Heterogeneous Impact of the Minimum Wage ⧉ ⓐ

Implications for Changes in Between- and Within-Group Inequality

Tatsushi Oka
Ken Yamada

ABSTRACT

In the United States, most of the workers who earn at or below the minimum wage are either less educated, young, or female. We examine the extent to which the minimum wage influences the wage differential among workers with different observed characteristics and the wage differential among workers with the same observed characteristics. Our results suggest that changes in the real value of the minimum wage account in part for the patterns of changes in education, experience, and gender wage differentials and for most of the changes in within-group wage differentials for workers with lower levels of experience.

Tatsushi Oka https://orcid.org/0000-0002-8868-6136
Ken Yamada https://orcid.org/0000-0003-3030-4112

I. Introduction

Expectations for the role of the minimum wage in addressing inequality have increased worldwide with concerns over growing inequality in recent decades. The minimum wage has been introduced and expanded in many countries to lift the wages of the lowest paid workers. It has been pointed out, however, that the minimum wage can cause both intended and unintended consequences (Card and Krueger 1995; Neumark and Wascher 2008). The intended consequences are the beneficial effects on the distributions of wages and earnings (DiNardo, Fortin, and Lemieux 1996; Lee 1999; Teulings 2003; Neumark, Schweitzer, and Wascher 2004; Autor, Manning, and Smith 2016; Dube 2019). The unintended consequences are the adverse effects on employment, consumer prices, firm value and profitability, and firm entry and exits (Aaronson and French 2007; Dube, Naidu, and Reich 2007; Draca, Machin, and Van Reenen 2011; Hirsch, Kaufman, and Zelenska 2015; Aaronson et al. 2018; Bell and Machin 2018). Proponents of the policy have typically assumed the view that the intended effects are substantial and the unintended effects are negligible. On the other hand, opponents have raised concerns that the unintended effects are not negligible. Most studies have focused on proving or disproving the existence of adverse effects of the minimum wage, and fewer studies have examined the distributional impact of the minimum wage in recent years (Card and Krueger 2017).

The proportion and characteristics of minimum wage workers serve as starting points for a discussion on the distributional impact of the minimum wage. According to the Current Population Survey (CPS), the proportion of workers who earn at or below the minimum wage in the United States ranges between 3 and 9 percent for the years 1979–2012 (Figure 1A). Less than 10 percent of workers have been directly affected by the minimum wage in the U.S. labor market. The extent to which the minimum wage affects the wage structure depends on the magnitude of the spillover effects on workers who earn more than the minimum wage. In theory, spillover effects can arise in many economic models (Lazear and Rosen 1981; Teulings 2003; Flinn 2006; Aaronson and French 2007; Phelan 2019). The minimum wage can exert a substantial influence on the wage structure if there are strong spillover effects.

Perhaps a less well-known fact is that minimum wage workers are concentrated in particular demographic groups. Approximately 90 percent of workers who earned at or below the minimum wage in the United States between the years 1979 and 2012 were high school graduates or less, younger than 25 years old, or female (Figure 1B). The reason was not that the minimum wage policy had been targeted based on education, experience, or gender, but because the lowest paid workers were mostly either less educated, young, or female. In light of this, the minimum wage may affect the relationship of hourly wages with workers' characteristics.

Motivated by the fact above, we examine the distributional impact of the minimum wage in different ways from previous studies. We first consider a standard wage equation, in which the logarithm of real hourly wages is determined by education, experience, and gender. We then look at changes in the distribution of wages resulting from the minimum wage through the lens of the wage equation. We adopt quantile regression approaches to allow for spillovers and heterogeneity in the impact of the minimum wage with respect to unobserved, as well as observed, characteristics of workers. A rise in

