Worker Heterogeneity and the Asymmetric Effects of Minimum Wages*

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Abstract

This paper theoretically and empirically explores the notion that minimum wages affect low-skill workers asymmetrically due to productivity differences. I develop a search model of unemployment with worker heterogeneity, endogenous search intensity, and moral hazard, that predicts asymmetries in the effects of a minimum wage across the labor force. A rising minimum wage lowers the employment and labor force participation of low-productivity workers by pricing them out of the market, while it increases the employment, participation, and wages of more productive workers that remain hirable. Using Current Population Survey micro data, I find empirical evidence of the model's predictions. Within the labor market for low-education (high school or lower) workers, increments in the minimum wage have diametrically opposed effects: they reduce the employment and labor force participation of teenagers with less than high school education, while increasing the employment and labor force participation of mature workers with high school educational attainment. A calibrated version of the model targeting the low-education labor market shows that, despite its opposite effects across the labor force, an increase in the minimum wage negatively impacts aggregate employment, labor force participation, and social welfare.

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1 Introduction

The effects of minimum wages on labor market outcomes have been extensively investigated in economics. Most of these studies focus on low-wage industries which, although diverse in nature, share a common and heterogeneous labor supply due to low technical requirements and high substitutability among workers. This heterogeneity is often overlooked by the literature and important asymmetries in the impact of minimum wages are missed by a representative-worker assumption. This paper explores the notion that minimum wages could affect the labor force asymmetrically due to worker heterogeneity. First theoretically, by developing a search model of unemployment with heterogeneous workers. Then empirically, by finding evidence supporting the model's main result: within the low-skill labor force, a rising minimum wage lowers the employment and labor force participation of the least productive workers as they are priced out of the market, while it increases the employment, participation, and wages of more productive workers that remain hirable.

I develop a search-and-matching model of unemployment with ex-ante worker heterogeneity, endogenous search intensity, and worker moral hazard as in Shapiro-Stiglitz (1984). The presence of worker moral hazard creates the need to incentivize workers at all times, which is optimally done by employers through a combination of efficiency wages and the threat of long unemployment spells. Worker heterogeneity generates a diverse array of optimal incentivizing schemes that depend on the worker's productivity and lead to differences in wages and unemployment rates across the labor force.

Under these circumstances, a binding minimum wage disrupts optimal incentivizing schemes and ultimately leads to disemployment and labor-force discouragement. When wages are negotiated via Nash-bargaining, a binding minimum wage can improve the workers' bargaining position without terminating or precluding future matches. However, with efficiency wages in place, the room for wage bargaining has been exhausted and employers cannot profitably raise wages. Match termination ensues. With bleak employment prospects, the worker's best option is to stop searching for a job since it is a costly activity with no expected payoffs; a minimum wage discourages low-productivity workers from participating in the labor force.

The model predicts improvements in the labor-market conditions of workers remaining in the market after a minimum wage hike. A rising minimum wage drives the lowest-skilled workers out of the labor force, which increases average worker productivity and the expected return of filling a vacancy. Equilibrium market tightness rises in response, which increases employment and creates spillover effects on wages through higher job-finding rates and better wage-bargaining terms for workers. These improvements encourage the labor force participation and search intensity of hirable workers.

Using Current Population Survey (CPS) data I test the model's predictions. Identifying heterogeneity in the labor force is fundamental for the analysis, so I consider two-way disaggregation by educational attainment and age. Two important results emerge from the analysis: 1) the minimum wage affects mostly low-education (high school or lower) labor markets; and 2) increments in the minimum wage have diametrically opposed effects within the low-education labor force: they reduce the employment and labor force participation of teenagers with less than high school education, while increasing the employment and labor force participation of mature workers with high school educational attainment .[1]

To theoretically assess the effects of increments in the minimum wage in the low-education labor market, I calibrate the model using the empirical results. Simulations of increases in the minimum wage show that, although the effect on individual labor-market outcomes vary widely by productivity, aggregate employment, aggregate labor force participation and social welfare, defined as total output net of search and recruiting costs, decrease with a rising minimum wage. According to the simulation, increasing the binding minimum wage from \$7.25 to \$15 would cause an employment and labor force participation reduction of roughly 50%, and a 70% decrease in social welfare for the low-education labor force.

This paper's contributions are theoretical and empirical. Theoretically, it presents a tractable and versatile model for the analysis of worker heterogeneity which predicts asymmetric outcomes across the labor force such as diverse unemployment rates, labor force participation rates, and wages. This characteristic makes the model useful for the analysis of policies affecting workers differently according to their skills and productivity.

Applying this model to the analysis of minimum wages offers an additional set of advantages. The model's setting emulates an environment where a minimum wage is most likely binding and consequential; low-wage labor markets which are mostly characterized by unspecialized jobs with high substitutability between workers and no skill-signaling. The assumptions of ex-ante worker heterogeneity and random search make the model fit this description.

The model offers an intuitive and cohesive explanation of the ripple effects and the asymmetries in the impact of minimum wages. This is achieved by assuming moral hazard and imperfect monitoring in a unified low-wage labor market where all outcomes are driven by the same general equilibrium effect; changes in equilibrium market tightness. As the minimum wage binds at the low end of the worker productivity distribution, it changes the firm's incentives to open vacancies. The effects of the minimum on the outcomes of workers on the upper part of the distribution depend on whether the market tightens or loosens. The presence of moral hazard delivers stark predictions about minimum wages hikes; market tightness unambiguously increases through a "weeding-out" effect in the labor force.

The model is also capable of generating and explaining a number of other phenomena related to minimum wages in a parsimonious way. It describes the well-documented wage spillover effect as a general equilibrium result. After a minimum wage hike, market tightness increases and jobs arrive to remaining workers at higher rate than workers do to open vacancies, relative to before the hike. The worker's bargaining strength is then higher and the firm's lower, which results in higher wages.[2] It also sheds light on the use of suboptimal minimum wages: situations where, due to regulations, employers could actually pay workers less than the minimum and yet decide not to.[3] The situation occurs even when some firms paid a starting wage below the new minimum before it became effective. In my model, a higher minimum wage increases market tightness: workers who remain hirable have better outside options, which increases the endogenous efficiency wage floor. So, it could be the case that workers earning below a new minimum before it becomes effective must be paid above the new minimum to be incentivized.

The paper also contributes to the empirical literature on minimum wages by documenting that increases in the min-

[1] I define mature workers as the workers aged between 25 to 59.

[2] For evidence on wage spillover effects see: Katz and Krueger (1992); Card and Krueger (1995); Dolado, Felgueroso, and Jimeo (1997); Teulings (2003).

[3] Freeman, Wayne, and Ichnioski (1981); Katz and Krueger (1991), (1992); Manning and Dickens (2002).

imum wage impact low-education workers only, and that the nature and magnitude of the effects depend on education and age. My results are consistent with the bulk of literature finding negative employment and labor force participation effects for the young low-educated population, with estimated elasticities of -0.20 and -0.15 respectively. A new finding of the present study is the positive impact on the employment and labor force participation for mature workers with high school educational attainment, with predicted elasticities of 0.05 and 0.04 respectively.

According to my results, neglecting to consider worker heterogeneity masks important intra-labor force minimum wage effects; their impact on labor market outcomes depends on the specific population under study. The implementation of a minimum wage must identify and acknowledge who the truly affected workers are, and the direction and magnitude of the impact.

The paper is organized as follows. Section 2 gives a review of the related literature. Section 4 presents the search-and-matching model with heterogeneous workers. Section 5 presents empirical evidence of asymmetric minimum wage effects on labor market outcomes. Section 6 calibrates the model and shows the simulation's results of increases in the minimum wage. Finally, Section 7 concludes. Tables, derivations, and proofs are included in the Appendix.

2 Related Literature

This paper relates to several strands of the literature. First, it is related to the work studying the effect of changes in minimum wages on labor market outcomes and welfare in a Mortensen-Pissarides framework. The main difference between the present paper and previous works is the inclusion of worker heterogeneity in a random search environment, that is,the assumption that different workers participate in the same labor market. The best known work in the field is Flinn(2006). He considers heterogeneity in the workers' outside values to account for the labor-force participation effects that a higher minimum could create, but once workers have decided to enter the labor market, they are ex-ante identical and their productivity is determined by a random draw from a productivity distribution. This ex-post heterogeneity does not make it possible to create a link between market outcomes and workers' individual characteristics, such as the empirical correlation between wages and age. Flinn (2010) presents an extension of that model introducing ex-ante worker heterogeneity captured by differences in the parameters of the productivity distribution determining the product of a match. With randomness in the productivity, endogenous contact rates can be derived only when directed search is considered, that is, when different workers are assumed to participate in different labor submarkets. Rocheteau and Tasci (2008) investigate the effect of minimum wages in an array of different environments within a search framework. However, they do not consider worker heterogeneity. Gorry (2013) presents a search model to explore the effects of minimum wages on experience accumulation. His model includes worker heterogeneity but search is directed.

To the best of my knowledge, my paper is the first one to study minimum wages in an environment with worker heterogeneity and random search. These two characteristics absent in other models are necessary to understand how asymmetries in the way a minimum wage affects workers in the same labor market arise. With these characteristics, a minimum wage binding only for a small portion of workers has repercussions on the outcomes of all the workers in the market.

Another important difference with Flinn (2006) is that his empirical analysis focuses on estimating the workers' bargaining power to determine if the Hosios (1990) efficiency condition is satisfied and assess the welfare properties of a minimum wage. In my model, the Hosios (1990) rule of optimality does no longer hold due to the heterogeneity in the workforce and the constraint on the Nash bargaining. Whether the minimum wage has detrimental or improving welfare effects depends on the model's parameterization. Based on the results of the reduced form estimation, I asses the welfare properties of a minimum wage on the low-education labor market with a calibrated version of the model.

The paper also relates to the vast empirical literature exploring the effect of minimum wages on employment, broadly reviewed in Neumark and Wascher (2007). They report that the majority of the studies give a consistent indication of negative employment effects, and that among the papers that according to them provide the most credible evidence, almost all point to negative employment effects, both for the United States as well as for many other countries. The studies that focus on the least-skilled groups provide relatively overwhelming evidence of stronger disemployment effects for these groups. My results are consistent with the literature; teenagers and the least educated workers experience negative employment effects. My result show positive, although small, positive employment effect for 25 to 59 year-olds with high school educational attainment. To the best of my knowledge, this is the first study to find positive employment effects for this specific demographic.

This paper also explores the effect of minimum wages on labor force participation. Previous works such as Kaitz (1970), Mincer (1976), Ragan (1977), and Wessels (1980) find that the minimum wage decreased, or left unchanged, the labor force participation rate of low-wage workers. Using more recent econometric techniques, Wessels (2005) shows that minimum wage hikes had a small but significant negative effects on the labor force participation of teenagers. My results are overall consistent with these findings; I also find significant negative elasticities for teenagers of -0.15. However, this first paper to find significant positive effects on labor force participation on 25-59 year olds with high-school educational attainment and find a statically significant elasticity of 0.04.

3 The Model

In this section, I present a search-and-matching model of unemployment with worker heterogeneity, moral hazard, and endogenous search intensity. The environment is the same as Pissarides (2000) chapter 5 with two important differences: workers vary in their productivity, and there is imperfect monitoring of a worker's effort as in Shapiro and Stiglitz (1984).[4]

[4]The model is based on previous models of search unemployment with moral hazard and imperfect monitoring: Mortensen (1989), Mortensen and Pissarides (1999), and Rocheteau (2001).

3.1 The Model's Environment

Time is continuous, endless, and is denoted by t. All agents are risk neutral and discount utility flows at rate $r \in \mathbb{R}^{+}$. There are n kinds of workers with ex-ante productivities $y_1, ..., y_n$ satisfying $0 < y_1 <, ..., < y_n$. There is a continuum of identical firms which can be matched with one worker at most. Search is random or undirected; firms can be matched with any type of worker. Productivity is perfectly observable by firms and workers, so a worker with productivity y_i, hereinafter type-i worker, is hired upon meeting with an endogenous probability Π_i. As it will be shown later, Π_i is optimally chosen by firms as a motivating device.

Firms are identical, so the production flow of a match depends entirely on the worker's type.[5] There are two levels of work intensity; e and 0. If a type-i worker exerts effort, the flow product is y_i, and the worker bears a disutility of e. If the worker shirks, the product of a match is zero. The effort exerted by the worker is observable only after an inspection, which obeys a Poisson process with an exogenous arrival rate $\lambda \in \mathbb{R}^{+}$. If the worker is caught shirking the match is terminated. There are no reputational effects, so upon meeting a worker, a firm does not know whether the worker has a shirking history or not.

An employed worker receives a wage $w_i \leq y_i$. When unemployed, a worker receives an income $b < y_1$, which can be interpreted as unemployment benefits or the utility a workers derives from not working. Unemployed type-i workers, must decide how actively they search for a job. This search intensity is denoted by s_i and in the model's setting, it is tantamount to labor force participation. If $s_i = 0$, the worker is not participating in the labor market and higher levels of s_i will be interpreted as higher labor force participation. Search intensity comes at a cost $c(s_i)$, where $c'(s_i) > 0$, $c''(s_i) > 0$, $c(0) = c'(0) = 0$ and $c(\infty) = \infty$. Similarly, a firm with a vacant job must incur a flow cost $\gamma \in \mathbb{R}^{+}$ to advertise its vacancy.

Worker population is given by $p_1, ..., p_n$, where p_i is the share of type-i workers. I denote the unemployment rate of each type of worker as u_i, and the number of vacancies as a fraction of the worker population as υ. Labor market tightness is defined as

$$\theta \equiv \frac{v}{\sum\limits_i p_i s_i u_i},$$

where $\sum\limits_i p_i s_i u_i$ is the measure of active unemployed workers. The number of matches made per-unit of time is given by the constant-returns matching function $h(\sum\limits_i p_i s_i u_i, v)$, differentiable and increasing in both arguments. The matching rate per active unemployed worker is defined as

$$f(\theta) \equiv \frac{h(\sum\limits_i p_i s_i u_i, v)}{\sum\limits_i p_i s_i u_i} = h(1, \theta).$$

Similarly, a firm's matching rate is given by

[5] Other search-and-matching models where search is undirected are Acemoglu (1999), Shimer(2001), Dolado et al. (2003) and Pries (2008). Acemoglu (1999) makes a case for undirected search by pointing out that skill is imperfectly correlated with observable characteristics, such as years of education and age, making it difficult for employers to recruit workers with a particular skill level.

$$q(\theta) \equiv \frac{h(\sum_i p_i s_i u_i, v)}{v} = h(1/\theta, 1).$$

Unemployed workers are matched faster in a tighter market, that is, when there are more vacancies relative to job seekers. Similarly, firms are matched with workers faster when there are more unemployed workers relative to vacancies. Matches are terminated by an exogenous shock following a Poisson process with parameter $\delta \in \mathbb{R}^+$. There is no on-the-job search.

3.1.1 Worker Behavior

Once hired, it is the worker's decision to exert effort or shirk. This decision is made based on the lifetime expected utility of each action. A non-shirker is a worker who chooses not to shirk in all periods while his current job lasts. He gets a wage w_i and suffers a disutility e per unit of time, and could have his job terminated exogenously with probability δ. The lifetime expected utility of a type-i non-shirker, E_i, obeys the flow Bellman equation:

$$rE_i = w_i - e + \delta(U_i - E_i), \tag{1}$$

where U_i is the lifetime expected utility of a type-i unemployed worker. E_i represents the asset value of employment, so (1) states that the opportunity cost of holding a job without shirking is equal to the current income flow minus the disutility of effort plus the expected capital loss from a change of state.

The expected lifetime utility of a worker who chooses to shirk, S_i, during a length of time dt, satisfies

$$S_i = w_i dt + \exp(-rdt)\left\{\Pr[\min(\tau_\delta, \tau_\lambda) \le dt] U_i + (1 - \Pr[\min(\tau_\delta, \tau_\lambda) \le dt]) E_i\right\}, \tag{2}$$

where τ_λ is the length of time until the next inspection and τ_δ is the duration of the job. These two processes are characterized by an exponential distribution with parameters λ and δ respectively. According to (2), during the time interval dt a shirker receives a real wage $w_i dt$ and has no disutility from work, he loses his job if he is caught shirking or if the match is terminated by an idiosyncratic shock. If neither of these two events occur during the time interval dt, the employed worker stops shirking in all subsequent periods. A worker will chose to exert effort over shirking if and only if the lifetime expected value of not shirking is greater the lifetime expected value of doing so. As dt approaches zero, it can be shown that a type-i worker will choose effort over shirking if and only if

$$E_i - U_i \ge \frac{e}{\lambda}, \tag{3}$$

this is the no-shirking condition (NSC) and its derivation is shown in the appendix. The condition states that in order to incentivize a worker to exert effort in the production process, his surplus from a match must be at least equal to e/λ, the expected disutility from working before the next inspection. When a workers decides to shirk he saves the disutility of effort e but has an expected capital loss of $\lambda(E_i - U_i)$. In equilibrium, workers will never have an incentive to shirk since firms will never hire a worker if they cannot guarantee their effort, so the lifetime expected utility of unemployment of a type-i worker satisfies

$$rU_i = \max_{s_i \geq 0} \{b - c(s_i) + s_i \Pi_i f(\theta)[E_i - U_i]\}, \tag{4}$$

where $s_i \Pi_i f(\theta)$ is the unemployment-exit rate. According to (4), when an unemployed worker finds a job he becomes a non-shirker given that the NSC is always satisfied. It is important to remark that the permanent income of unemployed workers is increasing with market tightness since the probability of coming into contact with a firm increases with more vacancies per worker, which shortens the average duration of unemployment. Workers set their search intensity to maximize rU_i taking θ and the rest of the parameters as given. The optimal choice of search intensity solves:

$$c'(s_i) = \Pi_i f(\theta)[E_i - U_i]. \tag{5}$$

The restrictions imposed on the cost function $c(s_i)$ guarantee a unique solution to (5). Combining (1) and (4) the surplus of a match for a type-i worker is:

$$E_i - U_i = \frac{w_i - e - b + c(s_i)}{r + \delta + s_i \Pi_i f(\theta)}. \tag{6}$$

A worker will accept a match if and only if $E_i - U_i$ is positive and, according to the NSC (3), will choose not to shirk if and only if it is greater than e/λ.

