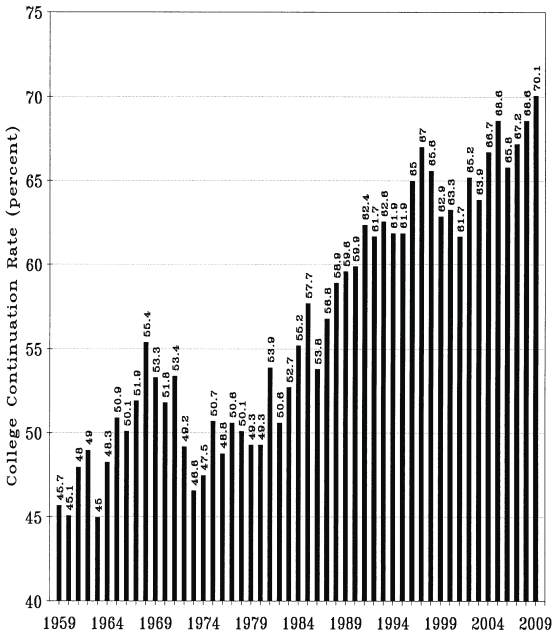


Figure 9: College Continuation rates as a percentage of high school graduates in US (1959-2009). Source: Postsecondary Education Opportunity.

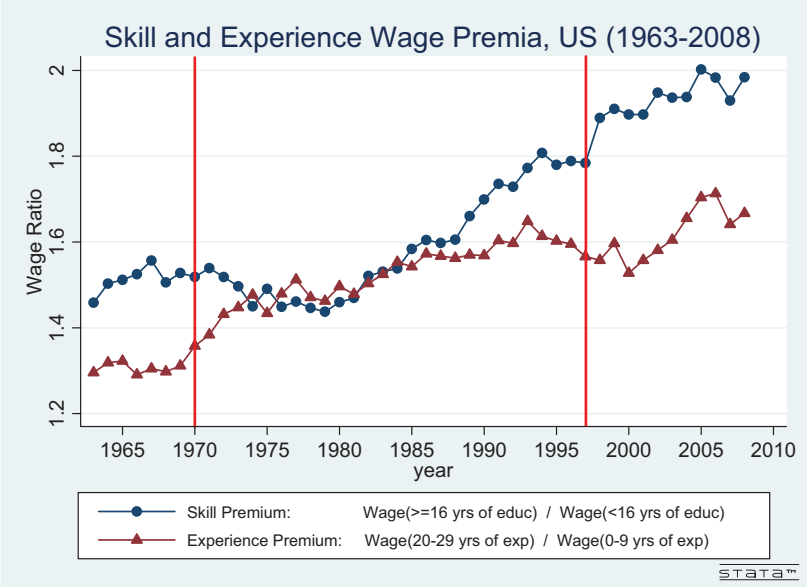


Figure 10a: The skill premium is defined as the ratio between the average weekly wage of workers with at least 16 years of schooling, and the average weekly wage of workers with less than 16 years of schooling. The experience premium is defined as the ratio between the average weekly wage of workers with 20 to 29 years of potential experience, and the average weekly wage of workers with 0 to 9 years of potential experience.

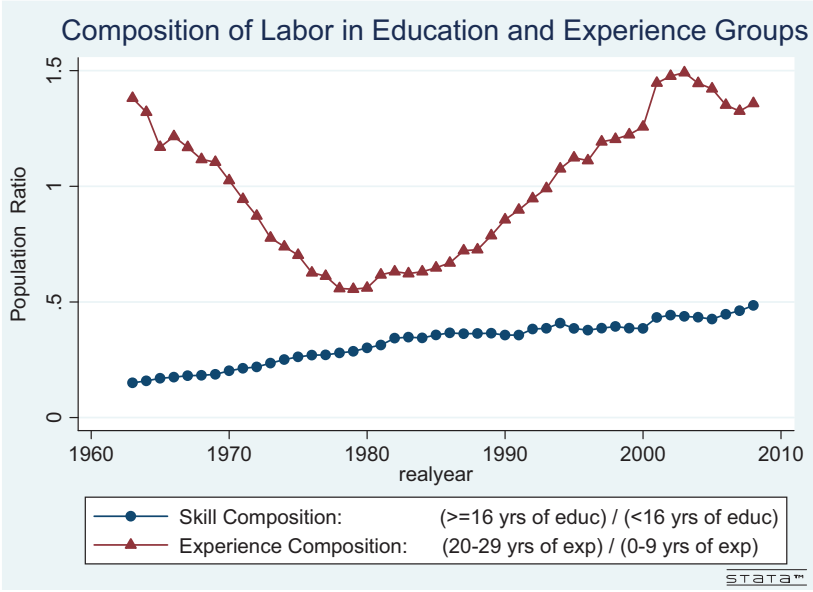


Figure 10b: The composition of skills is the ratio of skilled to unskilled workers, namely the population of workers with at least 16 years of schooling over the population of workers with less than 16 years of schooling. The composition of experience is the ratio of experienced to inexperienced workers, namely the number of workers with 20 to 29 years of potential experience over the number workers with 0 to 9 years of potential experience. Recall that the sample is for white males only for the US. Source: March CPS 1963-2008.

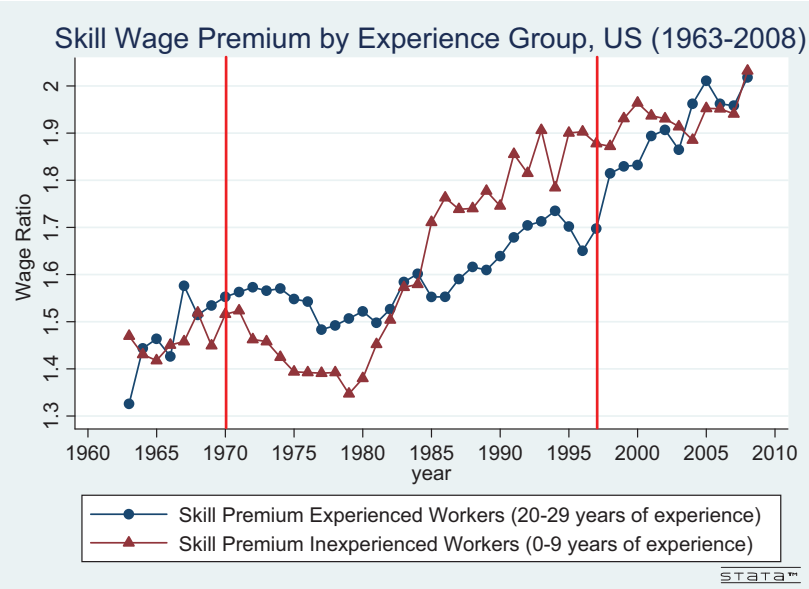


Figure 11a: The skill premium for experienced workers is the same ratio as the skill premium, with the only difference that is calculated only for workers with 20 to 29 years of potential experience. Potential experience is defined as age minus years of schooling. Accordingly, the skill premium for inexperienced workers is the wage ratio for workers with 0 to 9 years of potential experience.