Panel A: How Many Workers Earn the Minimum Wage?
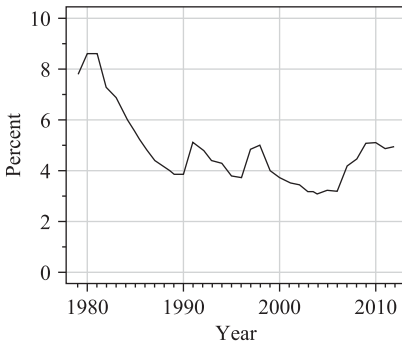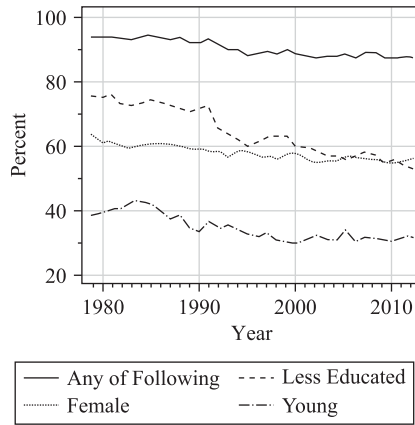
Panel B: Who Earns the Minimum Wage?

Figure 1

Proportion and Characteristics of Minimum Wage Workers

Notes: Panel A is reproduced from Figure 2 in Autor, Manning, and Smith (2016) (© American Economic Association; reproduced with permission of the *American Economic Journal: Applied Economics*). In Panel B, less-educated workers are those with a high school degree or less, and young workers are those aged 24 years or younger.

wage inequality in the United States results from an increase in both between- and within-group inequality (Katz and Autor 1999; Card and DiNardo 2002). Quantile regression approaches enable us to measure the impact of the minimum wage not only on the wage differential among workers with different observed characteristics for each quantile of the distribution of unobserved characteristics but also on the wage differential among workers with the same observed characteristics using interquartile ranges. The aim of this work is to evaluate quantitatively the contribution of the minimum wage to changes in between- and within-group inequality.

We show how changes in the real value of the minimum wage over recent decades have affected the relationship of hourly wages with workers' characteristics in the United States. The impact of the minimum wage is heterogeneous across workers depending on education, experience, and gender. Consequently, changes in the real value of the minimum wage account in part for the patterns of changes in education, experience, and gender wage differentials. We further show that changes in the real value of the minimum wage over recent decades have affected wage differentials among workers with the same observed characteristics. The impact of the minimum wage is heterogeneous across quantiles of workers' productivity not attributable to their observed characteristics. Consequently, changes in the real value of the minimum wage account for most of the changes in within-group wage differential among workers with lower levels of experience.

The next section reviews the related literature. Section III describes the data and institutional background. Section IV presents an econometric framework to evaluate the

quantitative contribution of the minimum wage to changes in between- and within-group inequality. Section V provides the empirical results. The final section concludes.

II. Related Literature

The literature has proven that the minimum wage has an effect on the distribution of hourly wages in the United States, although the magnitude and mechanisms of the effect vary across studies (DiNardo, Fortin, and Lemieux 1996; Lee 1999; Teulings 2003; Autor, Manning, and Smith 2016). These studies develop and adopt different approaches that take into account different degrees of heterogeneity and spillovers in the impact of the minimum wage. DiNardo, Fortin, and Lemieux (1996) develop a semiparametric approach to estimating discontinuous changes in the wage distribution at the minimum wage.[1] Lee (1999) develops a semiparametric approach to estimating heterogeneous effects of the minimum wage across quantiles of the wage distribution. Teulings (2003) develops a parametric approach to estimating the impact of the minimum wage on the wage distribution. When comparing semiparametric approaches developed by DiNardo, Fortin, and Lemieux (1996) and Lee (1999), DiNardo, Fortin, and Lemieux (1996) adopt an approach that allows for heterogeneous effects with respect to workers' observed characteristics, whereas the approach of Lee (1999) does not. The DiNardo, Fortin, and Lemieux (1996) approach, however, requires additional assumptions to estimate the impact of the minimum wage from the cross-sectional distribution of wages.[2] Consequently, DiNardo, Fortin, and Lemieux's (1996) approach does not allow for spillover effects, whereas Lee's (1999) approach does. The approaches also differ in robustness to unobserved state and time effects. If there is sufficient variation in the minimum wage across states over time, Lee's (1999) approach can separately identify the impact of the minimum wage from unobserved state and time effects. Autor, Manning, and Smith (2016) refine and apply Lee's (1999) approach to data covering a longer period,[3] and develop a test for the presence of spillover effects under a distributional assumption. However, no study has incorporated heterogeneous effects across workers with different observed characteristics in Lee's (1999) approach.

