Minimum Wages and Youth Unemployment

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Abstract

This paper constructs a labor search model to explore the effects of minimum wages on youth unemployment. To capture the gradual decline in unemployment for young workers as they age, the standard search model is extended so that workers gain experience when employed. Experienced workers have higher average productivity and lower job finding and separation rates that match wage and worker flow data. In this environment, minimum wages can have large effects on unemployment because they interact with a worker’s ability to gain job experience. The increase in minimum wages between 2007 and 2009 can account for a 0.8 percentage point increase in the steady state unemployment rate and a 2.8 percentage point increase in unemployment for 15-24 year old workers in the model parameterized to simulate outcomes of high school educated workers. Minimum wages can also help explain the high rates of youth unemployment in France compared to the United States.

Keywords: Minimum Wage, Youth Unemployment, Experience, Fair Minimum Wage Act, France

JEL codes: E24, J08, J24, J64

1. Introduction

Youth unemployment is an important issue for economies around the world. The recent financial crisis and ensuing global downturn disproportionately impacted young workers. According to International Labour Organization (2013), youth unemployment worldwide peaked in 2009 at the highest level ever recorded and is nearing that peak again in 2013. In June 2010, the unemployment rate for young workers in the United States reached 20%. Jaimovich and Siu (2009) show that young workers account for the majority of employment fluctuations at business cycle frequencies. Additionally, early career outcomes are important to a worker’s development, and large cross country differences in employment outcomes are concentrated among young workers.

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This paper constructs a labor search model with worker experience that can replicate observed age patterns of unemployment. The model is then used to quantitatively assess the impact of minimum wages on unemployment rates for young workers with low levels of education. To replicate observed age patterns of unemployment, a standard labor search model is extended to include two types of workers: inexperienced and experienced. Young workers enter the labor market inexperienced and become experienced by working on the job. Experienced workers have higher average productivity and potentially different job finding and job separation rates that are targeted to match rates observed in data. Including minimum wages in the model constrains the Nash bargaining solution for inexperienced workers, preventing jobs at some productivity levels from being created and leading others to be established at the minimum wage. A novel finding is that minimum wages can have nonlinear effects on unemployment with low minimum wages not having large effects and high levels of minimum wages leading to large increases in unemployment.

A key mechanism in the model is that inexperienced workers, who are typically young, are willing to take lower wages because employment gives them the possibility of gaining experience. The total surplus of a job includes both the value of their wage and the additional option value of experience. While investment in human capital is not treated as a decision, the effects of minimum wages are amplified as they prevent young workers from accepting low wage matches that allow them to gain skills in the labor market. This mechanism can also influence average unemployment for older workers as high minimum wages prevent individuals from gaining experience when young. To assess the quantitative importance of changes in the minimum wage on unemployment, the model features idiosyncratic productivity shocks for inexperienced workers and payroll taxes. It is important to include idiosyncratic productivity shocks so that changes in the minimum wage can influence the equilibrium job separation rate while payroll taxes have important interactions with the minimum wage level because they alter the firm’s cost of hiring a worker.

The distribution of wages for young high school educated workers suggests that increases in the minimum wage could have substantial effects on unemployment. In 2006 the minimum wage in the U.S. was $5.15 per hour. In data from the Current Population Survey, 5.0% of 18-24 year old workers with a high school degree or less earned less than or equal to the minimum wage. The Fair Minimum Wage Act of 2007 increased minimum wages to $7.25 between 2007 and 2009. 28.9% of these young workers with low education earned less than $7.25 in 2006. European minimum wage levels are even higher. At the extreme, France had a minimum wage equivalent to $10.14 in 2006. In the U.S. that year, 72.1% of 18-24 year old workers with less

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2Rosen (1972) was one of the first to characterize the market for worker’s skills gained through job experience. In a competitive labor market, workers can be paid a lower wage if their jobs provide them with learning opportunities.

3The mechanism in the model relates to a literature on the effects of minimum wages on job training that finds mixed empirical support. Mincer and Leighton (1980) and Hashimoto (1982) formally study the effects of minimum wages on job training and find modest support for the conclusion that minimum wages reduce training. More recently, Acemoglu and Pischke (1999) formulate a model where minimum wages can increase training in a non-competitive labor market and provide new empirical evidence that minimum wage changes have no effect on training.
than or equal to high school education earned less than that amount. Of course not all workers currently earning less than a new minimum wage level would become unemployed; if their productivity is high enough, firms may be able to adjust their wages to keep them employed. This paper uses an equilibrium model to understand the total effects of such changes in minimum wage policy.

Simulating the effects of the Fair Minimum Wage Act, the model implies that the increase in minimum wages generated a 2.8 percentage point increase in the unemployment rate for high school educated workers between the ages of 15 and 24. One contribution of this approach is that the model disentangles the unemployment effects of the minimum wage changes from the overall increase in unemployment as a result of the recession. Between 2006 and 2010, unemployment for 15-24 year old workers with high school education increased by 3.3 percentage points more than the overall unemployment rate for individuals with high school education. The model implies that the increase in minimum wages accounts for 59.2% of this difference or 25.6% of the total increase in unemployment for 15-24 year old workers during this period when overall unemployment increased substantially.\(^4\) Finally, simulations of the model imply that if France reduced its minimum wage to levels in the U.S. its youth unemployment rate would decline substantially, nearly equaling that in the U.S. baseline simulation.

Much of the macro-labor literature focuses on representative agent models that abstract from differences in labor market decisions over an individual’s life cycle.\(^5\) Including experience in a general equilibrium model is important to assess the effect of minimum wages on unemployment because the value of experience enters into the wage equation for inexperienced workers, changing the distribution of bargained wages. As a simple way to capture the returns to experience, experienced workers in the model have a high fixed productivity level, a lower rate of exogenous job separations, and are not subject to idiosyncratic productivity shocks that generate endogenous job separations.\(^6\) The model generates differences in employment outcomes by age because older workers are more likely to be experienced, making the basic framework ideal for evaluating the effect of policy on young workers.

The way that minimum wages are modeled in this paper is closely related to recent search models

\(^4\)It should be noted that the aggregate results in this paper are for the group of workers with only a high school degree. For this group unemployment increased from 11.34% in 2006 to 22.52% in 2010 compared with an increase from 10.3% to 18.43% for all workers. Given that workers with a high school education or less only account for about 36% of the civilian population over age 25, the aggregate effects of minimum wage increases on the overall unemployment rate are likely to be substantially smaller as workers with more education are not impacted as greatly.

\(^5\)There is a growing related literature on life cycle search models including Cheron et al. (2011), Esteban-Pretel and Fujimoto (2011), Menzio et al. (2012), and Gorry (2013).

\(^6\)Parameters for experienced worker’s productivity and job separation rates are targeted to match observed wage growth and job separation rates of older workers respectively. Elsby et al. (2010) show that job separation rates are fairly stable over time for different age groups with 16-24 year-old workers facing separation rates about three times as high as workers aged 25-54. While simply targeting these parameters provides a good measure of the return to experience and keeps the model tractable, it misses potentially important interactions between the choices of human capital type and job separation rates that could be developed in a richer model of human capital. For example, Wasmer (2006) shows that when there are high job separation rates workers are more likely to invest in more general rather than job specific skills. Such a mechanism could potentially have implications for how these targets interact with the minimum wage.
that study the effects of minimum wages. Flinn (2006, 2010) studies the effects of minimum wages in a Mortensen-Pissarides equilibrium search environment and Rocheteau and Tasci (2008) study the effects of minimum wages in a variety of equilibrium search models. This paper follows Flinn (2006) by introducing minimum wages in a search model as a constraint on the Nash bargaining solution. His analysis is extended by considering a model where workers can improve their labor market outcomes by gaining work experience. As workers gain experience their wages increase and minimum wages become less binding. This implies that it is important to consider how minimum wages interact with experience accumulation as it can have equilibrium effects on the number of experienced workers.

This paper also complements a research agenda that seeks to quantitatively assess the impact of labor market institutions on labor market outcomes as described by Rogerson (2006). Comparing outcomes across countries, most differences are concentrated among 15-24 and 55-64 year-old workers. While previous work focuses broadly on explaining differences between the U.S. and Europe, this paper examines factors that explain why the differences are concentrated among young workers. This paper adds to previous explanations such as Prescott (2004) and Ljungqvist and Sargent (1998) who argue that the disparity in employment between the U.S. and Europe can be accounted for by taxes and differences in unemployment benefits coupled with loss of human capital when unemployed. While explaining large differences in unemployment, neither of these explanations account specifically for the unemployment rates of young workers.

Finally, this paper provides theoretical support for findings in the empirical literature about the effects of minimum wages on employment outcomes. It explains why the effects of minimum wages are only found among young workers. The nonlinear effect of minimum wages on unemployment rates generated by the model helps reconcile the literature that finds small effects of minimum wage laws in the U.S. where minimum wages are low with the literature that finds larger effects in Europe.

The model is presented in section 2. Section 3 parameterizes the model to match the age patterns of employment found in the U.S. Section 4 documents the predictions from the model, and section 5 uses the model to conduct policy experiments. Section 6 concludes.