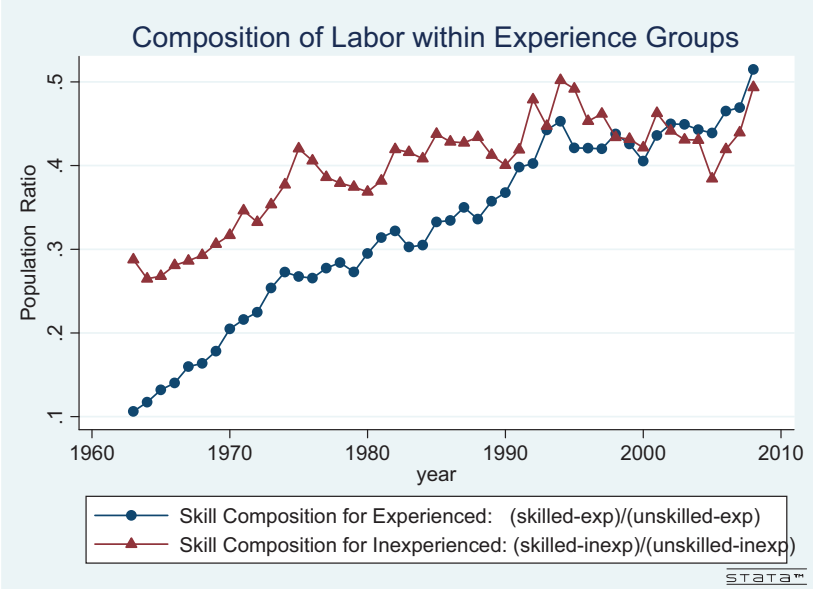


Figure 11b: The composition of skills for experienced workers is the the population of workers with at least 16 years of schooling over the population of workers with less than 16 years of schooling, for workers with 20 to 29 years of potential experience. The composition of skills for inexperienced workers is the the population of workers with at least 16 years of schooling over the population of workers with less than 16 years of schooling, for workers with 0 to 9 years of potential experience. The sample is for white males only for the US. Source: March CPS 1963-2008.

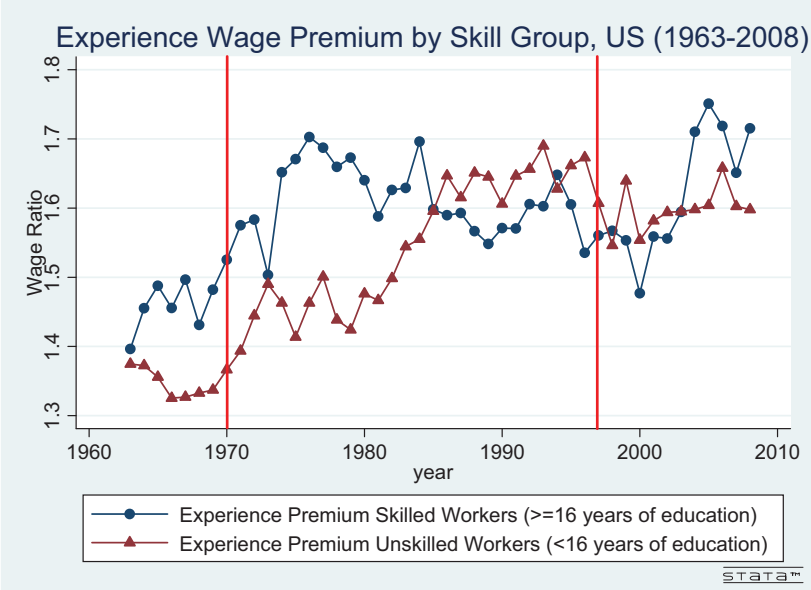


Figure 12a: The experience premium for skilled workers is the same ratio as the experience premium, with the only difference that is calculated for workers with at least 16 years of schooling. Accordingly, the experience premium for unskilled workers is the experience wage premium for workers with less than 16 years of schooling.

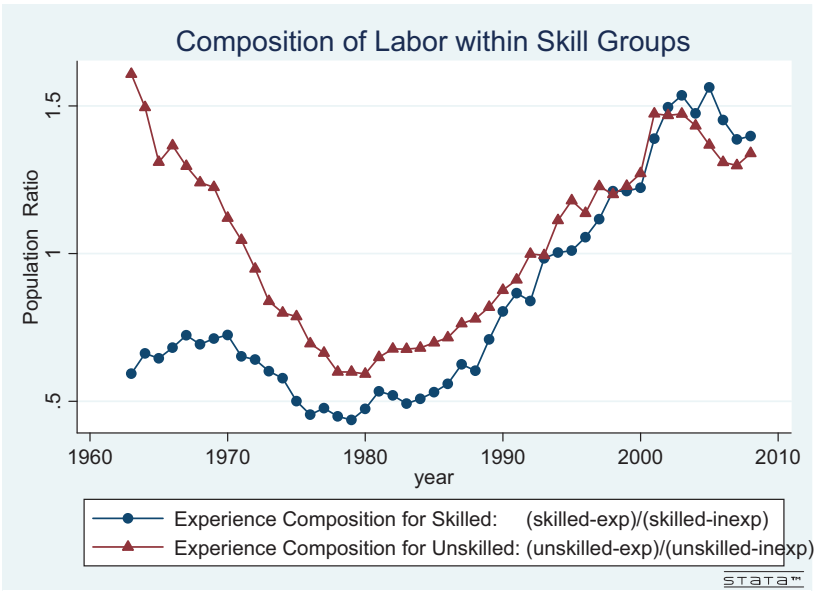


Figure 12b: The composition of experience for skilled workers is the the population of workers with 20 to 29 years of experience over the population of workers with 0 to 9 years of experience, for workers with at least 16 years of education. The composition of experience for unskilled workers is the the population of workers with 20 to 29 years of experience over the population of workers with 0 to 9 years of experience, for workers with less than 16 years of education. The sample is for white males only for the US. Source: March CPS 1963-2008.