3.1.2 Firm Behavior

The present discounted value of expected profits from a vacant job, V, must satisfy the Bellman equation

$$rV = -\gamma + q(\theta)[\sum_i \Pi_i \mu_i (J_i - V)], \tag{7}$$

where γ is the flow cost of keeping a vacancy open. The value function of a filled vacancy by a type-i worker is denoted by J_i, and μ_i is the fraction of active unemployed type-i workers in the active unemployed population. Equation (7) states that the capital cost of an open vacancy has to be exactly equal to the rate of return of the vacancy, i.e., the flow costs of recruiting plus the expected capital gain. The fraction of unemployed type-i workers is given by

$$\mu_i = \frac{p_i s_i u_i}{\sum_j p_j s_j u_j}. \tag{8}$$

The asset value of an occupied vacancy by a type-i worker satisfies a similar Bellman equation:

$$rJ_i = y_i - w_i + \delta(V - J_i). \tag{9}$$

Firms will hire workers only if the NSC is satisfied, so the capital gain of a filled vacancy is equal to the income flow, $y_i - w_i$, plus the expected capital loss when the match is exogenously destroyed. Each firm takes the strategy of other firms as given, i.e. they take market tightness as given, and chooses Π_i in order to maximize its expected profits. The best response function of a firm satisfies the following rule:

$$\begin{array}{lcl} J_i - V > 0 & \Rightarrow & \Pi_i = 1 \\ J_i - V < 0 & \Rightarrow & \Pi_i = 0 \\ J_i - V = 0 & \Rightarrow & \Pi_i \in [0,1] \end{array} . \tag{10}$$

In words, if the firm's surplus of a match is strictly positive the firm will always hire the worker. If the surplus is negative the firm will never hire the worker. If the surplus is zero, the firm is indifferent between hiring the worker and keep searching for a worker, so the firm's best response is to hire a worker with any probability.

3.1.3 Wage determination

Wages are determined through Nash bargaining subject to the constraint of the NSC.[6] Wages solve:

$$w_i = \arg\max\, (E_i - U_i)^{\beta} J_i^{1-\beta} \text{ s.t. } E_i - U_i \geq \frac{e}{\lambda}, \tag{11}$$

where β is the worker's bargaining power. Using (6) and (9), the expression for the unconstrained Nash-bargaining wage, w_i^N, is

$$w_i^N = y_i \left[\frac{\beta (r + \delta + s_i \Pi_i f(\theta))}{r + \delta + \beta s_i \Pi_i f(\theta)} \right] + \left[\frac{(r+s)(1-\beta)}{r + \delta + \beta s_i \Pi_i f(\theta)} \right] [b + e - c(s_i)] . \tag{12}$$

With an unconstrained Nash-bargaining wage, the worker's surplus of employment is

$$E_i - U_i = \frac{\beta [y_i - e - b + c(s_i)]}{r + \delta + \beta s_i \Pi_i f(\theta)}. \tag{13}$$

When the NSC cannot be satisfied with the unconstrained Nash-bargaining wage, firms set the wage to incentivize workers. The minimum wage that a firm must pay to induce effort from the worker is the wage that makes the NSC bind. Substituting (6) into the NSC and solving for w with an equality, we get that the efficiency wage, w_i^E, is

$$w_i^E = b + e - c(s_i) + \frac{e}{\lambda} [r + \delta + s_i \Pi_i f(\theta)]. \tag{14}$$

This is the minimum wage required to incentivize workers to exert effort. Without the threat of moral hazard, i.e. if $e = 0$ or $\lambda \to \infty$, the unconstrained Nash-bargaining wage would be enough to guarantee the worker's effort into the production process. In the presence of moral hazard, guaranteeing effort requires a moral-hazard premium defined as

[6] Using formal econometric analysis, Malcomson and Mavroeidis (2011), show that this constrained Nash-bargaining mechanism fits the wage patterns in the US data better than the canonical unconstrained Nash-bargaining model in Mortensen and Pissarides (1994), or the credible bargaining model of Hall and Milgrom (2008).

the difference between the efficiency wage and the unconstrained Nash-bargaining wage, $w_i^E - w_i^N$. It can be showed that this premium is inversely related to productivity and it increases with the relative value of the worker's outside options. If his current job is likely to end or if the expected length of unemployment is short, the outside options are relatively more valuable so the moral hazard premium must be larger. Consistent with the efficiency-wage literature, the no-shirking wage is higher when the effort to be exerted is larger or the detection probability is lower. Notice that the efficiency wage is an increasing function of market tightness just like the Nash-bargaining wage but, unlike it, the efficiency wage is not bounded above. This is the result of the fact that the moral hazard premium goes to infinity along with market tightness. If the worker's valuation for his job must be kept above a threshold to prevent shirking, as the market tightens, the wage premium gets increasingly large to compensate the worker for the improvement of his outside options.

Depending on whether the NSC is binding, equilibrium wages are determined either through Nash bargaining or with the expression for efficiency wages. Using (3) and (13), the solution to (11) can be specified as:

$$w_i = \begin{cases} w_i^N, & y_i > b + e - c(s_i) + (r + \delta + s_i \Pi_i f(\theta)\beta)\frac{e}{\lambda\beta}, \\ w_i^E, & y_i \leq b + e - c(s_i) + (r + \delta + s_i \Pi_i f(\theta)\beta)\frac{e}{\lambda\beta}. \end{cases} \tag{15}$$

High-productivity workers will receive unconstrained Nash-bargaining wages while low-productivity workers will be paid an efficiency wage. This function is monotonically increasing and continuous on market tightness and productivity.

3.2 Equilibrium

I only consider symmetric Nash equilibria; all firms adopt the same hiring strategy. This optimal hiring strategy must satisfy the hiring rule in (10) and no firm must have an incentive to change its strategy given the other firms' strategies. The free-entry condition for firms implies that the value of a vacancy is zero, $V = 0$. Using this fact, the equilibirum best response hiring function can be derived. For a given θ and s_i, the firm's best-response hiring function for a type-i worker is:

$$\Pi_i(\theta) = \begin{cases} 1, & y_i \geq y_M(\theta), \\ \frac{y_i - b - e + c(s_i) - (r+\delta)\frac{e}{\lambda}}{s_i f(\theta)\frac{e}{\lambda}}, & y_M(\theta) > y_i \geq y_L, \\ 0, & y_L > y_i. \end{cases} \tag{16}$$

,where $y_H(\theta) \equiv b + e - c^E + [r + \delta + s^E f(\theta)\beta]\frac{e}{\lambda\beta}$, $y_M(\theta) \equiv b + e - c^E + [r + \delta + s^E f(\theta)]\frac{e}{\lambda}$, $y_L \equiv b + e + (r + \delta)\frac{e}{\lambda}$, s^E is such that $c'(s^E) = f(\theta)\frac{e}{\lambda}$, and $c^E \equiv c(s^E)$. The derivation of this function is shown in the appendix. The function describes the firm's hiring behavior upon contact with a type-i worker. Workers with high productivities will always be hired by firms since they can be encouraged profitably; firms are strictly better off hiring them. Workers with lower productivities will be hired with a probability less than one because upon contact with these workers, firms are indifferent between hiring them and not, they generate no surplus for the firm. Workers with very low productivities cannot be encouraged without generating a negative surplus for the firms; firms will never hire these workers. Using these results, the equilibrium search intensity function for a type-i worker can be derived.

$$s_i(\theta) = \begin{cases} s_i^N, \quad \text{s.t. } c'(s_i^N) = \frac{\beta(y_i - e - b + c(s_i))}{r+\delta+\beta s_i^N f(\theta)} & y_i \geq y_H(\theta), \\ s^E, \quad \text{s.t. } c'(s^E) = f(\theta)\frac{e}{\lambda} & y_H(\theta) > y_i \geq y_M(\theta), \\ s_i^L, \quad \text{s.t. } c'(s_i) = \frac{y_i - e - b + c(s_i) - (r+\delta)\frac{e}{\lambda}}{s_i} & y_M(\theta) > y_i \geq y_L, \\ 0, & y_L > y_i. \end{cases} \tag{17}$$

The results in (17) describe the optimal search intensity of workers according to their productivity. It can be shown that $0 \leq s_i^L \leq s^{E \leq} s_i^N$, so more productive workers will participate more intensely in the market since the gains of finding a job are larger for them. Using the information from the optimal search intensity and hiring rule functions, the wage equation (15) can be expressed as:

$$w_i(\theta) = \begin{cases} w_i^N(\theta), & y_i \geq y_H(\theta), \\ w^E(\theta) \equiv b + e - c^E + \frac{e}{\lambda}[r + \delta + s^E f(\theta)], & y_H(\theta) > y_i \geq y_M(\theta), \\ y_i, & y_M(\theta) > y_i \geq y_L. \end{cases} \tag{18}$$

Equations (16), and (18) describe the equilibrium wage-hiring incentivizing scheme for a given market tightness. Upon contact with a worker, firms hire him with a probability and a wage that ensures that the NSC is not violated. The rationale behind the incentivizing-hiring scheme is presented in Figure 1. If the product of a match is high enough ($y_i > y_H(\theta)$), wage is set using Nash-bargaining since it generates surplus for both, worker and firm, without violating the NSC. Worker surplus is above the no-shirking threshold so he will be incentivized to work, and the surplus that a firm gets is positive so it will hire the worker with probability one. When productivity is not so high ($y_H(\theta) \geq y_i > y_M(\theta)$), the Nash-bargaining wage is not high enough to prevent a worker from shirking, efficiency wages are necessary to ensure that the match is productive. The firm still gets a positive surplus so the worker is hired with probability one. Workers such that $y_i \geq y_M(\theta)$ will be referred to as "perfectly employable" since firms can always hire them and get a strictly positive match surplus.

When $y_M(\theta) \geq y_i > y_L$, the worker's efficiency wage is greater than the product of a match ($w_i^E = b + e - c(s_i) + \frac{e}{\lambda}[r + \delta + s_i \Pi_i f(\theta)] > y_i$), the worker can still be encouraged to work with a wage equal to his productivity, $w_i = y_i$, if his outside options are eroded by a lower probability of transition out of unemployment. If Π_i were equal to one, the no-shirking wage would have to be superior to the worker's productivity so firms would never hire them. Conversely, if Π_i were equal to zero, the worker would generate positive profits for his employer so he would always be hired. The equilibrium answer to this conundrum is that employers adopt a mixed strategy, they hire the worker with a probability

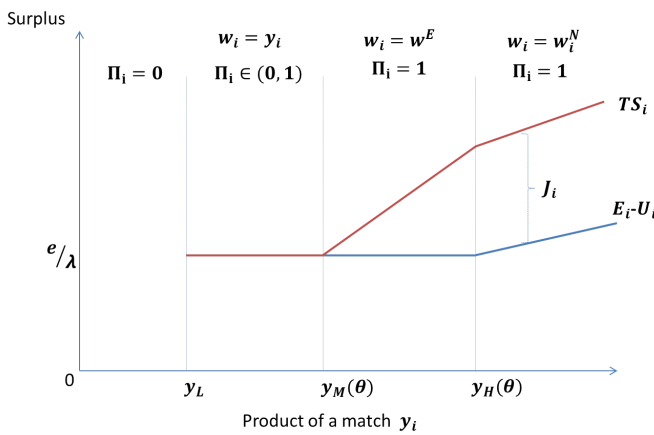

Figure 1: The firm's hiring strategy.

For a given θ, upon contact with a worker the firm's hiring response (w_i, Π_i) will depend on the product of the match. If $y_L \geq y_i$, the productivity of a worker is so low that the total surplus of a match (TS_i) in not enough to guarantee his effort $(TS_i < \frac{e}{\lambda})$, no match will be made. If $y_M(\theta) > y_i > y_L$, the worker is barely employable and will be discriminated with a hiring probability $\Pi_i \in (0,1)$ that will reduce his outside options to the point his wage, $w_i = y_i$, is just enough to guarantee his effort $(TS_i = \frac{e}{\lambda})$. If $y_H(\theta) \geq y_i > y_M(\theta)$, the worker's productivity is high enough to generate a positive surplus for the firm $(J_i = TS_i - \frac{e}{\lambda} > 0)$ so he will always be hired $(\Pi_i = 1)$. However, it is not large enough to guarantee his effort under Nash-bargaining so he will get the efficiency wage, $w = w^E$. If $y_i > y_H(\theta)$, the match will generate positive surplus for a firm $(\Pi_i = 1)$ and the productivity of a worker is high enough to guarantee his participation with Nash-bargaining wages, $w = w_i^N$.

proportional to his productivity, that is $\Pi_i = [y_i - b - e + c(s_i) - (r+\delta)\frac{e}{\lambda}]/s_i f(\theta)\frac{e}{\lambda}$.[7] The decrease in the exit rate of unemployment can be interpreted as a disciplinary device for less productive workers. Notice that firms hiring these workers do not get any surplus from being matched, so they are indifferent between hiring them and not. For this reason, I will refer to these workers as "barely employable". If the productivity of a worker is extremely low ($y_L \geq y_i$), then even if the worker is fully discriminated, his no-shirking wage would have to be larger than the product of his match so he will never be hired. This differentiated treatment to workers creates wages dispersion and different unemployment rates, shares in the pool of unemployed and exit rates of unemployment.

The worker can receive either an unconstrained Nash-bargaining wage w_i^N, or an efficiency wage w_i^E. According to (14) and (18), the highest an efficiency wage can be is $w^E \equiv b + e - c^E + \frac{e}{\lambda}[r + \delta + s^E f(\theta)]$ and it corresponds to the only efficiency wage that can motivate workers without a complementary hiring discrimination. This is the wage that all perfectly employable who get an efficiency wage receive and from now on I will refer to it as "the" efficiency wage.

To determine equilibrium unemployment we use the fact that at a steady state the inflow and outflow from unemployment must be equal, that is $p_i[1-u_i]\delta = s_i(\theta)\Pi_i(\theta)f(\theta)p_i u_i$. Solving for u_i:

$$u_i = \frac{\delta}{\delta + s_i(\theta)\Pi_i(\theta)f(\theta)}. \tag{19}$$

This expression states that for a given separation rate there is a unique equilibrium unemployment rate determined by equilibrium market tightness. It can be shown that $u_1 \geq u_2 \geq, ..., \geq u_n$, workers with higher productivities have lower unemployment rates. Given the assumption that in equilibrium all profit opportunities from new jobs are exploited driving rents from vacant jobs to zero, $V = 0$, and combining equations (7) and (9), the vacancy supply condition (VSC) is derived:

$$\sum_i \Pi_i(\theta)\mu_i[y_i - w_i(\theta)] = (r+\delta)\frac{\gamma}{q(\theta)}. \tag{20}$$

Equation (20) uniquely determines equilibrium market tightness θ^*. It can be verified that

$$\frac{\partial\theta^*}{\partial e} < 0,\ \frac{\partial\theta^*}{\partial\lambda} \geq 0,\ \frac{\partial\theta^*}{\partial b} < 0,\ \frac{\partial\theta^*}{\partial\delta} < 0,\ \frac{\partial\theta^*}{\partial r} < 0,$$

and

$$\frac{\partial\theta^*}{\partial y_i} \geq 0\ i = 1, ..., n.$$

To complete the notation for the model before I introduce the minimum wage, a steady-state equilibrium of the model is defined as follows:

Definition 1: A steady-state equilibrium consists of a collection of values $\{w_i, \Pi_i, s_i, u_i\}_{i=1}^n$, and θ, satisfying (18) (16) (17) (19), and (20).

[7] We can verify that this is indeed a probability, that is $\Pi_i \in [0,1]$ by observing that it is the solution to the equation $y_i = (1-x)y_L + xy_M(\theta)$. And by assumption $y_M(\theta) \geq y_i > y_L$.

3.3 Minimum Wage

Now I introduce a minimum wage m with full compliance, that is, no wage below m will ever be paid. Hitherto, market tightness alone characterized every outcome of the market: wages, unemployment rates, etc. Although equilibrium market tightness is a function of m itself, it is convenient for the analysis to specify all outcomes as functions of a market tightness θ, and the minimum wage m. The minimum wage adds a restriction to the functions that describe the equilibrium.

Functions (18), (16), and (17) that describe the equilibrium can be expressed as follows:

Equilibrium wage,

$$w_i(m,\theta) = \begin{cases} y_i, & y_M(\theta) > y_i \geq \max\{m, y_L\}, \\ \max\left\{m, w^E(\theta)\right\}, & y_H(\theta) > y_i \geq \max\{m, y_M(\theta)\}, \\ \max\left\{m, w_i^N(\theta)\right\}, & y_i \geq \max\{m, y_H(\theta)\},. \end{cases} \tag{21}$$

Equilibrium hiring probability,

$$\Pi_i(m,\theta) = \begin{cases} 0, & \max\{m, y_L\} > y_i, \\ \frac{y_i - b - e + c(s_i) - (r+\delta)\frac{e}{\lambda}}{s_i^L f(\theta)\frac{e}{\lambda}}, & y_M(\theta) > y_i \geq \max\{m, y_L\}, \\ 1, & y_i \geq \max\{m, y_M(\theta)\}. \end{cases} \tag{22}$$

Equilibrium search intensity,

$$s_i(m,\theta) = \begin{cases} 0, & \max\{m, y_L\} > y_i, \\ s_i^L, & y_M(\theta) > y_i \geq \max\{m, y_L\}, \\ \max\left\{s^m(\theta), s^E(\theta)\right\}, & y_H(\theta) > y_i \geq \max\{m, y_M(\theta)\}, \\ \max\left\{s^m(\theta), s_i^N(\theta)\right\}, & y_i \geq \max\{m, y_H(\theta)\}, \end{cases} \tag{23}$$

where $s^m(\theta)$ solves $c'(s_i) = f(\theta)[m - e - b + c(s_i)]/[r + \delta + s_i f(\theta)]$, $s_i^N(\theta)$ solves $c'(s_i^N) = \beta[y - e - b + c(s_i^N)]/[r + \delta + \beta s_i^N f(\theta)]$, $s^E(\theta)$ solves $c'(s^E) = f(\theta)\frac{e}{\lambda}$, and s_i^L solves $c'(s_i^L) = [y_i - e - b + c(s_i^L) - (r+\delta)\frac{e}{\lambda}]/s_i^L$. When $m = 0$, (21), (22), and (23) reduce to (18), (10), and (17) respectively.