Understanding the sources of changes in between- and within-group inequality is key to understanding the mechanisms of changes in wage inequality in the United States (Card and DiNardo 2002; Autor, Katz, and Kearney 2008). However, little is known concerning the extent to which changes in between- and within-group wage differentials are attributed to changes in the real value of the minimum wage. In the literature, changes in between-group wage differentials have been typically attributed to changes in technology, workforce composition, and gender discrimination

---

1. See also Machado and Mata (2005) and Chernozhukov, Fernández-Val, and Melly (2013) for related approaches.
2. The same applies to its variants and extensions in Machado and Mata (2005) and Chernozhukov, Fernández-Val, and Melly (2013).
3. See also Bosch and Manacorda (2010); Kambayashi, Kawaguchi, and Yamada (2013); and Fortin and Lemieux (2015).

(see Katz and Autor 1999; Blau and Kahn 2017, for surveys). There is no consensus on the quantitative contribution of the minimum wage to changes in between-group wage differentials. DiNardo, Fortin, and Lemieux (1996) and Lee (1999) conclude that changes in the educational wage differential are attributable only to a small extent to changes in the real value of the minimum wage, whereas Teulings (2003) concludes that changes in the educational wage differential are attributable to a large extent to changes in the real value of the minimum wage. The literature identifying the sources of changes in within-group (or residual) wage differentials have been less conclusive than the literature identifying the sources of changes in between-group wage differentials (Lemieux 2006; Autor, Katz, and Kearney 2008). Juhn, Murphy, and Pierce (1993) attribute a rise in residual inequality among male workers from the 1960s to the 1980s to a rise in the returns to unobserved skills. DiNardo, Fortin, and Lemieux (1996) attribute changes in residual inequality in the 1980s to the erosion of the real value of the minimum wage.

III. Data

The data used in our analysis are repeated cross-sectional data from the Current Population Survey Merged Outgoing Rotation Group. We construct variables in the same way as in Autor, Manning, and Smith (2016) and focus on the period between 1979 and 2012 to ensure the comparability of results. Hourly wages are deflated by the personal consumer expenditure price index using 2012 as the base year. We restrict the sample to male and female workers aged 18–64, including full-time and part-time workers, but excluding self-employed workers, in the same way as in Autor, Manning, and Smith (2016). We, however, add in the sample individuals for whom we cannot observe wages. The yearly sample size ranges from 142,000 to 235,000. Following DiNardo, Fortin, and Lemieux (1996); Lee (1999); and Autor, Manning, and Smith (2016), we weight each individual according to the sampling weight multiplied by hours worked. Online Appendix A provides summary statistics for variables used in the analysis.

Minimum wage laws differ across states and change over time in the United States. The federal government sets the federal minimum wage that applies to all states. State governments can set the state minimum wage higher than the federal minimum wage. The statutory minimum wage is the maximum of the federal minimum wage and the state minimum wage.