7There is a large microeconomic literature on the effects of minimum wages on worker outcomes that is too large to fully summarize. Card and Krueger (1994) revived interest in research on minimum wage by arguing that a minimum wage increase in Pennsylvania had no adverse impact on employment. Since then, many empirical papers have sought to evaluate the effects of the minimum wage on employment outcomes. For a recent survey of the literature see Neumark and Wascher (2007). While there is no consensus on the overall effect of minimum wages, most empirical studies conclude that minimum wages slightly reduce employment of young workers, though often the effects are not statistically significant.

8Dolado et al. (1996) studies the effects of minimum wages across countries in Europe and finds that minimum wages adversely affect youth unemployment. Using longitudinal data, Abowd et al. (1997) find that young men employed at the minimum wage in both France and the United States experience a significant decline in their probability of remaining employed after an increase in the minimum wage and Bazen and Skourias (1997) find a negative effect of minimum wages on youth employment in France despite finding no significant effects for other groups. Looking over 17 OECD countries, Neumark and Wascher (2004) find that in general minimum wages cause decreased employment among young workers.
2. A Search Model with Worker Experience

This section develops an infinite horizon search model that generates observed life cycle patterns of unemployment. After characterizing the solution of the basic model, minimum wages are introduced in Section 2.6. The model extends the matching models of Mortensen and Pissarides (1994) by having two types of workers: inexperienced and experienced. Time is continuous and at each date new unemployed, inexperienced workers enter the labor force to replace those who exit. Workers become experienced at a constant rate when employed and exit the labor force at a different exogenous rate.

The focus of this paper is to understand labor market outcomes for young workers, so the model of experienced workers will be kept as simple as possible. To assess the impact of minimum wages on youth unemployment, it is important that the model captures key determinants of the labor market for young workers including the appropriate return to experience that enters into inexperienced workers’ wage bargaining equation and the ability for policy to influence both job finding and separation rates for young workers. To properly measure the gains from experience, the model is developed to match observed patterns of wage growth, job finding rates, and job separation rates over the life cycle. These objects jointly determine the value of experience.

To capture these patterns, experienced workers are different than inexperienced workers on four dimensions. First, their productivity level is fixed while inexperienced workers have match specific productivity draws from a known, fixed distribution. Match specific productivity is necessary for inexperienced workers so that the minimum wage influences some but not all potential matches. Second, inexperienced workers face idiosyncratic match productivity shocks that allow changes in labor market policies to influence job separation rates while experienced workers do not. Third, experienced and inexperienced workers face potentially different exogenous separation probabilities. Finally, workers search for jobs in separate labor markets with different flow costs of posting vacancies and match rates. While the equilibrium in this environment is a stationary distribution of experienced and inexperienced workers, the model can be simulated to generate hypothetical histories for individual workers that can be compared with data on unemployment by age.

2.1. Agents

There is a unit mass of workers who discount the future at rate $r$ and exit the labor market at rate $\delta$. A new cohort of size $\delta$ enters the labor force at each date to replace the workers who exit. Hence, there

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9These first two features are used to keep the model for experienced workers simple, rather than for realism. Both features are important for assessing the impact of minimum wages, but can be excluded for experienced workers to simplify the analysis. In a previous version of the paper experienced workers were assumed to draw wages from the same productivity distribution as inexperienced workers. In that model, wage differences were generated as experienced workers had lower job separation rates and were therefore pickier about the jobs that they were willing to accept. In that model all of the main results were similar with the exception that minimum wages had a slightly larger impact on unemployment outcomes compared to the current model.
is a constant number of workers in the labor force at any given time. New workers are inexperienced and unemployed when they enter.

Additionally, there is a continuum of infinitely lived agents, called firms, who can post any number of vacancies for workers of type \( i \in \{e, n\} \), where \( e \) denotes experienced and \( n \) denotes inexperienced, at a flow cost of \( c_i \) consumption units for an open vacancy.

2.2. Production and Worker Flows

Production occurs when a worker is paired with a firm. Experienced and inexperienced workers search for jobs in separate markets characterized by the constant returns to scale matching function \( m(v_i, u_i) \), where \( v_i \) and \( u_i \) denote the number of vacancies and unemployed workers of type \( i \in \{e, n\} \), respectively. Let \( \theta_i = \frac{v_i}{u_i} \) denote the market tightness in market \( i \). A worker of type \( i \) meets a vacant job at rate \( p(\theta_i) = m_i(v_i, u_i)/u_i \). Symmetrically, an open vacancy of type \( i \) meets a worker at rate \( q(\theta_i) = m_i(v_i, u_i)/v_i \).

When an inexperienced worker and vacancy meet, the pair draw a match specific productivity \( y \) from distribution \( F(y) \). The worker and firm immediately observe the productivity draw and must decide either to form a match and produce or to remain separate. As is standard in the matching literature, the solution to this problem consists of a reservation productivity, \( y^*_n \), for inexperienced workers. To keep the analysis simple, all experienced workers have productivity \( y_e \). In the calibration, \( y_e \) is targeted to match the observed level of wage growth.

Based on their productivity firms pay inexperienced workers a wage \( w_n(y) \) and pay experienced workers a wage \( w_e \). Wages are determined by Nash bargaining and are subject to a payroll tax \( \tau \). While payroll tax changes do not have large effects on unemployment on their own, it is important to include them in the model as they have important interactions with the minimum wage as shown in Pries and Rogerson (2005). This occurs because higher payroll taxes directly influence the costs paid by a firm when hiring a worker at the minimum wage.

Three types of shocks hit productive matches. First, both experienced and inexperienced workers are hit by exogenous separation shocks at different rates, denoted by \( s_i \) for \( i \in \{e, n\} \). Second, inexperienced workers are hit by idiosyncratic productivity shocks at rate \( \lambda \). If the shock arrives, the match draws a new productivity from the distribution \( F(y) \). When the new productivity is observed the firm and worker choose either to continue production or to separate.\(^{10}\) Finally, at rate \( \alpha \), inexperienced workers become experienced

\(^{10}\) The idiosyncratic productivity shocks do not matter much for generating steady state predictions from the model because the effect of \( \lambda \) on the steady state level of job separation rates is ambiguous. The intuition is as follows. For any given value of the reservation wage, \( y^*_n \), an increase in \( \lambda \) increases the probability that a match ends because it is subject to more frequent changes in productivity. However, increases in \( \lambda \) also reduce the equilibrium reservation wage as both individuals and firms know that any given productivity level is less permanent, making them more willing to tolerate a low productivity level because it will not last very long. The magnitude of the second effect depends on how costly it is to search (key parameters being the cost of posting vacancies for firms and the flow value of being unemployed for workers) as workers and firms can hold on to low productivity matches to avoid having to search. However, including this channel of endogenous separations in the model allows changes of the minimum wage to influence the job separation rate. Due to the importance of this potential interaction, idiosyncratic productivity shocks are included in the model.
and separate from their inexperienced match.

Given the reservation productivity for inexperienced workers, it is straightforward to define the job finding and job separation rates for each type of worker. An unemployed inexperienced worker will find a job at rate $p(\theta_n)(1 - F(y_n^*))$ while an unemployed experienced worker will find a job at rate $p(\theta_e)$.\(^{11}\) Similarly, an employed inexperienced worker becomes unemployed at rate $s_n + \lambda F(y_n^*) + \alpha$ while an employed experienced worker loses her job at rate $s_e$.

2.3. Value Functions

Workers in the model can be in any one of four possible states. The value functions for unemployed inexperienced ($U_n$), unemployed experienced ($U_e$), employed inexperienced ($E_n$), and employed experienced ($E_e$) workers are as follows:

\[(r + \delta)U_n = b + p(\theta_n) \int_{y_n^*}^{\infty} (E_n(x) - U_n) dF(x)\]  
\[(r + \delta)U_e = b + p(\theta_e) (E_e - U_e)\]  
\[(r + \delta)E_n(y) = w_n(y) + s_n(U_n - E_n(y)) + \lambda \left( \int \max\{E_n(x), U_n\} dF(x) - E_n(y) \right) + \alpha (U_e - E_n(y))\]  
\[(r + \delta)E_e = w_e + s_e (U_e - E_e)\]

All workers discount the future at rate $r$ and exit at rate $\delta$. Unemployed workers get flow value $b$ that can be interpreted as unemployment benefits or the value of home production, and meet firms at rate $p(\theta_i)$ that depends on their type $i \in \{e, n\}$. When they meet a firm inexperienced workers get a draw from the productivity distribution $F(y)$ and either become employed with productivity $y$ or remain unemployed. Employed inexperienced workers are paid a wage $w_n(y)$ based on their productivity $y$ and experienced workers become employed with productivity $y_e$. At rate $s_n$ inexperienced workers are exogenously separated from their job, at rate $\lambda$ they are hit with an idiosyncratic productivity shock, and at rate $\alpha$ they become experienced. Finally, employed experienced workers get paid $w_e$ and are exogenously separated from their job at rate $s_e$. Note that becoming experienced is an absorbing state; experienced workers remain so until they leave the labor force.