In representative worker world, analyzing the relation between efficiency wages and minimum wages would be trivial; a minimum wage below the efficiency wage has no effects on the labor market. However, introducing heterogeneity allows the possibility to have only a fraction of workers under efficiency wages being affected by the minimum wage and, through a general equilibrium effect, change the outcomes of all the participants. Figure 2 presents the wage schedule in (21) when $m < w^E(\theta)$.

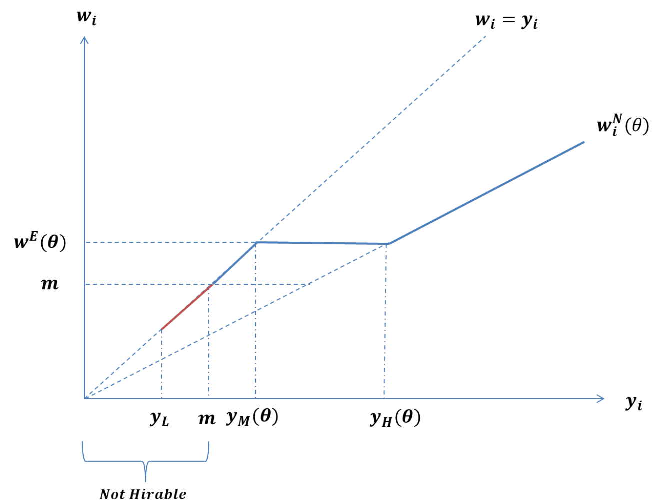

Figure 2: Wage schedule under a minimum wage $m < w^E(\theta)$.

The minimum wage is binding only for barely employable workers. Since these workers are being paid their productivity, a binding minimum can only price them out of the market by making it impossible to find a firm willing to hire them. Perfectly hirable workers will not be directly affected by the minimum wage, but will still experience ripple effects through a general equilibrium effect.

Since all outcomes are defined by equilibrium market tightness, it is fundamental to determine how changes in the minimum wage affect it. The presence of moral hazard allows some stark predictions.

Proposition 1 : *Let θ and θ' be the equilibrium market tightness under m and m' respectively. If $m < m' \leq w^E(\theta)$, then $\theta \leq \theta'$.*

Proof: Appendix.

The result in proposition 1 summarizes the most important finding in the paper. When an increase in the minimum wage is not large enough to make it binding for perfectly employable workers, equilibrium market tightness increases. This is a very intuitive result and a direct consequence of the presence of moral hazard. The need of worker motivation makes the workers at the low end of the productivity distribution get a wage equal to their productivity and as the minimum wage raises, it simply prices them out; the efficiency wage they receive has exhausted the possibility of a raise in the salary. Assuming full compliance with the law, the firm has no option but to terminate the match.

According to (23), it is the worker's best response to stop looking for a job since it is costly activity with no expected payoffs. Workers with productivities below the minimum stop participating in the labor market, which means that the average productivity of workers participating in the labor force increases. This "weeding-out" effect in the labor force generates a more attractive environment for firms to open vacancies. The probability of being matched with a high-productivity worker increases along with the expected return of an open vacancy, which results in a higher equilibrium market tightness.

This is a sharp result of the model that contrasts with the ambiguous predictions of models without moral hazard. Without moral hazard, wages would be determined via Nash-bargaining, which leaves room for a raise in wages without representing a negative surplus for the firm. Under these conditions, a higher minimum wage increases the expected productivity of a worker, but it also increases their wages. The effect on the profitability of an open vacancy is ambiguous.

What a higher minimum wage represents for the market outcomes of different workers directly follows from Proposition 3.

Corollary to Proposition 1 *: Let θ and θ' be the equilibrium market tightness under m and m' respectively. If $m < m' \leq w^E(\theta)$, then $u_i(m,\theta) \geq u_i(m',\theta')$, $s_i(m,\theta) \leq s_i(m',\theta')$,* and *$w_i(m,\theta) \leq w_i(m',\theta')$ $\forall i \in \Omega(m')$. Also, $u_i(m',\theta') = 1$ and $s_i(m',\theta') = 0$ $\forall i \in \Omega^c(m')$.*

The corollary highlights the asymmetry in the effects of the minimum wage. For those workers who remain hirable after a minimum wage hike, their unemployment rates fall and the wages increase, also their participation in the labor market increases as result of these improvements. These results contrast sharply with the consequences a higher minimum wage brings for the workers that have been priced out. These workers are no longer hirable so, their unemployment rate is one. With this outlook, it is their best response to stop looking for a job, so their search intensity and participation in the labor force drop to zero.

These results apply as long as the efficiency wage remains above the minimum. When $m' > w^E(\theta)$, two scenarios can arise. If $m' > \max\{w^E(\theta), w^E(\theta')\}$, all barely hirable workers are priced out of the market and the minimum wage could also price out workers otherwise perfectly hirable. Perfectly hirable workers remaining in the market see their wages increased to the minimum. Figure 3 describes the situation. In these conditions, the effects of a minimum wage are ambiguous since, on the one hand, the average productivity of the labor force increases, and on the other hand, wages increase as well. The effect that a higher minimum wage has on the expected profit of a match will heavily depend on the specific productivity distribution and the rest of the parameter values. The model's calibration for the Low-education labor market in Section 4 shows that this situation does not arise for realistic values of increments in the minimum. Even when the minimum increases by 100%, the efficiency wage increases and remains above the imposed wage floor.

The other possibility is that $w^E(\theta) < m' < w^E(\theta)$, this particular situation generates suboptimal use of minimum wages.

3.3.1 Suboptimal use of Minimum Wages

Falk, Fehr and Zenhder (2006) raise the following question: Why do profit-maximizing employers not take advantage of the possibility of reducing wages below the legal minimum, and why do they pay more than the minimum for those workers who earned less than the new minimum wage before it was introduced? This question follows from the evidence reporting low utilization of minimum wages in situations where in principle, employers could pay the

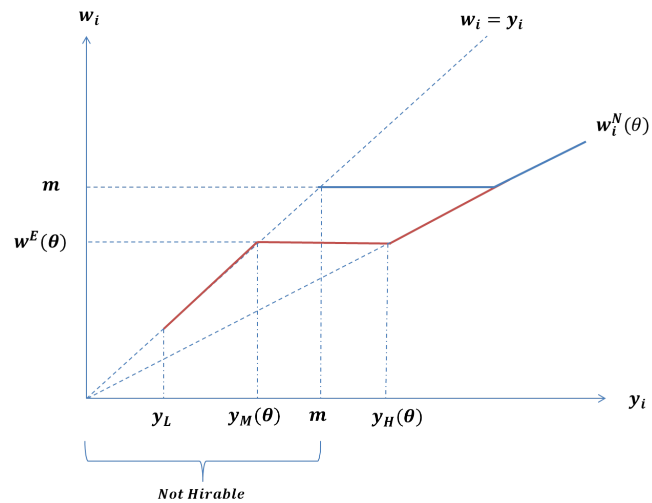

Figure 3: Wage schedule under a minimum wage $m' > \max\{w^E(\theta), w^E(\theta')\}$.

minimum or less.[8] Using data from a laboratory experiment, they argue that the introduction of a minimum wage increases workers' reservation wages due to a constant perception of what a fair wage is. Workers perceive a wage as a fair if it, to a certain degree, is above the minimum regardless of what the minimum wage is. As a result, firms end up paying wages above a new minimum even when workers where earning less than the new minimum before its introduction.

The model offers an explanation of this phenomenon that is also related to changes in the reservation wage. The efficiency wage is the minimum wage required to induce worker participation in the production process, in this sense it constitutes an effective reservation wage. Which workers get an efficiency wage and what this efficiency wage is, depends on market tightness. So a new minimum, if it changes market tightness enough, could drastically alter the wage schedule. Figure 4 presents a situation where the minimum wage is binding for perfectly employable workers so in principle, their new wage should be equal to the minimum, however this is not the case.

Let θ be the equilibrium market tightness under the old minimum m. Before the increase to a minimum m', the salary for worker s was $w^E(\theta) < m'$. When the minimum wage changed to m', worker s was still hirable and should have receive a salary equal to m'. However, a higher minimum created a tighter market with improved outside options for workers. In equilibrium, the efficiency wage has to adjust to compensate workers for this improvement. The wage recived by the worker is $w^E(\theta') > m'$. Firms are not paying the worker the minimum although in principle, they could. Studies show that this practice is common. For example, Katz and Krueger (1992) report that some fast-food restaurant managers were not using the subminimum wage option because they believed that it would not attract qualified teenage workers at that wage. Notice that as long as $w^E(\theta) > m$, even if for some exception the employer could pay wages below the minimum, he will choose not to do so due to moral hazard.

[8] Freeman, Wayne, and Ichniowski 1981; Katz and Krueger 1992; Manning and Dickens 2002

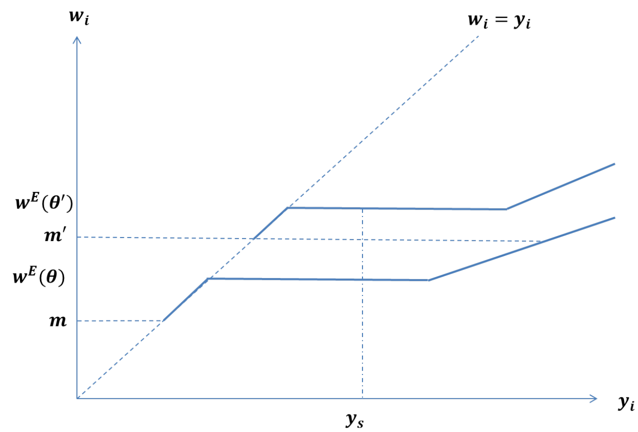

Figure 4: Suboptimal use of minimum wages

Unfortunately, since the new minimum m' is above the level $w^E(\theta)$, characterizing when these situations can arise is difficult since it depends on the parameter values and the workerproductivity distribution.

4 Evidence on Asymmetric Effects of Minimum Wages on Labor Market Outcomes

In this section, I use individual data on labor market outcomes to investigate the existence of asymmetries in the way minimum wages affect the employment, labor force participation, search intensity, wages, and labor hours of workers with different productivities. According to the results of the model described in Section 3, a minimum wage lowers the employment and labor force participation of low-productivity workers while it increases the employment, encourages labor force participation, and augments wages of more productive workers. To identify heterogeneity in productivity I consider two-way disaggregation by educational attainment and age. The data suggest that older and more educated workers are more productive.

The empirical results provide support for the model's predictions and can be summarized as follows: 1) the minimum wage affects only low-education labor markets; and 2) the low-education workforce is asymmetrically affected by minimum wages depending on individual productivities. In fact, increments in the minimum wage have diametrically opposed effects; they reduce the employment and labor force participation of the younger and less educated workers(teenagers with less than high school education) while increasing the employment and labor force participation of older more educated workers (25-59 year olds with high school educational attainment). Despite the dichotomy, the disemployment and discouraging effects are much stronger than the employment and encouraging effects.

4.1 Data

I compile a repeated cross-sectional sample at individual level from the CEPR uniform data extracts, which are based on the Outgoing Rotation Group (ORG) of the CPS, for the years 1994-2013.[9] The CEPR ORG extracts contain detailed information on individuals' demographic characteristics such as education, age, employment status, and hourly earnings. Using the CPS basic monthly files, I augment the data to include individual information about unemployed workers' job-searching efforts. As a proxy for job-search intensity, I use the number of different job-finding methods used by unemployed workers in the 4 weeks preceding the CPS interview.[10] Each observation is merged with a monthly minimum wage variable; the federal or the state minimum, whichever is higher.[11] Additionally, observations are merged with data that capture overall labor market conditions and labor supply variation; monthly state-wide unemployment rates and population shares for the relevant demographic groups.[12]

Table 1 provides descriptive statistics for the different demographic groups analyzed: teens (16 to 19 year olds), young workers (16 to 24 year olds), mature workers (25 to 59 year olds), and elderly workers (60 to 64 year olds). Observations are also classified by educational attainment: Less than high school (LTHS), high school, some college, college, and advanced education.[13] Not surprisingly, individuals with higher educational attainment are older on average. Average worked weekly hours and average hourly wage increase with educational attainment and age. Older and more educated individuals use on average more different methods to find a job. Unemployment rates drop with age and education; teenagers have the highest unemployment rate, 16.6%, while individuals with advanced education have the lowest, 2.2%. Employment and labor force participation are larger in older and more educated groups giving the contrasting employment and participation rates of 38.5% and 46.1% for teenagers, against 86.4% and 88.3% for the advanced education group.

Young workers and teenagers have been the most widely analyzed demographics in the minimum wage literature, so I report their share on each educational group. Teenagers are mostly concentrated in the LTHS group constituting almost 40% of that population. Young workers constitute 44% of the LTHS group, 16% of High School group, and 19% of those with some college.

To begin the analysis of the effects of the minimum wage, I compute the share of the population in each education group that could be considered as directly affected by it; those earning a wage within a 10% range of the minimum wage. Figure 1 displays the wage distribution in terms of the effective minimum wage for each of the categories.

[9] http://ceprdata.org/cps-uniform-data-extracts/

[10] This variable is constructed using the variables PELKM1, PULKM2, PULKM3, PULKM4, PULKM5, and PULKM6 from the CPS basic monthly data. Each one of these variables allows the interviewed to choose one of the following responses: contacted employer directly/interview, contacted public employment agency, contacted private employment agency, contacted friends or relatives, contacted school/university employment center, sent out resumes/filled out application, checked union/professional registers, placed or answered ads, other active, looked at ads, attended job-training programs/courses, nothing, and other passive.

[11] I constructed the minimum wage variable using data from the United States Department of Labor and each state's department of labor, when available, to accurately record effective dates.

[12] Population shares are exogenous (aside from migration). Although the unemployment rate is potentially endogenous, by using state-wide unemployment rates rather than unemployment rates of the specific demographic groups, I hope to capture an aggregate demand indicator.

[13] Classifications follow Jaeger (1997) who defines high school attainment as completing the 12th grade regardless of high school diploma receipt. Advanced schooling is defined as having a master's degree, a professional school degree, or a doctorate degree.

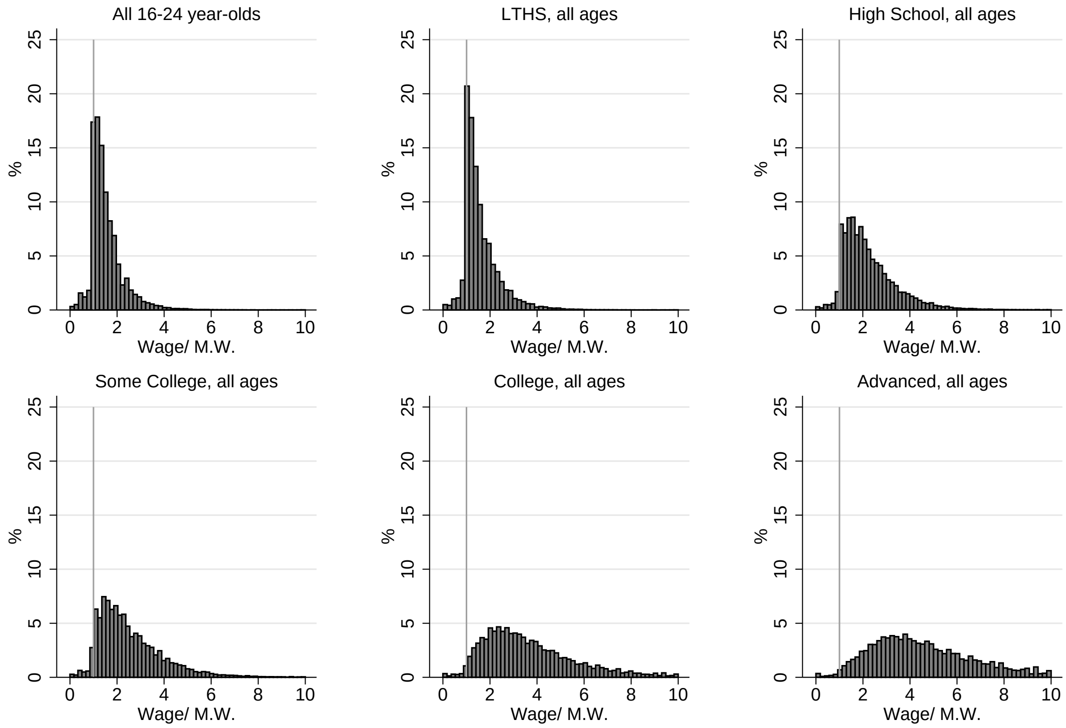

Figure 5: Wage Distributions by Educational Attainment, 1994-2013

Those directly affected by the minimum wage are concentrated in the youngest population, they constitute 32 % of teenagers and 19% of young workers. In terms of education groups; 20% of workers with LHTS education are impacted directly by the minimum wage and this proportion decreases with educational attainment; the share reduces to 6% for workers with high school education, 5% for workers with some college, and 1% for workers with college or advanced education. The wage distributions of younger and low educated workers concentrate closer to the minimum wage and as education increases the distributions spread out. Not surprisingly, and as next section will show, when disaggregating by educational attainment only LHTS and high school groups are affected by changes in the minimum wage. For this reason, I divide the education groups into high-education (some college, college and advanced), and low-education (LTHS and high school). The analysis concentrates on the latter group.

According to the BLS, 26% of total jobs in 2012 had no educational requirements. On the same year, only 8% of the labor force had LTHS education. This suggests a unified labor market of significant size for workers with different educational attainment. The fact that only low-education groups are affected by the minimum wage suggests that they constitute a labor market of their own.