Figure 2 shows the trend in the statutory minimum wage. For ease of reference, we divide all 50 states evenly into three groups according to the level of statutory minimum wage. During the period, 17 states had no state minimum wage (Figure 2A). The statutory minimum wage equals the federal minimum wage in these states. The federal minimum wage increased four times: 1979–1981, 1989–1991, 1996–1998, and 2007–2010. The remaining 33 states set their state minimum wages (Figures 2B and 2C). The statutory minimum wage has been higher than the federal minimum wage for many years in these states. In the 1980s there was not much variation across states or changes over time in the minimum wage. On the other hand, in the 1990s and onwards there was substantial variation in the minimum wage across states over time. We exploit the

Panel A: Low Minimum Wage States
(17 States)

Panel B: Medium Minimum Wage States
(17 States)

Panel C: High Minimum Wage States
(16 States)
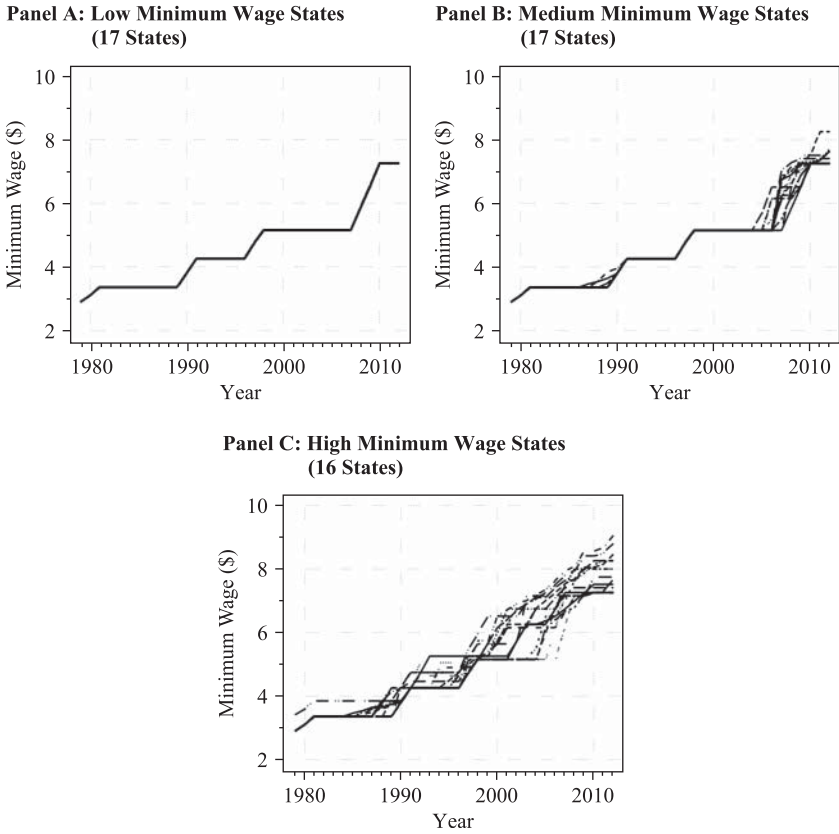
Figure 2

The Statutory Minimum Wage, 1979–2012

Notes: Panel A includes Alabama, Georgia, Idaho, Indiana, Kansas, Louisiana, Mississippi, North Dakota, Nebraska, Oklahoma, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, and Wyoming. Panel B includes Arkansas, Arizona, Colorado, Kentucky, Maryland, Michigan, Minnesota, Missouri, Montana, North Carolina, New Hampshire, New Mexico, Nevada, Ohio, Pennsylvania, Wisconsin, and West Virginia. Panel C includes Alaska, California, Connecticut, Delaware, Florida, Hawaii, Iowa, Illinois, Massachusetts, Maine, New Jersey, New York, Oregon, Rhode Island, Vermont, and Washington.

variation in the statutory minimum wage across states over time to identify the impact of the minimum wage.

