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

By Theodore Koutmeridis*

This paper offers a unified explanation for the perplexing fact that the education premium grows more for low-experienced labor, while the experience premium rises only for low-educated workers. The interaction of private employer learning, signaling and financial constraints solves this puzzle. When credit expands, talented individuals acquire skills and leave the uneducated pool. This decreases unskilled-inexperienced wages and boosts inequality, highlighting that more equal opportunities increase wage inequality. This explanation fits US data, indicating that for three decades the rise in the education and the experience premium coincided with falling unskilled-inexperienced wages, while skilled or experienced wages remained relatively flat. (JEL D31, J31)

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. Some patterns of increasing wage inequality, such as the rise in the education premium, are well-documented in the literature. Nevertheless, 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 since 1970's 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. Even though there is a debate of whether growing wage inequality should be a worry, politicians agree that more equality of opportunity is a virtuous development. This paper provides an explanation for the puzzling patterns of US wage distribution and establishes that the improved functioning of markets over that period played an important role in generating more opportunities but also in boosting wage inequality.

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 importance in understanding the effects of technical change on inequality, this approach fails to explain the rising wage gap between groups with

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

different levels of working experience, as well as the evolution of wage inequality within different education and experience groups.[2]

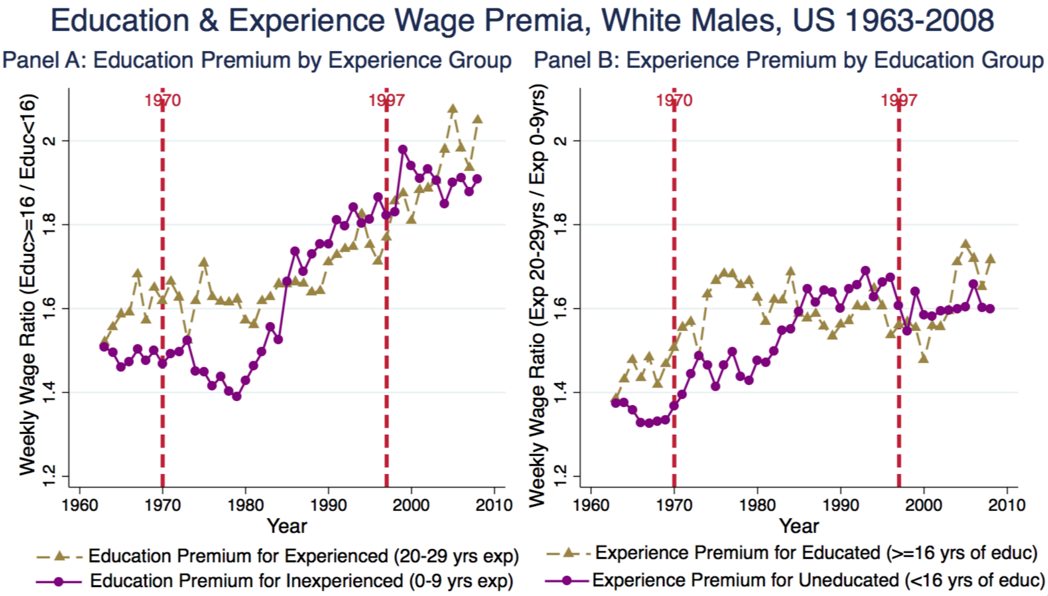


FIGURE 1: WAGE PREMIA WITHIN EDUCATION AND EXPERIENCE GROUP

Source: Current Population Survey, March Supplement, 1963-2008, white males, United States.

Several studies document the rise in the education wage premium but they usually focus on the average ratio of both experienced and inexperienced workers.[3] A more careful examination reveals that the education premium rises sharply for low-experienced workers and only moderately for the highly experienced ones (Card and Lemieux [2001]). Similarly, the experience premium grows only for low-educated labor (Weinberg [2004]). Figure 1 compares and contrasts these wage premia. Table 1 shows that over the period 1970-1997 the annual rise of the education premium for low-experienced workers is three times larger than the rise in the education premium for the highly experienced ones, while the experience premium increases only for low-educated labor and for highly educated workers it remains flat.[4] Wages are influenced more by education in the absence of working experience, while experience affects wages more in the absence of higher education, suggesting that ability is revealed to uninformed firms either through formal education signals or with experience as employers observe their workers and informally learn their talents.

The introduction of private employer learning in a model of education signaling with credit constraints explains these patterns. 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 in a pooling wage for all uneducated workers. However, with working experience firms privately learn their workers' type. Private learning implies that incumbent employers are better informed for the type of their own employees compared to potential competitors.

[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.
[4]Columns (1)-(3) of panel C, Table 1 show that the trend for the pooled education premium is 0.0079, for inexperienced workers it is 0.0111, while for the experienced ones it is 0.0036. Columns (1)-(3) of panel D show that the trend for the pooled experience premium is 0.0055, for low-educated workers it is 0.0072, while for highly-educated it is an insignificant -0.0003. Similar results with composition adjustment.

Table 1: Log Wage Premia Regressions Within Education-Experience Groups

Panel A: Education Premium within Experience Group, 1963-2008

	Dependent Variable: log(Education Premium):Wage(Educ>=16)/Wage(Educ<16)					
	Without Composition Adjustment			Composition-Adjusted Wage Premium		
	All	Exper<10	Exper>=10	All	Exper<10	Exper>=10
	(1)	(2)	(3)	(4)	(5)	(6)
Year	0.0073***	0.0078***	0.0053***	0.0155***	0.0095***	0.0088***
	(0.0005)	(0.0006)	(0.0004)	(0.0009)	(0.0010)	(0.0010)
Composition				-0.3555***	-0.1581**	-0.1274***
				(0.0364)	(0.0775)	(0.0346)
Adj R-squared	0.829	0.806	0.767	0.946	0.819	0.819
Observations	46	46	46	46	46	46

Panel B: Experience Premium within Education Group, 1963-2008

	Dependent Variable: log(Experience Premium):Wage(Exp>=10)/Wage(Expc<10)					
	Without Composition Adjustment			Composition-Adjusted Wage Premium		
	All	Educ<16	Educ>=16	All	Educ<16	Educ>=16
	(1)	(2)	(3)	(4)	(5)	(6)
Year	0.0054***	0.0048***	0.0022***	0.0061***	0.0051***	0.0047***
	(0.0004)	(0.0004)	(0.0005)	(0.0003)	(0.0004)	(0.0007)
Composition				-0.0777***	-0.0639***	-0.1073***
				(0.0109)	(0.0175)	(0.0228)
Adj R-squared	0.838	0.727	0.275	0.924	0.787	0.511
Observations	46	46	46	46	46	46

Panel C: Education Premium within Experience Group, 1970-1997

	Dependent Variable: log(Education Premium):Wage(Educ>=16)/Wage(Educ<16)					
	Without Composition Adjustment			Composition-Adjusted Wage Premium		
	All	Exper<10	Exper>=10	All	Exper<10	Exper>=10
	(1)	(2)	(3)	(4)	(5)	(6)
Year	0.0079***	0.0111***	0.0036***	0.0161***	0.0128***	0.0035
	(0.0008)	(0.0011)	(0.0007)	(0.0019)	(0.0023)	(0.0030)
Composition				-0.3478***	-0.1445	0.0025
				(0.0752)	(0.1644)	(0.1116)
Adj R-squared	0.762	0.786	0.509	0.867	0.784	0.489
Observations	28	28	28	28	28	28

Panel D: Experience Premium within Education Group, 1970-1997

	Dependent Variable: log(Experience Premium):Wage(Exp>=10)/Wage(Expc<10)					
	Without Composition Adjustment			Composition-Adjusted Wage Premium		
	All	Educ<16	Educ>=16	All	Educ<16	Educ>=16
	(1)	(2)	(3)	(4)	(5)	(6)
Year	0.0055***	0.0072***	-0.0003	0.0060***	0.0073***	0.0019*
	(0.0004)	(0.0006)	(0.0008)	(0.0004)	(0.0007)	(0.0009)
Composition				-0.0405**	-0.0104	-0.0907***
				(0.0155)	(0.0246)	(0.0267)
Adj R-squared	0.854	0.838	-0.031	0.881	0.832	0.267
Observations	28	28	28	28	28	28

Notes: Annual time trend from log wage premium OLS regressions within education-experience group for white males. Columns (1)-(3) correspond to the unadjusted log wage ratio, while columns (4)-(6) link to the equivalent ratio adjusting for the relative supply of workers (composition effect). The first of the three columns with and without composition adjustment relates to all workers, while the other two for particular education or experience groups, as specified on the table. Panels A and B correspond to the period 1963-2008, while panels C and D to the period 1970-1997. In the parentheses standard errors are displayed. Source: March Current Population Survey, US. Significance at the 1%, 5%, 10% significance level is indicated respectively by ***, ** and *.

Privately observable performance allows firms to derive an information rent by sorting their workers better, which consequently leads to different wage paths for uneducated workers, depending on their revealed ability-type. When financial frictions relax, a larger fraction of talented persons 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 boosts inequality.[5]

This microfounded model explains: the increase in the skill premium despite the growing supply of skills; the understudied 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.[6]

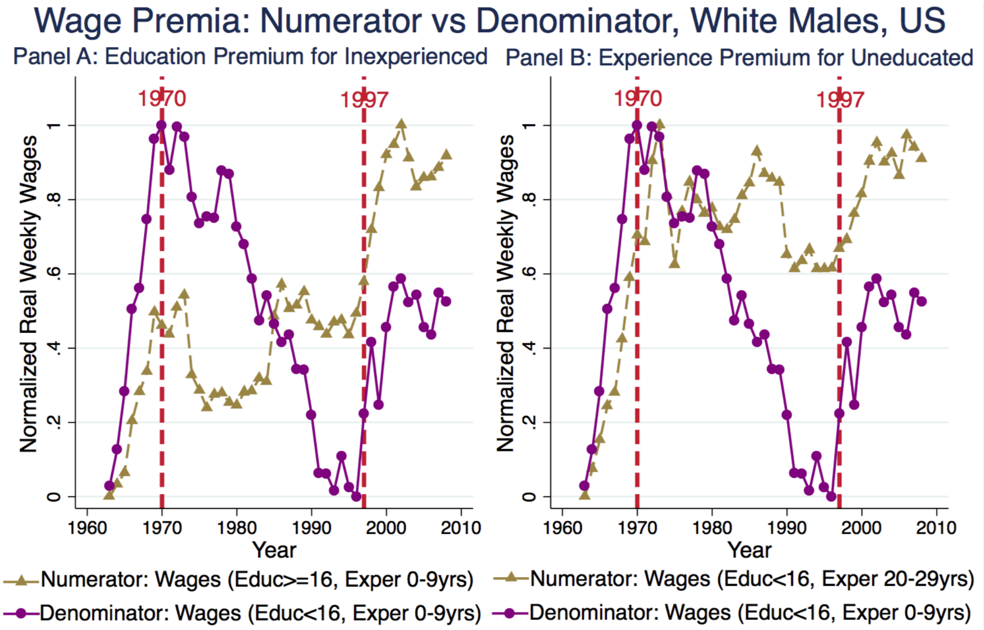


FIGURE 2: INCREASING WAGE PREMIA: RISING NUMERATOR OR FALLING DENOMINATOR?

Notes: Sample: Current Population Survey, March Supplement, 1963-2008, white males, United States.

An important prediction 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 education and the experience premium coincides with a fall in unskilled-inexperienced wages (denominator), while skilled or experienced wages (numerator) remain constant (see figure 2). My theory suggests that on average, ability for uneducated workers has dropped. Using the National Longitudinal Surveys of Youth, I confirm empirically this sorting hypothesis, by showing that the average uneducated worker has become of lower ability. I also exclude other potential explanations by showing that for the relatively more educated workers, there might be a decline in ability too, however this decline over time is not always statistically significant and it is smaller in magnitude compared to the one for low-educated workers.[7] Ultimately, I examine the fit of my model and I compare this

[5] The reason why we focus on wage inequality trends without composition adjustment (columns (1)-(3) on Table 1), is precisely that labor productivity for each education-experience group can change.

[6] These results can also hold when the purely informational model with signaling and employer learning, extends with returns to education due to human capital and returns to experience due to employee learning.

[7] Carneiro and Lee (2011) find that ability falls mainly for college graduates.

to the skill-biased technical change (SBTC) approach. The two models are complementary, as I focus on supply factors, while the SBTC approach emphasizes labor demand. The two theories together seem to provide a better understanding of labor income distribution, compared to each approach alone.

This paper contributes to a *microeconomic debate* on the signaling and the human capital returns to education. Existing relevant studies relate to three branches of the literature centering on signaling, employer learning and credit constraints. In this sense this paper links to earlier models incorporating two of these features. However, none of them builds on a unified framework of all three elements, each of which is crucial in evaluating the effects of education and experience on inequality.

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", which dates back to Spence's (1973) seminal contribution that education also conveys information about worker's ability to uninformed firms.[8] However, employers can also derive information for the type of their workers through labor market experience. In this sense experience can also convey information generating a "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. That is why for both education and experience there exists an informational and a non-informational return.

Importantly, 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 others, for instance college graduates, which I call "employer learning asymmetric to the worker". Some of these effects have been investigated separately empirically or theoretically but to my knowledge no study has examined all these informational aspects of the labor market in a unified framework, yet.

Schönberg (2007) supports that there is no evidence for asymmetric employer learning, apart from the case of college graduates, while Kahn (2009) strongly favors asymmetric employer learning. Arcidiacono et al. (2010) show that education principally reveals ability, that is why ability is almost perfectly observed for college graduates, while for high school graduates ability is gradually revealed with tenure.[9] That is why employer learning is important only for this group.[10] This is in line with my model of asymmetric employer learning to the firm and the worker, as I assume that incumbent firms learn better their workers' type compared to potential competitors and I find that learning matters only for low-educated employees.[11]

Card (2001) highlights the consistently higher IV estimates of education on wages,

[8]Bedard (2001) examines credit constraints in education to find that signaling is empirically more plausible than the human capital explanation, while Chevalier et al. (2004) find the opposite.

[9]Dustmann and Meghir (2005) distinguish general experience from sector tenure and firm-specific tenure and suggest that while the acquisition of transferable skills is important for the wage growth of skilled workers early in their career, unskilled workers benefit primarily from being attached to a particular firm. This shows that informational frictions are important for unskilled young workers and this asymmetric effect might drive the rise in the experience premium when different skill groups are pooled together.

[10]Bauer and Haisken-DeNew (2001) find no evidence of employer learning apart from the case of blue-collar workers at the lower end of distribution, while Galindo-Rueda (2003) finds that learning among blue-collar workers, favors incumbent employers (asymmetric employer learning).