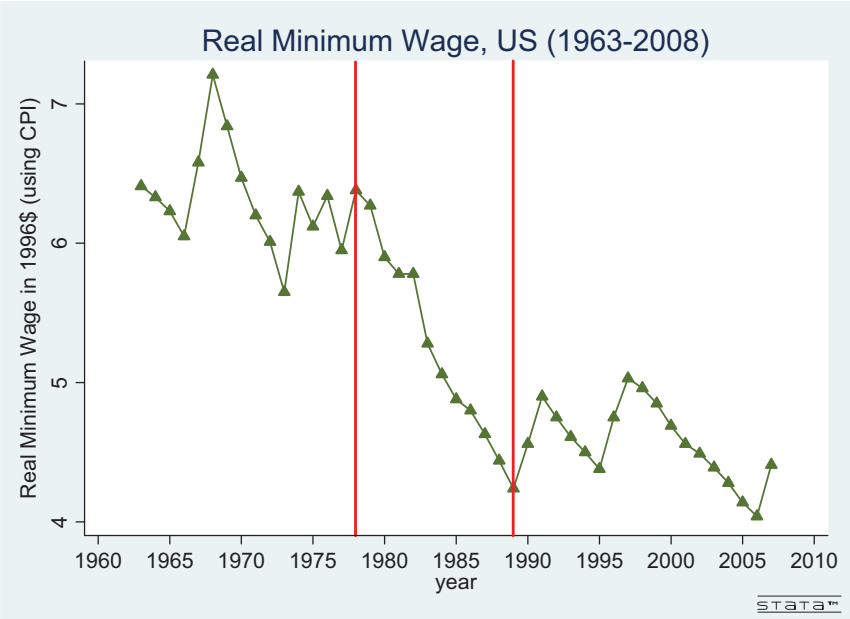


Figure 13: The time series for the real minimum wage is calculated using the CPI deflator in 1996 US dollars. Most of the decline of the real minimum wage occurred during the period 1978-1989. Compared with this graph with graph 15, we can see that the decline of the real wage for the group of unskilled inexperienced workers started almost a decade earlier, in particular in 1970 and extended for a decade later, more precisely until 1997. This implies that probably it was not the mere fact that real minimum wage declined that led to an increase in wage inequality. On the contrary, it should be something fundamental, such as the decline of the productivity of the average worker at the group of unskilled inexperienced workers that led to a decrease in the average wage of that group and this in turn boosted wage inequality. Source: US Department of Labor.

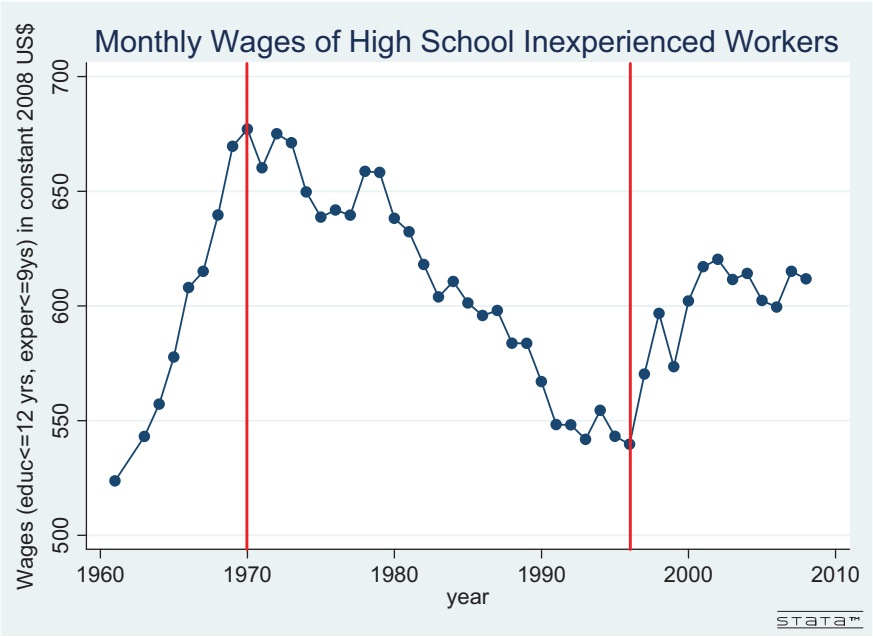
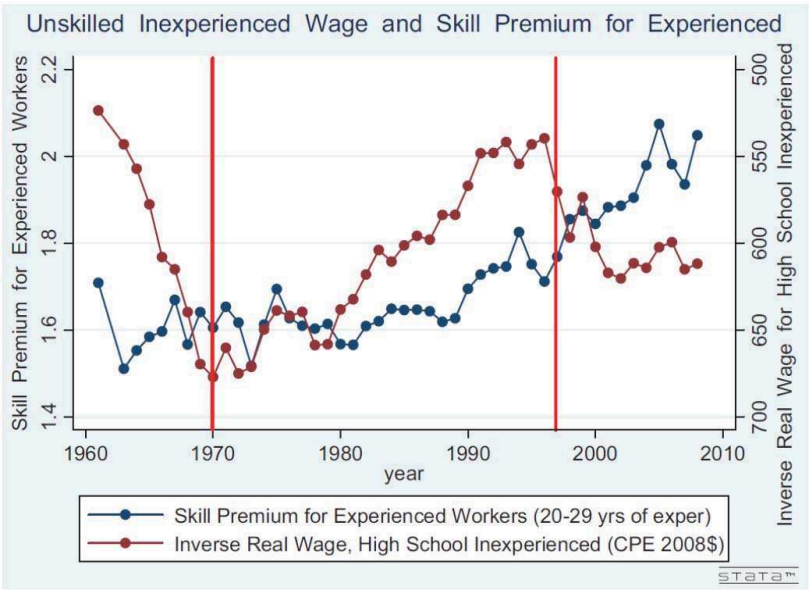
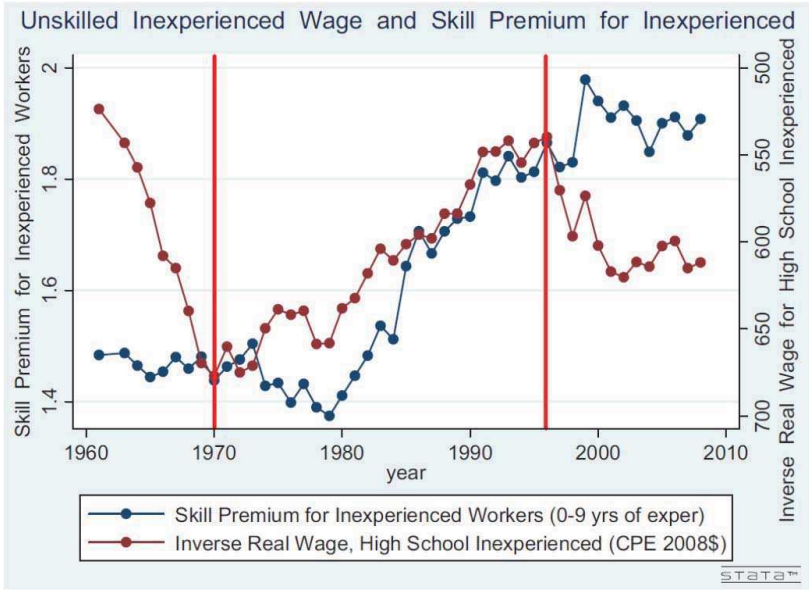
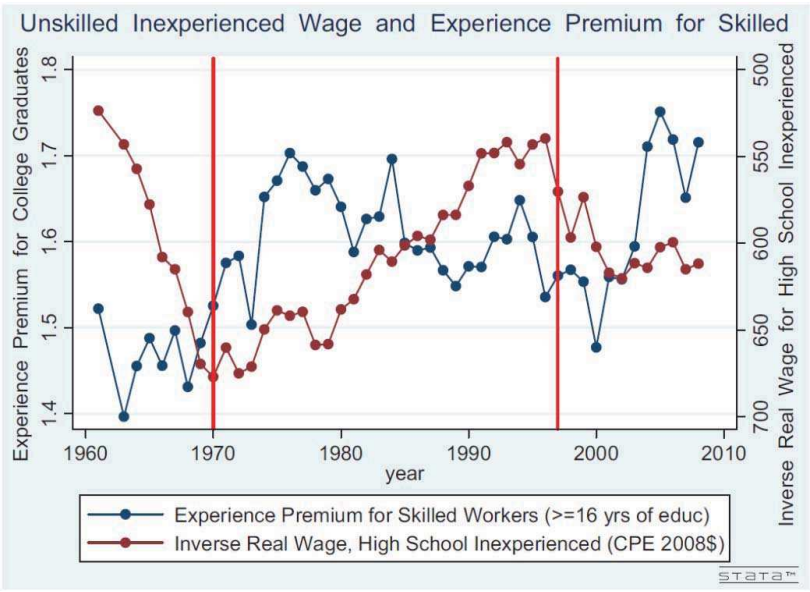