Next, firms can choose to open vacancies for either inexperienced or experienced workers. Their value functions for inexperienced and experienced vacancies ($V_n$ and $V_e$) and filled jobs ($J_n$ and $J_e$) are as follows:

\[rV_n = -c_n + q(\theta_n) \int_{y_n^*}^{\infty} J_n(x) dF(x)\]  
\[rV_e = -c_e + q(\theta_e) J_e\]

\(^{11}\)For $y_e$ consistent with observed patterns of wage growth, all experienced matches are accepted.
\[(r + \delta)J_n(y) = y - (1 + \tau)w_n(y) + s_n(V_n - J_n(y)) + \lambda \left(\int_{y_n}^{\infty} J_n(x)dF(x) - J_n(y)\right) + \alpha(V_n - J_n(y)) \quad (7)\]

\[(r + \delta)J_e = y_e - (1 + \tau)w_e + s_e(V_e - J_e) \quad (8)\]

If a firm posts a vacancy for an inexperienced worker, it pays a flow cost \(c_n\) for having the open vacancy and meets a worker at rate \(q(\theta_n)\). When the match occurs the job is established or remains vacant depending on the realization of the productivity draw. Experienced vacancies pay flow cost \(c_e\), meet workers at rate \(q(\theta_e)\), and form a match with productivity \(y_e\) when they meet a worker. A firm matched with an inexperienced worker gets the output from the match \(y\) less the wage and payroll taxes paid to employ the worker \((1 + \tau)w_n(y)\). At rate \(s_n\) the match is exogenously separated, at rate \(\lambda\) the match is subject to a productivity shock, and at rate \(\alpha\) the worker becomes experienced, leaving the match. Finally, a firm matched with an experienced worker gets output \(y_e\) and pays wage and payroll taxes \((1 + \tau)w_e\). The match is exogenously destroyed at rate \(s_e\). Note that matched firms discount the future at rate \(r + \delta\) because when the worker exits the match ends.

### 2.4. Equilibrium

To complete the notation for the model let the masses of unemployed inexperienced workers, unemployed experienced workers, inexperienced matches, and experienced matches be denoted by \(u_n\), \(u_e\), \(e_n\), and \(e_e\). A steady state competitive equilibrium of the model is defined as follows:

**Definition 1.** A steady state equilibrium consists of the value functions for the worker, \(U_n\), \(U_e\), \(E_n(y)\), and \(E_e\), the value functions of the firm, \(V_n\), \(V_e\), \(J_n(y)\), \(J_e\), the aggregate state variables, \(u_n\), \(u_e\), \(e_n\), \(e_e\), \(\theta_n\), and \(\theta_e\), wages, \(w_n(y)\) and \(w_e\), and the reservation productivity level for inexperienced workers, \(y_n^*\), such that:

1. Value functions are satisfied: Given \(w_n(y)\), \(w_e\), \(u_n\), \(u_e\), \(y_n^*\), \(\theta_n\), and \(\theta_e\), then \(U_n\), \(U_e\), \(E_n(y)\), \(E_e\), \(V_n\), \(V_e\), \(J_n(y)\), and \(J_e\) satisfy equations (1)–(8).

2. Match Formation: Given \(w_n(y)\), \(w_e\), \(u_n\), \(u_e\), \(\theta_n\), and \(\theta_e\), the reservation productivity level \(y_n^*\) is an optimal decision rule.

3. Free Entry: Given \(w_n(y)\) and \(w_e\), then \(u_n\), \(u_e\), \(\theta_n\), and \(\theta_e\) must be such that the value of vacancies are zero, \(V_n = V_e = 0\).

4. Bargaining: \(w_n(y)\) and \(w_e\) are determined by the Nash bargaining equations with weight \(\gamma\) given to the workers:

\[E_n(y) - U_n = \gamma[J_n(y) + E_n(y) - V_n - U_n] \quad (9)\]

\[E_e - U_e = \gamma[J_e + E_e - V_e - U_e] \quad (10)\]

5. Steady State: The following four worker flow equations hold:

\[\delta + (s_n + \lambda F_n(y_n^*))u_n = (\delta + p(\theta_n)(1 - F(y_n^*)))u_n\]
\[ p(\theta_n)(1 - F(y^*_n))u_n = (\delta + \lambda F(y^*_n) + \alpha)e_n \]
\[ \alpha e_n + s_e e_e = (\delta + p(\theta_e))u_e \]
\[ p(\theta_e)u_e = (\delta + s_e)e_e \]

2.5. Characterizing the Solution

Solving the model involves solving for the reservation productivity level for inexperienced workers. By continuity of the value function \( E_n(y) \), the reservation productivity is defined either by the indifference point between unemployment and being employed at the reservation productivity level or by the firm’s match formation rule of zero value at the reservation productivity. In the analysis that follows, the firm’s match formation rule of \( J_n(y^*_n) = 0 \) will be used.

Lemma 1. Wages for experienced and inexperienced workers are given by:

\[ w_e = \frac{\gamma}{1 + \gamma}(y_e + \theta_c e_c) + \frac{1 - \gamma}{1 + \gamma}b \]
\[ w_n(y) = \frac{\gamma}{1 + \gamma}(y + \theta_c n_c) + \frac{1 - \gamma}{1 + \gamma}b - \frac{\alpha \gamma}{(r + \delta)(1 + \gamma)}(c_e e_e - c_n e_n) \]

Proof. See Appendix.

Using the wage equations, the equilibrium of the model can be reduced to three equations in \( \theta_e, y^*_n \), and \( \theta_n \). These equations arise from the match formation condition for inexperienced jobs (\( J_n(y^*_n) = 0 \)) and zero profit conditions for experienced and inexperienced firms (\( V_i = 0 \) for \( i \in \{e, n\} \)). The zero profit condition for experienced vacancies gives:

\[ \frac{c_e}{q(\theta_e)} = \frac{1}{r + \delta + s_e}(y_e - (1 + \tau)w_e) \]

Similarly, for inexperienced workers the match formation condition gives:

\[ y^*_n = (1 + \tau) \left( \frac{\gamma}{1 - \gamma} c_n \theta_n + b - \frac{\alpha \gamma}{(r + \delta)(1 - \gamma)}(c_e e_e - c_n e_n) \right) - \frac{1 + \gamma \tau}{1 - \gamma} \frac{c_n}{q(\theta_n)} \]

and the zero profit condition for inexperienced vacancies implies:

\[ \frac{c_n}{\theta_n^\eta} = \frac{1 - \gamma}{(r + \delta + \alpha + s_n + \lambda)(1 + \gamma \tau)} \int_{y_n^*}^\infty (x - y^*_n) dF(x) \]

2.6. The Model with Minimum Wages

The key assumptions in the model provide experienced workers with a stable productivity that will be on average higher than that for inexperienced workers. Moreover, experienced jobs are not subject to idiosyncratic productivity shocks and have different exogenous separation rates than inexperienced workers.
With these assumptions, a minimum wage will tend to restrict the ability for younger workers to become employed and gain experience while having little to no effect on experienced workers.

Minimum wages, \( \bar{w} \), are introduced as a binding wage floor in the model. For a match to form, the wage paid must be equal to or exceed this minimum level. This changes the equilibrium concept that was previously described. Now both the firm and the worker need to agree to form a match while the minimum wage law is satisfied. Under a minimum wage, workers may be willing to work at the minimum wage while the firm is unwilling to compensate the worker at that level because the productivity is too low.

A second difference in the model with minimum wages concerns Nash bargaining. As in Flinn (2006), Nash bargaining is still used with the additional constraint that \( w_i(y) \geq \bar{w} \). This implies that \( E_i(y) - U_i \geq \gamma [J_i(y) + E_i(y) - V - U_i] \) for \( i \in \{e, n\} \). The equation holds with equality if \( w_i(y) > \bar{w} \). Under this setup, workers get share \( \gamma \) of the surplus when \( w_i(y) > \bar{w} \), but receive a higher share when the minimum wage binds. This section focuses on the case where the minimum wage is binding for inexperienced workers. The same method can easily be extended to solve for a higher minimum wage that is binding for both types. To solve the model with a binding minimum wage, when \( \bar{w} > w_n(y^*_n) \), two new thresholds must be solved for. First, let \( y_{nMW} \) be the match formation threshold that is derived from the condition \( J_n(y_{nMW}) = 0 \) when the firm is paying the minimum wage. This condition is:

\[
y_{nMW} = (1 + \tau)\bar{w} - \lambda \frac{c_n}{q(\theta_n)}
\]

Next, let \( \bar{y}_{nMW} \) be the wage threshold defined as the productivity level where wages paid to workers begin to rise above the minimum wage level. This threshold occurs when \( w_n(\bar{y}_{nMW}) = \bar{w} \). Solving for \( \bar{y}_{nMW} \) gives:

\[
\bar{y}_{nMW} = \frac{1 + \gamma \tau}{\gamma} \bar{w} - \frac{1 - \gamma}{\gamma} b - c_n\theta_n + \frac{\alpha}{r + \delta} (c_e\theta_e - c_n\theta_n)
\]