[11]Farber and Gibbons (1996) develop a model with employer learning and they conclude that ability measures, unobserved by employers, are increasingly correlated with wages as experience rises. Altonji (2005) argues that markets might delay to learn that a worker is highly able if her low-skill-level job reveals little about her talent. See also Jovanovic (1979) for one of the earliest contributions on employer learning.

compared to the standard OLS. He attributes this difference of 20-30 percent to the existence of credit constraints.[12] Carneiro and Heckman (2002) provide an alternative view on this *policy debate* by showing that credit constraints are not important after controlling for long-run constraints related to student ability. They also question the validity of IVs on education in the existing literature and they conclude that at the most an 8 percent of the US population is credit constrained.[13]

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.[14] 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.[15] Their influential framework provides a new explanation for the rising education premium but it is inappropriate for the study of the experience premium, as well as for the evolution of within group wage inequality.

The main finding in Hendel et al. (2005) that unskilled wages fall and this accounts for the rising education premium, finds weak empirical support. However, once we break down the education premium to different experience groups, I can show that the decline of unskilled-inexperienced wages leads to rising wage inequality. Over the period 1970-1997 real unskilled wages declined only by 2.6 percent, while wages for unskilled-inexperienced workers have fallen by 15.7 percent (see online Appendix A2). To reconcile this fact with theory, apart from education I also study experience by introducing private employer learning. The fact that the inclusion of employer learning in a signaling model explains the perplexing patterns of wage inequality, is not a coincidence. 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.[16] This extension not only explains some puzzling empirical facts but also yields some realistic policy implications.

My paper also contributes to a *macroeocnomic debate* related to technology and wage inequality. Katz and Murphy (1992) suggest that in the US the contribution of education and experience on wages has increased since 1970's despite the rising supply of skills, mainly due to technology-skill complementarity.[17] Krueger et al. (2010) show that the skill premium 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 is similar for most countries and consists a fact that is ignored in most existing studies.[18] My study fills this gap in the macro-labor literature related to the experience premium.

Heathcote et al. (2010) stress that "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 weak, while the emphatic focus on technology has diverted attention away from

[12]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.

[13]Lochner and Monje-Naranjo (2011 and 2012) focus on the sources of funding, providing evidence on the allocation of talent in education, and survey the literature on credit constraints in education, respectively.

[14]Townsend (1979) and Krugman (2000) combine credit constraints and information asymmetries, too.

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

[16]Altonji and Pierret (1996), Habermalz (2006), Lange (2007) and Kaymak (2007) find that a high speed of employer learning leads to a limited signaling value, which is 22-25 percent of the total value of education.

[17]Berman et al. (1998) provide international evidence supporting SBTC.

[18]Murphy and Welch (1992), Juhn et al. (1993), Lemieux (2006a) and Goldin and Katz (2007) also suggest that education and experience explain a large component of wage variation.

other interesting developments in the wage structure, such as the rising experience premium, which cannot be easily explained by SBTC.[19] They conclude that technology might have been responsible for the widening inequality of the 1970's; however, since 1980's other factors might had a stronger influence.[20,21]

The surprisingly enough, few existing studies that examine the experience premium are based on: SBTC with on-the-job training (Heckman et al. [1998]), general purpose technologies (Aghion et al. [2002]), technology-experience complementarity in adoption (Weinberg [2004]), vintage human capital (Hornstein et al. [2005]), demographic change (Jeong et al. [2010]).[22] All these studies emphasize how technology affects experience. I approach experience from a different angle and I focus mainly on employer learning, which is the informational component of experience.[23]

The most important theoretical explanations on the education premium, relate to directed technical change (Acemoglu (1998) and Kiley [1999]) and technological revolutions (Caselli [1999]).[24] 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.[25]

I summarize below these between and withing group inequality facts for the period 1970-1997: *i)* the education and the experience premium increase despite the growing supply of educated and experienced labor, *ii)* the education premium grows sharply for inexperienced workers and only moderately for the experienced ones, *iii)* there is a puzzling coexistence of rising experience premium for unskilled workers and a flat pattern for the skilled ones (see Table 1, panels C and D).

The main contribution of this paper is the revelation of a unified theory for these wage inequality facts, which finds strong empirical support in the US and yields some interesting policy implications. Chapters I, II and III provide the static model, comparative statics and a dynamic framework, respectively. Chapter IV connects theory to evidence. Chapter V explores empirically the allocation of ability in education, the fit of the theoretical model, and its relation to the SBTC approach. Chapter VI provides robustness checks, while the last chapter concludes.[26]

I. A Static Model of Sorting

The theoretical model builds on Hendel et al. (2005), which combines Spence's (1973) signaling approach with credit constraints as in Galor and Zeira (1993)

[19]This debate extends to the causes of rising residual wage inequality, which according to Violante (2002) relates to SBTC, while Lemieux (2006b) challenges this view, highlighting measurement error problems.

[20]They show evidence of the effect of minimum wages on inequality (see also Autor et al. (2010).

[21]Other sources of rising inequality include trade liberalization, immigration and the decline of labor unions. For literature reviews see Card et al. (2004), Card (2009), and Harrison et al. (2011), respectively.

[22]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).

[23]Lagakos et al. (2012) find that the experience premium is flatter in poor countries. I focus on the experience premium in the US over time but if the US of the 1970's were similar to some poor countries nowadays, then my theory might also explain the differences in the experience premium across countries.

[24]In one of the most plausible recent explanations, Autor and Dorn (2013) show that technology has mainly routinized tasks in the middle of the skill distribution, leading to employment and wage polarization.

[25]Gould et al. (2001), show that depreciation of technology raises wage inequality within skill group.

[26]See online Appendices for model's fitness, the case of zero-profits and continuum types, respectively.

to explain how the skill premium increases when credit constraints become less severe. A distinguishing feature of my model is the introduction of *private employer learning*, which allows us to examine not only the education but also the experience premium, as well as within group wage inequality.

A. 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 (good types) and a proportion $1-\pi$ of low ability ones (bad types). Workers have private information about their own type. 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.[27] 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 in the second period some of them can acquire education using the unskilled wage they have accumulated in period 1. Notice that education is a mere signal, since it does not affect worker's productivity.[28]

Firms.—Companies 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 at least two firms in order wages to equal the perfectly competitive ones. The production function exhibits constant returns to scale in labor, which is the only input (see Chapter V for diminishing returns and SBTC). 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.—The sequence of events is essential in this three-period model. In particular, during the first period of their lives some agents go to school, while others

[27]One can think of this cost as paying additional tutors, purchasing extra materials or simply time costs.
[28]This paper examines the signaling approach of wage determination, which can be combined with the human capital one and generate more realistic results (see Chapter VI).

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. For simplicity, 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: i) asymmetric information, ii) credit market imperfections and iii) private employer learning. Agents have a private information about their ability type. Individuals of high ability invest in education, try to signal their type to their potential employers and this sorting increases their wage. Education is a *costly signal*, as in Spence (1973) and the total cost differs depending on agents' type.

The second market failure relates to credit market imperfections, which are modeled as in Galor and Zeira (1993). 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 workers 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 own workers. The potential competitors still face informational frictions about the type of potential new workers. All the above is common knowledge.

Together with price taking behavior and constant returns to scale, we also assume that human capital investments are *indivisible*, which implies that education is a discrete binary choice taking either the value 0 or 1.

Lifetime Earnings.—Each agent i maximizes his lifetime earnings y^i, given his ability type j and initial wealth b^i. In this economy there are four groups of workers. I calculate lifetime earnings for each group.

Self-Funded Young Students (Group A): The first group is comprised by those who have enough wealth to cover the tuition and the effort cost when young without borrowing. Those with wealth $b^i \geq T + k^j$ get a lifetime income of:

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

Young Borrowers (Group B): 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, they seek for external funding, they borrow and their lifetime income is:

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

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

Self-funded Old Students (Group C): 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:

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

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

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

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

Assumptions.—I propose the following four assumptions that affect agents' actions. 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 assume that:

Assumption 1 (AS1): The effort cost for the low type is sufficiently high.

$$k^l > \frac{(1 + r^l)(w_2^s - w_2^{u,l}) + w_3^s - w_3^{u,l} - (1 + r^l)^2(w_1^u + T)}{(1 + r^l)^2} \tag{5}$$

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 (AS2): Even the lowest possible unskilled wage can cover the tuition.

$$T \leq (1 + r^l)q^l \tag{6}$$

All constrained high types can go to school when old after working as unskilled in period 1, since even the lowest unskilled wage ($w_1^u(min) = q^l$) can cover the tuition

(which is the only cost for high types; recall $k^h = 0$). No agent borrows when old.
Assumption 3 (AS3): Credit constraints make it profitable only for some high types to borrow and go to school when young.

$$b^i \geq \frac{(1+r^b)^2 T + (1+r^l) w_1^u - (1+r^l)(w_2^s + T)}{(1+r^b)^2 - (1+r^l)^2} \equiv b^* \tag{7}$$

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 at least the richest 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 credit constraints imply that when you are young, it is always better to be self-funded rather than borrow $y^A > y^B$.
Assumption 4 (AS4): High types prefer to separate themselves from the pool of uneducated workers at the second period of their lives, when they are old.

$$T < \frac{w_3^s - w_3^{u,P} + (1+r^l) w_2^{u,P}}{1+r^l} \tag{8}$$

High types who do not go to school young (those with initial wealth $b^i < b^*$), prefer 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:

$$y^D = (1+r^l)^2 (w_1^u + b^i) + (1+r^l) w_2^{u,P} + w_3^{u,P}, \text{ where } w_1^u \equiv w_2^{u,P} \equiv w_3^{u,P}.$$

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 $w_2^s = w_3^s = q^h$. 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 $w_2^u = w_3^u = q^l$. Notice that nobody 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_1^u.

Unambiguously there are *off-the-equilibrium path beliefs*, which I eliminate 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, uneducated high types try to work for other firms for a higher wage" can be eliminated too. The logic is that before trying to work for outside 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, generating a pooling wage for all the uneducated workers $w_2^{u,P} = w_3^{u,P} = w_1^u$. But assumption 4 yields that high types prefer to separate themselves from low types by going to school when old rather than pooling with all uneducated workers. By assumption 2 we know that this is feasible.

B. Equilibrium

I employ the following equilibrium concept

DEFINITION 1: *A Perfect Bayesian signaling equilibrium is defined as:*

1) *choices of education in the first and second period, based on ability and initial wealth:* $A_1^*(q^j, b^i) \in \{school, not\}$, $A_2^*(q^j, b^i) \in \{school, not\}$;
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:* $w_1^u, w_2^{u,h}, w_2^{u,l}, w_2^s, w_3^{u,h}, w_3^{u,l}$ *and* w_3^s.

Such that: (i) workers maximize their lifetime earnings, (ii) firms maximize their profits and (iii) labor markets clear.

We know all wages apart from w_1^u, which we have to derive to find an equilibrium.

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

$$P(u|h) = P(b^i < b^*). \tag{9}$$

Where $P(\cdot)$ represents the cumulative density function of the initial wealth distribution for high ability workers. In Figure 3 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. The higher b^* is, the greater is the number of high ability agents who do not get an education: $b^* \uparrow\ \Rightarrow P(u|h) \uparrow$. The supply curve is upward sloping, as a rise in the first period unskilled wage raises the wealth cutoff b^* by reducing the payoff to education, which raises $P(u|h)$ (see equation (7) above). An increase in tuition level T increases b^* by driving down the return to education. So, for any given unskilled wage, more high type workers do not get an education, shifting the supply curve to the right.

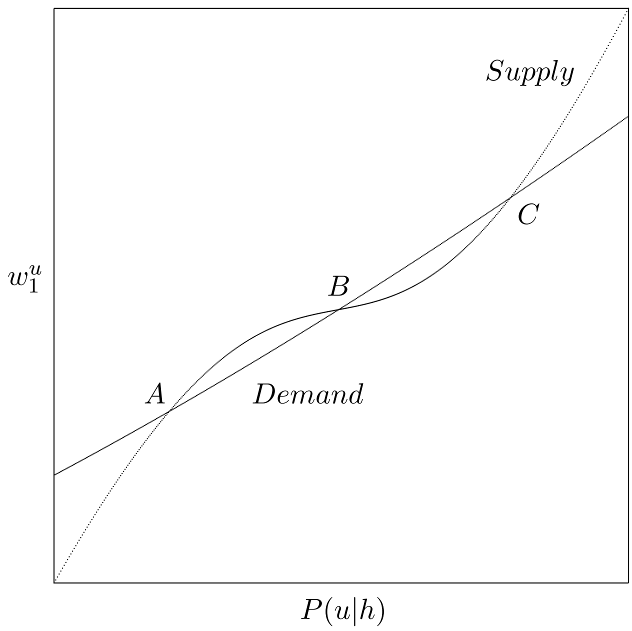


FIGURE 3: UNSKILLED-LABOR MARKET

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 (rotates it clockwise). 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 important for the comparative statics analysis. To see why, re-write b^* from equation (7) as:

$$b^* = \frac{(1+r^b)^2 T + (1+r^l) w_1^u - (1+r^l)(w_2^s + T)}{(1+r^b)^2 - (1+r^l)^2} \tag{10}$$

From the above equation it is clear that for a given world interest rate r^l an increase in the borrowing interest rate r^b leads to a higher b^* and thus a higher supply of unskilled labor. Furthermore, a larger r^b raises the slope of the supply curve. Intuitively, more severe credit constraints means that workers are more sensitive to changes in the return to education. Overall, given w^s and r^l it is true that:

- Changes on the Supply curve: $P(b^i < b^*)(w_1^u(+); T; r^b)$. A rise (fall) in w_1^u, raises (drops) the probability that a high type is uneducated $P(u|h)$.
- Shifts of the Supply curve: $P(b^i < b^*)(w_1^u(+); T; r^b)$. A rise (fall) in tuition T or the borrowing interest rate r^b, shifts the supply curve outwards (inwards).
- Changes on the Slope of the Supply curve: $P(b^i < b^*)(w_1^u(+); T; r^b)$. A rise (fall) in the borrowing rate r^b, raises (drops) the slope of the supply curve.

Demand for Unskilled Labor in Period 1.—The demand curve is in fact, 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. Constant returns to scale guarantee that wages do not depend on the quantity of unskilled workers. Equation (11) below, determines the unskilled wage.

$$w_1^u = q^l \left(\frac{1-\pi}{1-\pi+\pi P(u|h)} \right) + q^h \left(\frac{\pi P(u|h)}{1-\pi+\pi P(u|h)} \right). \tag{11}$$

Solving (11) for $P(u|h)$ gives the following demand function:

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

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:

$$(13) \qquad f : [q^l, q^P] \rightarrow [q^l, q^P] : f(w_1^u) = \frac{(1-\pi)q^l + \pi q^h P(b^i < b^*(w_1^u; T, r^b))}{1 - \pi + \pi P(b^i < b^*(w_1^u; T, r^b))}.$$

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.*

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.