Figure 14: The time series of the real monthly wage for workers with less than or equal to 12 years of schooling (less than high school graduates) and with less than 9 years of experience. The sample is for white males only for the US. The two vertical lines highlight the decline of the unskilled inexperienced wage during the period 1970-1997. Source: March CPS 1961, 1963-2008.







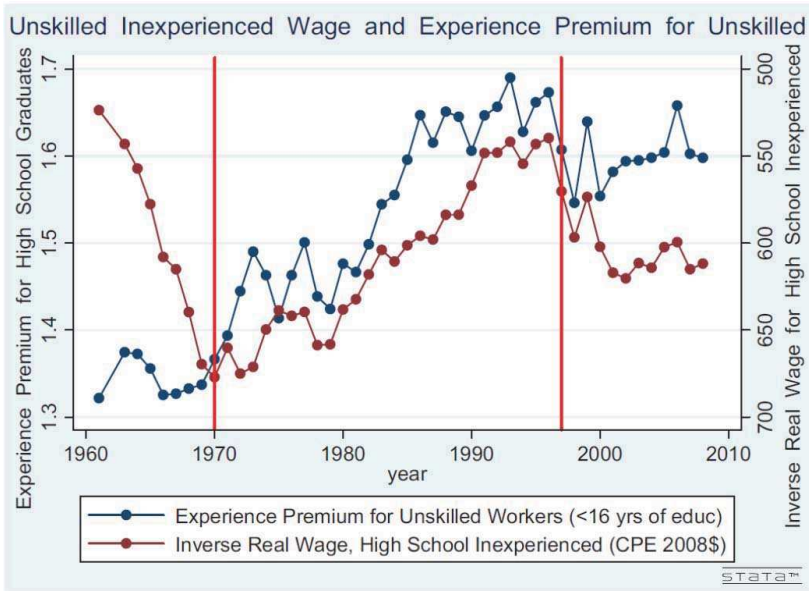


Figure 15: The inverse of the real wage for unskilled inexperienced workers almost coincides with both the skill premium for experienced and inexperienced workers, as well as with the experience premium for unskilled workers (see the north-west, north-east and south-east graphs respectively). This happens during the period 1970-1997 (indicated by the two vertical lines on each graph), when credit constraints relaxed and college attendance increased, as my study suggests. The north-west graph illustrates that the inverse of the real wage for unskilled inexperienced workers and the skill premium for experienced workers co-move but the rise in this wage premium is smaller compared to the skill premium for inexperienced ones. A fact in line with my theoretical results. On the contrary, the south-west graph shows that the experience premium for skilled workers does not relate with the real wages for unskilled inexperienced workers and has a constant trend from 1970 to 1997. All these facts are in perfect harmony with the predictions of my theoretical model, since the increase in the three out of the four wage premia occurs due to the decline of the wage for unskilled inexperienced workers, while there is no increase in the experience premium for skilled workers.

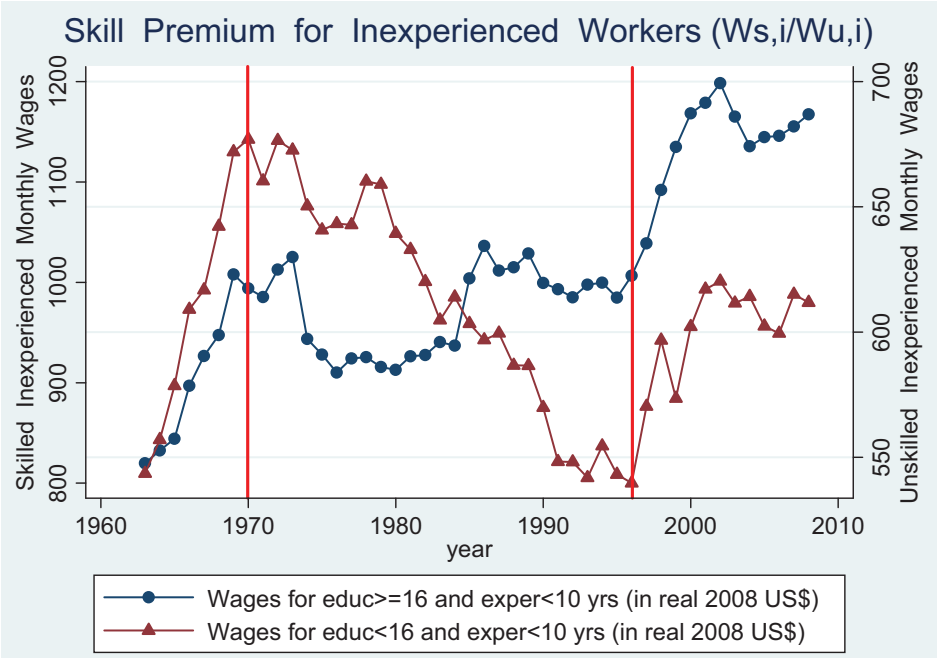


Figure 16: The skill premium for inexperienced workers, expressed as the ratio of skilled-inexperienced to unskilled-inexperienced wages, increases mainly due to the fall of the denominator. The figure highlights that especially during the period 1970-1997, unskilled-inexperienced wages have declined significantly, while skilled-inexperienced wages have remained constant. Source: March CPS 1963-2008.