It is the thesis of this paper that heterogeneity plays an important role in the way the minimum wage affects individuals within the same labor market. For this reason, I further disaggregate and analyze low-education groups by

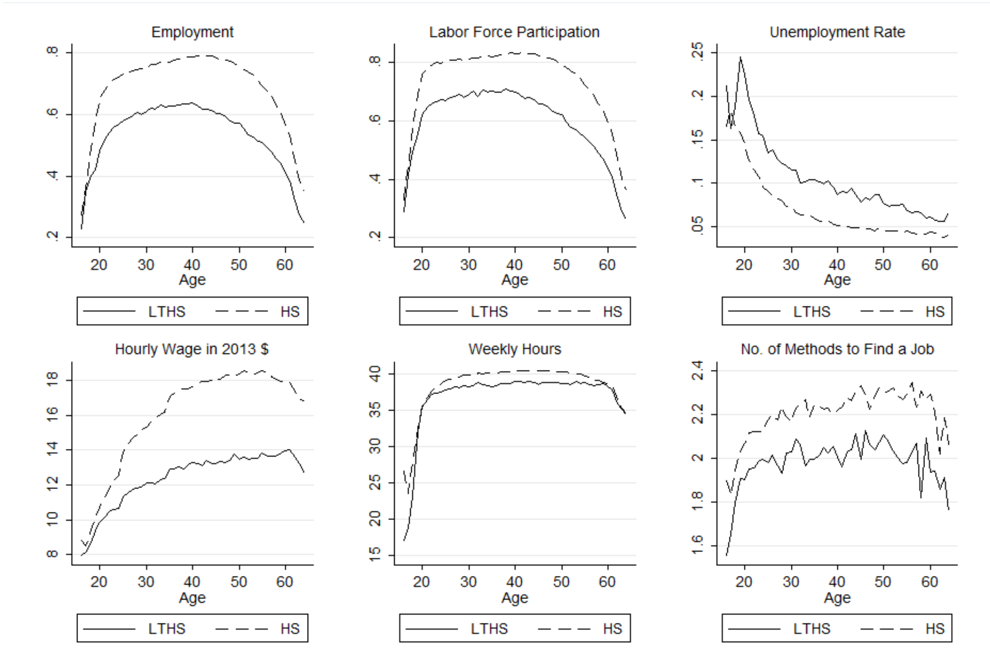

Figure 6: Mean Low-Education Labor Market Outcomes, 1994-2013.

age, another variable commonly used as a proxy for skill.

Figure 2 shows the average market outcomes of low-education groups by age. With the exception of unemployment rate, there is non-monotonic relation between these variables and age. The gap in outcomes between groups is relatively small for younger workers but it widens as they reach the prime of life only to start closing again as they enter the late years. Employment, wages, and weekly hours reach a maximum around 40 years of age in both groups. Labor force participation and search intensity are a measure of labor market activity and they increase with age and are in general grater for those with high school education.

These results suggest that within the low-education labor force, mature workers with high school education are the most productive while teenagers with LTHS education are at the bottom of the productivity distribution. For the reminder of the analysis I will underscore the importance of the two-dimensional proxy for productivity, education and age, to account for worker heterogeneity. Whether completing the 12th grade actually increases human capital or merely signals aptitudes, those with high school education are on average more productive than those less educated. The differences across ages could mirror differences in experience and the natural cycle of ability decay.

4.2 Estimation Strategy

My objective is to estimate the effect of minimum wage increments on employment, labor force participation, search intensity, hours, and wages. I use four different specifications popular in the literature as robustness checks. All of them are estimated at individual level and with standard errors clustered at the state level to account for dependence among observations within the same state. The baseline specification is the panel difference-in-difference canonical model:

$$y_{ist} = \alpha + \beta MW_{st} + \delta Z_{st} + \lambda X_{ist} + \gamma_s + \tau_t + \varepsilon_{ist}, \qquad (1)$$

where i, s, and t denote, respectively, individual, state, and time indexes. The dependent variables y_{ist}, are: a dichotomous employment variable, a dichotomous labor force participation variable, search intensity as previously defined, the natural log of weekly hours, and the natural log of hourly earnings. MW is the log of the effective minimum wage; Z is a vector of state characteristics that includes the aggregate unemployment rate, the population share of the demographic of interest, and aggregate average wage. X is a vector of individual characteristics: race, age, education, marital status and gender. γ_s denotes the state-fixed effect and τ_t represents time dummies in months.

According to Dube, Lester, and Reich (2010), failing to control for spatial heterogeneity in trends generates biases toward negative elasticities of the dependent variable. To address this issue, I follow Allegretto, Dube, and Reich (2011) and I add two sets of controls. First, I include census division-specific time effects, which removes the variation across census divisions by controlling for spatial heterogeneity in regional economic shocks:

$$y_{ist} = \alpha + \beta MW_{st} + \delta Z_{st} + \lambda X_{ist} + \gamma_s + \tau_{dt} + \varepsilon_{ist}, \qquad (2)$$

where τ_{dt} is the census division-specific time effect.[14] The third specification adds state-specific linear trends that capture long-run growth differences across states:

$$y_{ist} = \alpha + \beta MW_{st} + \delta Z_{st} + \lambda X_{ist} + \gamma_s + \tau_{dt} + \pi_s \cdot t + \varepsilon_{ist}, \qquad (3)$$

where $\pi_s \cdot t$ represents the time trend for state s.[15] Earlier findings indicate that the minimum wage effects can take some time to fully become apparent.[16] To account for possible lagged effects I estimate the distributed lag model that includes the contemporary, the six-month lag, and the one-year lag of the log of the minimum wage:

$$y_{ist} = \alpha + \beta_0 MW_{st} + \beta_1 MW_{st-6} + \beta_2 MW_{st-12} + \delta Z_{st} + \lambda X_{ist} + \gamma_s + \tau_t + \varepsilon_{ist}. \qquad (4)$$

[14] Census divisions are: New England: ME, NH, VT, MA, RI, and CT. Middle Atlantic: NY, NJ, and PA. East North Central: OH, IN, IL, MI, and WI. West North Central: MN, IA, MO, ND, SD, NE, and KS. South Atlantic: DE, MD, DC, VA, WV, NC, SC, GA, and FL. East South Central: KY, TN, AL, and MS. West South Central: AR, LA, OK, and TX. Mountain: MT, ID, WY, CO, NM, AZ, UT, and NV. Pacific: WA, OR, CA, AK, and HI.

[15] According to Meer and West (2015), if changes in minimum wages affect a variable over time, through changes in growth rather than through an immediate shift, specifications including state-specific time trends will fail to capture these effects. They attenuate the estimates of the impact of the minimum wage on the growth of a variable so even real causal effects on the level of the variable can be attenuated to be statistically indistinguishable from zero. It is for this reason that a specification including only linear state-specific time trends is omitted and specification 4 including division-specific fixed effects and linear state-specific time trends should be taken with considerable skepticism.

[16] Baker, Dwayne,and Suchita (1999); Neumark and Wascher (1992); Neumark, Schweitzer, and Wascher (2004).

4.3 Results

The presentation of the results goes as follows. First, I analyze the impact of the minimum wage on high-education groups and show that the minimum wage has no statistically significant impact on any of their labor market outcomes. Then, I discuss the results for low-education workers at an aggregate level and its disaggregation by age to document differences within low-education groups. For comparison to previous work and validation of the estimation strategy, I also present and discuss the results for all teenagers.

The relevant resulting estimates of the four specifications are presented in tables 2 through 11. All tables report the coefficient of the log of the minimum wage on each of the five dependent variables and the associated elasticity. For specification 4, I report summed contemporaneous and lagged effects. For the wage and hours estimates, the dependent variable is already in logs, so the estimated coefficients are directly interpretable as elasticities. It is not my intention to enter the debate of "the right model" to identify the impact of the minimum wage on labor outcomes, but to provide evidence supporting the notion that minimum wages have asymmetric effects on the labor force. For this reason, there is no preferred specification, and I consider an effect to be significant only if there is a consistent pattern across the four specifications.

4.3.1 Minimum Wage Effects on High-Education Workers

Table 2 reports the estimates of the impact of changes in the minimum wage on employment. The results across the three high-educations groups vary in sign, but overall are not significant with the exception of specification 1 showing a significant employment coefficient of -0.018 with a corresponding employment elasticity of -0.022 for workers with college education.[17] Table 3 shows the estimates on labor force participation; they are statistically indistinguishable from zero and varying in sign from specification to specification. These results do not support any employment or labor force participation effects associated with minimum wage increments.

The estimated impact of minimum wages on my proxy variable for search intensity is presented in Table 4. For workers with some college, only specifications 2 and 3 show a statistically significant negative elasticity of -0.142 and -0.175. For workers with a college degree, the situation is the opposite; only specifications 1 and 4 show significant positive elasticities of 0.3 and 0.34 respectively. The coefficients on advanced education workers are statistically indistinguishable from zero. If this variable reflects indeed job-search efforts, negative coefficients would suggest that the minimum wage decreases the surplus of a match for workers with some college and it increases the surplus of a match for workers with college education despite the fact that, according to results on employment and participation, the minimum wage is not binding in this market. This situation could be due to the fact that this proxy is too imprecise and responds to some general equilibrium effect of the whole economy.

Table 6 reports the results for the log of weekly hours, which show no discernable effects on the worked hours of high-education groups. Only specifications 3 and 4 give a relatively small elasticity of -0.023 and –0.019, respectively, for workers with some college. Finally, the effects on the log of wages are displayed in Table 7. The estimates are consistently non-significant through high-education groups and their signs vary from specification to specification.

[17] The elasticity is obtained by dividing the coefficient by the fraction of employed individuals in the demographic of interest.

In summary, the results do not provide evidence of significant effects of changes in the minimum wage on labor market outcomes of high-education workers.

4.3.2 Minimum Wage Effects on Low-Education Workers

Now I turn to the analysis of low-education groups and teenagers. It is one of the goals of this paper to stress that one way disaggregation, either by age or education, could mask worker heterogeneity, a fundamental aspect to understand the workings of the labor market. Two-way disaggregation captures heterogeneity better and enables more precise identification of the effects of minimum wages. For the analysis of low-education groups, I additionally estimate the effects on age subgroups; teenagers, young workers, mature workers, and elderly workers.

First, I discuss the estimated employment effects reported in Table 2. Consistent with previous findings, the canonical model of specification 1 produces a significant negative estimate for teenage employment elasticity of -0.084. Controlling for division-specific economic shocks and heterogeneity in the underlying employment trends, specifications 2 and 3, render estimates that, unlike previous work (Allegretto, Dube, and Reich (2011)), are significant and stronger than the estimate of the canonical model; -0.14 and -0.12 respectively. Specification 4, which includes lag terms to capture changes in growth rate, gives a negative but insignificant effect of -0.06. When disaggregated by educational attainment, LTHS teenagers show strong and significant elasticities (-0.2, -0.19, -0.19 and -0.19) while teenagers with high school education do not show effects in employment.

The estimates of the LTHS groupas a whole are insignificant across specifications although it has a teenage composition of 40%. Table 7 shows that behind the insignificant results is the fact that the magnitude of the effect is much related to age, only young workers display statistically significant disemployment effects.

The paper's most relevant finding is the effect that hikes in the minimum wage have on 25-59 year-old workers with high school educational attainment. Table 2 shows that specifications 1, 2, and 4 produce statistically significant point estimates with elasticities of 0.02, 0.03 and 0.03 respectively. It is important to stress that the results do not contradict the bulk of studies finding negative employment effects since most of those studies focus on teenage employment. Teenagers constitute only 6% of the workforce with high school education. Further disaggregation by age makes the sign, magnitude, and significance of the estimates vary widely across age subgroups. Table 7 shows that the positive employment effect is restricted to 25-59 year-olds. Elasticities range from 0.025 to 0.042 and are significant in all specifications. These results are consistent with Neumark (2007) who also reports insignificant employment effects for workers under 25 with high school education.

Now I turn to labor force participation effects reported in Table 4. Consistent with previous findings, the results show significant participation-discouraging effects among teenagers.[18] Specifications 1, 2, and 3 produce significant elasticities ranging from -0.10 to -0.06. Specification 4 also predicts a negative elasticity but it is non-significant. Disaggregating by educational attainment, Table 8 shows that not all teenagers are affected equally. The minimum wage has a strong discouraging effect only on teenagers with LTHS education; the estimated elasticity is consistently

[18] Kaitz (1970), Mincer (1976), Ragan (1977), and Wessels (1980). They estimated the effects of the minimum wage on labor force participation and found that minimum wage decreased (or did not affect) the labor force participation rate of low-wage workers. More recently Wessels (2001), and Wessels (2005) investigate the effect on teenage participation and conclude that minimum wages decreases teenage labor force participation and their proportion of new entrants into the labor force.

significant across all specifications with values around -0.15. The results for teenagers with high school education are not statistically significant with the exception of specification 4 that gives a significant elasticity value of 0.1. The results in table 4 for the LTHS group as a whole are not significant since, according to Table 8, the minimum wage influences only the participation decisions teenagers with LTHS education. The participation decision of older workers with LTHS education is not affected.

Another key finding of this paper is the participation-encouraging effects of minimum wages on mature workers with high school education. Tables 3 and 8 show that, although the elasticity estimates are statistically significant for the high school demographic as a whole, the effects of minimum wages are concentrated on workers aged between 25 and 59. All the specifications give very significant elasticity estimates ranging from 0.029 to 0.043.

Tables 4 and 9 contain the results for the proxy variable for search intensity. Only workers with LTHS education show a significant effect. Specifications 1 and 4 produce a significant elasticity of -0.15 and -0.19 respectively. Surprisingly, age desegregation shows no significant effects on teenagers. Only specification 4 for young workers (-0.15), specifications 1 and 4 for mature workers (-0.19 and -0.22), and specification 2 for the elderly (-1.5) show a negative and significant elasticity.

The effect on hours by education level and it disaggregation by age are shown in tables 5 and 10. Minimum wages do display a significant impact in worked hours for workers with high school education as a whole. However, for teenagers and workers with LTHS education, the estimates are negative and significant; the four specifications indicate very significant elasticities; -0.12, -0.22, -0.21, and -0.12 for teenagers; and -0.07, -0.11, -0.1, and -0.06 for LTHS workers. Further disaggregation shows that reduction in hours concentrates on teenagers with LTHS education with negative elasticities ranging from -0.24 to -0.16 and significant in all specifications. Teenagers with high school education report negative and smaller effects, significant only for specifications 2, 3, and 4. Within LTHS workers, the effects vary non-monotonically with age and specification. For teenagers, all specifications are significant, for young workers only specifications 2 and 3 are significant with coefficients of -0.15 and -0.16 respectively. For 25-59 year-olds, only specifications 1, 2 and 4 report significant results of -0.05, -0.07, and -0.05. Elderly workers report significant results in specifications 1 and 4 with elasticities of -0.16 and -0.19. Taken together, the estimates suggest that the size of the effect is inversely related to age and education.

Finally, I discuss the wages effect of the minimum wage. Consistent with previous findings (Neumark (2007), Allegretto, Dube, and Reich (2011)) the results in Tables 6 and 11 give a positive and statistically significant wage effect for teenagers regardless of the specifications. The estimated elasticities range from 0.14 to 0.16. For LTHS and high school groups, only specifications 2 and 3 show statistically significant wage effects. Age disaggregation shows that the wage effects are concentrated in the youngest populations of both education groups. All the specifications report a significant positive effect that is strongest in teenagers with LTHS education, ranging from 0.17 to 0.22, and is weakest in the group of 16 to 24 year olds, raging from 0.08 to 0.14. No significant effects on wages can be found in older groups regardless of their education.

4.3.3 Theoretical Implications of the Results

Now I analyze the empirical results in the light of the model's framework. The evidence indicates that changes in the minimum wage affect labor market outcomes of low-education groups only. According to the model, this situation is explained by the fact that low-education groups and high-education groups belong to different labor markets and the minimum wage is binding only in the low-education labor market. If the minimum wage binds in the high-education groups, the share of workers affected by the changes must be negligible. The ripple effects observed in the low-education labor market indicate that the proportion of workers in that market who are affected directly by hikes in the minimum wage must be large enough to have considerable changes in equilibrium market tightness. Figure 5 shows that this is the case, the proportion of workers with LTHS and high school education with wages barely above the minimum is much larger than those in high-education groups.

Age disaggregation shows that the effects are concentrated mostly in two demographics. Teenagers with LTHS education perversely affected with disemployment and lower participation, and mature workers with high school education who are encouraged with positive employment effects. According to the model, although these two groups participate in the same market, the contrasting effects indicate significant productivity differences. LTHS teenagers must be concentrated at the bottom of the productivity distribution, while mature workers with high school education concentrate at the top. The lack of significance in the impact on other demographics in the same labor market is explained by the fact that those groups are scattered around the center of the productivity distribution. Consequently, there are some individuals being perversely affected and others are benefited, rendering an average change difficult to identify by the regressions. This finding points out that there are two fundamental components to average productivity: educational attainment and age. Figure 6 and the results in table 12 reinforce the notion of the double dimensionality in the determination of productivity.

The model predicts that more productive individuals will receive higher wages, will have lower unemployment rates and will participate more actively in job search. We can observe that average labor market outcomes indicate that the most productive individuals are on average mature workers with high school education, followed by other mature workers, the elderly, and young workers in no particular order.[19]

[19] In some market outcomes elderly workers outperform mature workers, however the labor market conditions of elderly workers are understandably determined by conditions other than productivity, making it difficult to fully be consistent with the model

Table 12: Low-Wage Mean Labor Market Outcomes

		16-19	20-24	25-59	60-64
Wages					
	LTHS	8.3	10.3	12.9	13.5
	High School	9.6	11.6	17.2	17.3
Unemployment Rate					
	LTHS	19%	18.3%	9.4%	5.9%
	High School	16.3%	11.8%	5.5%	4.1%
Labor Force Participation					
	LTHS	38.5%	65.2%	64.3%	34.5%
	High School	60.1%	78.5%	79.6%	48%
Search Intensity					
	LTHS	1.68	1.95	2	1.9
	High School	1.97	2.1	2.24	2.17

An innovative feature of the empirical approach is the use of the number of different methods to find a job as a proxy for workers' search efforts. The results show no discernable significant effects of the minimum wage on this variable. This contradicts the theoretical prediction that labor force participation and search intensity should move in the same direction and are, in fact, the same decision. The inconsistency casts doubt on the validity of this proxy variable and the results should serve as reference for future studies attempting to find a valid proxy for search intensity in the context of search models. The regressions indicate that labor force participation is a better proxy for search intensity.