In figure 3, 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, only A and C are stable equilibria, while B is unstable. Stability implies that the supply curve has a higher slope of the demand curve but both are upward sloping. Now consider a wage $\overline{w_1^u}$ above the equilibrium level. At this level we have excess demand.[29] This wage will decline in order to reach the equilibrium level, since for this wage $\overline{w_1^u}$, we have excess demand for uneducated high types $P(u|h)^D > P(u|h)^S$ (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 of uneducated high types and wages increase until they reach the equilibrium level.

Verify the Solution.—So far, the assumptions (1-4) depended on endogenous variables, too. However, I have solved the game for these values and now I can verify the solution that I guessed. This transforms assumptions (1-4) to equations (15)-(18):

$$(14) \qquad \text{Assumption 1:} \quad k^l > \frac{r^l(q^h - q^l) - (1+r^l)^2(w_1^{u*} + T)}{(1+r^l)^2}$$

$$(15) \qquad \text{Assumption 2:} \quad T \leq (1+r^l)q^l$$

[29] 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).

$$(16) \qquad \text{Assumption 3:} \qquad b^* = \frac{(1+r^b)^2 T + (1+r^l) w_1^{u*} - (1+r^l)(q^h + T)}{(1+r^b)^2 - (1+r^l)^2}$$

$$(17) \qquad \text{Assumption 4:} \qquad T < \frac{q^h + r^l w_1^{u*}}{1+r^l}$$

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. Nevertheless, after firms having privately observed the productivity of their workers, there can be mutually beneficial bargaining between firms and workers.

Firms know that high types with $b^i < b^*$, produce q^h. However, during period 1 they offer them w_1^u, as workers cannot afford signaling their type. During period 2, worker type is revealed to their 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 other firms do not know their type. That is why in the absence of a degree they cannot receive the skilled wage. Instead, they get $w_2^{u,P}$ and $w_2^{u,P}$ for the remaining two periods. Workers reply that they can acquire education to signal their type to other firms and get the skilled wage. By assumption 2 firms know that this threat is *credible* for all credit constrained high types, who are uneducated in period 1. Consequently, firms agree to offer bargainers 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 period 3. By assumption 4 high types find it profitable to separate themselves from the unskilled pool, even when old. Additionally, under a cost for switching jobs, workers are better off by accepting their employment firms' offers. Similarly, if there is a cost for unsuccessful bargaining, low types will never choose to bargain. Notice that mutually beneficial bargaining implies that nobody invests in education when old!

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 constraints and asymmetric information. 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 high types, since all of them have enough wealth to cover the cost of education in period 2.

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 their employment 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 education signaling, credit constraints and privately observable productivity after the first period of employment (private employer learning).*

Intuitively, firms initially employ workers without deriving profits; however, as they learn the type of their employees, they can sort them and obtain a surplus.[30] 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 mutually beneficial, as both firms and bargainers become better off.

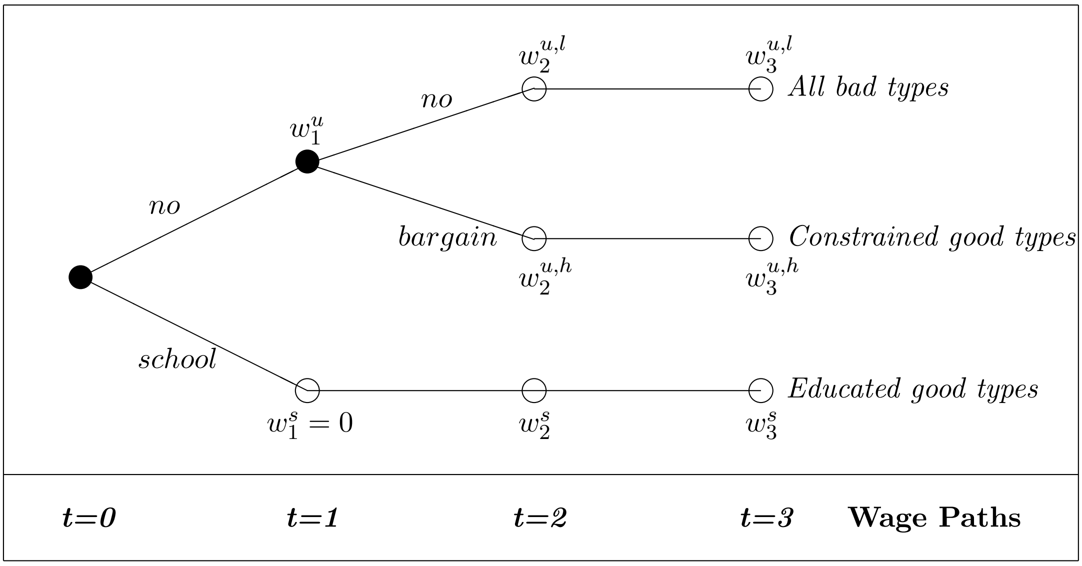


FIGURE 4: EQUILIBRIUM TREE

The functioning of the Economy.—So far, I have presented the basic features of the model and now I can review the functioning of this economy using Figure 4. The black nodes denote that a decision is taken by the agent, while in the transparent

[30] This happens because firms maximize profits at each period. However, even if they could transfer the profits from periods 2 and 3 to period 1 to attract the credit constrained high types, they would have zero profits in all three periods, without this affecting any of the results (see online Appendix A4).

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 figure also displays the wage path for each agent. This graph is essential in understanding the functioning of the economy.

II. Comparative Statics for less binding Credit Constraints

This chapter examines the interaction among asymmetric information and wage inequality. 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 unskilled wage decreases and the skill premium raises. If the borrowing interest rate drops, fewer high ability workers remain uneducated and by (10) we can see that b^* falls, generating a decrease in the initial wage of unskilled-inexperienced workers, which in turn leads to an increase in the skill premium. However, the skill premium increases also for experienced workers as fewer high types are uneducated even in period 2. This logic is summarized below:

PROPOSITION 3: *In any stable equilibrium, less severe credit constraints increase the skill premium for both experienced and inexperienced workers.*

Less severe credit constraints decrease unskilled-inexperienced wages, which in turn increase the experience premium too. Notice that the rise in the experience premium is generated only for the group of uneducated 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 only for unskilled workers. For skilled workers the experienced premium remains unchanged.*

The findings summarized in Propositions 3 and 4 find strong empirical support in the US over the past 4 decades (see Figure 1). The main result of propositions 3 and 4 is that less severe credit constraints increase wage inequality in a dual way: by raising both the skill and the experience premium. Importantly, policies that equalize educational opportunity such as lowering r^b, actually raise wage inequality.

Notice that less severe credit constraints, 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 unskilled wages and so it raises the experience premium for unskilled, as well as the skill premium for experienced and inexperienced workers, since the denominator falls for these wage ratios (see Figure 5). In unstable equilibria the results are reverted.

Table 1 illustrates the evolution of the skill premium within experience group and the experience premium within educational group. The education premium increases for both experience groups, while the experience premium increases significantly within the group of high school graduates, while it remains constant within the group of college graduates (see figure 1). Propositions 3 and 4 lead to the following corollary, which is supported by US data (see Figure 1 and Table 1).

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

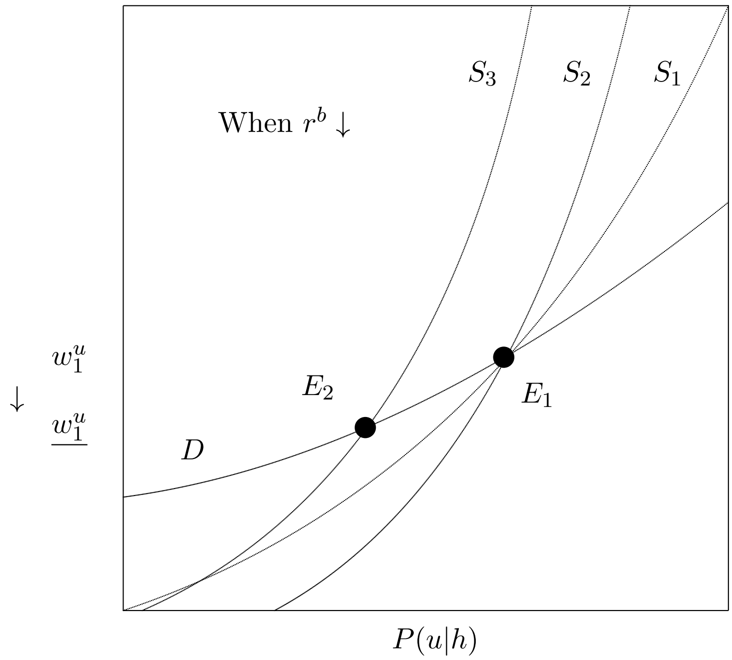


FIGURE 5: COMPARATIVE STATICS IN A STABLE EQUILIBRIUM

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_1^u) compared to the average unskilled wage for *experienced* workers ($\overline{\underline{w_2^u}}$). This result comes directly from the proof of proposition 4. Additionally, we know that the skilled wages for inexperienced and experienced workers are equal ($w_2^s = w_3^s = q^h$) and remain unaltered as credit frictions relax. Therefore, the increase in the skill premium for inexperienced workers (w_2^s/w_1^u) is larger in magnitude compared to the increase in the skill premium for experienced workers ($w_3^s/\overline{\underline{w_2^u}}$), as the numerators 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.

A. *Multiple Equilibria, Selection and Minimum Wage Policy*

In Figure 5 there is only one stable equilibrium before the relaxation of credit constraints E_1 and only one stable equilibrium after E_2. However, there can be multiple equilibria. When the supply curve intersects the demand curve from below, the equilibrium is stable, otherwise it is unstable. For instance in Figure 3 there are three equilibria A, B and C, of which only A and C are stable.

Minimum wage policy can affect the equilibrium outcome and ultimately wage inequality. This can be illustrated in Figure 3. Consider the three equilibria A, B and C. If the minimum wage is set at a level above the one that corresponds to the unstable equilibrium B, the economy would reach the stable equilibrium C that relates to a relatively high unskilled-inexperienced wage, which in turn would keep wage inequality at a low level. Alternatively, when the minimum wage is set below or equal to the level that corresponds to equilibrium A, the economy converges to the stable equilibrium A, which relates to a relatively low unskilled-inexperienced wage and therefore to higher wage inequality. For minimum wages above the level of equilibrium A but below the wage of the unstable equilibrium B, 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.

The finding that low minimum wages raise wage inequality is supported by several studies, which report 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.[31] Autor et al. (2010) show that falling minimum wages raise 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.

Additionally, this result raises concerns related to unemployment, as governments might wish to decrease minimum wages to increase employment. A discussion on this tradeoff is beyond the scope of this study. However, Card and Krueger (1994) show that decreasing minimum wages does not necessarily raises employment.

III. The Dynamic three-period OLG Economy

In this section I extend the static three-period 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. The dynamic economy is comprised by a mass 1 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 agents reach the second period of their lives they give birth to an agent.[32] 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 in Figure 6.

I extend the static setting to a dynamic three-period OLG model for consistency with 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. Econometricians calculate the skill and the experience wage premia annually but at every 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.

In the static model I have implicitly assumed that agents collect their wealth and consume it in the last period of their lives. This is biologically unrealistic, as agents have to consume every period in order to survive. At the dynamic three-period OLG 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 improves further the model.

Furthermore, I assume that initial endowments are stochastic and there are no

[31] 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.

[32] 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).

intergenerational bequests. Actually, there are intergenerational concerns, as parents feed both their children and their grandchildren; however, for simplicity I do not allow for parental bequests. This assumption can be relaxed in a new model, which would be more appropriate for the examination of intergenerational justice.

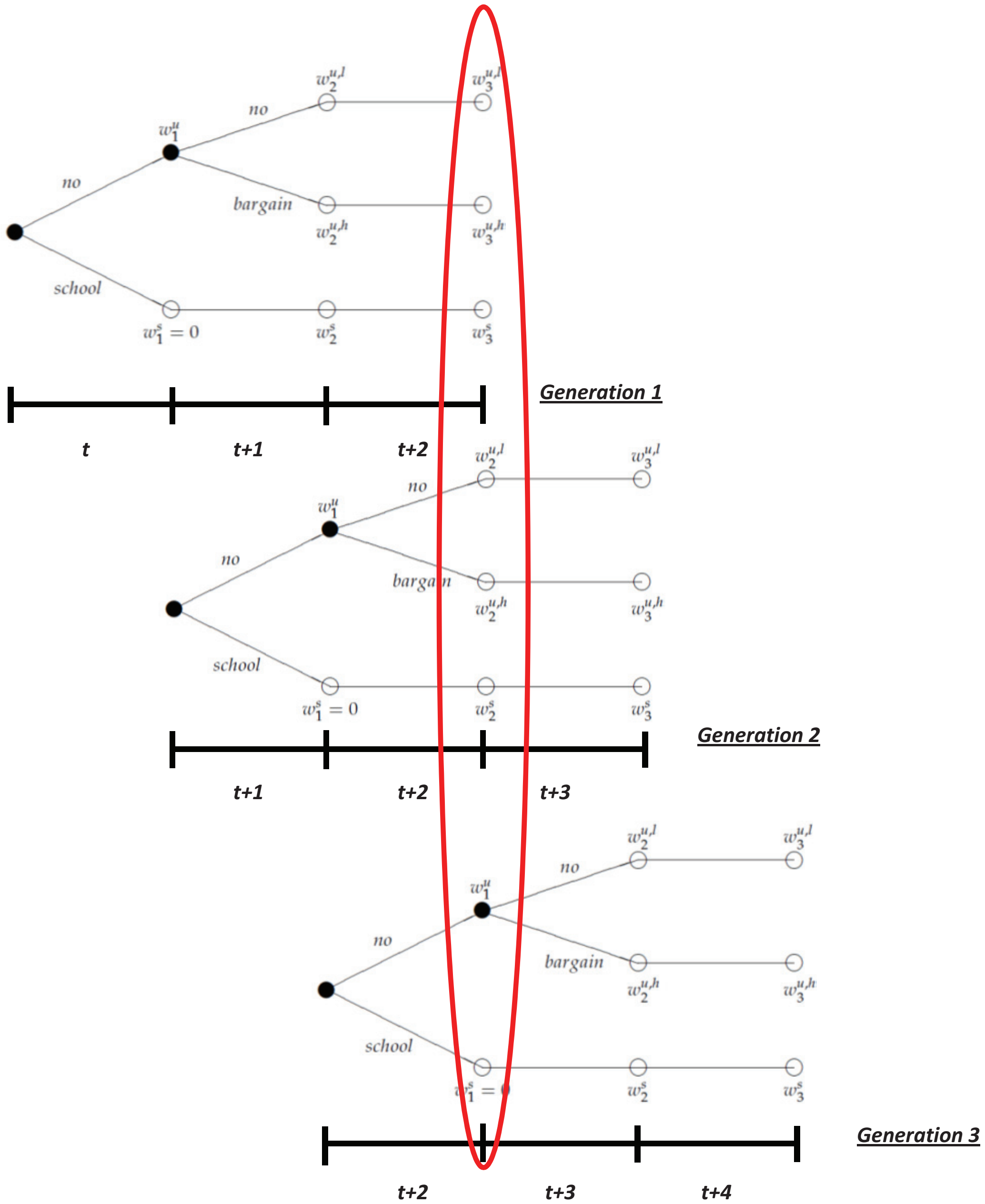


Figure 6: The Dynamic 3-period OLG Economy

The cohort analysis that is based on the static model can be extended to a three-period OLG model that resembles more the demography of the dataset that I use, which is the Current Population Survey. 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.