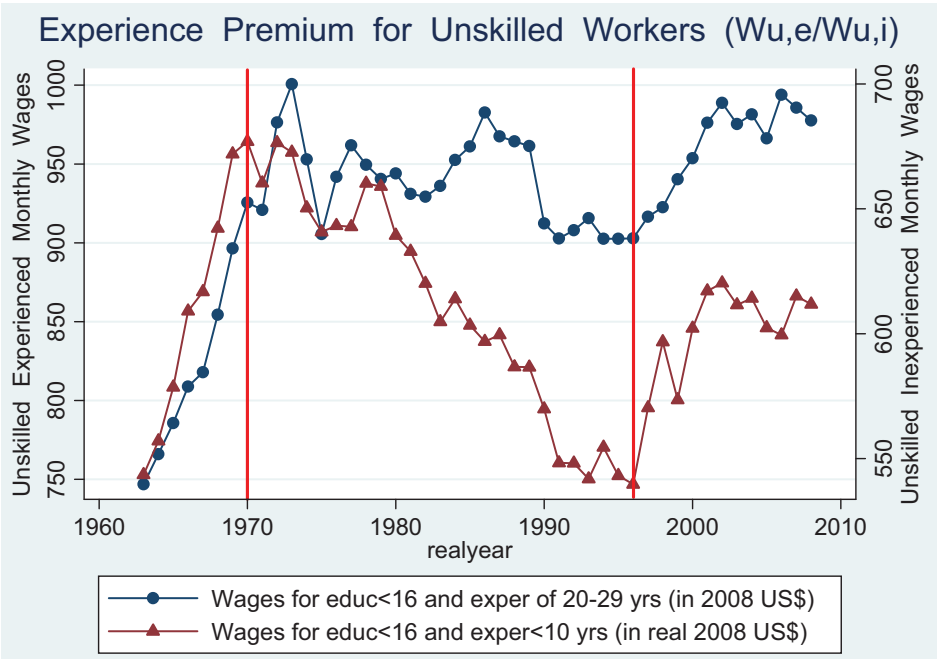


Figure 17: The experience premium for unskilled workers, expressed as the ratio of unskilled-experienced to unskilled-inexperienced wages, increases mainly due to the fall of the denominator. The figure highlights that especially during the period 1970-1997, unskilled-inexperienced wages have declined significantly, while unskilled-experienced wages have remained constant. Source: March CPS 1963-2008.

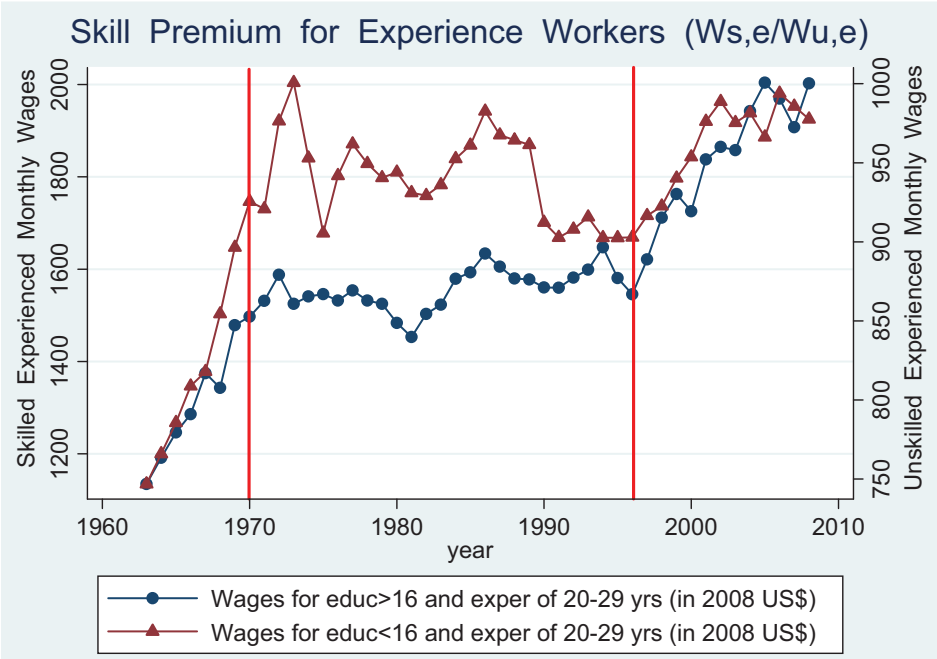


Figure 18: The skill premium for experienced workers, expressed as the ratio of skilled-experienced to unskilled-experienced wages, increases slightly mainly due to fluctuations on the denominator. The figure highlights that especially during the period 1970-1997, unskilled-experienced wages have declined slightly, while skilled-experienced wages have remained constant. Source: March CPS 1963-2008.

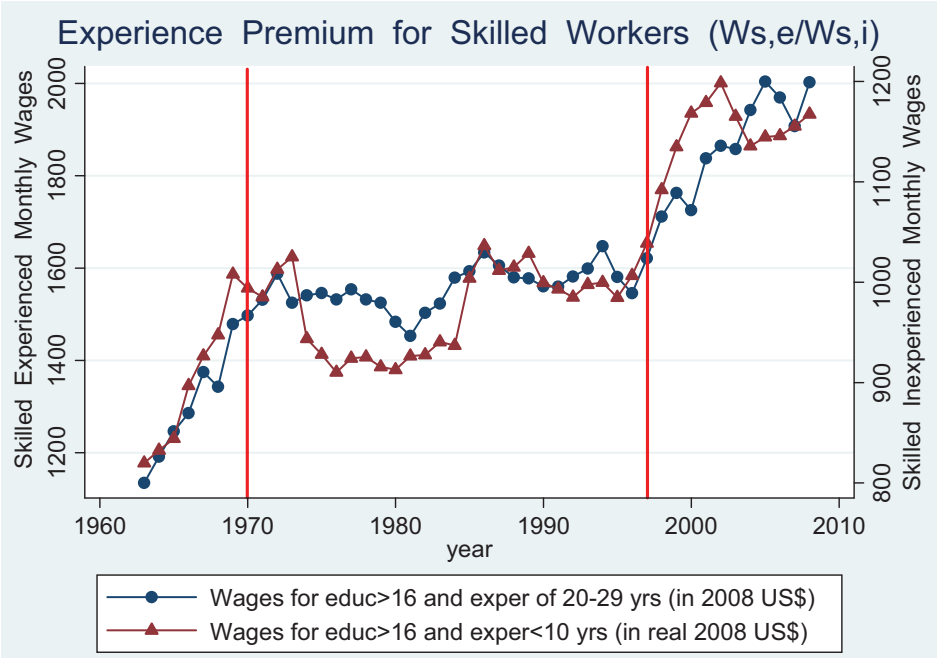


Figure 19: The experience premium for skilled workers, expressed as the ratio of skilled-experienced to skilled-inexperienced wages, remained constant. The figure highlights that the nominator and the denominator co-move. Source: March CPS 1963-2008.