Workers with productivity between \( y_{nMW} \) and \( \bar{y}_{nMW} \) earn the minimum wage while workers with higher productivity earn the same wages defined by the wage functions in the model with no minimum wage. Finally, under these new thresholds the zero profit condition for the firm becomes:

\[
\frac{c_n}{q(\theta_n)} = \frac{1}{r + \delta + \alpha + s_n + \lambda} \left( \int_{y_{nMW}}^{\bar{y}_{nMW}} (x - y_{nMW}) dF(x) + \frac{1 - \gamma}{1 + \gamma \tau} \int_{\bar{y}_{nMW}}^{\infty} (x - \bar{y}_{nMW}) dF(x) + (1 - F(\bar{y}_{nMW})) (\bar{y}_{nMW} - y_{nMW}) \right)
\]

To build better intuition of how the minimum wage works, Figure 1 depicts the Nash bargaining solution for the model with a minimum wage. The vertical axis labels the wage function for inexperienced workers and the minimum wage line. Productivity is plotted on the horizontal axis. The 45-degree line in the figure represents the value of the worker’s output. When the wage is above the 45-degree line, there is no
surplus, so matches do not form. The point where the wage curve crosses this line defines the reservation productivity level $y^*_n$ for the model with no minimum wage. With a binding minimum wage, the minimum wage line crosses the firm profitability threshold at $y^{MW}_n$ and the original wage function at $\tilde{w}^{MW}_n$. If worker productivity is $y \in [y^{MW}_n, \tilde{w}^{MW}_n]$ the worker is paid the minimum wage $\tilde{w}$. For values above $\tilde{w}^{MW}_n$ the worker is paid the wage given by unconstrained Nash bargaining. These changes mean that a minimum wage has both a direct effect on which jobs will be available for the worker and an equilibrium effect on the profitability of vacancies in the economy. The indirect effect arises because when the probability that any given contact with a firm results in a match decreases, posting a vacancy has less value. Therefore, for the free entry condition to be satisfied, fewer vacancies are posted. With these changes, the model can be solved for unemployment dynamics given a specified level of the minimum wage.

Under a minimum wage, the equilibrium productivity threshold where workers would accept a job $y^*_n$ is potentially different than in the model without minimum wages. There are three effects that cause the threshold to vary. First, the minimum wage implies that some jobs that were previously available to workers are no longer available. This decreases the value of being unemployed and hence $y^*_n$. Second, there is a general equilibrium effect where firms find it less profitable to post vacancies for workers because they have a lower match rate and have to pay a minimum wage above the value of the bargained wage to a group of workers. This lowers $y^*_n$ even further. Finally, for a range of productivity levels the workers will get paid the minimum wage, which is above the unconstrained wage function. This increases $y^*_n$. In parameterizations

Figure 1: Graphical depiction of Nash bargaining solution.
of the model considered in the paper, the first two effects are larger than the third so that minimum wages decrease the job finding rates for young workers and hurt their ability to gain experience.

3. Parameterization

The model is parameterized to match key features of the labor market in the United States. To understand the implications of minimum wages the parameterization must capture the employment situation facing young workers and their gains from experience. The model quantitatively captures the returns to experience by matching patterns of wage growth, job finding rates, and job separation rates over the life cycle. The parameterization focuses on workers with high school education between the ages of 18 and 55 in the year 2006.\textsuperscript{12} Basing the parameterization on individuals with exactly high school education helps to control for compositional biases in age patterns of worker flows and wage growth, focuses the analysis on the groups most impacted by the minimum wage, and avoids the issue of measuring outcomes for young workers who transition into and out of the labor force between periods of schooling. Simulations of the model are truncated at age 55 because the model has little to say about retirement decisions.

Workers’ job finding and job separation rates are constructed with data from the Current Population Survey (CPS). Throughout the paper job finding and job separation rates are measured in the same way as in Shimer (2012). Job finding rates are constructed from transitions between unemployment and employment while job separation rates are constructed from transitions between employment and unemployment in a three state model that includes employment, unemployment, and out of the labor force. The sample is restricted to workers with high school education. The quarterly flows from the procedure in Shimer (2012) are averaged over the period from 1976-2007 to get the values reported here. Since the model only has employed and unemployed workers, focusing on unemployment to employment and employment to unemployment transitions makes the data more consistent with the model. The focus on these transitions also avoids measuring workers who leave a job to go back to school as separations. Features of the wage distribution are parameterized with data from the CPS Merged Outgoing Rotation Group (MORG).

First, a number of parameters are chosen to be consistent with values from the literature. One period in the model corresponds to one month. Inexperienced unemployed workers enter the model at age 18 replacing the mass of workers who exit. For the baseline parameterization the payroll tax rate $\tau = 0.082$ is set to the payroll tax level at the minimum wage in the United States in 2006 as reported by OECD (2006). $\delta$ determines the rate at which individuals exit the labor force. Assuming that workers stay an average of 40 years, $\delta$ is set to $\frac{1}{480}$. The discount rate is set using $r + \delta = 0.003$, which is equivalent to a 4\% annual interest rate. Matching functions take the standard Cobb-Douglas form, $m_i(u_i,v_i) = u_i^\eta v_i^{1-\eta}$ for $i \in \{e,n\}$. $\eta$ is

\textsuperscript{12}The parameterization uses 2006 data to match wage and policy targets. For worker flow targets, long run averages are used because of small sample sizes for particular age-education groups. The aggregate worker flows from 2006 are not much different than the averages from 1976-2007.
set to 0.5 in both value functions. This value is within the range of estimates in Petrongolo and Pissarides (2001) and is comparable with the calibration in Pries and Rogerson (2005). The Nash bargaining parameter is set to $\gamma = 0.5$. The choice of $\gamma = \eta$ insures that the Hosios (1990) condition applies.\(^{13}\)

The productivity distribution for inexperienced workers is assumed to be log normal ($\log y \sim N(\mu, \sigma^2)$). As a normalization, the median of the productivity distribution is set to one. This implies $\mu = 0$. The remaining parameters are the shape parameter of the productivity distribution, $\sigma$, the productivity level for experienced workers, $y_e$, the cost of posting a vacancy for an inexperienced worker, $c_n$, the cost of posting a vacancy for an experienced worker, $c_e$, the rate of idiosyncratic productivity shocks for inexperienced matches, $\lambda$, the exogenous separation rate for inexperienced workers, $s_n$, the exogenous separation rate for experienced workers, $s_e$, the rate at which employed inexperienced workers become experienced, $\alpha$, the flow value of unemployment, $b$, and the minimum wage level, $\bar{w}$. These parameters are jointly set to target features of labor market flows and the wage distribution in the economy. The remainder of this section provides the value of each parameter along with the most closely associated target from the data. While each parameter is associated with a target, the parameterization occurs in an equilibrium model, so changing a target can have an impact on other parameters.

$\sigma$ determines the dispersion of the productivity distribution. Higher values of $\sigma$ make workers more selective about the jobs that they are willing to accept, increasing observed wages for inexperienced workers. To set this parameter, the model is targeted to match the dispersion of wages for 18 year old workers. From the CPS MORG data, the ratio of the 80\(^{th}\) to 50\(^{th}\) percentile wages is 1.2. Matching this target gives $\sigma = 0.342$. As the model is parameterized to match observed worker flows, the results in Hornstein et al. (2011) suggest that it is unlikely that this type of model can generate the same magnitude of wage dispersion as seen in the data. Indeed, the model is not able to match any target of wage dispersion from the data leading to the choice of the 80/50 wage ratio. If the cross sectional wage dispersion from the model is lower than in the data it would imply that, for low values of the minimum wage, the impact of the minimum wage on unemployment rates would be understated. As the minimum wage begins cutting into the wage distribution, too few workers would be impacted. However, as the size of the minimum wage grows, the model could overstate the effects when the minimum wage reaches the main part of the distribution. For the results on the Fair Minimum Wage Act of 2007, it seems likely that the effects would be smaller as the minimum wage level is below the median of the productivity distribution.

The productivity for experienced workers, $y_e$, is targeted to match the mean wage for 45-54 year old workers relative to the median wage for 18 year old workers. The mean wage for older workers is used so that the average wage gains are captured by the model (as the mean and median are both equal to $w_e$),

\(^{13}\)This modeling assumption contrasts with Flinn (2006) who varies the Nash bargaining parameter to generate potential efficiency gains from higher levels of minimum wages.
Figure 2: Job finding rates (left panel) and job separation rates (right panel) for high school educated workers in the United States by five year age group and simulated from the model for the baseline target of the share of experienced workers equal to 0.8 and other targets of the share equal to 0.75 and 0.85.

while the median wage for inexperienced workers is easier to target. Targeting the ratio of mean wage of experienced workers to the median wage of inexperienced workers is 2.04 in the data. This target generates a value of $y_e = 1.83$.