For instance, notice that in period $t+2$, 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, we can infer that in the steady state an economy with less severe credit constraints has higher wage inequality, as both the skill and the experience premium are higher, 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 input of this study.

IV. Evidence from the Current Population Survey

One of the most important results 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 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. First, I examine in more detail the empirical facts that my study accounts for and then I show why the fall of unskilled-inexperienced wages is so crucial.

A. 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, for white males aged 16 to 64 that work full-time, full-year, 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), real wage are deflated using Personal Consumption Expenditure Deflator, which shows lower inflation compared to the widely used Consumer Price Index.

Figure 1 and Table 1 show that both the skill and the experience premium increase significantly. The skill premium increased sharply 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 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. Panel A in Figure 1 highlights that the skill premium increases for both the experienced and the inexperienced workers but the rise is greater for the latter. Panel B in Figure 1 shows that a large part of the increase in the experience premium can be attributed to the influence of the group of unskilled workers, while the experience premium remains relatively flat for skilled workers. Columns (4)-(6) of Table 1 indicate that this is not a mere composition effect for each education-experience group. Figure 2 shows that during the period 1970-1997 the drop in unskilled-inexperienced wages increased both the education premium for inexperienced and the experience premium for low-educated workers. Figure 7 shows that from 1970 to 1997 there was a mirror image between the real wage of unskilled-inexperienced workers and the education premium within experienced and inexperienced workers, as well as the experience premium only within unskilled labor (the experience premium remains constant for skilled workers).

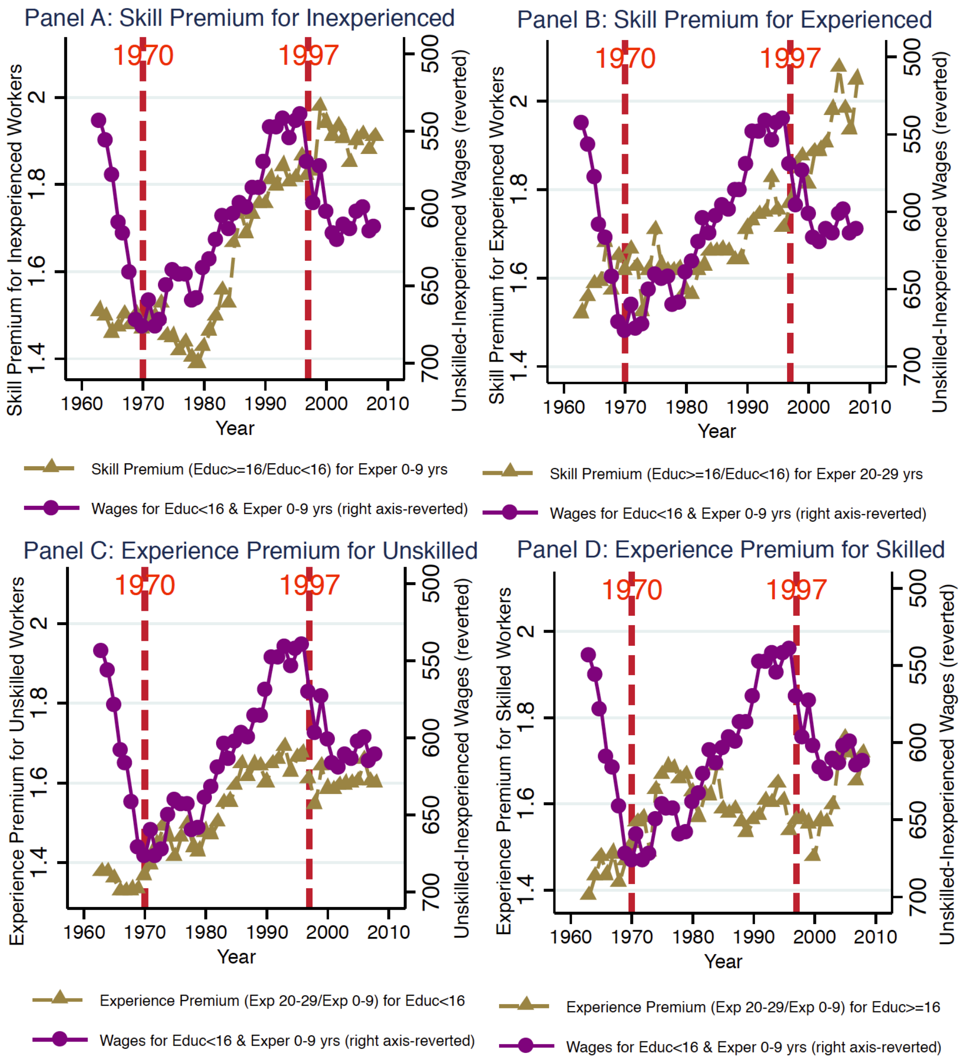


Figure 7: Declining Unskilled-Inexperienced Wages and Wage Premia, White Males, CPS.

B. *The Falling Unskilled-Inexperienced Wages*

Figure 2 shows that real wages for unskilled-inexperienced workers declined by 15.7 percent from 1970 to 1997. 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 is the tuition cost, which I treat as constant. Is this an empirically plausible assumption? Figure 8 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 colleges there was actually no change in real terms. This means that for the period 1970-1996 we can perform the comparative statics exercise.

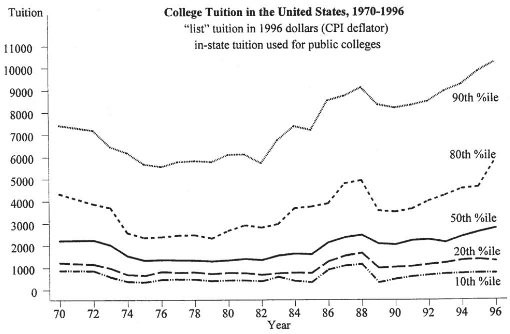


FIGURE 8: TUITION COST, US. SOURCE: HOXBY (2000)

Figure 7 shows that the inverse of the real wage for unskilled-inexperienced workers (right axis) almost coincides with the education premium for inexperienced and experienced workers, as well as with the experience premium for unskilled workers (see panels A, B and C), especially between 1970 and 1997 (indicated by the two vertical lines on each graph), when credit constraints have relaxed and college attendance have increased, as my study suggests. On the contrary, the south-west graph (Panel D) shows that the experience premium for skilled workers does not relate with the real wages for unskilled inexperienced workers and has not changed much between 1970 and 1997. These facts are in perfect harmony with my theoretical model.

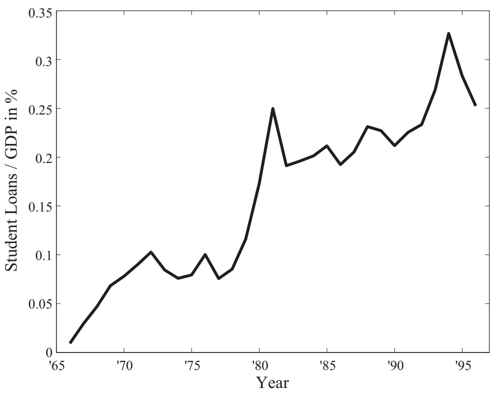


FIG. 9: FEDERAL FAMILY EDUCATION LOANS, % OF GDP. SOURCE: HENDEL ET AL. (2005).

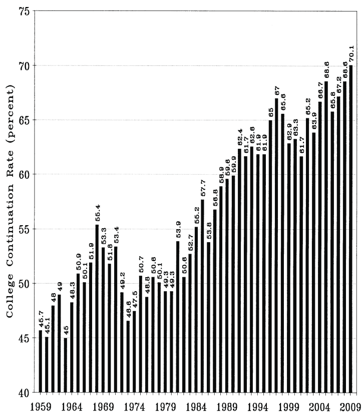


FIG. 10: % GOING TO COLLEGE AFTER HIGH SCHOOL. SOURCE: POSTSECONDARY EDUCATION OPPORTUNITY.

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 numerators (skilled or experienced real wages). Figure 2, Panel A indicates that the rise in the skill premium for inexperienced workers is influenced by the decline in the denominator (unskilled-inexperienced wages), while the numerator (unskilled-inexperienced wages) remained constant. Panel B indicates that the increase in the experience premium for unskilled workers is affected by the decline in the denominator (unskilled-inexperienced wages), while the numerator (unskilled-experienced wages) remains flat. The theoretical results find strong empirical support especially during the period 1970-1997 (in Figure 2 this period is highlighted by the two red vertical lines).

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 theoretical prediction.

V. Quantitative Analysis

A. *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.[33] 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 show that ability is better allocated in education nowadays compared to the past (see online Appendix A3).

I examine whether the relatively uneducated group is comprised of less able individuals nowadays, as this is a crucial prediction of my theoretical model. You can see these results in Table 2 by comparing columns (4)-(6) at the top panel A and bottom panel B. However, AFQT is not comparable in 1979 and 1997, as 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 appropriate for comparisons between the two surveys. I am using this adjusted AFQT for my empirical analysis.

Initially, I examine the correlation of AFQT with education for different groups. The results are displayed in Chart 1. All bars 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. I estimate the following regression (the results are displayed in Table 2 and Chart 2):

$$(18)\quad Educ_i = c+\beta_1 AFQT_i+\beta_2 Women_i+\beta_3 Black_i+\beta_4 Hisp_i+\beta_5 BirthYear_i+\epsilon_i$$

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

Chart 2 and Table 2 indicate that the coefficient on AFQT declines for both the less educated workers and 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 regression results are depicted in Chart 4, which illustrates that over time ability declines significantly only for the less educated workers (dark bars). 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,

[33] In this section I use several education thresholds for the less educated group and the results are robust.

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.[34]

Table 2: The Allocation of Ability (AFQT) in Education, NLSY 1979 & 1997, US

Panel A: The Allocation of Ability (AFQT) in Education, NLSY 1979

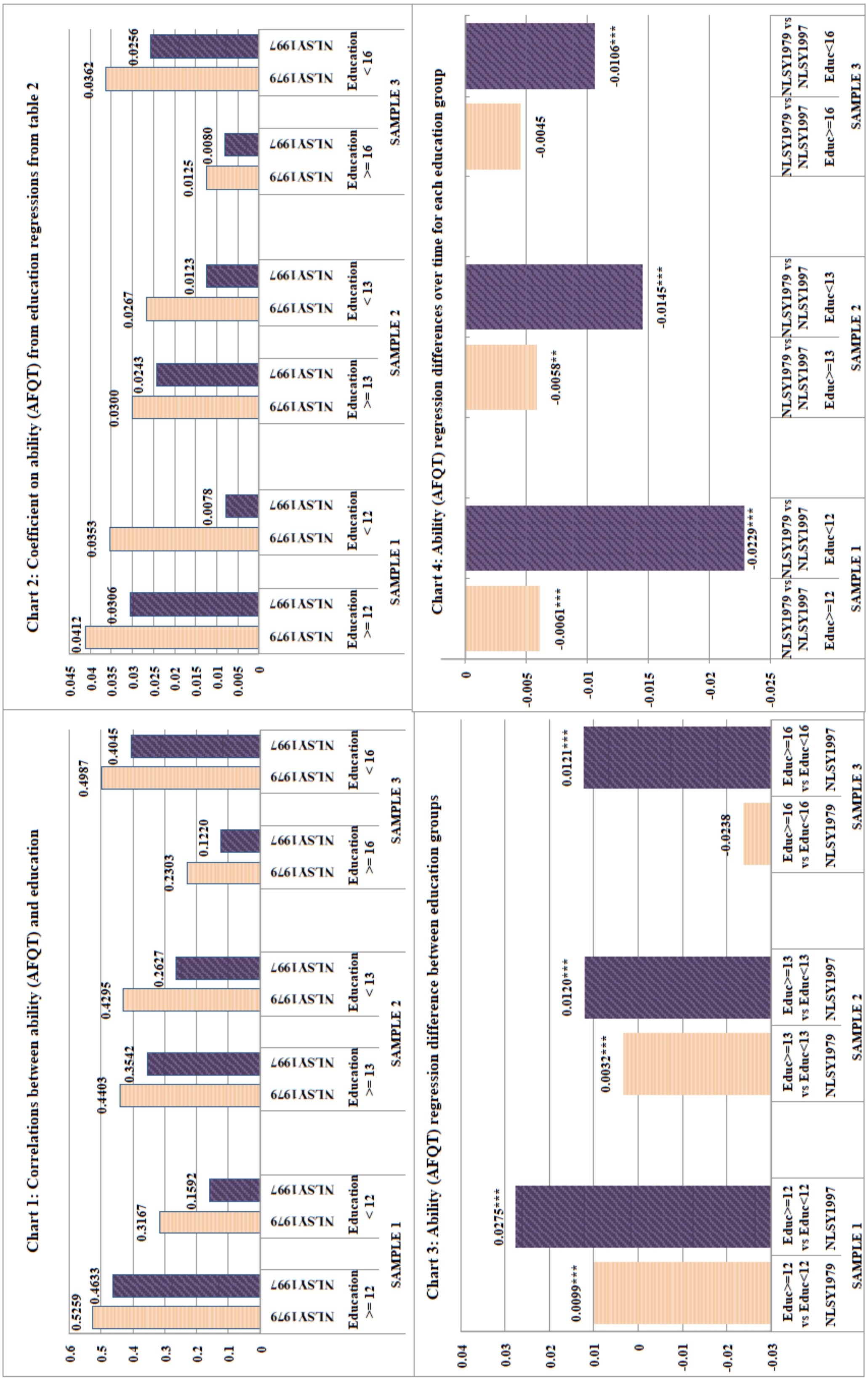
	Dependent Variable: Years of Education					
	NLSY1979			NLSY1979		
	Education>=12	Education>=13	Education>=16	Education<12	Education<13	Education<16
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	294.8720***	291.4874***	152.1252***	-32.2481	-59.5123	16.6283
	(-62.4682)	(-81.2068)	(-85.0348)	(-139.1065)	(-60.7767)	(-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)	(-0.001)
Female	0.0245	-0.1574**	-0.2390***	-0.1608	0.0401	0.1504***
	(-0.0602)	(-0.0777)	(-0.0799)	(-0.1372)	(-0.0595)	(-0.055)
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***	-0.015	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)	(-0.071)	(-0.031)	(-0.0289)
Adj 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

Panel B: The Allocation of Ability (AFQT) in Education, NLSY 1997

	Dependent Variable: Years of Education					
	NLSY1997			NLSY1997		
	Education>=12	Education>=13	Education>=16	Education<12	Education<13	Education<16
	(1)	(2)	(3)	(4)	(5)	(6)
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***
	(-0.001)	(-0.0013)	(-0.0013)	(-0.0013)	(-0.001)	(-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)	(-0.021)	(-0.0196)	(-0.0189)
Adj 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

Notes: Regressions of ability (AFQT) on years of education for different levels of education. Panels A and B correspond to 1979 and 1997. In the parentheses standard errors are displayed. Source: National Longitudinal Survey of Youth, US. Significance at the 1, 5 and 10 percent significance level is indicated respectively by ***, ** and *.