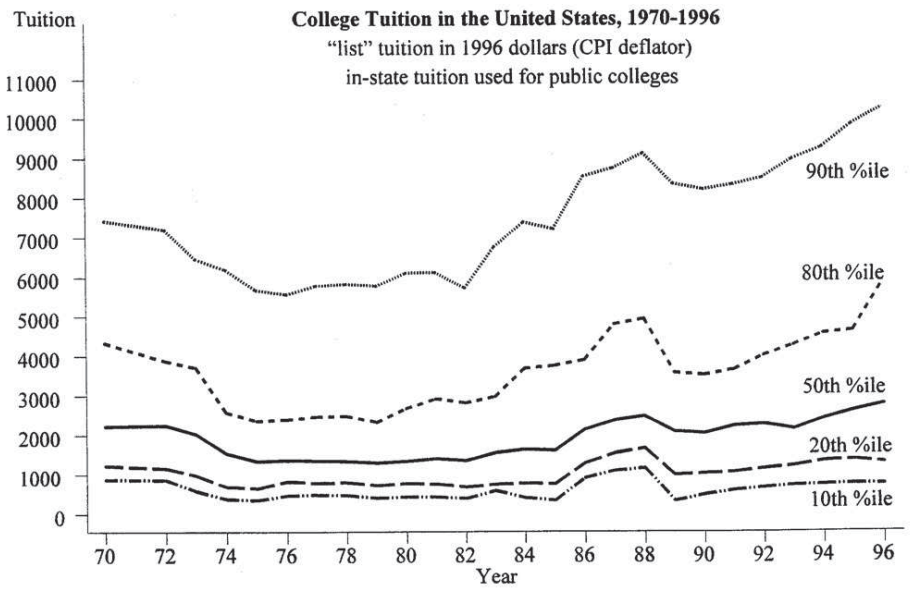


Figure 20: The tuition fees in real terms have not increased much over the period 1970-1996 for most of the colleges. The increase in the average tuition cost is mainly driven by the sharp rise at the top colleges. Source: Hoxby (2000).



Figure 21: The figure highlights that unskilled wages have declined significantly mainly for inexperienced workers. This figure provides a comparison of the empirical validity between the theoretical prediction of this paper (unskilled-inexperienced wages fall) and the one by Hendel et al. (2005) (unskilled wages fall). Sample: white males. Source: March CPS 1963-2008.

Appendix IV: Tables and Charts

Dependent Variable: log (wage)				
	1963		2008	
Constant	5.554***	5.350***	4.825***	4.604***
	(0.019)	(0.020)	(0.018)	(0.018)
Schooling	0.065***	0.063***	0.126***	0.122***
	(0.001)	(0.001)	(0.001)	(0.001)
Experience	0.009***	0.036***	0.013***	0.050***
	(0.0003)	(0.001)	(0.0003)	(0.001)
Experience^2		-0.0006***		-0.0009***
		(0.00002)		(0.00002)
Adj R-squared	0.19	0.23	0.30	0.33
Observations	10,762	10,762	29,932	29,932

Note: The dependent variable is log weekly real labor income in 2008 US dollars. The independent variables are schooling in year of completed education, potential experience that is age minus education minus 6, and potential experience square. All samples are comprised of white males of age 16-64, working full-time, full-year (more than 35 hours per week, more than 40 weeks per year). Standard errors are displayed in the parenthesis and asterisks indicate statistical significance at the 1% (***), 5% (**) and 10% (*) significance level.

Table 1: Comparisons of the standard mincerian log-wage regression for the years 1963 and 2008, with both linear and quadratic terms on potential experience. The sample is comprised of white males only for the US. Source: March CPS 1963 and 2008.

Dependent Variable: Years of Education						
	NLSY1979			NLSY1979		
	Education>11	Education>12	Education>15	Education<12	Education<13	Education<16
Constant	294.8720***	291.4874***	152.1252***	-32.2481	-59.5123	16.6283
	(62.4682)	(81.2068)	(85.0348)	(139.1065)	(60.7767)	(56.5152)
Ability (AFQT)	0.0412***	0.0300***	0.0125***	0.0307***	0.0268***	0.0362***
	(0.0012)	(0.0018)	(0.0023)	(0.0034)	(0.0012)	(0.0010)
Female	0.0245	-0.1574**	-0.2390***	-0.1608	0.0401	0.1504***
	(0.0602)	(0.0777)	(0.0799)	(0.1372)	(0.0595)	(0.0550)
Black	0.8636***	0.2543**	-0.0203	1.0429***	0.6957***	1.1336***
	(0.0833)	(0.1149)	(0.1298)	(0.1732)	(0.0785)	(0.0716)
Hispanic	0.3770***	-0.0150	0.1244	-0.4916***	-0.3116***	0.1673**
	(0.0957)	(0.1285)	(0.1521)	(0.1817)	(0.0873)	(0.0808)
Year of Birth	0.1472***	-0.1438***	-0.0703***	0.0192	0.0341	-0.0054***
	(0.0319)	(0.0415)	(0.0434)	(0.0710)	(0.0310)	(0.0289)
Adjusted R-squared	0.30	0.20	0.06	0.21	0.23	0.31
Observations	3,134	1,598	769	575	2,111	2,940

Table 2: Comparisons of regressions on education. Control variables include ability measured by the AFQT, year of birth and dummy variables on gender and race. Different columns correspond to different education groups. Education is measured in 1987 and individuals are between 26 and 30 years old. Source: NLSY1979.

Dependent Variable: Years of Education						
	NLSY1997			NLSY1997		
	Education>11	Education>12	Education>15	Education<12	Education<13	Education<16
Constant	16.1295	96.4154***	134.3090***	-38.4699	42.2241	-29.1668
	(41.2377)	(43.0594)	(41.1139)	(51.7319)	(38.9129)	(37.3145)
Ability (AFQT)	0.0353***	0.0243***	0.0080***	0.0078***	0.0123***	0.0256***
	(0.0010)	(0.0013)	(0.0013)	(0.0013)	(0.0010)	(0.0009)
Female	0.4730***	0.3505***	0.1265**	-0.0044	0.0913*	0.2262***
	(0.0582)	(0.0609)	(0.0574)	(0.0717)	(0.0547)	(0.0529)
Black	0.0925	-0.1459*	0.2066***	0.1967**	0.0696	0.3828***
	(0.0752)	(0.0798)	(0.0802)	(0.0908)	(0.0685)	(0.0655)
Hispanic	-0.1433*	-0.2487***	0.0643	0.2160**	0.0247	0.2106***
	(0.0807)	(0.0866)	(0.0878)	(0.0938)	(0.0713)	(0.0696)
Year of Birth	-0.0039	-0.0430**	-0.0600***	0.0237	-0.0167	0.0188***
	(0.0208)	(0.0217)	(0.0207)	(0.0210)	(0.0196)	(0.0189)
Adjusted R-squared	0.23	0.14	0.02	0.03	0.07	0.17
Observations	4,804	3,400	1,865	1,100	2,504	4,039

Table 3: Comparisons of regressions on education. Control variables include ability measured by the AFQT, year of birth and dummy variables on gender and race. Different columns correspond to different education groups. Education is measured in 2010 and individuals are between 26 and 30 years old. Source: NLSY1997. One can directly compare the results of table 3 with the ones displayed on table 2 from the NLSY1979, as the two datasets are adjusted for precise comparisons between the two surveys.

Correlations between ability and education for different education groups.