Figure 3 shows the national average trend in the real value of the minimum wage. The statutory minimum wage is deflated by the personal consumer expenditure price index using 2012 as the base year. During the period, there was a change in the trend in the year 1989. The real value of the minimum wage fell due to inflation from 1979 to 1989. Subsequently, the real value of the minimum wage exhibits an upward trend due to increases in the statutory minimum wage for the years 1989–2012.
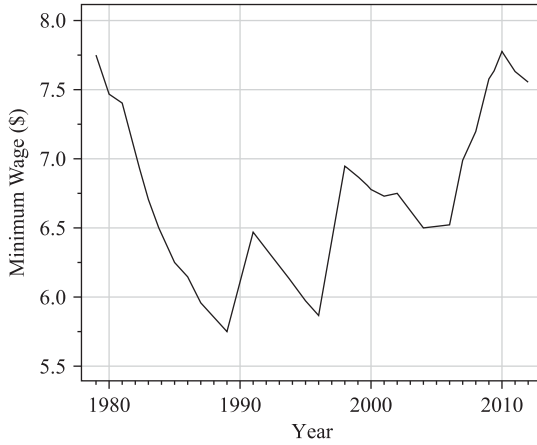
Figure 3

The Real Value of the Minimum Wage, 1979–2012

Notes: National means are reported. The base year is 2012.

IV. Econometric Framework

In this section, we present our econometric framework. We start by introducing the state-level panel quantile regression model. Then, we describe the censored quantile regression model. We end this section by describing our approach to evaluating the quantitative contribution of the minimum wage to changes in between- and within-group inequality.

A. Model

The key feature of our model is that it allows the impact of the minimum wage to be heterogeneous with respect to workers' observed and unobserved characteristics. This feature is essential for evaluating the contribution of the minimum wage to changes in between- and within-group inequality.

For the purpose of our analysis, we adopt the quantile regression approach pioneered by Koenker and Bassett (1978) and developed by Chetverikov, Larsen, and Palmer (2016). We have a repeated cross section of individuals $i = 1,\ldots,N_{st}$ in states $s = 1,\ldots,S$ and time $t = 1,\ldots,T$. For each state and year, the structure of wages can be expressed using the following quantile regression model:

(1) $Q_{st}(\tau \mid z_{ist}) = z'_{ist}\alpha_{st}(\tau)$ for $\tau \in (0, 1)$,

where $Q_{st}(\tau \mid z_{ist})$ is the τth conditional quantile of the log of real hourly wages, w_{ist}, given a $J + 1$ vector of observed individual characteristics, z_{ist}, for each state s and year t. The vector of parameters $\alpha_{st}(\tau)$ can vary across quantiles τ. The vector z_{ist} includes a constant term, the linear and quadratic terms in years of education, *educ* and *educ*², and

of potential experience (age minus education minus six), *exper* and *exper*², and an indicator for being male, *male*. There are three reasons we use these variables. First, they are determined prior to the entry of the labor market. Second, they are commonly used as regressors in the quantile regression of wages (Buchinsky 1994; Angrist, Chernozhukov, and Fernández-Val 2006). Finally, and most importantly, they are useful to distinguish minimum wage workers.[4] The quantile regression model (Equation 1) is more flexible than usual in that it allows all intercept and slope coefficients to vary across states and years.

Given the structure of wages described above, we examine the distributional impact of the minimum wage by looking at changes in the vector of coefficients, $\alpha_{st}(\tau) = [\alpha_{0st}(\tau), \alpha_{1st}(\tau),\ldots, \alpha_{Jst}(\tau)]'$, in Equation 1 resulting from changes in the real value of the minimum wage. We consider the following state-level panel data model:

$$(2) \quad \alpha_{jst}(\tau) = m_{st}\beta_j(\tau) + x_{st}'\gamma_j(\tau) + \epsilon_{jst}(\tau) \text{ for } j = 0, \cdots, J,$$