[34]I consider more appropriate the use of directly ability measures, such as the AFQT, compared to individual fixed from wage regressions, since Eeckhout and Kircher's (2011) suggests that such fixed effects cannot recover information related to the type of economic agents.



Charts 1 - 4: The Allocation of Ability (AFQT) in Education, NLSY 1979 & 1997, US

B. Technology vs Sorting

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.[35] 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:

$$Y = ZL \tag{19}$$

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

$$L = [(A_{U,I}L_{U,I})^{\sigma} + (A_{U,E}L_{U,E})^{\sigma} + (A_{U,EE}L_{U,EE})^{\sigma} + (A_{S,I}L_{S,I})^{\sigma} + (A_{S,E}L_{S,E})^{\sigma}]^{1/\sigma} \tag{20}$$

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

$$\frac{\partial Y}{\partial L_{U,I}} = Z(1/\sigma)[...]^{(1/\sigma)-1}\sigma A_{U,I}^{\sigma}L_{U,I}^{\sigma-1} \equiv w_1^u \tag{21}$$

$$\frac{\partial Y}{\partial L_{U,E}} = Z(1/\sigma)[...]^{(1/\sigma)-1}\sigma A_{U,E}^{\sigma}L_{U,E}^{\sigma-1} \equiv w_2^{u,P} \tag{22}$$

$$\frac{\partial Y}{\partial L_{U,EE}} = Z(1/\sigma)[...]^{(1/\sigma)-1}\sigma A_{U,EE}^{\sigma}L_{U,EE}^{\sigma-1} \equiv w_3^{u,P} \tag{23}$$

$$\frac{\partial Y}{\partial L_{S,I}} = Z(1/\sigma)[...]^{(1/\sigma)-1}\sigma A_{S,I}^{\sigma}L_{S,I}^{\sigma-1} \equiv w_2^s = q^h \tag{24}$$

$$\frac{\partial Y}{\partial L_{S,E}} = Z(1/\sigma)[...]^{(1/\sigma)-1}\sigma A_{S,E}^{\sigma}L_{S,E}^{\sigma-1} \equiv w_3^s (= q^h) \tag{25}$$

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. Similarly for skilled workers $A_{S,E} \geq A_{S,I}$.

The log of the marginal rate of transformation gives the log of the wage premium. What appears inside the brackets in equation (20) is denoted as [...] above and it cancels out. Equation (24) over (21) gives the skill premium for inexperienced:

$$\ln MRT_{SI,UI} = \ln \frac{w_2^s}{w_1^u} = \sigma \ln \frac{A_{S,I}}{A_{U,I}} + (1-\sigma)\ln \frac{L_{U,I}}{L_{S,I}} \tag{26}$$

According to the so called skill-biased technical change (SBTC) approach, the skill premium increased because technology favors the relatively more educated workers.

[35] 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.

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 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 (26), 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.[36]

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.

Fitness of the Theoretical Model.—It is interesting to examine the fitness of my theoretical model and compare it to the SBTC approach. One way to proceed is to incorporate my model of sorting into the SBTC. First, I re-write equation (26) but I decompose the productivity component to two parts as follows:

$$\ln \frac{w_2^s}{w_1^u} = \left(\ln \frac{\overline{A}_{S,I}}{A_{U,I}} + \ln \frac{A_{S,I}}{\overline{A}_{U,I}} \right) + \ln \frac{L_{U,I}}{L_{S,I}} \tag{27}$$

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 compared to other technological "improvements". However, we do not have a direct measure of labor productivity. That is why we use unskilled-inexperienced wages, in real 2008 dollars. To illustrate the functioning of my sorting model, I indicate changes in the variables of the model with arrows.

$$\ln \frac{w_2^s}{w_1^u \downarrow} = \sigma \left(\ln \frac{\overline{A}_{S,I}}{A_{U,I} \downarrow} + \ln \frac{A_{S,I}}{\overline{A}_{U,I}} \right) + (1-\sigma) \ln \frac{L_{U,I}}{L_{S,I}} \uparrow \tag{28}$$

This relationship suggests that the skill premium raises, despite the growing supply of skills, mainly because the productivity of unskilled workers declines. That is why the fall in the denominator is primarily responsible for the rise in the skill premium.

However, it is expected that if at the top of using demand and supply factors–as the SBTC approach–we include an additional variable, which captures the decline in the productivity, the model would fit data better. What is not obvious is which

[36]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 drop in the effort cost.

of the two models, the SBTC or my model of sorting, predicts better the evolution of wage premia. That is why initially I estimate the predictive power of the model described by equation (26) and I regress the following equation (the fitness of this model (SBTC) can be seen at the online Appendix A1):

$$\ln \frac{w_{2t}^{s}}{w_{1t}^{u}} = \beta_1 \ln \frac{L_t^{U,I}}{L_t^{S,I}} + year_t + error_t \tag{29}$$

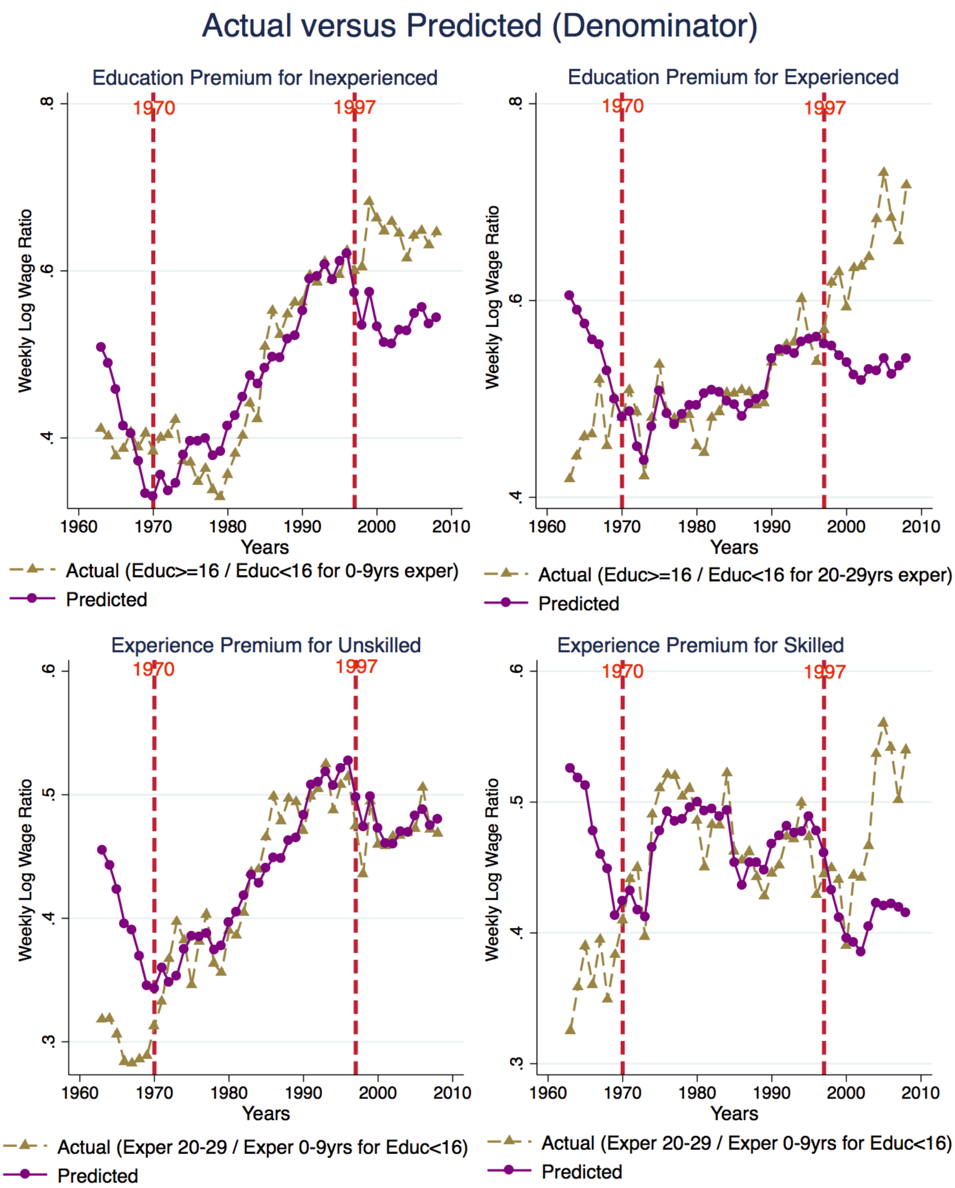


FIGURE 11: THE FITNESS OF THE THEORETICAL MODEL, WHITE MALES, CPS.

To compute the fitness of my model of sorting, I estimate this regression[37]:

$$\ln \frac{w_{2t}^{s}}{w_{1t}^{u}} = b_1 \ln A_t^{U,I} + year_t + error_t \tag{30}$$

[37]Notice that in both regressions (29) and (30) we do not include a constant.

Where $A_t^{U,I}$ denotes the productivity of unskilled-inexperienced labor (denominator), which is measured using the wages of this group. The fitness of the model for the skill premium of unskilled workers can be seen in Figure 11.

Figure 11 illustrates the fitness of the model for all four wage premia. The model has a satisfactory predictive power and fits the data better than the SBTC, especially during the period 1970-1997 (for a direct comparison see the online Appendix A1 Figures 12-17). However, one would expect a good fit since wages appear on both the right hand side (the denominator unskilled-inexperienced wages) and the left hand side (skill premium for inexperienced workers) of equation (30). I show that this is not the necessarily the case, as if I estimate the model described by (30) but instead for the productivity decline of unskilled $A_t^{U,I}$ control for the productivity rise of skilled $A_t^{S,I}$, which is measured by the real wages of skilled-inexperienced workers (the numerator), this counterfactual model cannot fit the data (see the online Appendix A1 Figure 16). The comparison between equations (29) and (30) is informative on whether changes in the *quantity* of workers for each skill group (composition effect) matters more than the changes in the *quality* of workers for each skill group (sorting effect). The online Appendix A1 compares and contrasts the SBTC model, my model of sorting using the denominator and the counterfactual model with the numerator. The conclusion is that the sorting model fits better the data, especially during the period 1970-1997. The SBTC model provides a satisfactory fit for some wage premia but not for all of them, as it fails to predict the evolution of the experience premium for unskilled workers.

VI. 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. Figure 2 shows that 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 it the education premium for inexperienced workers, a more moderate increase it the education premium for experienced workers and an increase in the experience premium *only* for unskilled workers, while the experience premium for skilled workers have remained constant (see figure 7).

This is precisely what my theoretical model predicts. Importantly, both my theoretical model and CPS data show that the increase in three out of the four wage premia, which I examine, occurs when unskilled-inexperienced wages fall.

I examine the effect of the decline in the wage of unskilled-inexperienced labor (denominator) on the education premium. Table 1 shows that indeed the education premium increases more for low experienced workers compared to the highly experienced ones and this difference is more striking if we restrict the sample in the period 1970-1997, while the experience premium increases mainly for low-educated workers and over the period 1970-1997 it rises *only* for low-educated labor. Also, figure 2 and table 3 below shows that the education premium for inexperienced workers increases mainly because the denominator (wages of *unskilled*-inexperienced labor) declines and not because the numerator (wages of *skilled*-inexperienced labor) rises.

This is displayed in columns (3) and (6), where the negative effect of the denominator is always statistically significant. This effect is emphatic over the period 1970-1997, where the entire time trend becomes insignificant when we control for the decline of the denominator. Almost the entire rise of the education premium for inexperienced workers is explained by the decline of unskilled-inexperienced wages. This is an important robustness check of my theory. Online Appendix A2 compares the sharp decline in unskilled-inexperienced wages to the moderate fall in unskilled wages and shows that decomposing unskilled wages by experience level is crucial.

All tables correspond to regressions with and without composition adjustment. In particular the SBTC approach assumes that labor inputs are identical over time and only controls for the supply of these inputs. My approach allows labor inputs to change and in particular unskilled-inexperienced labor becomes less productive recently compared to the past. That is why the analysis without composition adjustment might be more appropriate for my study.

Table 3: Falling Unskilled-Inexperienced Wages & Rising Inequality, White Males, CPS

Panel A: log Education Premium for Inexperienced Workers, US 1963-2008

Dependent Variable: log (WageEduc>=16 / WageEduc<16) for 0-9 years of experience

	Without Composition Adjustment			Composition-Adjusted Wage Premium		
	(1)	(2)	(3)	(4)	(5)	(6)
Year	0.0078***	0.0061***	0.0070***	0.0095***	0.0079***	0.0088***
	-0.0006	-0.001	-0.0005	-0.001	-0.0016	-0.0008
Numerator		0.2764*			0.1995	
		-0.145			-0.1521	
Denominator			-0.4933***			-0.5035***
			-0.1016			-0.0943
Composition				-0.1581**	-0.1216	-0.1705***
				-0.0775	-0.0818	-0.0606
Adj R-squared	0.806	0.817	0.872	0.819	0.822	0.889
Observations	46	46	46	46	46	46

Panel B: log Education Premium for Inexperienced Workers, US 1970-1997

Dependent Variable: log (WageEduc>=16 / WageEduc<16) for 0-9 years of experience

	Without Composition Adjustment			Composition-Adjusted Wage Premium		
	(1)	(2)	(3)	(4)	(5)	(6)
Year	0.0111***	0.0087***	0.0012	0.0128***	0.0073***	0.0029
	(0.0011)	(0.0006)	(0.0033)	(0.0023)	(0.0012)	(0.0033)
Numerator		1.0408***			1.0888***	
		(0.1093)			(0.1139)	
Denominator			-1.1358***			-1.2780***
			(0.3639)			(0.3566)
Composition				-0.1445	0.1054	-0.2532*
				(0.1644)	(0.0809)	(0.1388)
Adj R-squared	0.786	0.952	0.840	0.784	0.953	0.853
Observations	28	28	28	28	28	28

Human Capital.—However, college attendance apart from indicating unobservable ability, it also increases labor productivity. Even though this is a crucial point, I abstract from it to keep the framework simple and make clear the aspect of education that drives the results of this paper, which is 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, as not only unskilled wages drop but also skilled wages would raise. That is why my theory, may underestimate the rise in wage inequality. However, the results of this paper hold, even when the mere signaling approach is combined with human capital.