Although many previous studies distinguish between older and younger teens to look for labor substitution effects, the results show that this approach is limited since the substitutions does not occur within teenagers but is directed towards older and more educated workers. A word of caution about substitution; the employment effects predicted by the model have a broader interpretation than worker-for-worker labor substitution, they could also be interpreted as destruction of lower productivity matches and creation of new more productive matches. For this reason, the model could also be consistent with empirical work not finding labor substitution effects in a specific industry. For example, Dube, Lester and Reich (2011) do not find evidence of labor substitution within the restaurant workforce. Theoretically this result could be explained by the fact that the minimum wage does not really change the profitability of an employee-employer match, either because, in this industry, the minimum wage is too low to be binding or does not bind due to special considerations for tipped workers.

The model does not distinguish between hours worked and employment levels, a reduction in the unemployment rate could be interpreted either as more hours worked by individuals or as more workers being employed, so theoretically hours and employment levels in the data should be closely linked. The numbers of hours worked by teenagers does move in the same direction as employment, it decreases with an increase of the minimum wage. However, the hours worked by mature workers are not affected by changes in the minimum wage but their employment levels increase slightly. This could be attributed to legal restrictions on the maximum number of hours and does not contradict the model's predictions.

The model predicts spillover effects on wages for all the workers remaining in the workforce and their size depends mostly on the incentivizing scheme the workers is on; workers close to the minimum that do not need to be incentivized trough the treat of longer spells of unemployment have the greatest effect. Workers at the top of the productivity distribution whose wages are not subject to the NSC constraint have weaker gains in wages. The fact that spillover effects can be detected only in young workers in both education groups suggests that a large proportion of this demographic could be in the class of workers that are paid an efficiency wage. The effects found are contingent upon employment so they do not reflect the employment losses that come along with the wage increases for the group as a whole. Theoretically all workers that remain employed must see their wages being increased, however for those workers at the top of the distribution the effect could be so small that is not identifiable in the regressions.

5 Quantitative Exercises

In this section, I assess the quantitative properties of the model to evaluate the effects of an increase in the minimum wage on employment, labor force participation, wages and social welfare.

5.1 Calibration

Following the results in Section 4, the models' calibration simulates the low-education labor market, where minimum wage changes are consequential for the market outcomes. A productivity distribution must be specified based on the wages obtained from the CPS micro data. Observed wages are expressed in terms of the minimum wage by dividing them by the effective minimum. I restrict my attention to LTHS and high school observations that are less than three times the minimum wage but no less than the minimum since the model assumes compliance with the law. The resulting average wage is 1.78 times the minimum. After normalizing the wage distribution so the average wage is equal to one, the minimum wage is equal to $m_0 = 0.57$ and it corresponds with the lowest wage in the distribution, that is $w_1 = 0.58$. Wage observations are grouped into 40 intervals to create a wage distribution with 40 different values giving the lowest wage, $w_1 = 0.58$, and the highest wage $w_{40} = 1.7$. Figure 7 shows the resulting wage distribution.

Section 4 shows that when a minimum wage increases, it is teenagers with LTHS education who are the most perversely affected workers while mature workers with high-school education benefit from the increase. This observation motivates the key identifying assumption of the calibration,

$$w_{LTHS}^{16-19} < w^E \leq w_{HS}^{25-59}, \tag{24}$$

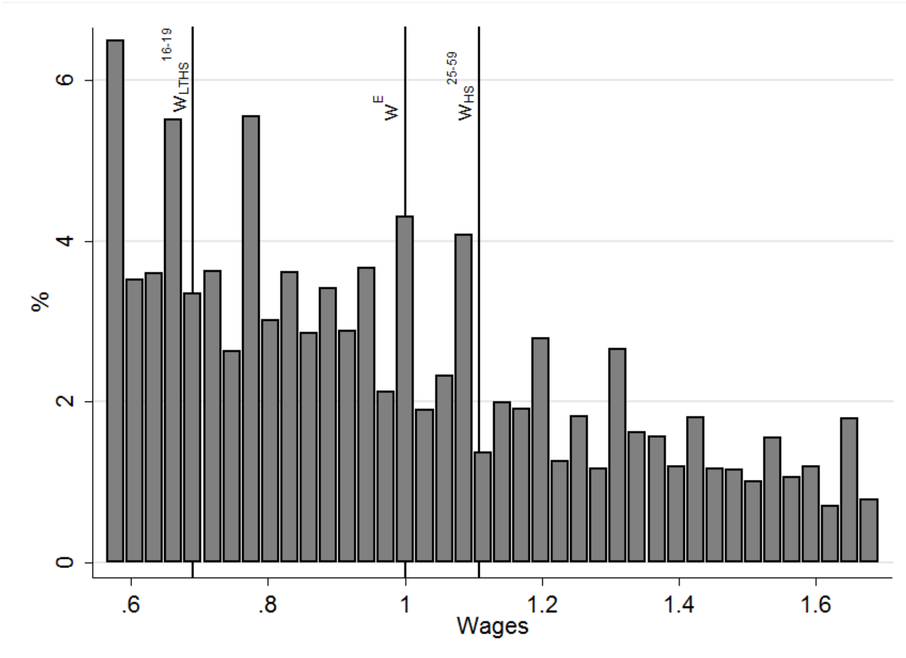

Figure 7: Empirical Low-Education Wage Distribution.

where w_{LTHS}^{16-19} is the average wage of teenagers with LTHS education and w_{HS}^{25-59} is the average wage of 25 to 59 year olds with high school education. Using this assumption I pin down the model's parameters and ultimately the underlying productivity distribution. The unemployment rates for these subpopulations can be computed from the data which generates four values ($w_{LTHS}^{16-19} = .7$, $w_{HS}^{25-59} = 1.1$, $u_{LTHS}^{16-19} = .19$, $u_{HS}^{25-59} = .055$) that along with a choice of a value w^E, and equations (21), (22), and (23) and (19), form the following system of equations:

$$c'(s^{HS}) = f^* \left[\frac{w_{HS}^{25-59} - e - b + c(s^{HS})}{r + \delta + s^{HS} f^*} \right],$$

$$u_{HS}^{25-59} = \frac{\delta}{\delta + s^{HS} f^*},$$

$$c'(s^E) = f^* \frac{e}{\lambda},$$

$$w^E = b + e - c(s^E) + \frac{e}{\lambda} \left(r + \delta + s^E f^* \right), \tag{25}$$

$$u_{LTHS}^{16-19} = \frac{\delta (e/\lambda)}{w_{LTHS}^{16-19} - b - e + c(s^L) - r(e/\lambda)},$$

$$c'(s^L) = \frac{w_{LTHS}^{16-19} - e - b + c(s^L) - (r+\delta)\frac{e}{\lambda}}{s^L},$$

subject to

$$w^E - w_1 \leq c(s_1) - c(s^E) + \frac{e}{\lambda} s^E f^*. \tag{26}$$

The restriction (26) ensures the labor force participation of all workers under the current minimum. For given values of b, δ, and r, the system defines e, λ, f^*, the theoretical search intensity of LTHS teenagers s^L,and the theoretical search intensity of mature high school workers s^H.

The time period is set to a quarter. I set $r = .012$ corresponding to an anual discount factor of 0.953. Also, b is set to 0.2, which corresponds to an income replacement ratio of 40% of the lowest productivity worker. For the choice of δ, I use the fact that the average unemployment duration for low-education workers is 1.8 quarters and the average unemployment rate is 8.1%. Using (19), I get a value of $\delta = 0.05$.

Some assumptions about the functional form of the matching function and the cost of search are necessary. For the choice of matching function I assume a Cobb-Douglas $h(\sum_i p_i s_i u_i, v) = \tau(\sum_i p_i s_i u_i)^\eta v^{1-\eta}$, therefore

$$f(\theta) = \tau\theta^{1-\eta}, \qquad \text{and} \qquad q(\theta) = \tau\theta^{-\eta}.$$

I set the elasticity of the probability of filling a vacancy to $\eta = 0.6$, which according to Petrongolo and Pissarides (2001) is at the middle of the rage of the parameter values, [0.5 ,0.7], estimated across the literature. Following Christensen et al. (2005), the cost of search function is

$$c(s) = c_0 \frac{s^{\alpha+1}}{\alpha+1},$$

with $\alpha = 1.18$ and $c_0 = 1$ as the normalization the calibration allows. The bargaining power of the workers is set to satisfy the Hosios (1990) rule, that is $\beta = 0.6$.

The calibration requires a value for w^E, and according to the wage function (21), there should be a relatively large concentration of workers with this wage. Inspecting the wage distribution in Figure 7, $w^E = 0.78$ seems a good candidate. However, with this choice the resulting values from the system of equations do not satisfy (26). The next candidate is $w^E = 1$, which returns values of $e = 0.295$, $\lambda = 0.24$, $f^* = 1.27$, and satisfies (26). With these values and using (21), the implied wage schedule is derived and presented in Figure 8.

The wage function is not injective, to recover the domain some assumption must be made. The calibration offers a value for $y_M = 1$ and a value for $y_H = 1.05$, I will assume that the weight on the efficiency wage is distributed uniformly between these two values. This creates 2 extra bins, so number of different productivities is now 42, with the lowest productivity being $y_1 = 0.58$, and the highest, $y_{42} = 1.75$.

Now, it is necessary to derive the productivity distribution $p_1, ..., p_{42}$. According to the model, workers with higher productivities have lower unemployment rates. This means that the empirical wage distribution over represents high-productivity workers and under represents low-productivity ones since wages are observed conditional on employment.

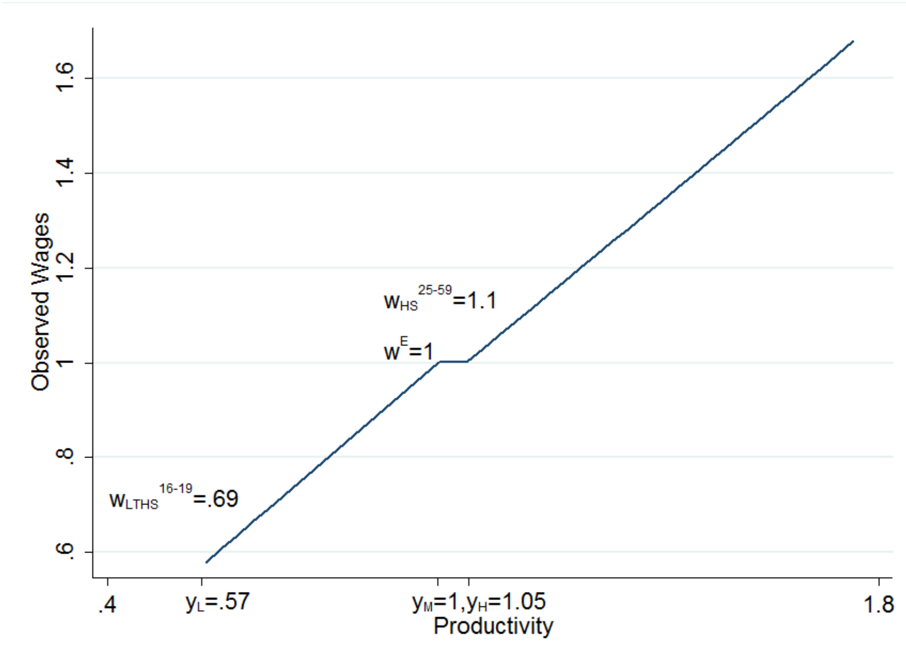

Figure 8: Wage Schedule

Let d_i be the share of observed wages w_i. Wages are observed contingent upon employment, so according to the model

$$d_i = \frac{(1-u_i)p_i}{\sum_j (1-u_j)p_j}.$$

Values u_i and s_i cannot be observed directly from the data for every worker type-i. However, under the assumption that LTHS teenagers are at the barely employable side of the wage distribution and mature workers are perfectly employable, an approximation for the share of type-i workers is

$$p_i \approx d_i \frac{Emp}{Emp_{LTHS}^{16-19}} \text{ if } \qquad w_i < w^E,$$

and,

$$p_i \approx d_i \frac{Emp}{Emp_{HS}^{25-59}} \text{ if } \qquad w_i \geq w^E,$$

where Emp is the employment rate of all the LTHS and high school population, Emp_{LTHS}^{16-19} is the employment rate of teenagers with LTHS education, and Emp_{HS}^{25-59} is the employment rate of mature workers with high school education. The resulting productivity distribution is presented in Figure 9.

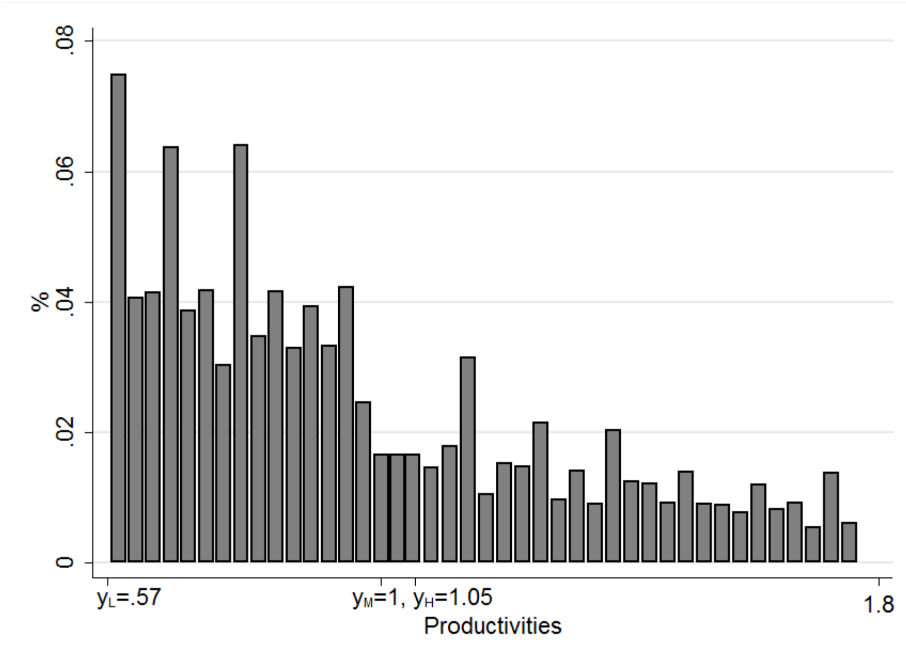

Figure 9: Estimated Productivity Distribution

Using the estimated productivity distribution, a new system of equations can be created to pin down the remaining parameter values γ, and τ:

$$\tau\theta^{*1-\eta} = f^* = 1.27,$$

$$\sum_i \Pi_i \mu_i(\tau,\theta^*)\left(y_i - w_i(\tau,\theta^*)\right) = (r+\delta)\frac{\gamma}{\tau\theta^{*-\eta}},$$

$$\sum_j p_j s_j(\tau,\theta^*) u_j(\tau,\theta^*) = 0.08.$$

The first equation comes from the definition of $f(\theta)$, the second equation is the VSC, and the third equation is the aggregate unemployment rate of 8%. The resulting parameter values are $\gamma = 0.95$, $\tau = 1.4$, and $\theta^* = 0.8$. Table 13 summarizes the parameter values.

Table 13: Parameter Values in Simulations of the Model.

Parameter	Value	Description
r	0.012	Discount rate: 5% annual rate.
δ	0.05	Separation rate.
b	0.2	Unemployment benefits.
e	0.295	Effort intensity.
λ	0.24	Inspection rate.
β	0.6	Worker bargaining power:
τ	1.4	Efficacy of matching.
η	0.6	Unemployment-elasticity of matching.
c_0	1	Search cost parameter.
α	1.18	Search cost parameter.
γ	0.95	Recruiting cost.

Notes: Most of the displayed values have been rounded since they are derived as the solution to a set of equations. Simulations use the real values.

5.2 Changes in the Minimum Wage.

In this section, I use the calibrated model to investigate the effects of increments in the minimum wage on employment, labor force participation, and total welfare. The model was calibrated so that the minimum wage is not binding for any type of workers; the experiment will be to see how the steady-state variables change with a higher minimum all else remaining equal. The fact the calibration targets exclusively the low-education workers should be borne in mind when interpreting the simulation's results and particularly when the welfare exercise results are reported.

The first important result of the simulations is that, under this calibration, the efficiency wage remains above the minimum. As the minimum wage increases from m to m', the equilibrium efficiency wage increases from $w^E(\theta)$ to $w^E(\theta')$, such that $m' < w^E(\theta')$. Figure 10 shows how these two wages behave. We can observe that, at least for increments of less than 100%, the efficiency wage adjusts so that it is always above the minimum although the difference between the two wages closes.

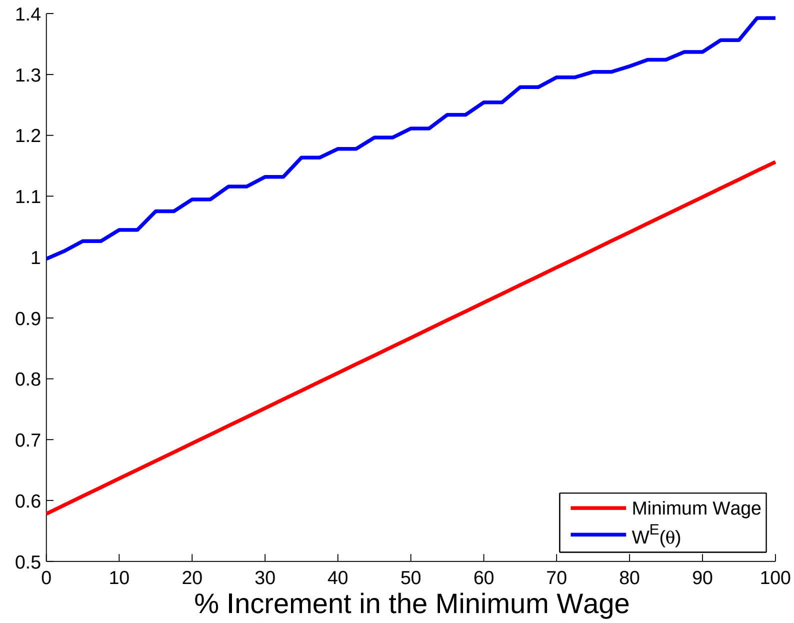

Figure 10: The Efficiency Wage and the Minimum

This means that the minimum wage is aggravating the moral hazard risk in the market; as it increases, it improves the hirable workers' working conditions so much that instead of receiving the unconstrained wage that once was enough to motivate them, now they must receive an efficiency wage. The situation is severe enough to generate the sub-optimal minimum wage utilization described in Section 3.3.1.