where m_{st} is the log of the real value of the minimum wage, and x_{st} is a vector of state–year characteristics.[5] The vector x_{st} includes state and year dummies and state-specific linear trends in the same way as in Autor, Manning, and Smith (2016).[6] A set of parameters, $\beta(\tau) = [\beta_0(\tau), \beta_1(\tau),\ldots, \beta_J(\tau)]'$, represents the heterogeneous impact of the minimum wage. Note that the first element of the vector z_{ist} is one. The second to last elements, $\beta_1(\tau)$ to $\beta_J(\tau)$, of the vector $\beta(\tau)$ measure the extent to which the impact of the minimum wage varies across individuals according to their observed characteristics. If the impact of the minimum wage is not heterogeneous with respect to observed characteristics, the parameter vector is $\beta(\tau) = [\beta_0(\tau), 0,\ldots, 0]'$ for a given τ. The quantile τ can be interpreted as the position in the distribution of workers' productivity not attributable to their observed characteristics. If the impact of the minimum wage is not heterogeneous with respect to unobserved characteristics, the parameter vector is $\beta(\tau) = [\beta_0, \beta_1,\ldots, \beta_J]'$ for all τ. Throughout the paper, we interpret $\beta(\tau)$ as the effects on coefficients in the wage equation for the τth conditional quantile. This interpretation does not require the rank invariance assumption. If we additionally imposed the rank invariance assumption, we could interpret $\beta(\tau)$ as the effects on coefficients in the wage equation for the τth quantile worker.

Following Chetverikov, Larsen, and Palmer (2016), Equations 1 and 2 can be estimated in two steps. In the first step, we perform separate quantile regressions of w_{ist} by state s and year t for each quantile τ using the individual-level cross-sectional data. We then obtain a set of estimated parameters $\hat{\alpha}_{st}(\tau) \equiv [\hat{\alpha}_{0st}(\tau), \hat{\alpha}_{1st}(\tau), \cdots, \hat{\alpha}_{Jst}(\tau)]'$. In the second step, we perform the linear regression of $\hat{\alpha}_{jst}(\tau)$ for each element j and quantile τ using the state-level panel data. Relative to several applications discussed in Chetverikov,

---

4. When we add an indicator of being white in individual characteristics, we find that the minimum wage has no effect on the racial wage differential. The proportion of Black workers was less than 20 percent among minimum wage workers throughout the sample period. Even if the linear and quadratic terms in years of education and years of experience are interacted with the indicator for being male, the results reported remain essentially unchanged.

5. Online Appendix B describes the conceptual framework that underlies the econometric model.

6. Bosch and Manacorda (2010); Kambayashi, Kawaguchi, and Yamada (2013); and Fortin and Lemieux (2015) also include state-specific linear trends to avoid a spurious correlation between changes in the minimum wage and the wage distribution.

Larsen, and Palmer (2016), we allow for interactions between the treatment variable and individual characteristics,[7] whereas we assume the exogeneity of the treatment variable. We, however, examine the possibility that differences in changes in the real value of the minimum wage across states may be driven by differences in changes in unobserved state characteristics.

The approach described above is related to the approach used in Lee (1999), who estimates the model of the form:

(3) $Q_{st}(\tau) - Q_{st}(0.5) = [m_{st} - Q_{st}(0.5)]\beta(\tau) + x'_{st}\gamma(\tau) + \epsilon_{st}(\tau),$

where $Q_{st}(\tau)$ is the τth unconditional quantile of w_{ist}. If the median wage, $Q_{st}(0.5)$, is absent, this model corresponds to the case in which all individual characteristics are excluded from Equation 1. The main reason for the use of the median wage is presumably that there was insufficient variation in the state minimum wage during the period of the author's analysis, 1979–1988. From the 1990s and onwards, there was substantial variation in m_{st} across states over time, which makes it possible to identify the impact of the minimum wage without relying on variation in $Q_{st}(0.5)$.

B. Estimation

We address the issues of censoring and truncation, building on the approach described above.

1. Censoring

The wage distribution has been left-censored due to the minimum wage in many states (DiNardo, Fortin, and Lemieux 1996; Lee 1999). This issue is evident from the data but typically ignored when estimating the wage equation. The main reason, presumably, is that the magnitude of the bias due to left-censoring at the minimum wage is negligible if the interest lies at the mean impact. However, the magnitude of the bias may not be negligible if the interest lies at the distributional impact. The left-censoring due to the minimum wage can cause the fitted wage equation to be flat. In this case, the intercept coefficient becomes larger, whereas the slope coefficients become smaller. This effect is stronger at quantiles closer to the minimum wage. As a likely consequence, the censoring effect (the impact of the minimum wage at the minimum wage) may suffer from a downward bias, whereas the spillover effect (the impact of the minimum wage above the minimum wage) may suffer from an upward bias.