$c_n$ and $c_e$ determine the number of inexperienced and experienced vacancies that firms post in equilibrium. They are determined by targeting the job finding rates (unemployment to employment transitions) of 20-24 year old and 50-54 year old workers. The left panel of Figure 2 shows average unemployment to employment transition rates for high school educated workers in the United States between 1976 and 2007 for each five year age group from 20-24 through 50-54. For inexperienced workers, the target is $p(\theta_n)(1 - F(y_n^{MW})) = 0.38$ to match the average job finding rate of high school educated 20-24 year-old workers from 1976-2007 in the United States. For experienced workers, $p(\theta_e) = 0.33$ matches the average for high school educated workers aged 50-54 (the averages are nearly identical for workers aged 40-49 as well). These targets yield values of $c_n = 7.15$ and $c_e = 11.8$. Figure 2 also shows the job finding rates for each age simulated from the model. The model is able to capture much of the observed declines in the job finding rate by age.

Separation rates for inexperienced and experienced workers and the rate of idiosyncratic productivity shocks for inexperienced workers are targeted to match separation rates for high school educated workers aged 20-24 and 50-54. Observed job separation rates by age are shown in the right panel of Figure 2. This implies the targets $s_e = 0.015$ and $s_n + \lambda F(y_n^{MW}) + \alpha = 0.0585$. Note that the first target sets the
value of $s_n$ directly while the second target leaves the relative values of $s_n$ and $\lambda$ unidentified. $\lambda > 0$ is an important parameter in the model as it generates endogenous separations that can interact with the level of the minimum wage through changes in the threshold productivity for forming matches. This implies that minimum wages can influence both the job finding and job separation margins in the model. However, given the lack of separate identification for $\lambda$ and $s_n$, the parameterization will proceed by setting the value of $\lambda = 0.05$ and allowing $s_n$ to adjust to capture the residual separations for inexperienced workers. In the baseline parameterization, these targets generate a value of $s_n = 0.05$. This is a fairly low value of shocks as they occur on average every 20 months. The robustness section in the appendix considers other values of $\lambda$ to check the robustness of the conclusions. In general, the results indicate that higher values of $\lambda$ generate smaller changes in unemployment from increases in the minimum wage. The exception to this is for small enough values of $\lambda$ where the minimum wage is no longer binding in the baseline due to the increase in $y^*_n$ (as is the case with $\lambda = 0$). In that case, increases in the minimum wage have no effect until they becomes binding.

The rate at which inexperienced employed workers become experienced, $\alpha$, jointly determines the rate of decline of job finding and job separations rates in the model. To set the value of $\alpha$, the fraction of workers with experience in the steady state of the model is targeted. For the baseline parameterization the fraction of experienced workers is targeted to be 0.8. This target implies a value of $\alpha = 0.009$. As there is no direct evidence for the share of experienced workers in the data, targets of 0.75 and 0.85 are also considered. One way to think about these targets is to look at the data to determine the fraction of workers who need to earn the experienced wage so that the model matches the overall average wage in the economy. The mean wage for 18 year-olds of $7.88 is taken to be the mean for inexperienced workers while the mean wage of 45-54 year-olds of $15.31 is taken to be the mean for experienced workers. Given that the mean wage for 18-64 year old workers is $13.52 implies a target of $\frac{7.88}{\bar{w} + 7.88} \approx 0.76$. A drawback of this approach is that the model doesn’t generate a distribution of wages for experienced workers observed in the data, so it is unclear how good of a target this provides. The results section shows that lower targets for the share of experienced workers generates larger effects on unemployment from changes in the minimum wage. Figure 2 plots the job finding and job separation rates by age for each of the three cases. The baseline case provides the best fit for the age patterns observed in the data, but results for the other two cases are also presented.

Next, $b$ is chosen to be 50% of the value of the minimum wage. This should be a slightly low target as the minimum wage is a low wage to use as a target for the replacement rate. Low values of $b$ imply more modest effects of minimum wages. Other values will be considered in the robustness section of the appendix. This target implies that $b = 0.274$. Finally, the level of the minimum wage is set by targeting the ratio of the legislated minimum wage and the median wage for 18 year-old workers. The median wage for 18 year-old workers in 2006 is $7.50 while the minimum wage was $5.15. This implies $\bar{w} = 0.55$. 

15
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \tau )</td>
<td>0.082</td>
<td>Payroll tax rate at minimum wage</td>
</tr>
<tr>
<td>( \delta )</td>
<td>1/480</td>
<td>40 year working life</td>
</tr>
<tr>
<td>( \epsilon )</td>
<td>0.003-0.003</td>
<td>Annual Interest rate of 4%</td>
</tr>
<tr>
<td>( \eta )</td>
<td>0.5</td>
<td>Petrongolo &amp; Pissarides (2001)</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>0.5</td>
<td>Hosios (1990)</td>
</tr>
<tr>
<td>( \mu )</td>
<td>0</td>
<td>Normalization</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>0.342</td>
<td>80/50 wage ratio = 1.2</td>
</tr>
<tr>
<td>( y_e )</td>
<td>1.83</td>
<td>Ratio of 45-54 wage to 18 year old wage of 2.04</td>
</tr>
<tr>
<td>( c_n )</td>
<td>7.15</td>
<td>( p(\theta_n)(1 - F(y_{MW}^n)) = 0.38 )</td>
</tr>
<tr>
<td>( c_e )</td>
<td>11.8</td>
<td>( p(\theta_e) = 0.33 )</td>
</tr>
<tr>
<td>( \lambda )</td>
<td>0.05</td>
<td>Normalization</td>
</tr>
<tr>
<td>( s_n )</td>
<td>0.05</td>
<td>20-24 year-old separation rates</td>
</tr>
<tr>
<td>( s_e )</td>
<td>0.015</td>
<td>50-54 year-old separation rates</td>
</tr>
<tr>
<td>( \alpha )</td>
<td>0.009</td>
<td>Share of experienced workers is 0.8</td>
</tr>
<tr>
<td>( b )</td>
<td>0.274</td>
<td>( b = 0.5\bar{w} )</td>
</tr>
<tr>
<td>( \bar{w} )</td>
<td>0.55</td>
<td>Minimum wage relative to median wage of 18 year-old workers</td>
</tr>
</tbody>
</table>

Table 1: Baseline values for model parameters along with targets.

A summary of the parameter values chosen is presented in Table 1. The steady state model implies that 0.6% of inexperienced workers earn the minimum wage. This is lower than in the CPS MORG data where about 3% of workers and 5% of those aged 18-24 earn the minimum wage or less. Comparing those who earn exactly the minimum wage gives numbers of 0.6% of all workers and 1% of those aged 18-24. This means that the baseline estimates of the effects of the minimum wage are conservative due to the combination of low minimum wage and potentially low wage dispersion generated from the model making fewer workers subject to the minimum wage. Additionally, the ratio of the minimum wage to \( w_e \) is 0.336 in the model. This is only slightly higher than the value of 32% for the ratio of the minimum wage to the median wage for all workers in the U.S. economy reported in the OECD minimum wage database.

4. Model Predictions

The parameterized model with minimum wage is consistent with labor market outcomes by age. This section describes the predictions of the model for unemployment rates and wage growth. The model provides a theoretical explanation for a variety of empirical findings in the literature.

4.1. Youth Unemployment

As an examination of the effects of these parameter choices, the steady state number of individuals in each state \( \{u_n, u_e, c_n, c_e\} \) is presented in Table 2. 6.9% of people are unemployed in the steady state of the model. This is similar to the average unemployment rate for the U.S. economy between 1976 and 2007, corresponding to the targets of the worker flows between employment and unemployment.
Inexperienced workers are subject to the minimum wage and therefore face higher rates of unemployment. As workers age they are more likely to be experienced and have stable employment. To see the added effects of this channel on youth unemployment, Figure 3 compares the simulated unemployment rates by age from the parameterized model and simulated outcomes from a model where all workers start off unemployed and experienced with average unemployment rates by age from the U.S. economy. The unemployment data is for workers with exactly high school education from the CPS in March 2006. The model generates the initial high levels of unemployment found in the data and much of the decline as workers age. The figure shows that the model without the experience channel converges too rapidly to its steady state level of unemployment. Initial conditions of unemployment are not able to generate the high youth unemployment rates observed in the data. As discussed in Shimer (2012) and Elsby et al. (2009), in standard search model with no experience where unemployed workers find jobs at rate $f$ and are separated from their jobs at rate $s$, if all workers start
off unemployed then unemployment at time $t$ is given by:

$$u(t) = u^* + (1 - u^*)e^{-(s+f)t}$$

where $u^* = \frac{s}{s+f}$ is the steady state level of unemployment. In this case the rate of convergence of the system is governed by $s + f$ since the half-life of any difference in unemployment from steady state is given by $t_{hl} = \frac{-\log 0.5}{s+f}$. With standard parameters for the U.S. $s + f \approx 0.5$ the half-life is just over one month. Hence, initial conditions cannot generate long age transitions for the unemployment rate. Even with lower transitions rates of about 0.1 found in many European countries the half-life is around 6 months. Moreover, empirical evidence suggests that underlying transitions on unemployment are generated by differences in the underlying flows for different ages. Modeling the changes in job finding and job separation rates as workers gain experience provides a mechanism for the model to generate high rates of unemployment observed for young workers.