Learning-by-Doing (LBD).—It is also true that workers learn by doing and this increases their productivity. However, my model abstracts from this element too, as labor productivity is constant for the entire life of each agent (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: $q^j_{t+1} = \lambda^j q^j_t$, where $t = 1, 2$, $j = \{l, h\}$ and $\lambda^j > 1$. We can even allow LBD to take a quadratic form, which would give a concave profile for wages over the life-cycle. In any case LBD would affect 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 LBD.

Minimum Wages.—In the model presented above, without human capital, it seems that the lowest wage or 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. 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. This total change depends on 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. 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. Consider an unskilled low type. In period 1 competitive firms offer a wage w^u_1, even for the low types who produce only q^l, which is lower than his wage $q^l < w^u_1$. If a firm offers a lower wage than w^u_1, 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. In period 2 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, since the observed pattern is 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 on wages*experience (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.

I propose that since 1970's credit constraints relaxed significantly and rendered education more easily accessible (see figure 9). This in turn increased the college continuation rates (see figure 10) and left only few who cannot attend college. 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 wage inequality.

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 exactly what happened in the US. 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 Card and DiNardo 2002a), a pattern that finds strong empirical support in many countries and especially in the US.

Therefore, the lowest wage is the initial wage of the unskilled worker w_1^u and the reduction of this wage generates higher wage inequality. This is an 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 the increase during the early 1980's is primarily attributed to the falling wages at the lower end of the distribution.

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. 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 7 shows that this is the case, especially over the period 1970-1997, when 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.

College Expansion, Tuition, Student Finance & Loans.—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 9). 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 universities, while the majority of students attend colleges that have lower average price and where inflation-adjusted tuition growth has been moderate. 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 8). The relaxation of credit constraints increased educational opportunities and college continuation rates (see figure 10) and left only few high type agents unskilled. Firms reacted to this by offering lower wages to unskilled and inexperienced workers, which in turn boosted wage inequality.

VII. Conclusion

This paper examines the perplexing coexistence of more equal opportunities and growing wage inequality in the US. 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, unskilled workers were more likely to be highly productive, as credit constraints were more severe and able but poor individuals could not acquire education. However, credit frictions relaxed significantly since then and educational opportunities have become more equal. That is why being unskilled nowadays is perceived by firms as a worse signal for worker's ability compared to the past. This logic justifies 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 declined 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 larger wage benefits for workers; but also *informal learning*, such as private employer learning, has a stronger impact on wages more recently.

Previous studies mainly focus on the education premium for all experience levels being pooled together. This simplification masks that the education premium increases sharply for low-experienced workers and only moderately for the highly experienced ones. Similarly, the experience premium grows significantly and most of the previous studies either ignore this aspect of rising inequality or they examine the experience premium for all education levels being grouped together. This conceals that the experience premium increases only for low-educated workers. My study explains how wage inequality evolves within education-experience groups. I show that the expansion of higher education in the US over the 1970's and the 1980's, has allocated talent better in education by allowing talented but poor individuals to go to college. This has an important effect on society. In fact, it implies that the eventual group of uneducated young and inexperienced workers becomes of lower average quality because most of the *rough diamonds* have now been plucked out of this group. In response, firms offer lower wages to the remaining workers of this unskilled and inexperienced group, which ultimately boosts wage inequality.

This model of signalling, credit constraints and private employer learning fits well US data on within group wage inequality, especially during the period 1970-1997. Related studies focusing on the pooled education premium are not supported by US evidence, as the decline in unskilled wages for all experience levels is much smaller in magnitude, while it also coincides with the sharp rise of skilled wages. Importantly, this new explanation provides a better prediction of within group wage inequality compared to approaches based on the skill-biased technical change or on minimum wages. As models of technical change fail to account for the growing experience wage premium, while theories of minimum wages cannot explain why the influence of declining wages at the lower end of the distribution on wage inequality extends to a longer period than the one that corresponds to the falling real minimum wage.

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. Additionally, in the presence of multiple equilibria, the selection of the level of minimum wage becomes essential. I show that through minimum wage policy, governments can affect unskilled-inexperienced wages and therefore the level of equilibrium wage inequality.

This paper focuses mainly on the role of labor supply to provide a microfounded game-theoretical reasoning for recent macroeconomic facts related to rising wage inequality. However, there is a large body of literature on the skill-biased technical change that focuses on the demand side. I feel that these two approaches are complementary, as together they seem to provide a better understanding of the laws that determine labor income distribution than each approach alone.

Appendix: Proof of Proposition 1

I prove proposition 1 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.

Appendix: Proof of Proposition 2

Firms have zero profits in period 1; while, they have positive profits in period 2 and 3. If the profit for the representative firm in period 2 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 period 2 and 3 profits are positive for all firms (see Appendix A4).

Appendix: 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 for inexperienced workers, which is denoted as w_2^s/w_1^u. From (10) we can see that in a stable equilibrium a fall in r^b decreases both 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 for experienced workers and it is 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 bargains 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 in period 2 $\underline{w}_2^u$. Given that w_3^s is constant an equal to q^h, the second skill premium increases too. The skill premium raises for both inexperienced and experienced as credit frictions relax (see Appendix A5 for a continuum of ability types).

Appendix: 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 comparing their wages of the first and second period $\underline{w_2^u}/w_1^u$ and the other by comparing the wages of the second and third period $\underline{w_3^u}/\underline{w_2^u} = 1$. Notice that the only experience premium that is not constant is the one of the unskilled workers for the first period of their experience and equals $\underline{w_2^u}/w_1^u$. In a stable equilibrium, less severe credit frictions caused by a decline in r^b decrease b^* and w_1^u. However, the lower cost of borrowing decrease $\underline{w_2^u}$ as well, since fewer high types are credit constrained and fewer agents in the uneducated pool get the higher wage $w_2^{u,h}$. This means that both the numerator 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 I try to derive a contradiction.

$$ExpPremium_{before} \geq ExpPremium_{after} \tag{31}$$

$$\frac{\underline{w_2^u}}{w_1^u}_{before} \geq \frac{\underline{w_2^u}}{w_1^u}_{after} \tag{32}$$

$$\frac{\overline{N_2^h} w_2^{u,h} + N_2^l q^l / [\overline{N_2^h} + N_2^l]}{\overline{N_1^h} q^h + N_1^l q^l / [\overline{N_1^h} + N_1^l]} \geq \frac{\underline{N_2^h} w_2^{u,h} + N_2^l q^l / [\underline{N_2^h} + N_2 l]}{\underline{N_1^h} q^h + N_1^l q^l / [\underline{N_1^h} + N_1^l]} \tag{33}$$

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 with 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 inequality above becomes:

$$\frac{\overline{N^h} w_2^{u,h} + N^l q^l}{\overline{N^h} q^h + N^l q^l} \geq \frac{\underline{N^h} w_2^{u,h} + N^l q^l}{\underline{N^h} q^h + N^l q^l} \tag{34}$$

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

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For Online Publication: Appendices of "The Market for Rough Diamonds: Information, Finance and Wage Inequality" by Theodore Koutmeridis

A1. Evaluating the Fitness of the Model

This part estimates, compares and contrast the SBTC model and the sorting model which is developed on the paper. The general form of the two models that we estimate is the following. For the SBTC approach the log of the relative wage ratio between skill and unskilled workers depends on the inverse of relative supply:

$$\ln \frac{w_t^S}{w_t^U} = \beta \cdot \ln \frac{L_t^U}{L_t^S} + \tau \cdot year_t + error_t \tag{A1}$$

For the sorting approach the log of the relative wage ratio between skill and unskilled workers depends on the productivity of unskilled workers:

$$\ln \frac{w_t^S}{w_t^U} = b \cdot \ln A_t^U + \tau \cdot year_t + error_t \tag{A2}$$

In particular, Figure 12 illustrates the fitted values from the following models:

Fig. 12 (left): $\ln \frac{w_{2t}^s}{w_{1t}^u} = 0.6414 \cdot \ln \frac{L_t^{U,I}}{L_t^{S,I}} + 0.0005 \cdot year_t + \text{error}_t$

$(0.1143)^{***}$ $(0.0000)^{***}$ $\overline{R^2} = 0.979$

Fig. 12 (right): $\ln \frac{w_{2t}^s}{w_{1t}^u} = -0.9166 \cdot \ln A_t^{U,I} + 0.0032 \cdot year_t + \text{error}_t$

$(0.0772)^{***}$ $(0.0002)^{***}$ $\overline{R^2} = 0.993$

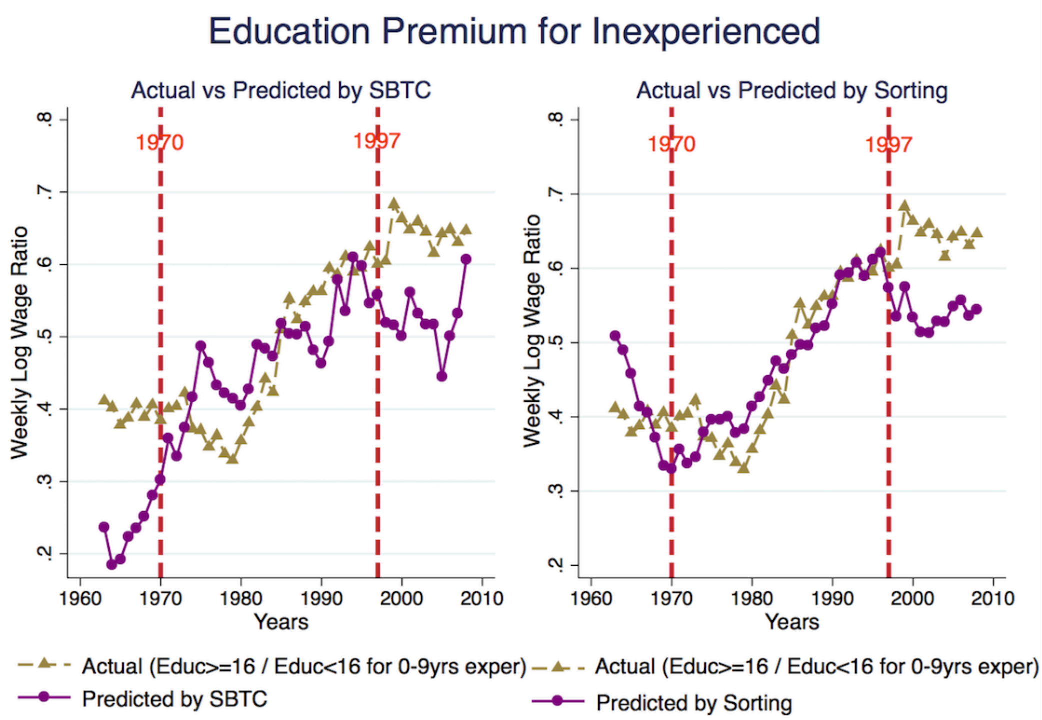

Figure 12: Education Premium for Inexperienced, White Males, CPS.

Notice that both models are regressed without a constant and they both include a linear time trend. The two models capture the importance of changes in the quantity and changes in the quality of each group on the skill premium. The regressions of the education premium for inexperienced workers correspond for the period 1970-1997 (the change in productivity of unskilled-inexperienced workers $A_t^{U,I}$ is approximated by the real wage of this group). The first one controls for the change in the inverse relative supply $L_t^{U,I}/L_t^{S,I}$, as the SBTC approach suggests, while the second one uses the change in the productivity of unskilled workers ($A_t^{U,I}$).

Figure 13 shows the fitted values from the following models, which correspond to the education premium for experienced workers:

$$\text{Fig. 13 (left):} \quad \ln \frac{w_{3t}^s}{w_{3t}^u} = \underset{(0.0252)^{***}}{0.1200} \cdot \ln \frac{L_t^{U,E}}{L_t^{S,E}} + \underset{(0.0000)^{***}}{0.0032} \cdot year_t + \text{error}_t \qquad \overline{R^2} = 0.997$$

$$\text{Fig. 13 (right):} \quad \ln \frac{w_{3t}^s}{w_{2t}^u} = \underset{(0.0895)^{***}}{-0.6579} \cdot \ln A_t^{U,E} + \underset{(0.0003)^{***}}{0.0025} \cdot year_t + \text{error}_t \qquad \overline{R^2} = 0.998$$

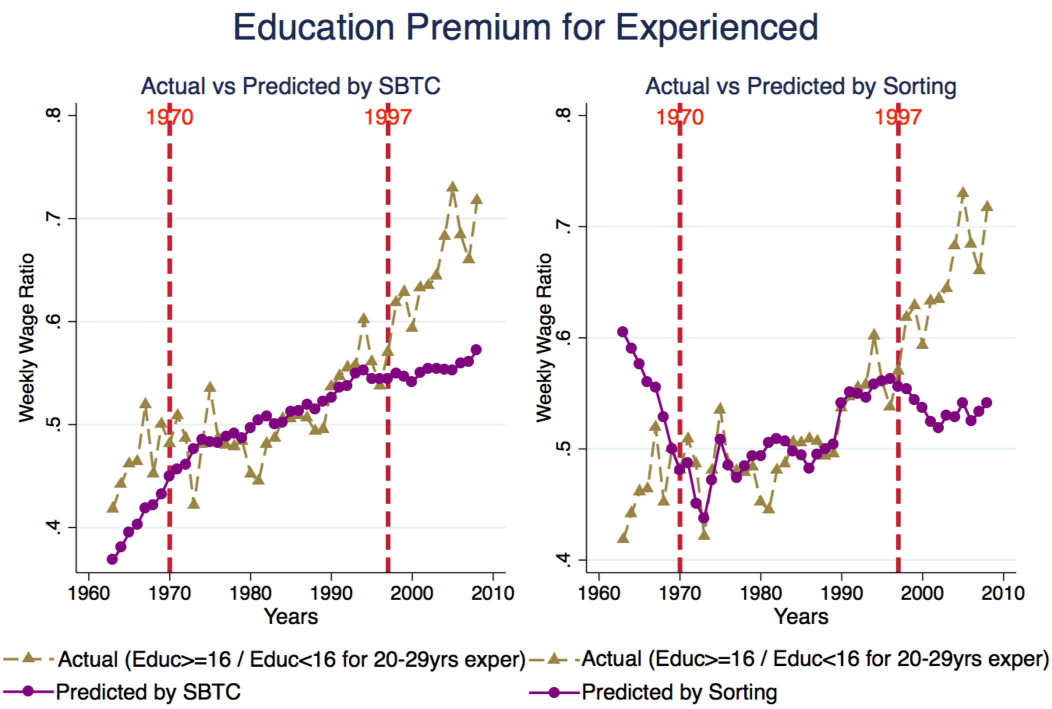

FIGURE 13: EDUCATION PREMIUM FOR EXPERIENCED, WHITE MALES, CPS.