For example, with a 90% increment the minimum goes from approximately 0.57 to 1.1. A worker earning a wage of 1 before the increment, instead of receiving a wage of 1.1, after the increment receives a wage above 1.3. The minimum wage is being under used. The premium above the minimum arises because of the increment in the risk of moral hazard. This means that the minimum wage increases market tightness, so there will be asymmetries in the outcomes of different workers as described in Section 3.

First I analyze individual market outcomes. Figure 11 shows the impact by deciles in the worker population. Panel a) shows the effects that of an increase in the minimum wage on labor force participation. Workers with the lowest productivity, the first decile, have productivities very close to the minimum wage so a 10% increase in the minimum would reduce their participation in the labor force by 60%. An increase of 18% would completely price them out and drive them out of the labor force. Increasing the minimum further, would affect more productive deciles the same way. A 100% increase would drive half of the worker population out of the market. The asymmetry in the participation effect is visible in the graph; as less productive workers are discouraged from participating, remaining workers increase their participation and the effect is stronger for workers at the high end of the distribution. Despite the asymmetry, the discouraging effects for low-productivity workers are much stronger. This is consistent with the results in Section 4 which show that the labor force discouraging effects on LTHS teenagers is much stronger than the encouraging effects for mature workers with high school educational attainment. Panel b) showing the effect on employment tells a similar study. As the employment falls for the least productive workers, those that remain hirable have small increases in employment. The situation is also in agreement with the results in Section 4.

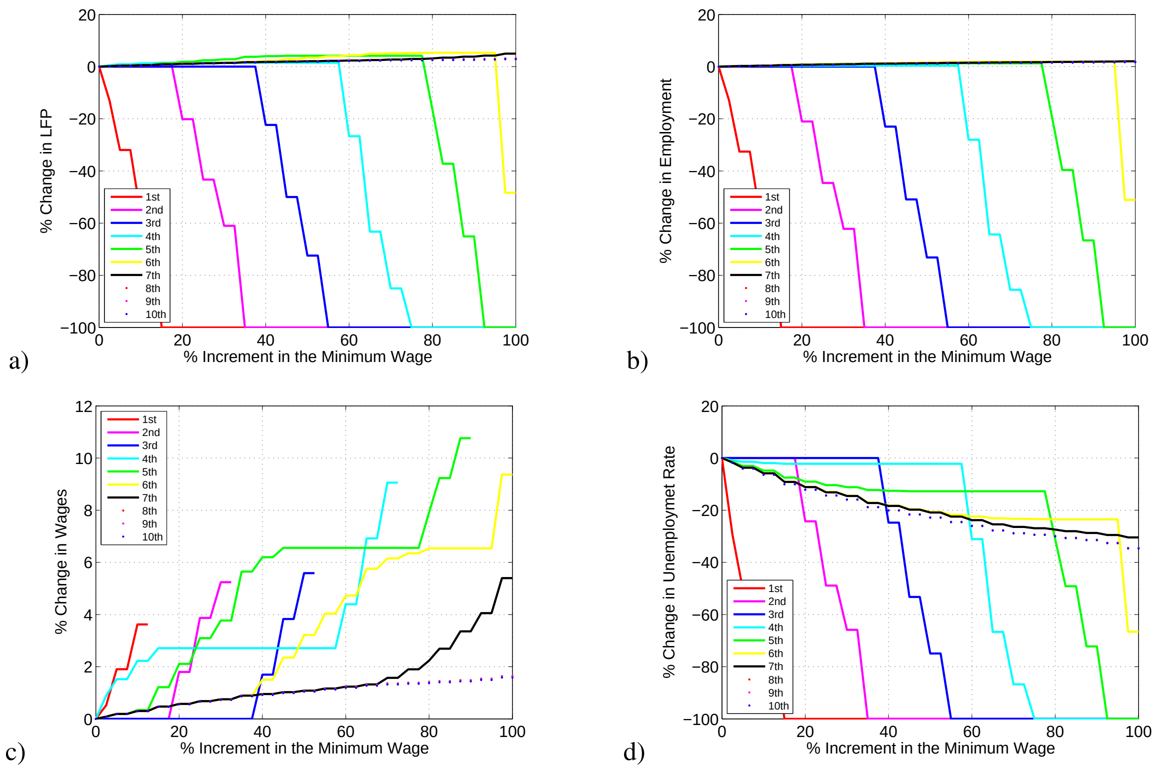

Figure 11: Labor Market Outcomes by Deciles

Panel c) shows the wage effects across deciles. Consistent with the theoretical predictions and the empirical results in Section 4, the simulations show wage spillover effects. A 10 % increase in the minimum wage increases the average wage of the lowest productivity decile above 3%. The effect on wages is reflected on the wages of perfectly employable workers and it decreases in intensity as productivity increases. The average wage of the fourth decile augments by 1%, and the average wage of top deciles by around 0.5%.

The situation is misleading. Wages are contingent on employment so the minimum wage is not really increasing wages in the first decile since these are barely employable workers who are being paid as much as they can. The increase in the average wage is due to the fact that a higher minimum drives some of the workers in the lowest decile out of the market, so the average wage in that decile increases because only the most productive workers have wages to report. This is not the case for the top 6 deciles who truly see their wages increase due to the general equilibrium effect, and not because workers are being driven out of the market.

This could explain why the wage spillover effects in Section 4 are significant only for teenagers and not for mature workers with HS education. Workers at the middle of the productivity distribution show strong increases on average wages since the minimum is trimming off low wages. After a hike in the minimum wage, teenagers reporting their wages are those productive enough to remain hirable.

Panel d) shows the effects on unemployment rates. The situation is misleading since the unemployment rate takes into account the search intensity that unemployed workers put into finding a job. For example, a 10% increase reduces the unemployment rates of the least productive and the most productive workers for very different reasons. Just as in the wage effects, the unemployment rates of workers at the low end of the distribution decreases because participation decreases, many workers stop reaching for a job, so after a minimum hike their unemployment rate is lower. On the other hand, perfectly employable workers see their unemployment rates decreases as their participation increases because they are actually more employable in a tighter market.

Now I analyze the effects on the market at an aggregate level. I start with aggregate employment and aggregate labor force participation. I define aggregate employment as the total amount of total workers employed, that is,

$$\text{Total Employment} = \sum_i p_i(1-u_i).$$

Total labor force participation is defined as the total amount of employed workers plus the measure of unemployed workers searching for a job,

$$\text{Labor Force Participation} = \sum_i p_i(1-u_i) + \sum_i p_i s_i u_i.$$

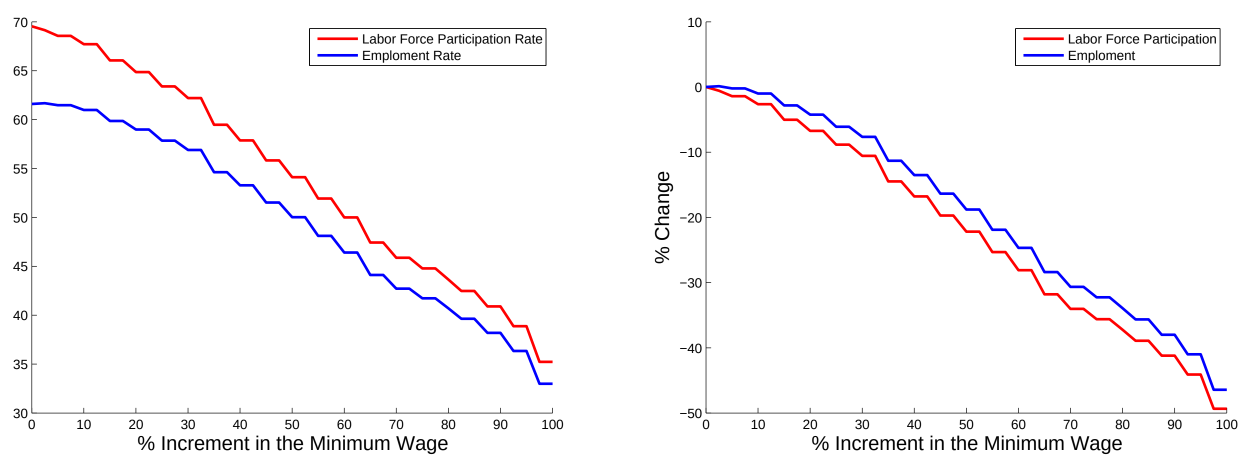

Figure 12: Total Employment and Labor Force Participation

Figure 12 presents the simulation's results. They confirm what is inferred from the desegregated results, increments in the minimum wage have a much stronger negative employment effect on low-productivity workers, than the positive employment effects they have on more productive workers. Overall, total employment falls drastically after a minimum wage increment. The effect on total labor force participation is similar; a hike in the minimum has an overall negative impact.

The fact that labor force participation and employment fall as the minimum wage increases does not entail a reduction of aggregate welfare in the market. To assess the welfare properties of an increase of the minimum wage, I compute aggregate welfare as the sum of all agents' utilities, that is

$$\text{Aggregate Welfare} = \sum_i p_i u_i rU_i + \sum_i p_i(1-u_i)rE_i + \sum_i p_i(1-u_i)rJ_i + vrV.$$

At the steady state it can be expressed as

$$\text{Aggregate Welfare} = \sum_i p_i u_i[b - c(s_i)] + \sum_i p_i(1-u_i)[y_i - e] - \theta[\sum_i p_i s_i u_i]\gamma.$$

Figure 13 presents the simulation's results. Increments in the minimum wage generate a reduction in aggregate welfare. The strong negative welfare effects of the minimum wage are due to the fact that most of low-education workers concentrate right above the minimum so even small increments drive a considerable percentage of workers out of the labor force. Figure 11 shows that an increase of 100% in the minimum drives half of the labor supply out of the market, which makes social welfare drop significantly.

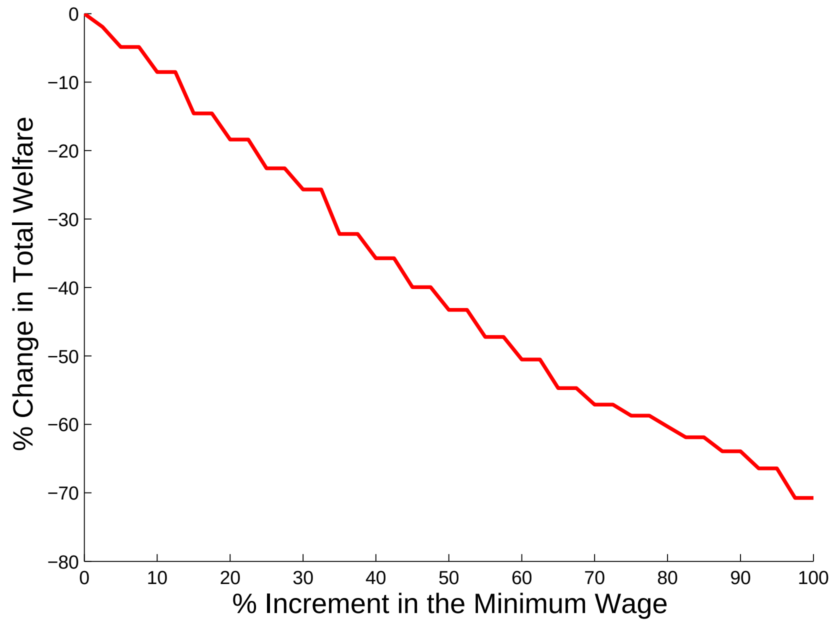

Figure 13: Aggregate Welfare

6 Concluding Remarks

This paper has explored the notion that minimum wages affect the labor force asymmetrically due to worker heterogeneity. I developed a search model of unemployment predicting that due to the presence of moral hazard, a rising minimum wage will price out of the labor force low-productivity workers and will increase the employment, encourage the labor force participation, and raise the wages of workers that remain hirable. These predictions hold in CPS micro data once I focus on the low-education labor market and I disaggregate workers by age and education.

The paper's results have important implications. First, they emphasize the inherent characteristics of the labor market that makes its analysis particular. Not only is it riddled with trading frictions, it also displays heterogeneity among participating agents and relatively strong government intervention. I have shown that including heterogeneity in the modeling of the market is consequential for the insights obtained from the model. Models of unemployment must incorporate all these elements to better understand the implications of labor market policies.

On the pragmatic side, the results emphasize that the aggregation level matters for the assessment of the disrupting effects of an imposed wage floor. They enrich the debate of "who" is truly affected by the minimum, by adding the notion of "how" they are affected. Even within the same labor market, not all workers are equally impacted, so a clear understanding of these differences is necessary if the goal of a minimum wage is to change the labor conditions of a specific group. If, on the other hand, the performance of a minimum is to be judged by its broad impact on low-wage labor markets, the results show that despite the asymmetries, the consequences of a higher minimum are detrimental for employment, labor force participation and welfare.

According to my results, the initiative to increase the federal minimum wage to $15 an hour in the United States would generate large-scale employment and welfare losses. For those states where the binding minimum is equal to the federal minimum, fixed at $7.25 per hour since 2009, the proposed new minimum would represent a 107% increase. According to the simulation for the low-education labor market, this increment would bring a decrement of around 50% in employment and labor force participation, and a reduction of 70% in social welfare. States with a relatively high minimum wage would experience smaller, although still considerable, losses. For example, California with a minimum wage of $9.00 would see a reduction of roughly 30% in employment and labor force participation, and a decrease of 55% in social welfare in the low-education labor market.

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Appendix A: Derivations and Proofs

Derivation of the No-Shirking Condition (NSC)

The expected lifetime utility of a worker who chooses to shirk during a length of time dt, satisfies

$$S_i = w_i dt + \exp(-rdt)\left\{\Pr\left[\min(\tau_{s\delta},\tau_\lambda)\leq dt\right]U_i + \left(1-\Pr\left[\min(\tau_\delta,\tau_\lambda)\leq dt\right]\right)E_i\right\},$$

where $\min(\tau_\delta,\tau_\lambda)$ is a Poisson process with parameter $\lambda+\delta$. This yields:

$$S_i = w_i dt + \exp(-rdt)\left\{(1-\exp(-(\delta+\lambda)dt))U_i + (\exp(-(\delta+\lambda)dt)E_i\right\}.$$

Using power series:

$$S_i = w_i dt + (1-rdt+o(dt))\left\{\left[(\delta+\lambda)dt+o(dt)\right]U_i + (1-(\delta+\lambda)dt+o(dt))E_i\right\},$$

with $\lim_{dt\to 0}\mathrm{o}(dt)/dt = 0$. Rearranging terms:

$$S_i = wdt + (1-rdt)\left\{(\delta+\lambda)dtU_i + \left[1-(\delta+\lambda)dt\right]E_i\right\} + \mathrm{o}(dt).$$

From (1), substituting :

$$S_i = E_i + edt - \lambda dt(E_i-U_i) - rdt^2(\delta+\lambda)(E_i-U_i) + \mathrm{o}(dt),$$

As $dt\to 0$, the worker's optimal decision is not to shirk if and only if

$$E_i - S_i \simeq \left[\lambda(E_i-U_i)-e\right]dt \geq 0$$

$$\iff$$

$$E_i - U_i \geq \frac{e}{\lambda}.$$

Derivation of the Equilibirum Best Response Hiring Function

Firt is is necessry to derive the best response hiring functions.

Proposition 2: *For a given θ and s_i, the firm's best-response hiring function for a type-i worker is:*

$$\Pi_i = \begin{cases} 1, & y_i \geq b+e-c(s_i)+(r+\delta+s_i f(\theta))\frac{e}{\lambda}, \\ \frac{y_i-b-e+c(s_i)-(r+\delta)\frac{e}{\lambda}}{s_i f(\theta)\frac{e}{\lambda}}, & b+e-c(s_i)+(r+\delta+s_i f(\theta))\frac{e}{\lambda} > y_i \geq b+e-c(s_i)+(r+\delta)\frac{e}{\lambda}, \\ 0, & b+e-c(s_i)+(r+\delta)\frac{e}{\lambda} > y_i. \end{cases}$$

Proof: Apendix

Proof of Proposition 2.