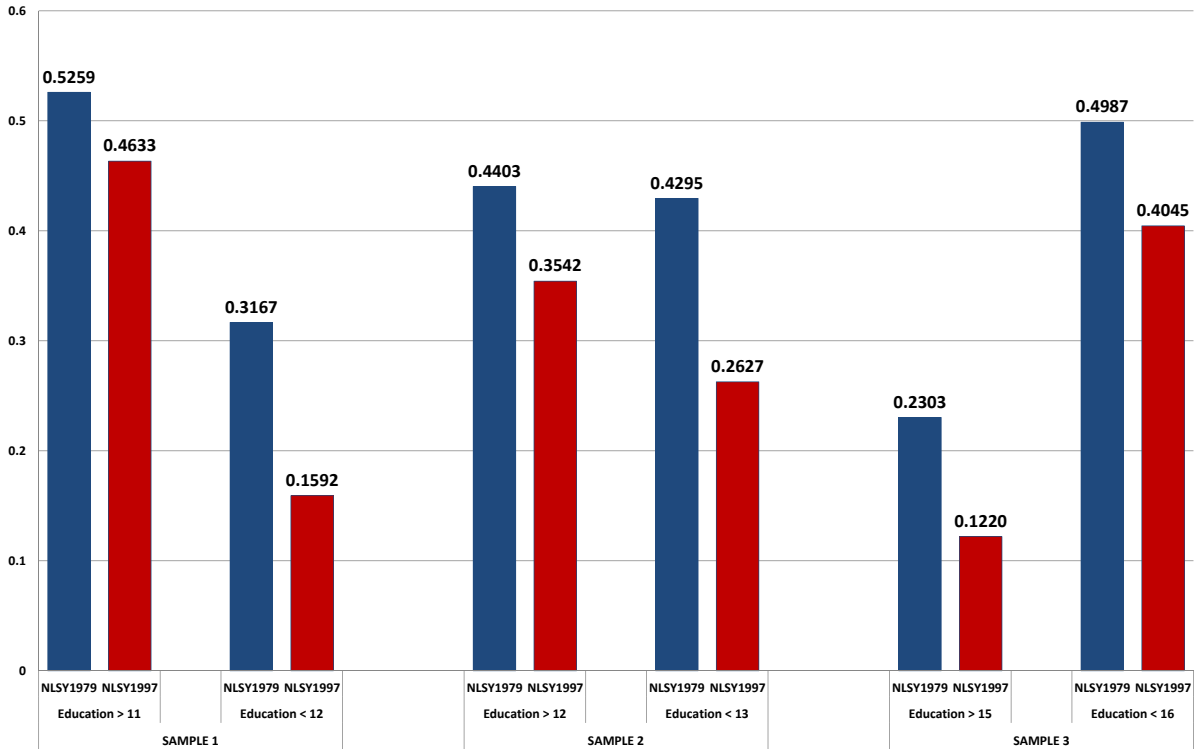


Chart 1: The charts display the allocation of ability, measured by AFQT, in education groups.

Coefficients on ability from regressions on education for different education groups.

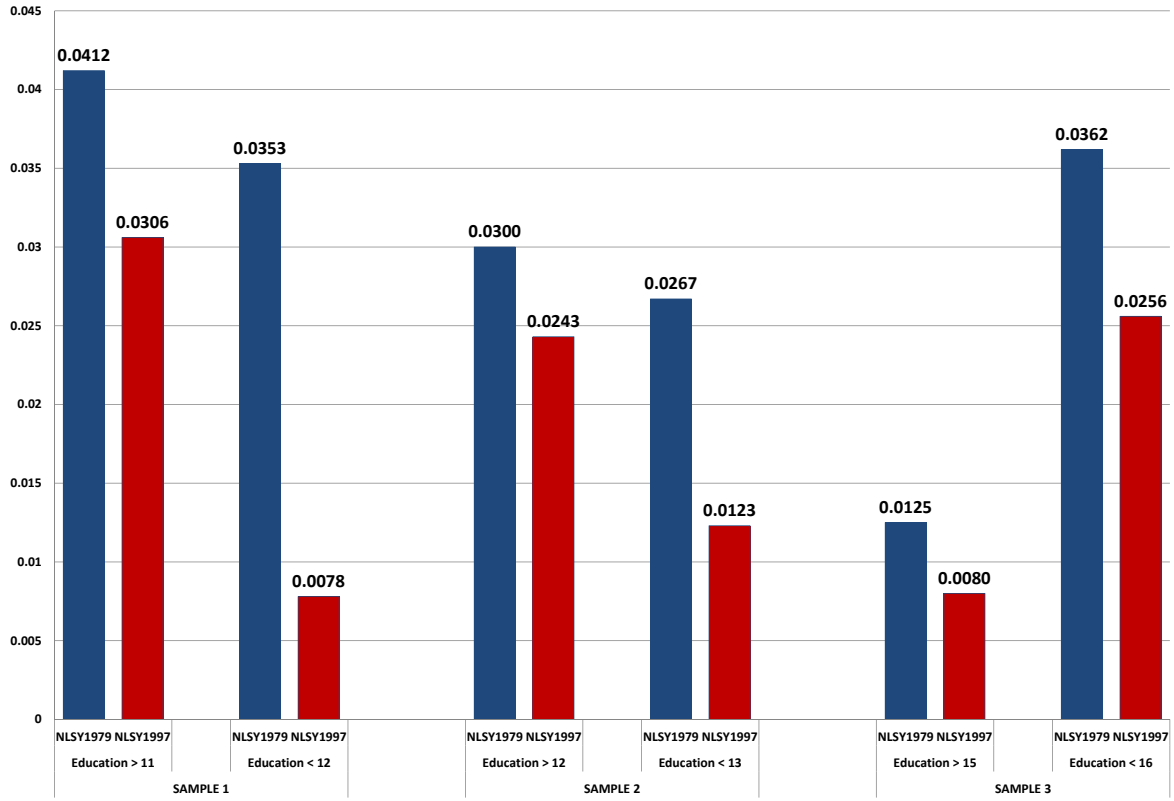


Chart 2: The charts compare the coefficients on ability measured by AFQT from regressions on education. Other control variables apart form AFQT include, year of birth and dummy variables on gender and race. Different columns correspond to different education groups for the NLSY1979 and NLSY1997. Education is measured in 1987 for the NLSY1979 and in 2010 for NLSY1997 and individuals are between 26 and 30 years old. AFQT is adjusted for both the difference at the time of examination and for pencil-based exams. Source: NLSY1979 and NLSY1997.

The difference between the coefficients on ability for different education groups.