Figure 13 depicts the skill premium for experienced workers, highlighting the fitness of the SBTC and the sorting approaches. The sorting theory seems to fit better the data, especially during the period 1970-1997.

In Figure 14 the contrast is sharper, as the SBTC model fails to predict the evolution of the experience premium for unskilled workers. On the contrary, the model of sorting seems to provide a satisfactory explanation. Figure 14 depicts the fitted values of the experience premium for unskilled workers of the following models:

$$\text{Fig. 14 (left):}\quad \ln \frac{w^u_{2t}}{w^u_{1t}} = \underset{(0.0515)^{***}}{0.0932} \cdot \ln \frac{L^{U,I}_t}{L^{U,E}_t} + \underset{(0.0000)^{***}}{0.0002} \cdot year_t + \text{error}_t \qquad \overline{R^2} = 0.981$$

$$\text{Fig. 14 (right):}\quad \ln \frac{w^u_{2t}}{w^u_{1t}} = \underset{(0.0454)^{***}}{-0.5739} \cdot \ln A^{U,E}_t + \underset{(0.0001)^{***}}{0.0021} \cdot year_t + \text{error}_t \qquad \overline{R^2} = 0.997$$

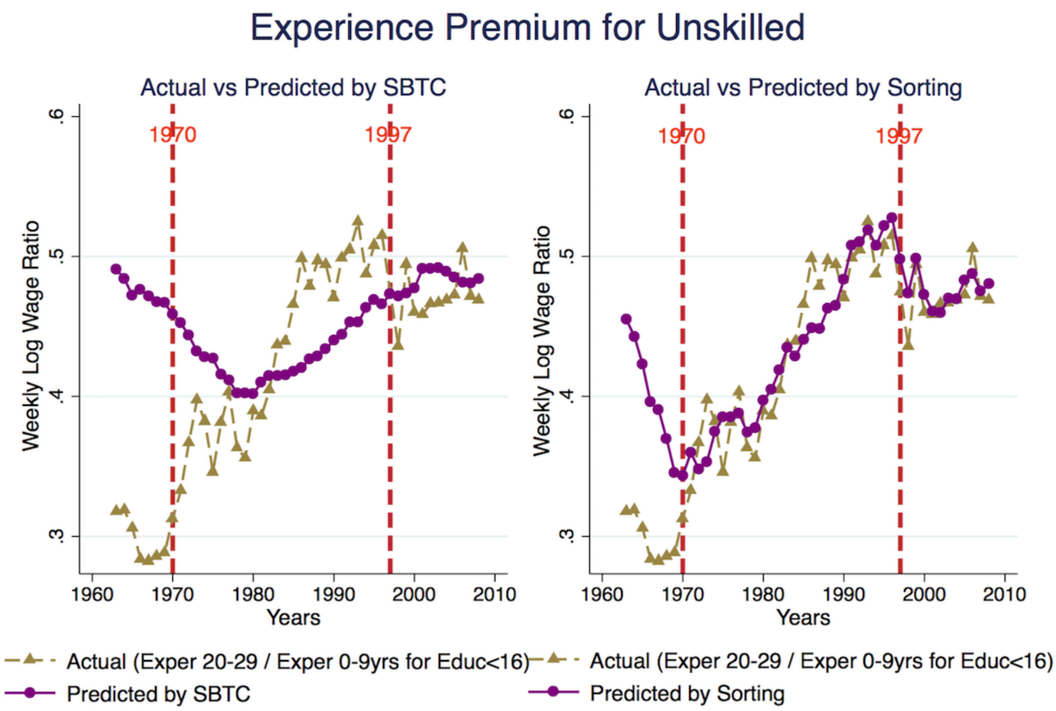

Figure 14: Experience Premium for Unskilled, White Males, CPS.

Accordingly, Figure 15 indicates that the experience premium for unskilled workers is predicted quite accurately by the sorting model, especially over the period 1970-1997. The fitted values of the following two models is shown in Figure 15:

$$\text{Fig. 15 (left):}\quad \ln \frac{w^s_{3t}}{w^s_{2t}} = \underset{(0.0198)^{***}}{-0.0575} \cdot \ln \frac{L^{S,E}_t}{L^{S,I}_t} + \underset{(0.0000)^{***}}{0.0002} \cdot year_t + \text{error}_t \qquad \overline{R^2} = 0.996$$

$$\text{Fig. 15 (right):}\quad \ln \frac{w^s_{3t}}{w^s_{2t}} = \underset{(0.1113)^{***}}{-0.6124} \cdot \ln A^{S,I}_t + \underset{(0.0004)^{***}}{0.0024} \cdot year_t + \text{error}_t \qquad \overline{R^2} = 0.998$$

The next step is to show that the influence of declining productivity at the group that comprises the denominator of this wage premia, is the main factor. In order to distinguish this, we perform a counterfactual analysis using the numerator instead of the denominator.

A comparison of Figure 17, which represents the fitness of the sorting model with declining productivity in the denominator, with Figure 16, which illustrates the counterfactual analysis of increasing productivity in the numerator, is informative for the predictive power of the model. The comparison reveals that the sorting model of declining productivity in the denominator explains fits better the actual wage premia, while the alternative model based on the counterfactual analysis has a much more limited predictive power.

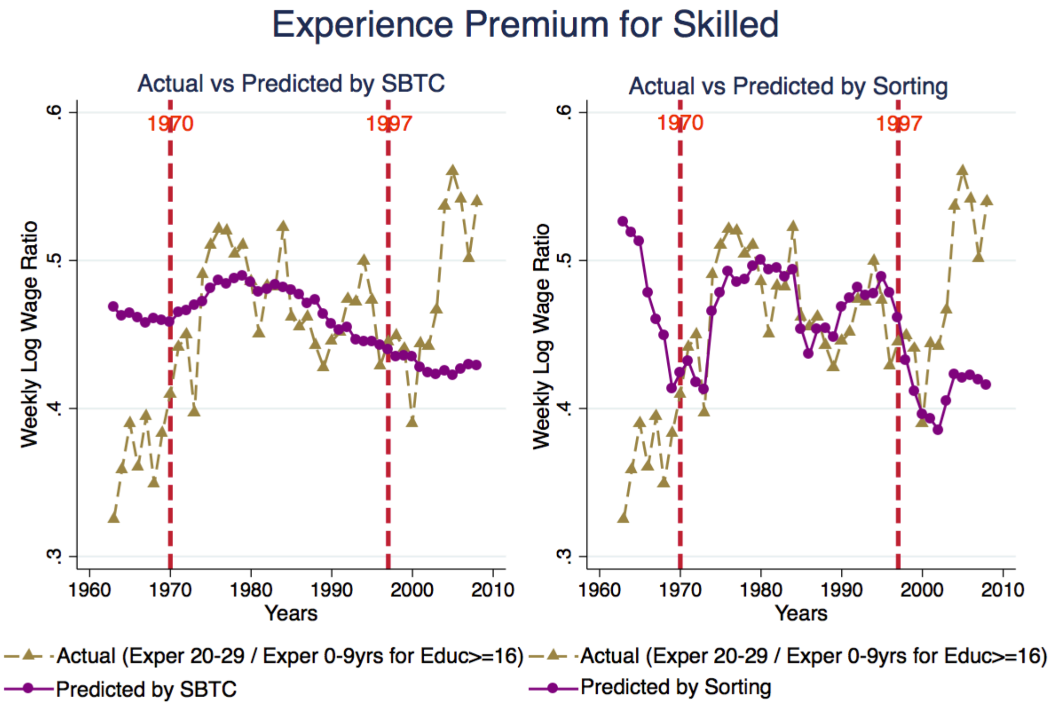

FIGURE 15: EXPERIENCE PREMIUM FOR UNSKILLED, WHITE MALES, CPS.

We contrast the results above with the counterfactual exercise, using the predictive power of the *numerator* instead of the *denominator*. The counterfactual regressions are the following. The education premium for inexperienced workers is:

$$\text{Fig. 16 (top-left):} \quad \ln \frac{w^s_{2t}}{w^u_{1t}} = \underset{(0.4767)}{0.4849} \cdot \ln A^{S,I}_t \; \underset{(0.0016)}{-0.0014} \cdot year_t \; + \text{error}_t \quad \overline{R^2} = 0.956$$

For the education premium for experienced workers we regress the following models:

$$\text{Fig. 16 (top-right):} \quad \ln \frac{w^s_{3t}}{w^u_{2t}} = \underset{(0.2751)}{-0.0518} \cdot \ln A^{S,E}_t \; \underset{(0.0010)}{-0.0004} \cdot year_t \; + \text{error}_t \quad \overline{R^2} = 0.994$$

For the experience premium for unskilled workers we regress the following models:

$$\text{Fig. 16 (bottom-left):} \quad \ln \frac{w^u_{2t}}{w^u_{1t}} = \underset{(0.1931)^{***}}{-0.8112} \cdot \ln A^{U,E}_t \; \underset{(0.0007)^{***}}{-0.0030} \cdot year_t \; + \text{error}_t \quad \overline{R^2} = 0.987$$

For the experience premium for unskilled workers we regress the following models:

$$\text{Fig. 16 (bottom-right):} \quad \ln \frac{w^s_{3t}}{w^s_{2t}} = \underset{(0.2356)}{0.1795} \cdot \ln A^{S,E}_t \; \underset{(0.0008)}{-0.0004} \cdot year_t \; + \text{error}_t \quad \overline{R^2} = 0.995$$

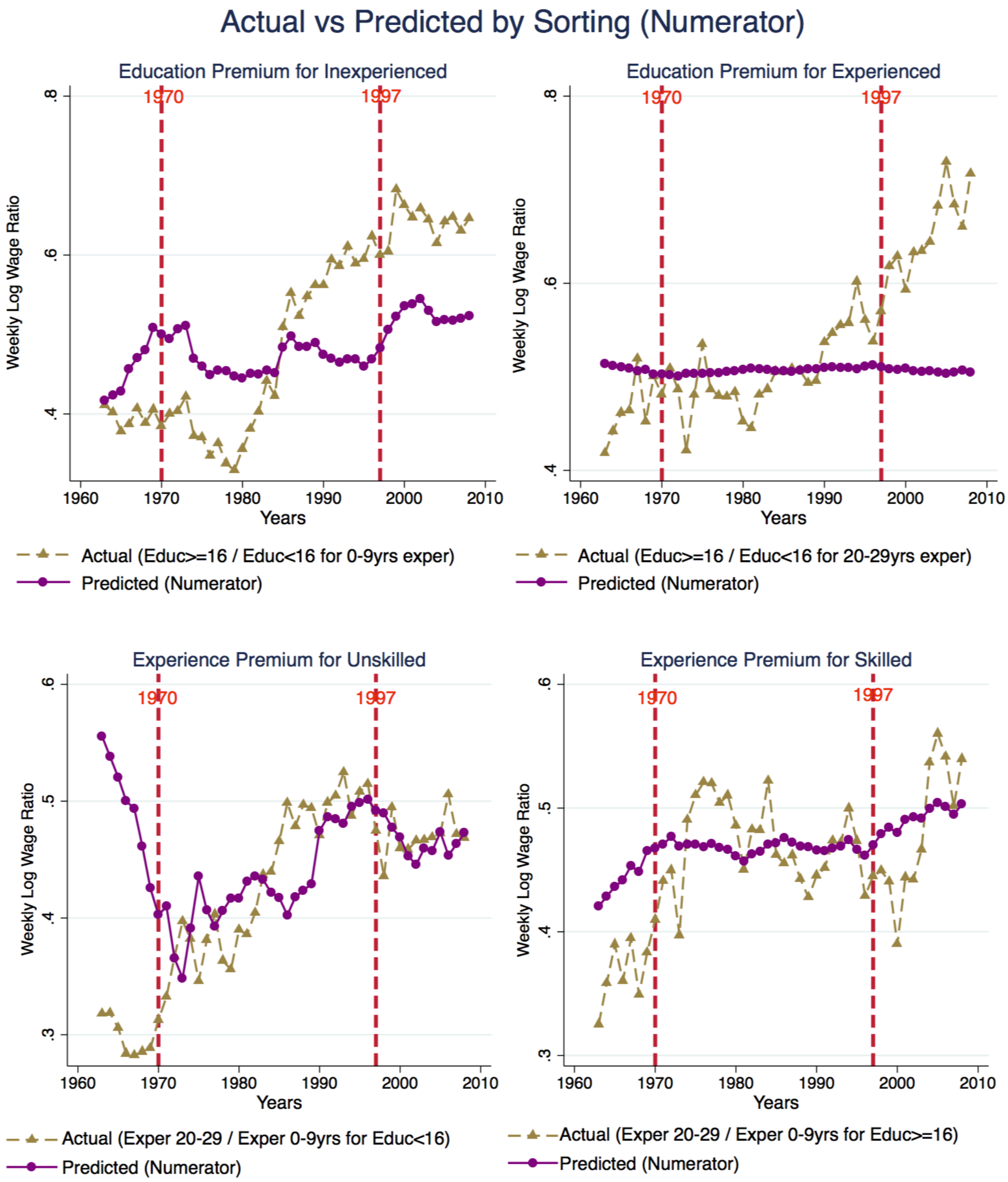

Figure 16: Counterfactual Analysis using the numerator, White Males, CPS.

In both Figure 16 and the corresponding regression results one can see that the fitness of the counterfactual model is not satisfactory. In particular, the regression results reveal the insignificant effect of the numerator on the wage premium. This is clear as all the coefficients are not statistically significant, apart from the case of the experience premium for unskilled workers.

Similarly, one can compare visually the actual data and the predicted values from the counterfactual exercise in Figure 16, to the ones from the sorting model which are collected and illustrated together in Figure 17 (this figure appears in the main paper as Figure 11). It is clear that the denominator plays an important role in explaining the evolution of wage premia, especially during the period 1970-1997.