For this proof two lemmas are necessary:

Lemma 1: *A match will never form if the NSC is not satisfied.*
Proof: Assume the NSC is not satisfied. Then, the worker's optimal behavior is to shirk, so nothing is produced. This implies that value of a match is $J = -w_i/(r+\delta)$, a firm will only accept the match if $w_i = 0$. If $w_i < b$ the worker will not accept the match. By assumption $b > 0$ so with $w_i = 0$ workers will not accept the match. Since both worker and firm must accept the match, if the NSC cannot be satisfied, the match will never form.□
Lemma 2: *If $y_i < y_L \equiv b+e-c(s_i)+(r+\delta)\frac{e}{\lambda}$, then the NSC can never be satisfied.*
Proof: Assume that $y_i < b+e-c(s_i)+(r+\delta)\frac{e}{\lambda}$ and that the NCS is satisfied, that is:

$$E_i - U_i = \frac{w_i - b - e + c(s_i)}{r+\delta+s_i\Pi_i f(\theta)} \geq \frac{e}{\lambda}.$$

Taking θ and s_i as given and considering the restrictions $w_i \leq y_i$ and $\Pi_i \in [0,1]$, the largest $E_i - U_i$ can be is

$$\frac{y_i - e - b + c(s_i)}{r+\delta} \geq \frac{e}{\lambda} \Longleftrightarrow y_i \geq b+e-c(s_i)+(r+\delta)\frac{e}{\lambda}.$$

By assumption $y_i < b+e-c(s_i)+(r+\delta)\frac{e}{\lambda}$, which contradicts the statement above. □

The proof of Proposition 1 follows from these two lemmas.
1. *If $b+e-c(s_i)+(r+\delta)\frac{e}{\lambda} > y_i$, then $\Pi_i = 0$.*
Proof: If $b+e-c(s_i)+(r+\delta)\frac{e}{\lambda} > y_i$, by lemma 2 the NSC cannot be satisfied. By lemma 1 a match will never form, so $\Pi_i = 0$. This is also a Nash equilibrium since no firm has incentive to deviate from this probability. If they hired a worker with some $\Pi_i > 0$, they would be strictly worse off since the NSC cannot be satisfied.□
2. *If $y_i \geq b+e-c(s_i)+(r+\delta+s_i f(\theta))\frac{e}{\lambda}$ then $\Pi_i = 1$.*
Proof: Given the assumption $V = 0$, according to (10), if $J_i > 0$ then $\Pi_i = 1$. By (9) $J_i > 0$ if and only if $y_i - w_i \geq 0$. From (15), there are two scenarios where this can happen:
a) If $w_i = w_i^N$, from the Nash-bargaining solution : $y_i - w_i^N \geq 0$. So from (15) if $y_i > b+e-c(s_i)+(r+\delta+s_i f(\theta)\beta)\frac{e}{\lambda\beta}$, then $\Pi_i = 1$.
b) If $w_i = w_i^E$, $y_i - w_i^E > 0$ if and only if $y_i > b+e-c(s_i)+\frac{e}{\lambda}(r+\delta+s_i\Pi_i f(\theta))$. So if $y_i > b+e-c(s_i)+\frac{e}{\lambda}(r+\delta+s_i f(\theta))$, then $\Pi_i = 1$.
Since $b+e-c(s_i)+(r+\delta+s_i f(\theta)\beta)\frac{e}{\lambda\beta} > b+e-c(s_i)+\frac{e}{\lambda}(r+\delta+s_i f(\theta))$, if $y_i \geq b+e-c(s_i)+(r+\delta+s_i f(\theta))\frac{e}{\lambda}$ then $\Pi_i = 1$. This is a Nash equilibrium since, upon being matched with a worker with a productivity above this threshold, any firm will be strictly better off hiring the worker, no firm has incentives to deviate.□
3. *If $b+e-c(s_i)+(r+\delta+s_i f(\theta))\frac{e}{\lambda} > y_i \geq b+e-c(s_i)+(r+\delta)$ then $\Pi_i = [y_i - b - e + c(s_i) - (r+\delta)\frac{e}{\lambda}]/s_i f(\theta)\frac{e}{\lambda}$.*
Proof: According to (10) if $J_i = 0$, any $\Pi_i \in [0,1]$ is a best response. If $J_i = 0$ then $y_i = w_i$ and according to (15) this is only posible if $w_i = w_i^E$, so $y_i = b+e-c(s_i)+\frac{e}{\lambda}(r+\delta+s_i\Pi_i f(\theta))$. With $\Pi_i \in [0,1]$ there is a range of productivities that make $J_i = 0$. This range is $y_i \in [b+e-c(s_i)+\frac{e}{\lambda}(r+\delta),\, b+e-c(s_i)+\frac{e}{\lambda}(r+\delta+s_i\Pi_i f(\theta))]$. Upon contact with a worker in this range, any $\Pi_i \in [0,1]$ is a best response but only $\Pi_i = [y_i - b - e + c(s_i) - (r+\delta)\frac{e}{\lambda}]/s_i f(\theta)\frac{e}{\lambda}$ is a

symmetric Nash equilibrium. To see this, assume that upon contract with a type-i worker, all firms adopted a strategy $\Pi_i > [y_i - b - e + c(s_i) - (r+\delta)\frac{e}{\lambda}]/s_i f(\theta)\frac{e}{\lambda}$. If this was the case then $y_i < w_i^E$ so $J_i < 0$ and firms would have the incentive to deviate to $\Pi_i = 0$.

If, on the other hand, the strategy was $\Pi_i < [y_i - b - e + c(s_i) - (r+\delta)\frac{e}{\lambda}]/s_i f(\theta)\frac{e}{\lambda}$, then $y_i > w_i^E$ so $J_i > 0$ and firms would have the incentive to deviate to $\Pi_i = 1$. □

Proof of Proposition 3

According to (5) and the wage schedule in (15), optimal participation intensity is determined by

$$c'(s_i) = \max\left\{\Pi_i f(\theta)\left[\frac{\beta[y_i - e - b + c(s_i)]}{r+\delta+\beta s_i \Pi_i f(\theta)}\right], \Pi_i f(\theta)\frac{e}{\lambda}\right\}. \tag{27}$$

Consider a worker with productivity such that $y_i = b + e - c(s_i) + (r + \delta + s_i \Pi_i f(\theta)\beta)\frac{e}{\lambda\beta}$, according to (15), $w_i = w_i^E$; and according to (16), $\Pi_i = 1$. His optimal participation effort is given by $c'(s_i) = f(\theta)\frac{e}{\lambda}$, which I will denote as s^E. This means that any worker with productivity $y_i > b + e - c(s^E) + (r + \delta + s^E f(\theta)\beta)\frac{e}{\lambda\beta}$ will set his wage according to $w_i = w_i^N$, and $\Pi_i = 1$. He will determine his participation intensity according to

$$c'(s_i) = \frac{\beta(y_i - e - b + c(s_i))}{r+\delta+\beta s_i f(\theta)},$$

where the resulting s_i is such that $s_i > s^E$. Accoding to (16) any worker with $y_i \geq b + e - c(s_i) + (r + \delta + s_i f(\theta))\frac{e}{\lambda}$, will be hired with a probability $\Pi_i = 1$, so workers $b + e - c(s^E) + (r + \delta + s^E f(\theta)\beta)\frac{e}{\lambda\beta} > y_i \geq b + e - c(s_i) + (r + \delta + s_i f(\theta))\frac{e}{\lambda}$, will choose optimal effort $c'(s_i) = f(\theta)\frac{e}{\lambda}$, so their participation intensity is s^E. Substituting we get the boundaries of productivity with participation intensity s^E is $y_H = b + e - c^E + (r + \delta + s^E f(\theta)\beta)\frac{e}{\lambda\beta}$, *and* $y_M = b + e - c^E + (r + \delta + s^E f(\theta))\frac{e}{\lambda}$.

For workers with $y_i < b + e - c(s^E) + (r + \delta + s^E f(\theta))\frac{e}{\lambda}$, according to (16), $\Pi_i = [y_i - b - e + c(s_i) - (r + \delta)\frac{e}{\lambda}]/s_i f(\theta)\frac{e}{\lambda}$. Substituting this last expression in (16), I get that the optimal participation intensity is given by

$$c'(s_i) = \frac{y_i - e - b + c(s_i) - (r+\delta)\frac{e}{\lambda}}{s_i}.$$

The LHS of this is expression is negative if $y_i < e - b + c(s_i) - (r+\delta)\frac{e}{\lambda}$, in which case optimal participation is $s_i = 0$. Substituting this value creates a lower bound for positive participation intensities at $y_i - e - b - (r+\delta)\frac{e}{\lambda}$. Any worker with a value below this threshold will not participate.□

Proof of Proposition 1

For the proof of this proposition, some set notation is convenient. Let $\{1,...,n\}$ be the set of all workers with productivities $\{y_1,....,y_n\}$, for a given equilibrium market tightness θ, and mimum wage m, define:

- The set of barely employable workers: $L(\theta) = \{i \in \{1,...,n\} \mid y_M(\theta) > y_i \geq y_L\}$.
- The set of perfectly employable workers with efficiency wages: $M(\theta) = \{i \in \{1,...,n\} \mid y_H(\theta) > y_i \geq y_M(\theta)\}$.
- The set of perfectly employable workers with Nash-bargainig wages: $H(\theta) = \{i \in \{1,...,n\} \mid y_i \geq y_H(\theta)\}$
- The set of employable workers under the minimum wage m: $\Omega(m) = \{i \in \{1,...,n\} \mid y_i \geq m\}$.
- The set of non-employable workers under the minimum wage m: $\Omega^c(m) = \{i \in \{1,...,n\} \mid i \notin \Omega(m)\}$.

Equilibrium market tightness is given by the VSC (20), which can be expressed as:

$$K(m,\theta) \equiv \sum_i \Pi_i(m,\theta)\mu_i(m,\theta)[y_i - w_i(m,\theta)] = (r+\delta)\frac{\gamma}{q(\theta)}.$$

First, I must prove that $K(m,\theta)$ is decreasing in θ. So, I show that for any θ and θ' s.t. $\theta < \theta'$, $K(m,\theta) \geq K(m,\theta')$. To do so, I can rewrite

$$K(m,\theta) = \sum_{i\in\Omega(m)\cap L(\theta)} \Pi_i(m,\theta)\mu_i(m,\theta)[y_i - w_i(m,\theta)] + \sum_{i\in M(\theta)\cup H(\theta)} \Pi_i(m,\theta)\mu_i(m,\theta)[y_i - w_i(m,\theta)]$$

Since $M(\theta)\cup H(\theta) = \Omega(m)\cap[M(\theta)\cup H(\theta)]$ given the assumption $m < w^E(\theta)$. Notice that according to ((21)), $y_i = w_i(m,\theta)$ $\forall i \in \Omega(m)\cap L(\theta)$. Also, from (22) $\Pi_i(m,\theta) = 1 \forall i \in M(\theta)\cup H(\theta)$. So we can write

$$K(m,\theta) = \sum_{i\in M(\theta)\cup H(\theta)} \mu_i(m,\theta)[y_i - w_i(m,\theta)].$$

From (19), (22), and (23) we have that $\sum_i p_i s_i(m,\theta)u_i(m,\theta) \geq \sum_i p_i s_i(m,\theta')u_i(m,\theta')$, and $s_i(m,\theta)u_i(m,\theta) = s_i(m,\theta')u_i(m,\theta')$ $\forall i \in L(\theta)$, so from (8), $\mu_i(m,\theta) \leq \mu_i(m,\theta')$ $\forall i \in L(\theta)$. Since $\sum_i \mu_i(m,\theta) = 1$, we have that

$$\sum_{i\in M(\theta)\cup H(\theta)} \mu_i(m,\theta) = 1 - \sum_{i\in L(\theta)} \mu_i(m,\theta),$$

so

$$\sum_{i\in M(\theta)\cup H(\theta)} \mu_i(m,\theta) \geq \sum_{i\in M(\theta)\cup H(\theta)} \mu_i(m,\theta').$$

Using that $[M(\theta)\cup H(\theta)] \supseteq [M(\theta')\cup H(\theta')]$ and that according to (21), $y_i - w_i(m,\theta) \geq y_i - w_i(m,\theta')\forall i$, we have that

$$\sum_{i\in M(\theta)\cup H(\theta)} \mu_i(m,\theta) \geq \sum_{i\in M(\theta)\cup H(\theta)} \mu_i(m,\theta') \implies \sum_{i\in M(\theta)\cup H(\theta)} \mu_i(m,\theta) \geq \sum_{i\in M(\theta')\cup H(\theta')} \mu_i(m,\theta').$$

From this last week inequality it follows that

$$\sum_{i\in M(\theta)\cup H(\theta)} \mu_i(m,\theta)[y_i - w_i(m,\theta)] \geq \sum_{i\in M(\theta')\cup H(\theta')} \mu_i(m,\theta')[y_i - w_i(m,\theta')].$$

So $K(m,\theta) \geq K(m,\theta')$ for any θ and θ' s.t. $\theta < \theta'$.

Now I must show that for any m and m' s.t. $m < m' < w^E(\theta)$, where θ is the equilibirum market tigthness under m, $K(m,\theta) \leq K(m',\theta)$.

To see this notice that according to (23) and (20) and (19), for any m and m' s.t. $m < m' < w^E(\theta)$, $s_i(m,\theta)u_i(m,\theta) \geq s(m,\theta')u_i(m,\theta')\ \forall i \in \Omega^c(m')$, and $s_i(m,\theta)u_i(m,\theta) = s(m,\theta')u_i(m,\theta')\ \forall i \in \Omega(m')$. So $\mu_i(m,\theta) \leq \mu_i(m',\theta)\ \forall i \in \Omega(m')$. Using that $w_i(m,\theta) = w_i(m',\theta)$, $\forall i \in M(\theta)\cup H(\theta)$ and $M(\theta)\cup H(\theta) = \Omega(m)\cap[M(\theta)\cup H(\theta)] = \Omega(m')\cap[M(\theta)\cup H(\theta)]$, we have

$$\sum_{i\in M(\theta)\cup H(\theta)} \mu_i(m,\theta)[y_i - w_i(m,\theta)] \leq \sum_{i\in M(\theta')\cup H(\theta')} \mu_i(m',\theta)[y_i - w_i(m',\theta)].$$

Now that I have stablisehd that the LHS of the VSC is non-increasing in θ and non-decreasing in m for small changes in m. The proof is straight forward.

For a given m^*, let θ^* be the equilibrium market tightness that solves the VSC (20), that is

$$K(m*,\theta^*) = (r+s)\frac{\gamma}{q(\theta^*)}.$$

Let m' be such that $m^* < m' \leq w_E(\theta^*)$. Since $K(m,\theta)$ is non-decreasing in m for $\triangle m < w_E(\theta^*) - m^*$, we have

$$K(m',\theta^*) \geq (r+s)\frac{\gamma}{q(\theta^*)}. \tag{28}$$

So the equlibrium market tightness θ' that give the equality in (28) must be such that $\theta' \geq \theta^*$, given that the LHS of (28) is decreasing in θ and the RHS is increasing in θ.□

Appendix B: Tables

Table 1: Descriptive Statistics by Age and Educational Attainment, 1994-2013.

	By Age				By Educational Attainment				
	16-19	16-24	25-59	60-64	LTHS	H. School	S. College	College	Advanced
Age	17.4	19.8	41.8	61.9	32.7	40.4	38.9	41	45
	(1.1)	(2.6)	(9.7)	(1.4)	(15.9)	(13.2)	(13.1)	(11.5)	(10.6)
No. of Hours Worked	24.12	31.55	40.6	37.8	33.7	39.21	38.61	40.89	42.59
	(13.3)	(14)	(12.8)	(14.6)	(14.5)	(12.6)	(13.5)	(12.9)	(13)
Wage	8.94	11.12	21.9	22.6	11.47	16.32	18.36	27.27	34.51
	(4.9)	(6.8)	(15.2)	(20.2)	(6.6)	(9.6)	(11.9)	(18.23)	(21.2)
No. of Methods to Find a Job.	1.78	1.94	2.32	2.23	1.86	2.18	2.3	2.52	2.56
	(1)	(1.1)	(1.3)	(1.2)	(1.1)	(1.2)	(1.3)	(1.3)	(1.4)
Unemployment Rate	16.58%	11.96%	4.55%	4.14%	12.63%	6.59%	4.90%	3.08%	2.20%
Employment	38.5%	54.1%	78.3%	50.1%	46.1%	70.9%	75.7%	82.9%	86.4%
Labor Force Participation	46.1%	61.5%	82%	52.3%	52.7%	75.9%	79.6%	85.6%	88.3%
16-19 year-olds %	100.0%	47.6%	0%	0%	37.4%	6.0%	4.1%	0.0%	0.0%
16-24 year olds %	100%	100%	0%	0%	44.2%	16.2%	19.2%	6.4%	0.0%
Share within 10% of MW	32.4%	18.8%	3.2%	3.6%	19.8%	5.9%	4.94%	1.35%	0.6%
Observations	438,772	920,844	3,821,826	377,615	757,518	1,620,648	1,429,204	885,237	427,678

Total number of observations is 5,120,285. Standard deviations are reported in parenthesis for continuous variables. Hourly wages expressed in 2013 dollars. Variable used for hourly wages is wage3 from the CEPR ORG extracts; the NBER recommended wage variable. For the hours variable I used hourslw from CEPR ORG extracts; it measures actual hours worked on all jobs the week before the interview. The share of the population within a 10% of de minimum wages is computed by dividing wages by their corresponding effective minimum wage, if this ratio is between .9 and 1.1 the observation counts for this share.

Table 2: Minimum Wage Effects on Employment.

Specification		(1)	(2)	(3)	(4)
High-Education, All Ages					
Some College					
	coefficient	0.003	-0.001	0.000	0.005
	s.e.	(0.009)	(0.012)	(0.011)	(0.010)
	elasticity	0.003	-0.002	0.001	0.007
College					
	coefficient	-0.018*	0.006	0.009	-0.025
	s.e.	(0.010)	(0.010)	(0.012)	(0.017)
	elasticity	-0.022*	0.007	0.011	-0.031
Advanced					
	coefficient	-0.022	-0.003	0.001	-0.024
	s.e.	(0.014)	(0.015)	(0.016)	(0.014)
	elasticity	-0.026	-0.004	0.001	-0.027
Low-Education, All Ages					
L.T. High School					
	coefficient	-0.008	0.010	-0.032	0.013
	s.e.	(0.018)	(0.024)	(0.022)	(0.021)
	elasticity	-0.010	0.044	-0.049	0.024
High School					
	coefficient	0.020**	0.028**	0.015	0.027**
	s.e.	(0.009)	(0.016)	(0.010)	(0.014)
	elasticity	0.028**	0.040**	0.021	0.038**
Teenagers					
	coefficient	-0.032**	-0.052**	-0.046**	-0.024
	s.e.	(0.016)	(0.027)	(0.022)	(0.019)
	elasticity	-0.084**	-0.136**	-0.120**	-0.061

The dependent variable is a dummy variable for employment. Results are reported for the coefficients of the natural logarithm of the minimum wage for specifications (1) to (3). For specification (4) the coefficient is the sum of the contemporary and lagged effects. Standard errors clustered at state level are reported in parentheses. Elasticities are calculated by dividing the coefficient by the relevant employment to population ratio. Significance levels are as follows: *** 1 percent, ** 5 percent, * 10 percent. Each specification includes individual controls for age, gender, race, marital status, education, as well as controls for seasonally adjusted unemployment rate, and the relevant population share for each demographic group. State-fixed effects are also included. Observations reporting to be out of the labor force due to retirement or disability were excluded. Observations: Teenagers 438,402; LTHS 755,968; HS 1,618,616; SC 1,428,006; College 884,821; Advanced 427,505.

Table 3: Minimum Wage Effects on Labor Force Participation..