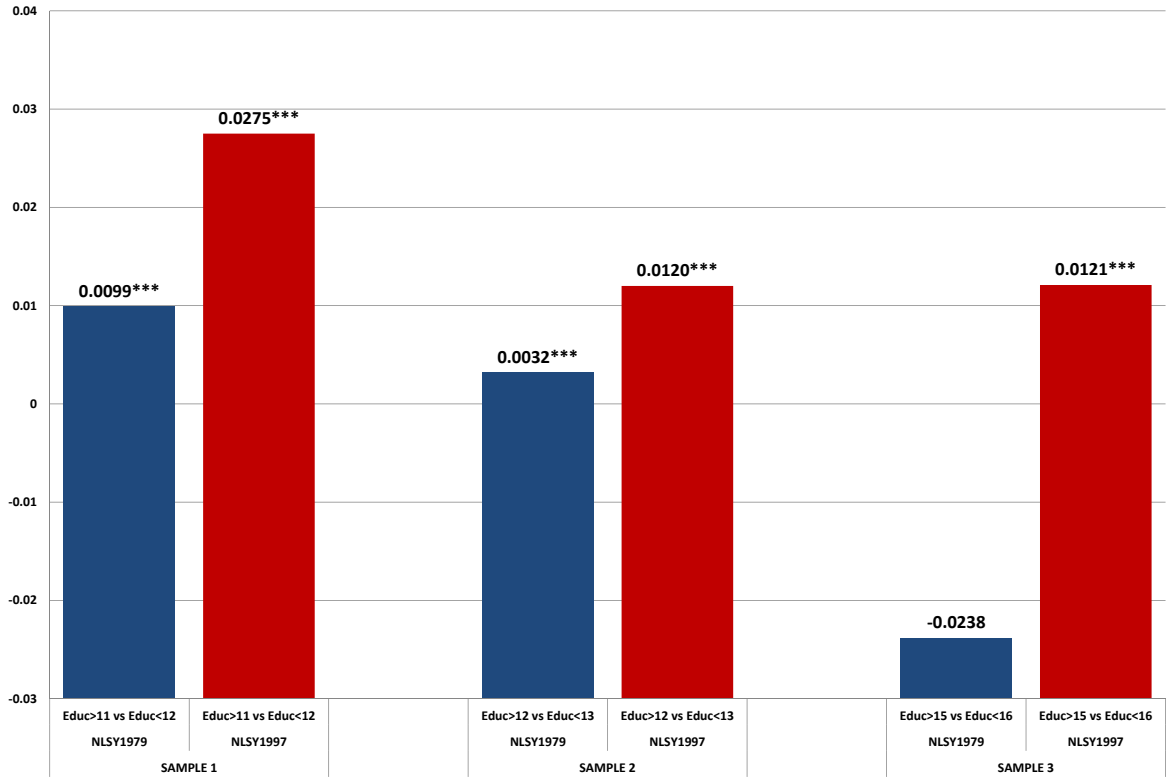


Chart 3: The charts illustrate the difference on ability between high and low educated groups for the same year. The dependent variable of the regression is education in years and the control variables include ability measured by AFQT, year of birth and dummy variables on gender and race, as well as interaction terms of all the above-mentioned control variables with a dummy which equals one if the individual belongs to one of the high educated groups (educ>11, educ>12 or educ>15). The charts display the coefficient on the interaction term of AFQT with the dummy for high education groups. All coefficients are statistically significant even at the 1% significance level, apart from the next to last for the value -0.0238. Different columns correspond to different education groups for the NLSY1979 and NLSY1997. Education is measured in 1987 for the NLSY1979 and in 2010 for NLSY1997 and individuals are between 26 and 30 years old. AFQT is adjusted for both the difference at the time of examination and for pencil-based exams. Source: NLSY1979 and NLSY1997.

The difference between the coefficients on ability for different years.

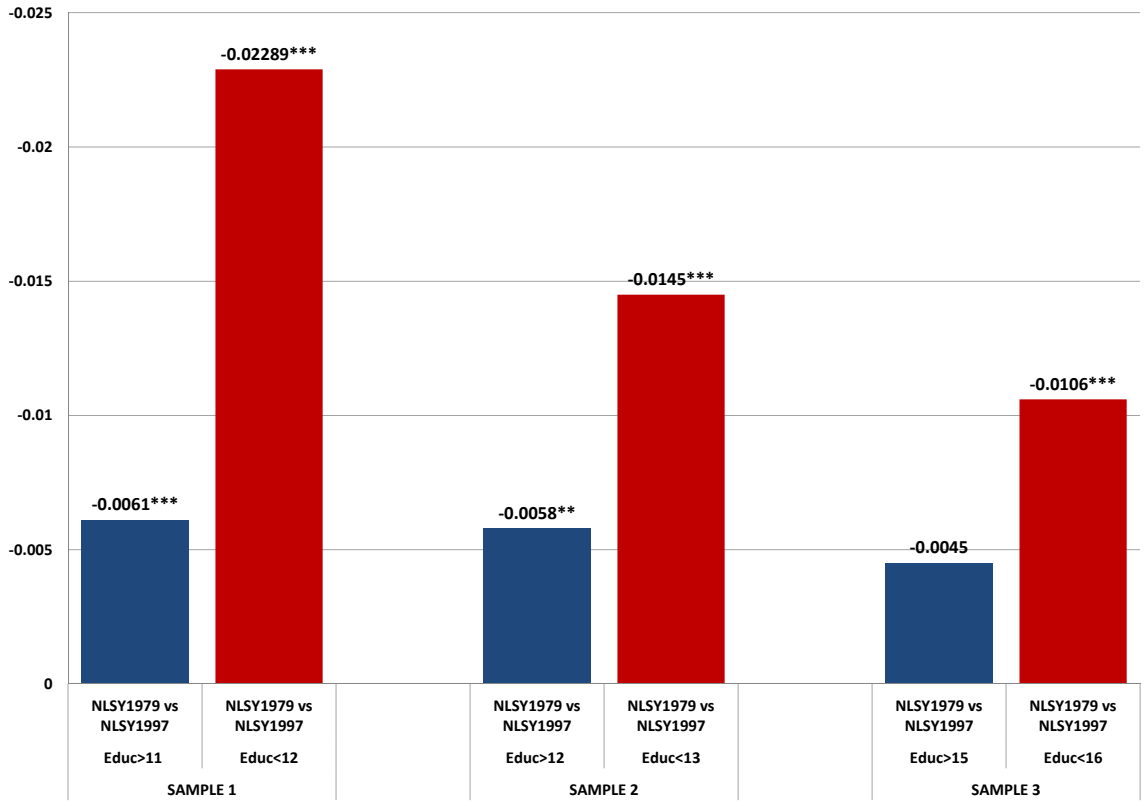


Chart 4: The charts illustrate the difference on ability for the same education group between the two surveys (NLSY1979 and NLSY1997). The dependent variable of the regression is education from the NLSY1979 and NLSY1997 and the control variables include ability measured by AFQT, year of birth and dummy variables on gender and race, as well as interaction terms of all the above-mentioned control variables with a dummy variable for individuals from the NLSY1997. For each regression individuals belong to the same education groups. The charts display the coefficient on the interaction term of AFQT with the dummy for NLSY1997. Asterisks denote significance levels, three for significance at the 1% level, two for the 5% level and one for the 10% level. Different columns correspond to different education groups for the NLSY1979 and NLSY1997. Education is measured in 1987 for the NLSY1979 and in 2010 for NLSY1997 and individuals are between 26 and 30 years old. AFQT is adjusted for both the difference at the time of examination and for pencil-based exams. Source: NLSY1979 and NLSY1997.

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