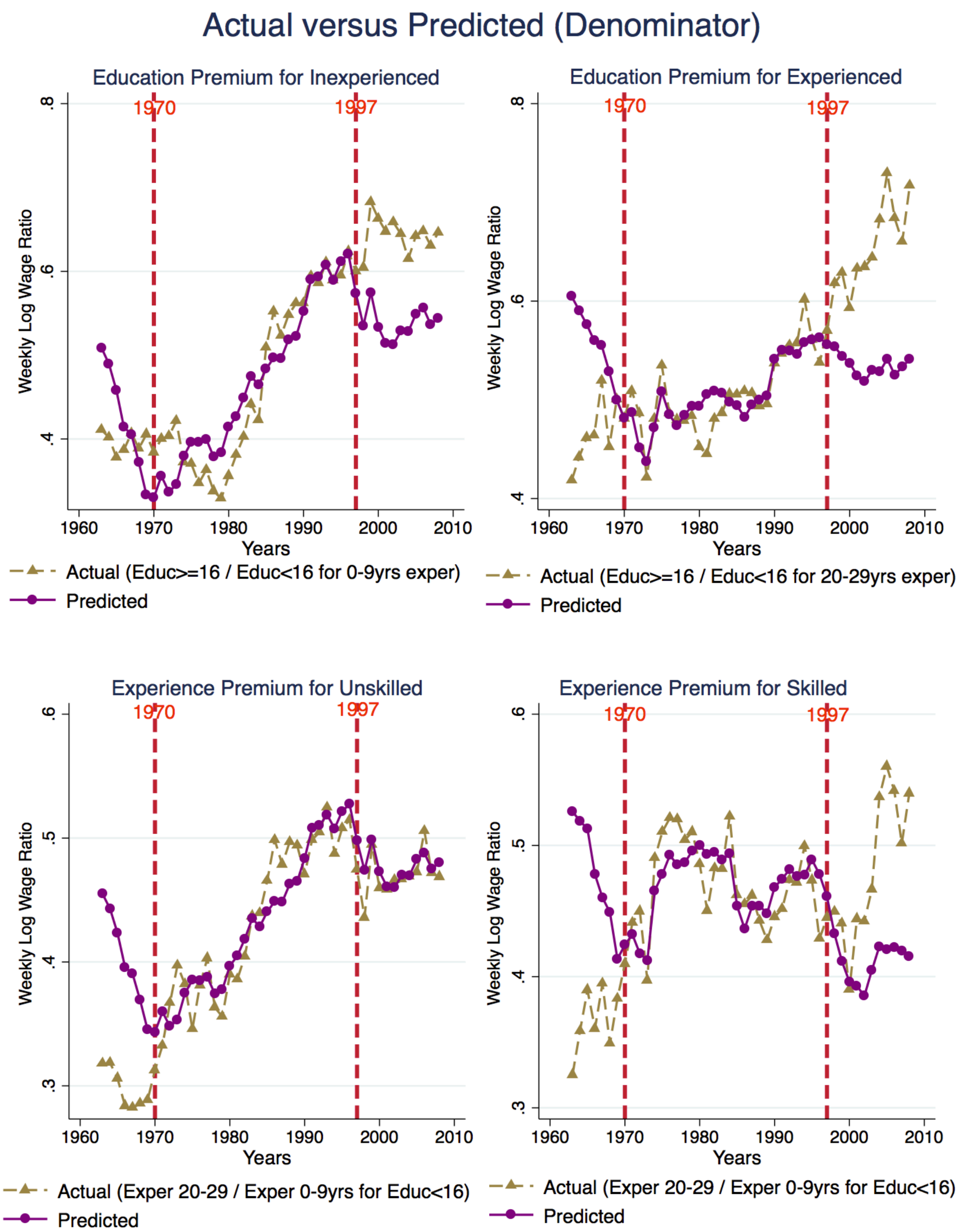

Figure 17: Sorting Model (denominator), White Males, CPS.

A2. Comparison between Unskilled-Inexperienced wages and Unskilled wages

One of the new elements of the model is the examination of wage inequality within group. For instance, the education premium is studied within experience level. This serves two purposes. First, it shows that the evolution of the education premium is very different for inexperienced and for experienced workers. In fact, it raises sharply for the former, while it increases only moderately for the latter. The second purpose is that the most important prediction of the model–that the decline in the denominator and not the rise in the numerator increases the education premium–does not hold if we examine the education premium for both experienced and inexperienced workers being pooled together, as Hendel et al. (2005) do in their influential paper.

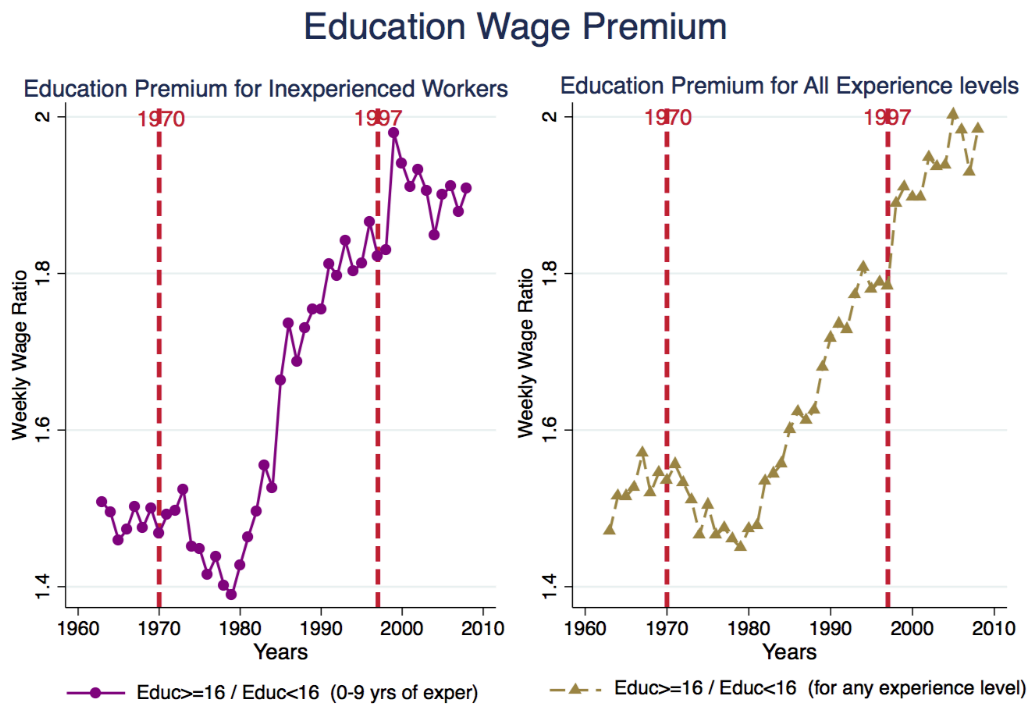

FIGURE 18: EDUCATION PREMIUM, WHITE MALES, CPS.

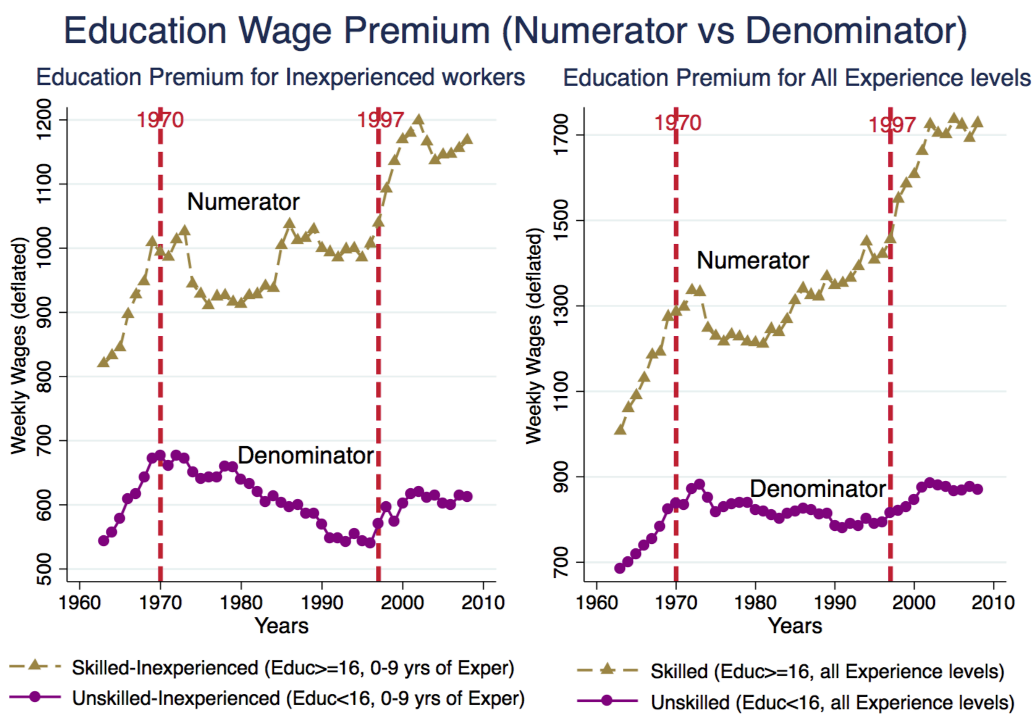

FIGURE 19: NUMERATOR VS DENOMINATOR, WHITE MALES, CPS.

I show this in two steps. First, Figure 18 depicts the education premium for inexperienced workers and the education premium for both experienced and inexperienced workers being pooled together. The rise in both wage premia looks similar.

However, the second step shows that the evolution of the numerator and the denominator for each of these wage premia is different. Figure 19 shows that during the period 1970-1997 the education premium for inexperienced workers increases mainly because the denominator (unskilled-inexperienced wages) falls, while the numerator (skilled-inexperienced wages) does not change much over the same period. One can see this by comparing the left panels in Figures 18 and 19. However, Figure 19 also shows that this is no longer the case when all experienced levels are grouped together, as the pooled education premium increases mainly because the numerator (skilled wages) raises and not due to the moderate decline of the denominator (unskilled wages). This can be illustrated by comparing the right panels in Figures 18 and 19. This suggests that the model developed in the paper is consistent with US evidence, especially during the period 1970-1997. This is not the case for a model that ignores experience and calculates the pooled education premium, as the one developed by Hendel et al. (2005).

My model takes the main insight by Hendel et al. (2005), modifies it with the inclusion of the experience premium, which is driven by private employer learning and shows that the combination of signaling and asymmetric information not only provides a theoretical explanation for rising wage inequality but also that this explanation is empirically plausible.

A3. The NLSY show that ability declines for low educated

I use the National Longitudinal Surveys of Youth for 1979 (NLSY79) and 1997 (NLSY97). I construct two samples, one for each survey that can be compared, to test whether ability (measured by AFQT) is better allocated to education groups in the past or nowadays. The two samples are made to be comparable over time, as explained in the paper. Below I describe the datasets.

NLSY1979: This is comprised of individuals of age 14-22 in 1979 (year of birth 1957-1965). I want to examine how AFQT is allocated to different education groups. This requires following the observations up to 1987, when the individuals are of age 22-30. I restrict my sample only to those who are 26-30 (the year of birth is between 1957-1961). I focus on ages 26-30 to allow them to acquire as much education as possible. The age of 18 or 22 would have been problematic as some individual acquire education when old.

NLSY1997: This is comprised of people of age 12-16 in 1997 (year of birth 1980-1984). I follow observations up to 2011, when the individuals are of age 26-30 (the year of birth is between 1980-1984). Then I derive the correlation between years of education and AFQT, as well as the coefficient of AFQT, from regressing education on AFQT, controlling for the year of birth, race and gender. The results are presented on Table 2 and Charts 1-4 of the paper, show that ability declines mainly for low-educated individuals.

A4. Mathematical Proof of Proposition 2 when Firm profits are zero

In the model firms maximize profits at every period, while workers maximize *lifetime* earnings. This generates positive profits in the second and third period for the firms. However, knowing that in the second period they will derive profits from the credit constraint high types, firms would be willing to offer a higher wage in the first period to attract those workers. Notice that in this case firms will have losses in the first period and benefits in the second and third, in order to break even in their 3-period lifetime. I also allow firms to borrow at zero cost and I prove that even in this case that firms have zero profits the skill premium increases when credit constraints relax.

The new wage for unskilled inexperienced workers in the first period would be higher in this case. The new wage will be the market clearing wage in period 1 plus the transfer from the profits from periods 2 and 3. Formally, $\overline{w_1^u} = w_1^u + \tau$. I have solved for w_1^u in the thesis and here I determine the transfer τ.

The wage for uneducated high types in the second and third period is $w_2^{u,h} = [q^h - (1 + r^l)T]/(2 + r^l)$ but the productivity for these workers is q^h. So, the total profit per worker in period 2 and 3 is:

$$\pi = q^h(2 + r^l) - q^h + T(1 + r^l) = (q^h + T)(1 + r^l)$$

The total profit that firms derive from the credit constrained high types in periods 2 and 3, are divided to all the unskilled workers in period 1. So, the transfer or the benefit that all uneducated inexperienced workers receive in period 1 at the top of w_1^u is τ and it is equal to the following:

$$\tau = \frac{(q^h + T)(1 + r^l)P(u|h)\pi}{(1 - \pi) + P(u|h)\pi}$$

When credit constraints relax, w_1^u falls. Here I prove that τ also falls when credit constraints become less severe and that is why the total wage $\overline{w_1^u}$ also falls. When credit constraints relax $P(u|h)$ falls. If the partial derivative of τ with respect to $P(u|h)$ is positive, it means that when $P(u|h)$ falls, τ also falls and this completes the proof.

$$\frac{\partial \tau}{\partial P(u|h)} > 0$$

$$(q^h + T)(1 + r^l)\pi[(1 - \pi) + P(u|h)\pi] - (q^h + T)(1 + r^l)P(u|h)\pi > 0$$

$$(q^h + T)(1 + r^l)\pi(1 - \pi) > 0$$

This is always true. Therefore, even when firms have zero total profits in over the three periods, when credit constraints relax, unskilled inexperienced wages fall ($\overline{w_1^u} = w_1^u + \tau$ falls as both w_1^u and τ fall) and the skill premium for inexperienced workers increases.

A5. Mathematical Proof of Proposition 3 with a continuum of ability types

The theoretical model of the thesis assumes that individuals have either high or low ability, q^j, where $j = \{l, h\}$. I relax this and here I allow ability to take any value from zero to one, $j \in [0,1]$. In particular, I prove that even when ability is a continuous variable the main results still hold.

Let the distribution of ability be uniform and before the relaxation of credit constraints those who have ability $j \in [0,\theta]$ to be uneducated, where $0 < \theta < 1$. The remaining $j \in [\theta, 1]$ get an education. After the relaxation of credit constraints an additional $\epsilon > 0$ gets an education. Before the change, the wage ratio between average educated and average uneducated should be smaller than after the change.

$$SkillPremium^{BEFORE} < SkillPremium^{AFTER}$$

$$\frac{w_2^s}{w_1^u}^{BEFORE} < \frac{w_2^s}{w_1^u}^{AFTER}$$

$$\frac{\frac{1-\theta}{2}}{\frac{\theta}{2}} < \frac{\frac{1-(\theta-\epsilon)}{2}}{\frac{\theta-\epsilon}{2}}$$

$$...$$

$$-\epsilon < 0$$

Which is always true. That is why even with a continuum of ability types the main results still hold. I prove this only for the skill premium but the same result holds for the experience premium.