4.2. Unemployment Effects of Minimum Wages

The empirical literature on minimum wages has looked at direct effects on unemployment, implications for the wage distribution, and future earnings of individuals who face high minimum wages. The model is consistent with empirical findings that minimum wages disproportionately harm young workers.
Table 3: Increase in unemployment rate (percentage point) by age group for various percentage increases in the minimum wage from the U.S. level in 2006.

<table>
<thead>
<tr>
<th>Minimum Wage</th>
<th>15-24</th>
<th>25-34</th>
<th>35-44</th>
<th>45-54</th>
<th>Steady State</th>
</tr>
</thead>
<tbody>
<tr>
<td>30%</td>
<td>1.4</td>
<td>0.7</td>
<td>0.3</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>50%</td>
<td>4.5</td>
<td>1.9</td>
<td>1.0</td>
<td>0.6</td>
<td>1.4</td>
</tr>
<tr>
<td>70%</td>
<td>15.4</td>
<td>7.9</td>
<td>4.3</td>
<td>2.2</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Figure 4 shows the unemployment effects of minimum wages simulated from the model. The average unemployment rate by age is plotted in the baseline case where the minimum wage is at the U.S. levels in 2006 and for increases of 30%, 50%, and 70%. Given the baseline minimum wage level corresponds to $5.15 per hour, these increases correspond to hypothetical minimum wages of $6.70, $7.73, and $8.76. The effects of minimum wages are non-linear. As minimum wages rise, unemployment increases among young workers become more dramatic. The solid line depicts the unemployment rate in the model with minimum wages at the U.S. level. Raising the minimum wage by 30% has very little effect on unemployment while increases of 50% and 70% have increasing effects. Moreover, Figure 4 shows that the effects of a minimum wage are initially large and die out over time as workers gain experience. Higher levels of the minimum wage also generate differences in unemployment for older workers as it is harder for young workers become experienced.

Table 3 shows the increase in the unemployment rate for each 10 year age band for various increases in the level of the minimum wage. From the simulated average unemployment rate of 11.8% for workers aged 15-24, the model predicts that a 30% increase in the minimum wage would only increase unemployment by 1.4 percentage points. Larger increases in the minimum wage of 50 and 70% increase unemployment for young workers by 4.5 and 15.4 percentage points respectively. Older workers are virtually unaffected by a 30% increase in the minimum wage while there are small effects for larger increases of the minimum wage that decline as workers age.

The model helps explain the failure of some papers, such as Card and Krueger (1994), to find significant effects of minimum wage on employment. Since minimum wages are relatively low in the United States and have a non-linear effect on unemployment, it is unsurprising that small changes in the minimum wage might have insignificant effects. Larger increases in the minimum wage would be more likely to show up in higher unemployment rates.

4.3. Long-Run Effects and Wage Growth

Neumark and Nizalova (2004) document that exposure to high minimum wages at young ages has long-run effects. They show that exposure to high minimum wages at young ages implies that workers both work and earn less even into their late 20’s. Moreover, Keane and Wolpin (1997) show that human capital accumulation while on the job is important to understanding worker’s labor market decisions and outcomes. Missing skill accumulation early in life has long run implications for wage growth if the agent is unable to
The model can account for differences in wage outcomes as experienced workers have a higher reservation productivity level and earn higher wages than inexperienced workers. Workers who are exposed to high minimum wages early in life will have a lower probability of becoming employed and experienced. The left panel of Figure 5 presents the percentage of people who are experienced by age from the baseline model and the model with a 50% increase in the minimum wage. Under a higher minimum wage a worker is less likely to be experienced. The lower rate of experience shows up in higher rates of unemployment and lower wages later in life.

The right panel of Figure 5 shows the effect of increasing minimum wages on the average wage of employed workers over their life cycle. The baseline model generates wages that grow from 0.86 to 1.6, slightly less than doubling between age 18 and 54. Wage growth mirrors the growth of the fraction of experienced workers, as wages grow most rapidly during the first 10 years of labor market participation then level off. In looking at the effects of an increase in minimum wages, young workers on average get slightly higher wages when employed, while older workers have on average lower wages. The higher wages for young workers come from the minimum wage itself while the lower wages for older workers come through workers having less experience. Both factors lead to a more compressed earnings profile by age.
5. Quantitative Exercises

This section uses the model to evaluate the effects of changes to the minimum wage. First, the model is used to assess the effects of the Fair Minimum Wage Act of 2007. Second, the model is used to answer the counterfactual question of how much lower unemployment would be in France if it adopted the level of minimum wages and payroll taxes of the United States.

The model can be used to calculate the extent to which observed differences in youth unemployment outcomes are explained by differences in minimum wages by simulating the model for each set of policy variables. For each set of parameters, the model is solved to generate job finding rates for inexperienced and experienced workers. These numbers along with job separation rates are used to simulate the model in continuous time. From the simulation, a worker’s employment status and experience are recorded at the end of each model period. For each specification, the model is simulated for 10,000 individual working careers. The data are then aggregated into annual data by age to make comparisons.

5.1. Fair Minimum Wage Act of 2007

The Fair Minimum Wage act of 2007 raised the minimum wage in the United States from $5.15 an hour to $7.25 an hour with three equally sized increases implemented between July 2007 and July 2009. While this large change in the minimum wage could have provided empirical evidence on the effects of minimum wage changes on unemployment, the recession and financial crisis that occurred over the same time period make it difficult to isolate the effects of the minimum wage. This section uses the model to compare predicted unemployment for the minimum wage level in 2006 with that in 2010 based on the observed increase in the minimum wage rate over that interval.

Between 2006 and 2010, the unemployment rate for high school educated workers aged 15-24 went from 11.3% to 22.5% while the overall unemployment rate for high school educated workers increased from 5.5% to 13.4%. The increase in unemployment during the recession was disproportionately focused on young workers. The model is used to answer the question of how much of the increase in youth unemployment can be attributed to the change in minimum wages. This is done in two different ways. First, for each age group the percent of the change in the data that is accounted for by the model is computed. Second, because there were large increases in unemployment rates for all ages during the time period under consideration due to factors related to the great recession that are not accounted for by the model, the percentage of change in the unemployment rate for each group relative to the overall change in unemployment is computed.

The simulation results are compared with observed unemployment outcomes in Figure 6. The figure shows that during the Great Recession there was a large increase in unemployment for each of the 10 year age bands under consideration in the US between 2006 and 2010. The increase in the unemployment rate was slightly larger for 15-24 year old workers and was smaller for the older age groups. The black dashed line shows the baseline simulation for the model parameterized to match unemployment rates for workers
in 2006. The baseline does a good job of matching the age pattern of unemployment for that year. The figure also shows the increase in unemployment in the model from the increase in minimum wages between 2007 and 2009. The dashed line shows that the minimum wage increase led to an increase in unemployment from 11.8% to 14.6% for 15-24 year old workers and smaller increases for the other age groups. While not accounting for the majority of the increase in unemployment during the recession, minimum wages can account for a substantial portion of the increase in unemployment observed for young workers between 2006 and 2010.

Solving the model under the new, higher level of the minimum wage for the baseline parameterization generates an aggregate unemployment rate of 7.7% compared with 6.9% in the baseline. The unemployment rate for 15-24 year-old workers increases by 2.8 percentage points from 11.8% to 14.6%. This 2.8 percentage point increase implies that minimum wages account for 25.6% of the 11.1 percentage point increase in unemployment rate observed in the U.S. data between 2006 and 2010. Alternately, the unemployment rate increased by 3.3 percentage points more for 15-24 year old workers than overall (from 11.3% to 22.5% compared to from 5.5% to 13.4%). The model generates a 2.0 percentage point increase in unemployment for 15-24 year old workers beyond the overall increase in unemployment. This implies that the model accounts for nearly 60% of the excess increase in youth unemployment during this period.

Table 4 presents the results from the simulated model with each target for the fraction of experienced
workers and computes the amount of the changes in unemployment that can be accounted for by the model for each age group. The percent of total changes explained is smaller for the older age groups as minimum wages have smaller effects on unemployment rates for older workers but unemployment increased for all groups. However, controlling for relative changes in unemployment compared to the total, the model accounts for a more sizable share of changes in unemployment for older groups. Table 4 also shows results for different targets of the share of experienced workers in the steady state model. With a target of 0.75 the changes in minimum wages generate larger increases in unemployment, accounting for 31\% of the total increase and 71.4\% of the relative increase in unemployment for 15-24 year old workers. When the model is targeted to have a share of experienced workers of 0.85 the effects of increased minimum wages are slightly smaller accounting for 19.5\% and 50.7\% percent of the total and relative changes in unemployment respectively for 15-24 year old workers. In all three parameterizations there is a substantial increase in the unemployment rate of young workers ranging from 2.2 to 3.4 percentage points. The robustness section in the appendix shows that these substantial changes in unemployment rates for young workers are robust to changes in the parameterization of the model.