Specification		(1)	(2)	(3)	(4)
High-Education, All Ages					
Some College					
	coefficient	-0.002	0.000	-0.002	0.002
	s.e.	(0.008)	(0.012)	(0.011)	(0.009)
	elasticity	-0.002	0.000	-0.003	0.002
College					
	coefficient	-0.014	0.010	0.010	-0.020
	s.e.	(0.009)	(0.011)	(0.011)	(0.013)
	elasticity	-0.017	0.012	0.012	-0.024
Advanced					
	coefficient	-0.015	0.000	0.001	-0.016
	s.e.	(0.011)	(0.012)	(0.014)	(0.013)
	elasticity	-0.017	0.000	0.002	-0.018
Low-Education, All Ages					
L.T. High School					
	coefficient	-0.005	0.023	-0.026	0.012
	s.e.	(0.021)	(0.025)	(0.021)	(0.025)
	elasticity	-0.010	0.044	-0.049	0.024
High School					
	coefficient	0.022**	0.029**	0.025*	0.032***
	s.e.	(0.009)	(0.015)	(0.013)	(0.010)
	elasticity	0.029**	0.038**	0.033*	0.042***
Teenagers					
	coefficient	-0.029*	-0.048*	-0.042**	-0.015
	s.e.	(0.015)	(0.026)	(0.021)	(0.018)
	elasticity	-0.062*	-0.103*	-0.092**	-0.033

The dependent variable is a dummy variable for labor force participation. Results are reported for the coefficients of the natural logarithm of the minimum wage for specifications (1) to (3). For specification (4) the coefficient is the sum of the contemporary and lagged effects. Standard errors clustered at state level are reported in parentheses. Elasticities are calculated by dividing the coefficient by the relevant labor force participation to population ratio. Significance levels are as follows: *** 1 percent, ** 5 percent, * 10 percent. Each specification includes individual controls for age, gender, race, marital status, education, as well as controls for seasonally adjusted unemployment rate, and the relevant population share for each demographic group. State-fixed effects are also included. Observations reporting to be out of the labor force due to retirement or disability were excluded. Observations: Teenagers 438,402; LTHS 755,968; HS: 1,618,616; SC 1,428,006; College 884,821; Advanced 427,505.

Table 4: Minimum Wage Effects on Search Intensity.

Specification		(1)	(2)	(3)	(4)
High-Education, All Ages					
Some College					
	coefficient	-0.088	-0.328*	-0.403**	-0.134
	s.e.	(0.157)	(0.194)	(0.194)	(0.166)
	elasticity	-0.038	-0.142*	-0.175**	-0.058
College					
	coefficient	0.299*	0.076	0.099	0.341**
	s.e.	(0.169)	(0.270)	(0.261)	(0.169)
	elasticity	0.119*	0.030	0.039	0.135**
Advanced					
	coefficient	0.046	0.089	-0.301	0.125
	s.e.	(0.272)	(0.424)	(0.466)	(0.317)
	elasticity	0.018	0.035	-0.117	0.049
Low-Education, All Ages					
L.T. High School					
	coefficient	-0.274**	-0.159	-0.067	-0.357**
	s.e.	(0.137)	(0.151)	(0.215)	(0.149)
	elasticity	-0.147**	-0.086	-0.036	-0.192**
High School					
	coefficient	0.002	-0.233	-0.326	0.008
	s.e.	(0.113)	(0.144)	(0.230)	(0.198)
	elasticity	0.001	-0.107	-0.150	-0.006
Teenagers					
	coefficient	-0.015	-0.089	-0.032	-0.126
	s.e.	(0.104)	(0.171)	(0.209)	(0.114)
	elasticity	-0.009	-0.050	-0.018	-0.071

The dependent variable is the number of methods used to find a job. Results are reported for the coefficients of the natural logarithm of the minimum wage for specifications (1) to (3). For specification (4) the coefficient is the sum of the contemporary and lagged effects. Standard errors clustered at state level are reported in parentheses. Elasticities are calculated by dividing the coefficient by the mean number of methods to find a job used in each demographic. Significance levels are as follows: *** 1 percent, ** 5 percent, * 10 percent. Each specification includes individual controls for age, gender, race, marital status, education, as well as controls for seasonally adjusted unemployment rate, and the relevant population share for each demographic group. State-fixed effects are also included. Additionally, each specification includes a control for unemployment duration, a possible cause of endogeneity; the variable used is undur. Observations: Teenagers 31,499; LTHS 43,998; HS 68,341; SC 48,469; College 20,902; Advanced 7,466.

Table 5: Minimum Wage Effects on Hours.

Specification		(1)	(2)	(3)	(4)
High-Education, All Ages					
Some College					
	coefficient	-0.015	-0.022	-0.023*	-0.019*
	s.e.	(0.011)	(0.015)	(0.013)	(0.011)
College					
	coefficient	-0.016	0.018	0.019	-0.014
	s.e.	(0.016)	(0.013)	(0.013)	(0.017)
Advanced					
	coefficient	-0.023	0.008	0.018	-0.025
	s.e.	(0.015)	(0.021)	(0.021)	(0.016)
Low-Education, All Ages					
L.T. High School					
	coefficient	-0.065**	-0.105***	-0.096***	-0.063**
	s.e.	(0.027)	(0.034)	(0.035)	(0.031)
High School					
	coefficient	-0.015	-0.018	-0.021*	-0.015
	s.e.	(0.010)	(0.015)	(0.012)	(0.011)
Teenagers					
	coefficient	-0.120***	-0.218***	-0.210***	-0.123***
	s.e.	(0.034)	(0.051)	(0.048)	(0.036)

The dependent variable is the log of weekly hours worked. Results are reported for the coefficients of the natural logarithm of the minimum wage for specifications (1) to (3). For specification (4) the coefficient is the sum of the contemporary and lagged effects. Standard errors clustered at state level are reported in parentheses. Significance levels are as follows: *** 1 percent, ** 5 percent, * 10 percent. Each specification includes individual controls for age, gender, race, marital status, education, as well as controls for seasonally adjusted unemployment rate, and the relevant population share for each demographic group. State-fixed effects are also included. Observations: Teenagers 162,009; LTHS 335,014; HS 1,105,666; SC 1,039,471; College 702,036; Advanced 348,697.

Table 6: Minimum Wage Effects on Wages.

Specification		(1)	(2)	(3)	(4)
High-Education, All Ages					
Some College					
	coefficient	0.003	-0.001	0.000	0.005
	s.e.	(0.009)	(0.012)	(0.011)	(0.010)
College					
	coefficient	-0.005	0.026	0.016	-0.003
	s.e.	(0.035)	(0.025)	(0.024)	(0.035)
Advanced					
	coefficient	-0.037	-0.004	-0.013	-0.052
	s.e.	(0.040)	(0.031)	(0.035)	(0.040)
Low-Education, All Ages					
L.T. High School					
	coefficient	0.053	0.102**	0.066*	0.054
	s.e.	(0.035)	(0.041)	(0.034)	(0.042)
High School					
	coefficient	0.009	0.050*	0.045*	0.004
	s.e.	(0.029)	(0.030)	(0.025)	(0.031)
Teenagers					
	coefficient	0.152***	0.163***	0.136***	0.163***
	s.e.	(0.026)	(0.037)	(0.032)	(0.028)

The dependent variable is the log of hourly wage. Results are reported for the coefficients of the natural logarithm of the minimum wage for specifications (1) to (3). For specification (4) the coefficient is the sum of the contemporary and lagged effects. Standard errors clustered at state level are reported in parentheses. Significance levels are as follows: *** 1 percent, ** 5 percent, * 10 percent. Each specification includes individual controls for age, gender, race, marital status, education, as well as controls for seasonally adjusted unemployment rate, and the relevant population share for each demographic group. State-fixed effects are also included. Observations: Teenagers 163,027; LTHS 312,185; HS 1,004,419; SC 946,401; College 623,667; Advanced 302,711.

Table 7: Minimum Wage Effects on Low-Education Employment by Age, 1994-2013

		LTHS				High School			
Specification		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
16-19									
	coefficient	-0.067***	-0.060**	-0.058***	-0.058***	0.042	-0.037	0.002	0.046
	s.e.	(0.021)	(0.026)	(0.022)	(0.023)	(0.033)	(0.055)	(0.051)	(0.038)
	elasticity	-0.215***	-0.192**	-0.187***	-0.186***	0.082	-0.073	0.004	0.038
16-24									
	coefficient	-0.049**	-0.038	-0.043*	-0.037*	0.021	-0.002	0.040	0.022
	s.e.	(0.020)	(0.026)	(0.023)	(0.021)	(0.020)	(0.030)	(0.027)	(0.022)
	elasticity	-0.141**	-0.109	-0.123*	-0.107*	0.034	-0.003	0.064	0.036
25-59									
	coefficient	0.018	0.026	-0.027	0.042	0.019**	0.032**	0.025*	0.030***
	s.e.	(0.026)	(0.026)	(0.032)	(0.029)	(0.009)	(0.014)	(0.014)	(0.010)
	elasticity	0.030	0.044	-0.046	0.073	0.025**	0.042**	0.033*	0.040***
60-64									
	coefficient	0.030	-0.007	-0.034	0.067	0.024	0.044	0.020	0.035
	s.e.	(0.034)	(0.057)	(0.077)	(0.040)	(0.031)	(0.030)	(0.033)	(0.036)
	elasticity	0.093	-0.020	-0.104	0.206	0.053	0.095	0.043	0.077

The dependent variable is a dummy variable for employment. Results are reported for the coefficients of the natural logarithm of the minimum wage for specifications (1) to (3). For specification (4) the coefficient is the sum of the contemporary and lagged effects. Standard errors clustered at state level are reported in parentheses. Elasticities are calculated by dividing the coefficient by the relevant employment to population ratio. Significance levels are as follows: *** 1 percent, ** 5 percent, * 10 percent. Each specification includes individual controls for age, gender, race, marital status, education, as well as controls for seasonally adjusted unemployment rate, and the relevant population share for each demographic group. State-fixed effects are also included. Observations reporting to be out of the labor force due to retirement or disability were excluded. LTHS Observations; 16-19: 283,310; 16-24: 334,182; 25-59: 368,059; 60-64: 53,727.HS Observations; 16-19: 96,467; 16-24: 251,226; 25-59: 1,234,738; 60-64: 132,652.

Table 8: Minimum Wage Effects on Low-Education Labor Force Participation by Age, 1994-2013

		LTHS				High School			
Specification		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
16-19									
	coefficient	-0.066***	-0.053**	-0.052**	-0.055**	0.041	-0.046	0.003	0.063*
	s.e.	(0.021)	(0.025)	(0.023)	(0.023)	(0.030)	(0.052)	(0.041)	(0.034)
	elasticity	-0.170***	-0.137**	-0.134**	-0.144**	0.068	-0.076	0.005	0.103*
16-24									
	coefficient	-0.037*	-0.017	-0.024	-0.026	0.022	-0.014	0.020	0.032*
	s.e.	(0.021)	(0.025)	(0.022)	(0.023)	(0.018)	(0.029)	(0.025)	(0.019)
	elasticity	-0.088*	-0.040	-0.056	-0.061	0.031	-0.019	0.028	0.045*
25-59									
	coefficient	0.009	0.031	-0.026	0.028	0.023***	0.034***	0.026**	0.034***
	s.e.	(0.028)	(0.027)	(0.033)	(0.032)	(0.009)	(0.013)	(0.013)	(0.010)
	elasticity	0.014	0.048	-0.040	0.044	0.029***	0.043***	0.033**	0.042***
60-64									
	coefficient	0.044	0.005	-0.050	0.081	0.018	0.051*	0.019	0.031
	s.e.	(0.037)	(0.057)	(0.078)	(0.043*)	(0.033)	(0.031)	(0.033)	(0.039)
	elasticity	0.125	0.016	-0.145	0.235	0.037	0.107*	0.039	0.064

The dependent variable is a dummy variable for labor force participation. Results are reported for the coefficients of the natural logarithm of the minimum wage for specifications (1) to (3). For specification (4) the coefficient is the sum of the contemporary and lagged effects. Standard errors clustered at state level are reported in parentheses. Elasticities are calculated by dividing the coefficient by the relevant labor force participation to population ratio. Significance levels are as follows: *** 1 percent, ** 5 percent, * 10 percent. Each specification includes individual controls for age, gender, race, marital status, education, as well as controls for seasonally adjusted unemployment rate, and the relevant population share for each demographic group. State-fixed effects are also included. Observations reporting to be out of the labor force due to retirement or disability were excluded. LTHS Observations; 16-19: 283,310; 16-24: 334,182; 25-59: 368,059; 60-64: 53,727.HS Observations; 16-19: 96,467; 16-24: 251,226; 25-59: 1,234,738; 60-64: 132,652.

Table 9: Minimum Wage Effects on Low-Education Search Intensity by Age, 1994-2013

		LTHS				High School			
Specification		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
16-19									
	coefficient	-0.095	-0.053	0.132	-0.222	0.304	-0.014	-0.191	0.177
	s.e.	(0.147)	(0.207)	(0.244)	(0.156)	(0.209)	(0.318)	(0.360)	(0.225)
	elasticity	-0.057	-0.032	0.079	-0.132	0.154	-0.007	-0.097	0.090
16-24									
	coefficient	-0.150	-0.245	-0.082	-0.267*	0.073	-0.257	-0.270	0.039
	s.e.	(0.151)	(0.186)	(0.239)	(0.155)	(0.173)	(0.215)	(0.263)	(0.210)
	elasticity	-0.087	-0.141	-0.047	-0.154*	0.036	-0.125	-0.131	0.019
25-59									
	coefficient	-0.384*	-0.005	-0.005	-0.448*	-0.011	-0.244	-0.363	-0.013
	s.e.	(0.216)	(0.214)	(0.270)	(0.251)	(0.135)	(0.186)	(0.231)	(0.143)
	elasticity	-0.190*	-0.002	0.010	-0.222*	-0.005	-0.109	-0.162	-0.006
60-64									
	coefficient	-1.406	-2.836*	-1.484	-0.753	0.058	-0.505	-1.102	-0.067
	s.e.	(0.905)	(1.631)	(2.260)	(0.985)	(0.522)	(0.856)	(1.045)	(0.524)
	elasticity	-0.744	-1.500*	-0.785	-0.398	0.027	-0.232	-0.506	-0.031

The dependent variable is the number of methods used to find a job. Results are reported for the coefficients of the natural logarithm of the minimum wage for specifications (1) to (3). For specification (4) the coefficient is the sum of the contemporary and lagged effects. Standard errors clustered at state level are reported in parentheses. Elasticities are calculated by dividing the coefficient by the mean number of methods to find a job used in each demographic. Significance levels are as follows: *** 1 percent, ** 5 percent, * 10 percent. Each specification includes individual controls for age, gender, race, marital status, education, as well as controls for seasonally adjusted unemployment rate, and the relevant population share for each demographic group. State-fixed effects are also included. Additionally, each specification includes a control for unemployment duration, a possible cause of endogeneity; the variable used is undur. LTHS Observations; 16-19: 19,522; 6-24: 24,992; 25-59: 18,212; 60-64: 794.HS Observations: 16-19: 9,034; 16-24: 21,988; 25-59: 44,340; 60-64: 2,013.

Table 10: Minimum Wage Effects on Low-Education Weekly Hours by Age, 1994-2013

		LTHS				High School			
Specification		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
16-19									
	coefficient	-0.159***	-0.238***	-0.230***	-0.162***	-0.077	-0.213***	-0.214***	-0.099*
	s.e.	(0.049)	(0.067)	(0.069)	(0.054)	(0.055)	(0.070)	(0.073)	(0.057)
16-24									
	coefficient	-0.072	-0.150***	-0.157***	-0.066	-0.020	-0.058*	-0.049	-0.028
	s.e.	(0.045)	(0.053)	(0.057)	(0.054)	(0.023)	(0.035)	(0.035)	(0.025)
25-59									
	coefficient	-0.051**	-0.070**	-0.035	-0.053**	-0.013	-0.012	-0.017	-0.010
	s.e.	(0.023)	(0.030)	(0.030)	(0.024)	(0.011)	(0.015)	(0.012)	(0.014)
60-64									
	coefficient	-0.161**	-0.183	-0.175	-0.185**	-0.044	-0.024	-0.028	-0.069
	s.e.	(0.084)	(0.128)	(0.125)	(0.088)	(0.041)	(0.045)	(0.043)	(0.045)

The dependent variable is the log of weekly hours worked. Results are reported for the coefficients of the natural logarithm of the minimum wage for specifications (1) to (3). For specification (4) the coefficient is the sum of the contemporary and lagged effects. Standard errors clustered at state level are reported in parentheses. Significance levels are as follows: *** 1 percent, ** 5 percent, * 10 percent. Each specification includes individual controls for age, gender, race, marital status, education, as well as controls for seasonally adjusted unemployment rate, and the relevant population share for each demographic group. State-fixed effects are also included. LTHS Observations: 16-19: 84,525; 16-24: 110,979; 25-59: 207,541; 60-64: 16,494. HS Observations: 16-19: 47,621; 16-24: 152,067; 25-59: 895,720; 60-64: 57,879.

Table 11: Minimum Wage Effects on Low-Education Wages by Age, 1994-2013

		LTHS				High School			
Specification		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
16-19									
	coefficient	0.194***	0.186***	0.174***	0.218***	0.094***	0.139***	0.102*	0.087**
	s.e.	(0.029)	(0.041)	(0.040)	(0.031)	(0.037)	(0.053)	(0.057)	(0.041)
16-24									
	coefficient	0.169***	0.160***	0.140***	0.184***	0.083***	0.141***	0.110***	0.083**
	s.e.	(0.030)	(0.044)	(0.041)	(0.033)	(0.031)	(0.043)	(0.037)	(0.035)
25-59									
	coefficient	-0.015	0.062	-0.001	-0.020	-0.003	0.033	0.029	-0.008
	s.e.	(0.046)	(0.047)	(0.040)	(0.057)	(0.030)	(0.032)	(0.026)	(0.032)
60-64									
	coefficient	0.079	0.173	0.231	0.090	-0.017	0.035	0.070	-0.034
	s.e.	(0.099)	(0.092)	(0.101)	(0.112)	(0.050)	(0.066)	(0.076)	(0.061)

The dependent variable is the log of hourly wage. Results are reported for the coefficients of the natural logarithm of the minimum wage for specifications (1) to (3). For specification (4) the coefficient is the sum of the contemporary and lagged effects. Standard errors clustered at state level are reported in parentheses. Significance levels are as follows: *** 1 percent, ** 5 percent, * 10 percent. Each specification includes individual controls for age, gender, race, marital status, education, as well as controls for seasonally adjusted unemployment rate, and the relevant population share for each demographic group. State-fixed effects are also included. LTHS Observations: 16-19: 85,030; 16-24: 110,744; 25-59: 187,331; 60-64: 14,110. HS Observation: 16-19: 47,771; 16-24: 150,447; 25-59: 804,586; 60-64: 49,386.