5.2. France Adopting Policies of the United States

The model can also be used to assess the effects of cross country differences in minimum wages on unemployment outcomes. Significant attention has been paid to explaining large discrepancies in unemployment between the U.S. and Europe. Differences in unemployment rates across countries are concentrated among

<table>
<thead>
<tr>
<th>Source</th>
<th>Value</th>
<th>15-24</th>
<th>25-34</th>
<th>35-44</th>
<th>45-54</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data U.S. 2006</td>
<td>11.3</td>
<td>6.2</td>
<td>5.4</td>
<td>3.6</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>Data U.S. 2010</td>
<td>22.5</td>
<td>16.6</td>
<td>12.1</td>
<td>10.5</td>
<td>13.4</td>
<td></td>
</tr>
<tr>
<td>Model Baseline</td>
<td>11.8</td>
<td>7.0</td>
<td>5.4</td>
<td>4.7</td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>Model 2010 policy</td>
<td>14.6</td>
<td>8.2</td>
<td>5.9</td>
<td>5.1</td>
<td>7.7</td>
<td></td>
</tr>
<tr>
<td>% explained</td>
<td>25.6</td>
<td>12.1</td>
<td>8.5</td>
<td>6.1</td>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>% explained: relative</td>
<td>59.2</td>
<td>14.4</td>
<td>27.8</td>
<td>47.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model, Exp. = 0.75 Baseline</td>
<td>12.5</td>
<td>7.9</td>
<td>6.0</td>
<td>5.1</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>Model, Exp. = 0.75 2010 policy</td>
<td>15.9</td>
<td>9.9</td>
<td>7.3</td>
<td>5.8</td>
<td>8.4</td>
<td></td>
</tr>
<tr>
<td>% explained: relative</td>
<td>71.4</td>
<td>37.3</td>
<td>-15.2</td>
<td>46.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model, Exp. = 0.85 Baseline</td>
<td>10.8</td>
<td>5.8</td>
<td>4.8</td>
<td>4.4</td>
<td>6.4</td>
<td></td>
</tr>
<tr>
<td>Model, Exp. = 0.85 2010 policy</td>
<td>13.0</td>
<td>6.7</td>
<td>5.1</td>
<td>4.6</td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>% explained: relative</td>
<td>50.7</td>
<td>14.6</td>
<td>14.6</td>
<td>34.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Unemployment rate by age group and overall for high school educated workers from the CPS (March of each year) and simulated from the model along with the percentage of difference in data accounted for by the model for the difference between 2006 and 2010. The results are shown for the baseline model where the share of experienced workers is targeted to be 0.8 and for alternate calibrations with targets of 0.75 and 0.85. The \% explained rows depict the percentage of the overall difference in employment for that group that the change in minimum wages can account for and the \% explained relative rows show the percent of the relative change of that age group relative to the overall change in unemployment that the model can account for in each age group.
young and old workers. However, much of the research on cross country unemployment rates focuses on older workers. Minimum wages complement other explanations such as unemployment benefits, taxes, structural change, and firing costs. While these other explanations generate level differences in unemployment, this paper contributes to the literature on European unemployment by showing that minimum wages help account for unemployment rates of young workers.

France has among the highest minimum wages and payroll taxes found in Europe, making it a good country to study for comparison with the U.S. Converting French minimum wages to their value in U.S. dollars in 2006 gives a French minimum wage of $10.14 per hour. Payroll taxes in France are 17.6% compared to 8.2% in the U.S.

To conduct the simulations, the model is re-parameterized to account for lower job finding and job separation rates found in France. Worker flows are much higher in the U.S. than in many European countries. For instance, Elsby et al. (2013) find an average monthly job separation rate of 3.6% in the U.S. compared with 0.8% in France, and Cohen et al. (1997) find that there are much lower job loss rates among French workers. Since France has lower average job separation rates than the U.S., workers can gain experience even with a very low job finding rate. To compute rough estimates of job finding and job separation rates, OECD data on Labor Force Statistics by Sex and Age are used.\footnote{The drawback of this data is that the unemployment duration data are not available when controlling for educational attainment.} First, the implied separation rates based on the OECD reported average duration of unemployment for 15-24 year old workers of 6.7 months and for 25-54 year old workers of 12.8 months are used to construct targets for job finding rates for inexperienced and experienced workers respectively. These values imply job finding rates of 0.15 and 0.078 for inexperienced and experienced workers. Using the identity that relates the steady state unemployment rate to job finding and separation rates, $u^* = \frac{s}{s+f}$, means that the separation rates can be computed using unemployment rates for each group. Average unemployment rates for 15-24 and 25-54 year old French workers between 1983 and 2007 are 22.7 and 8.5% respectively. Using these values, the implied separation rate targets for inexperienced and experienced workers are 0.044 and 0.007.

As there are not separate targets for French wage data, the following steps are taken to parameterize the model and assess the changes in unemployment that would arise from France adopting the level of minimum wages and payroll taxes found in the U.S. First, the model is parameterized with the same targets as in the U.S. baseline case to fix the values of $\sigma$, $y_e$, $\alpha$, $b$, and $\bar{w}$. Next, keeping those parameters fixed, the model is solved to target the levels of job finding and separation rates in France with the minimum wages and payroll taxes set to levels observed in France and no productivity shocks for young workers ($\lambda = 0$). This generates the baseline simulation for France. Finally, the model is solved again using the parameters in the French baseline with policy parameters set to the U.S. level. With the lower job finding and job separation rates
found in France, the U.S. levels of minimum wages and payroll taxes mean that the minimum wage no longer binds in the model (but unemployment is still higher than in the U.S. baseline). This means that another way to interpret the policy simulation is that it shows the effects of France eliminating their minimum wage.

The results from both simulations along with the original baseline simulation are presented in Figure 7. The baseline simulation for France has higher unemployment rates for young workers at 21.5 percent for those aged 15-24 and 12.3 percent for those aged 25-34 and eventually dropping to 8.8 percent for those aged 45-54. The figure shows that when the model with French job finding and separation rates is solved with U.S. levels of policy parameters, the unemployment rates for young workers are substantially lower with slight reductions in unemployment for older ages. Indeed, the level of unemployment for 15-24 year old workers declines to 12.2 percent, nearly as low as the 11.8 percent in the baseline US simulation. The unemployment rates for older ages remain higher to be consistent with the worker flow data in France.

To get a better sense of the magnitude of the results, Table 5 shows the unemployment rates from each simulation along with data from the OECD Labor Force Statistics by sex, age, and educational attainment for workers with below upper secondary education by age group for France and the United States in 2006. Even though the educational groupings are slightly different than those used in the baseline parameterization, the data provide comparable measures of unemployment across countries. The OECD only reports unemployment outcomes by age group for workers aged 25 and above. Unemployment rates in both countries are higher among young workers with low levels of education at 20.2% for France and 11% for the U.S. While
Table 5: Average unemployment rate by age band in 2006 for workers with below upper secondary education taken from OECD Labor Force Statistics by age, sex, and educational attainment, simulated unemployment rates by age band from model, and the percentage of differences in unemployment rates between the France and the U.S. explained by a reduction of French minimum wage and payroll taxes to U.S. levels.

<table>
<thead>
<tr>
<th>Source</th>
<th>Value</th>
<th>15-24</th>
<th>25-34</th>
<th>35-44</th>
<th>45-54</th>
<th>25-64 or Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>OECD Data</td>
<td>France</td>
<td>20.2</td>
<td>12.1</td>
<td>8.3</td>
<td>11.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>U.S.</td>
<td>11.0</td>
<td>8.6</td>
<td>5.9</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>Model</td>
<td>U.S. Baseline</td>
<td>11.8</td>
<td>7.0</td>
<td>5.4</td>
<td>4.7</td>
<td>6.9</td>
</tr>
<tr>
<td></td>
<td>France Baseline</td>
<td>21.5</td>
<td>12.3</td>
<td>10.0</td>
<td>8.8</td>
<td>13.5</td>
</tr>
<tr>
<td></td>
<td>U.S. Policy</td>
<td>12.2</td>
<td>8.4</td>
<td>8.0</td>
<td>7.9</td>
<td>10.7</td>
</tr>
<tr>
<td>Data % Explained</td>
<td>42.0</td>
<td>57.0</td>
<td>39.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model % Explained</td>
<td>95.7</td>
<td>72.7</td>
<td>43.1</td>
<td>22.6</td>
<td>42.4</td>
<td></td>
</tr>
</tbody>
</table>

Both countries show large declines in unemployment rates as workers age, about 8% of prime aged males in France are still unemployed compared with about 6% in the U.S.15

Table 5 shows the results for the model simulations, first reproducing the baseline simulation for the U.S. in 2006, then showing the baseline simulation for France and the simulation for France with U.S. policy parameters. The results of the simulations show that reducing the minimum wage to U.S. levels (where it does not bind in the model) would lead to substantial reductions in unemployment in France, especially for young workers. To get a better sense of the magnitude of these declines, the table shows calculations of the percent of the difference in unemployment rates between France and the U.S. that can be accounted for by the model. The results indicate that the reduction of minimum wages and payroll taxes to U.S. levels can account for 42.0, 57.0, and 39.4 percent of the observed differences in unemployment rates for workers aged 25-34, 35-44, and 45-54, respectively. Finally, the Table 5 reports the percent of the difference in unemployment rates between the baseline France simulation and the baseline U.S. simulation accounted for by reducing minimum wages and payroll taxes in the model. This comparison is reflected in the simulations presented in Figure 7.

In this case, the reduction in minimum wages accounts for over 95 percent of the difference in unemployment between the baseline simulations for France and the U.S. The percentage explained declines steadily with age before reaching 22.6 percent for 45-54 year old workers. The reduction in minimum wages and payroll taxes can account for 42.4 percent of the difference in steady state outcomes between the simulations. Overall, the results suggest that minimum wages play a major role in driving up unemployment rates for young French workers, and reducing or eliminating them could bring down youth unemployment rates in France close to U.S. levels. However, such policy changes are unlikely to change overall worker flows across countries so substantial differences in unemployment remain among older workers.

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15 For comparison, the total unemployment rate for all 15-24 year-old workers not controlling for education is 21.7% in France compared to 10.5% in the U.S.
6. Discussion

This paper constructs a labor search model that accounts for early life cycle changes in unemployment and explores the effects of minimum wages. The model shows that the interaction of experience and minimum wages can generate large increases in the unemployment rate for young workers. While the interaction of minimum wages with optimal human capital accumulation has been recognized at least since Rosen (1972), this paper applies such a distortion to a dynamic general equilibrium setting. Inexperienced workers are unable to pay for their training through reductions in their wages. To gain experience, they must maintain employment in a segment of the labor market characterized by high job separation rates. The equilibrium model is used to understand the effects of minimum wages on the aggregate labor market.

The model is used to assess the effects of recent minimum wages increases in the U.S. and to compare cross-country outcomes between the U.S. and France. The model predicts that the U.S. minimum wage increases between 2007 and 2009 increased unemployment for 15-24 year old workers by 2.8 percentage points. This increase accounts for 25.6% of the increase in youth unemployment for high school educated workers between 2006 and 2010 and almost 60% percent of the increase in the unemployment for this group compared to the overall increase in unemployment. Moreover, parameterizing the model to French levels of worker flows implies that if France reduced its minimum wages and payroll taxes to U.S. levels, it would generate substantial reductions in their unemployment rate, especially for young workers.

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Appendix

A. Proof of Lemma (1)

Claim 1. Wages for experienced and inexperienced workers are given by:

\[ w_e = \frac{\gamma}{1 + \gamma \tau} (y_e + \theta_e c_e) + \frac{1 - \gamma}{1 + \gamma \tau} b \]

\[ w_n(y) = \frac{\gamma}{1 + \gamma \tau} (y + \theta_n c_n) + \frac{1 - \gamma}{1 + \gamma \tau} b - \frac{\alpha \gamma}{(r + \delta) (1 + \gamma \tau)} (c_e \theta_e - c_n \theta_n) \]

Proof. Since being experienced is an absorbing state, start by solving for the wages of experienced workers. The Nash bargaining rule implies that:

\[ -(1 - \gamma) U_e = \gamma (J_e + E_e) - E_e \]

Substituting in from equations (4) and (8) and using the above bargaining rule gives:

\[ -(1 - \gamma)(r + \delta) U_e = \gamma y_e - (1 + \gamma \tau) w_e \]

Simplifying equation (2) then using the bargaining rule and equation (6) gives:

\[ (r + \delta) U_e = b + p(\theta_e)(E_e - U_e) \]

\[ = b + \frac{\gamma}{1 - \gamma} p(\theta_e) J_e \]

\[ = b + \frac{\gamma}{1 - \gamma} c_e \theta_e \]

Solving for \( w_e(y) \) gives:

\[ w_e = \frac{\gamma}{1 + \gamma \tau} (y + \theta_e c_e) + \frac{1 - \gamma}{1 + \gamma \tau} b \]

For inexperienced workers, the bargaining rule is given by:

\[ -(1 - \gamma) U_n = \gamma (J_n(y) + E_n(y)) - E_n(y) \]

Substituting from equations (3) and (7) and noting that the terms with \( \lambda \) all cancel implies that the bargaining equation can be written as:

\[ -(1 - \gamma)(r + \delta) U_n = \gamma y_e - (1 + \gamma \tau) w_n(y) - \alpha(1 - \gamma)(U_e - U_n) \]
From equations (1) and (5):

\[(r + \delta)U_n = b + \frac{\gamma}{1 - \gamma}c_n\theta_n\]

Substitution gives the desired result:

\[w_n(y) = \frac{\gamma}{1 + \gamma\tau}(y + \theta_n c_n) + \frac{1 - \gamma}{1 + \gamma\tau}b - \frac{\alpha\gamma}{(r + \delta)(1 + \gamma\tau)}(c_e\theta_e - c_n\theta_n)\]

B. Robustness

This section considers how robust the conclusions are for alternate choices of the parameters \(\lambda\) and \(b\). For each exercise, the baseline model is solved holding all other parameters at their baseline levels and changing the parameter under consideration.

<table>
<thead>
<tr>
<th>Parameterization</th>
<th>15-24</th>
<th>25-34</th>
<th>35-44</th>
<th>45-54</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2.9</td>
<td>1.3</td>
<td>0.6</td>
<td>0.4</td>
<td>0.8</td>
</tr>
<tr>
<td>(\lambda = 0.0)</td>
<td>1.9</td>
<td>0.9</td>
<td>0.4</td>
<td>0.0</td>
<td>0.6</td>
</tr>
<tr>
<td>(\lambda = 0.01)</td>
<td>1.4</td>
<td>0.3</td>
<td>0.3</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>(\lambda = 0.15)</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td>(b = 0)</td>
<td>2.2</td>
<td>1.2</td>
<td>0.7</td>
<td>0.2</td>
<td>0.7</td>
</tr>
<tr>
<td>(b = 0.2)</td>
<td>2.8</td>
<td>1.2</td>
<td>0.6</td>
<td>0.2</td>
<td>0.8</td>
</tr>
<tr>
<td>(b = 0.4)</td>
<td>2.8</td>
<td>1.5</td>
<td>0.5</td>
<td>0.2</td>
<td>0.9</td>
</tr>
<tr>
<td>(b = 0.6)</td>
<td>3.4</td>
<td>1.7</td>
<td>0.7</td>
<td>0.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Table 6: Simulation results for the difference in unemployment rates (in percentage points) for changing from minimum wage levels in the U.S. in 2006 to the level in 2010 for various parameter changes.

To see how the choice of \(\lambda = 0.05\) in the original parameterization influences the results, the model is solved for values of \(\lambda\) of 0.0, 0.1, and 0.15. \(\lambda\) determines the rate at which inexperienced matches are hit by idiosyncratic productivity shocks. Higher values of \(\lambda\) has two equilibrium effects. First, it makes it more likely that productive matches will be hit by shocks and separate. Second, because the productivity of the match is less permanent, agents are less selective about which offers to accept. These effects have opposite implications for unemployment rates. For values of minimum wages considered in the U.S. between 2006 and 2010, the second effect is dominant with the exception of the case where \(\lambda = 0\) because the minimum wage is not binding in the baseline simulation for that parameter choice. The left panel of Figure 8 plots unemployment outcomes by age band for the U.S. economy at the 2010 minimum wage for different values of \(\lambda\), and the baseline simulation from 2006. The baseline parameterization at 2006 minimum wages has the similar unemployment outcomes for all values of \(\lambda\) (again with the exception of \(\lambda = 0\)). To compare values to the baseline, Table 6 reports the difference in unemployment rates for simulations with minimum wages at levels found in 2006 and 2010. This difference for the baseline parameterization is included for reference. For \(\lambda = 0\), the increase in minimum wages generates a 1.9 percentage point increase in unemployment for 15-24
year-old workers, while for $\lambda = 0.1$ the increase is 1.4 percentage points. When $\lambda = 0.15$, unemployment only goes up by 0.3 percentage points for 15-24 year-old workers. The differences for other age groups and overall unemployment rates are reported in Table 6. The basic patterns remain the same with declining effects of minimum wages by age while magnitudes slightly vary across the parameterizations.

Next, different values of the flow value of being unemployed, $b$, are considered. In the baseline parameterization $b = 0.287$ is set to be half of the minimum wage. To understand how sensitive the results are to the choice of $b$, values of 0, 0.2, 0.4, and 0.6 are considered. The right panel of Figure 8 shows results for the unemployment rate by age for $b = 0$ and $b = 0.6$ for minimum wages set to the level of both 2006 and 2010 along with the results from the baseline simulations. The figure shows that changes in the value of $b$ influence the overall levels of the unemployment rate but do not dramatically change how sensitive unemployment rates are to changes in the minimum wage. For each level of $b$ both the 2006 and 2010 simulations are shifted up or down by similar amounts. Unemployment is only slightly more responsive to changes in minimum wages for higher values of $b$. When $b = 0$ the minimum wage change generates a 2.2 percentage point increase in the unemployment rate for 15-24 year-old workers compared to a 3.4 percentage point increase when $b = 0.6$. The initial target for $b$ seems to be on the low end of estimates for $b$ especially when combining the value of leisure and other potential unemployment benefits. This implies that the baseline results are a conservative estimate of the effects of the minimum wage. Changes in unemployment rates for all values of $b$ and all age groups are reported in Table 6.
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