In addition, the earnings data from the CPS are right-censored due to top-coding. This issue has been widely recognized in the literature. Many studies using the CPS data make some adjustments for top-coding. Hubbard (2011) develops a maximum likelihood approach to addressing this issue under a distributional assumption and shows that an increase in top-coded observations causes a serious bias in the trend in the gender

---

7. Koenker (2017) recently notes that "somewhat neglected in the econometrics literature on treatment response and program evaluation is the potentially important role of the interactions of covariates with treatment variables."

wage differential. The trends in the education and experience wage differentials are also subject to the influence of top-coding.[8]

We adopt the censored quantile regression approach developed in Powell (1986), Chernozhukov and Hong (2002), and Chernozhukov, Fernández-Val, and Kowalski (2015) to address the issue of censoring. This approach is semiparametric in the sense that it does not require a distributional assumption. We consider the following censored quantile regression model to deal with left-censoring due to the minimum wage and right-censoring due to top-coding.

$$(4) \quad Q_{st}(\tau \,|\, z_{ist}) = \begin{cases} m_{st} & \text{if } m_{st} \leq w_{ist}, \\ z'_{ist}\alpha_{st}(\tau) & \text{if } m_{st} \leq w_{ist} \leq c_{it}, \\ c_{st} & \text{if } w_{ist} \geq c_{it}, \end{cases}$$

where c_{it} denotes the top-coded value.[9] The key concept of this approach is to estimate the quantile regression model using the subsample of individuals who are unlikely to be left- or right-censored.[10] Online Appendix C.1 details the estimation procedure.

2. Missing wages

There are diverse views on the employment effect of the minimum wage (Card and Krueger 1995; Neumark and Wascher 2008). Given the importance of this issue, a valid question may be whether changes in the wage distribution are due in part to a potential change in the number and composition of workforce resulting from a rise in the minimum wage. Suppose, for the sake of discussion, that workers lose their jobs in the order of those with the lowest to highest productivity after an increase in the minimum wage. Or, suppose that workers with higher reservation wages are drawn into the workforce after an increase in the minimum wage, as consistent with the results of Giuliano (2013). In either case, percentile wages can mechanically increase even without any actual increase in wages. This implies that if the sample is restricted to employed individuals, the censoring effect and the spillover effect might be subject to an upward bias. We control for potential bias by imputing the wages of nonemployed individuals.

Our approach builds on the quantile imputation approach developed in Yoon (2010) and Wei (2017). For the purpose of imputation, we use the censored quantile regression model, instead of the standard quantile regression, to take into account left- and right-censoring. In the process of imputation, we assume that nonemployed individuals are less productive than median employed individuals, as is common in the literature on the

---

8. This issue can be solved by winsorizing for the τth quantile regression, only if the conditional probability of not being censored given z_{ist} is higher than τ.

9. The CPS sample is composed of hourly paid workers and monthly paid workers. Earnings for monthly paid workers are top-coded, whereas wages for hourly paid workers are not. For monthly paid workers, earnings are divided by hours worked to calculate hourly wages. Although the top-coded value of earnings is constant for a given year, the top-coded value of wages differs according to hours worked. We, thus, allow the top-coded value to vary across individuals.

10. In practice, it does not matter which values are assigned to the wages of workers who earn below the minimum wage in the range less than or equal to the minimum wage. Similarly, it does not matter which values are assigned to the wages of workers who earn above the top-coded value in the range greater than or equal to the top-coded value.

gender wage differential (Johnson, Kitamura, and Neal 2000).[11] We allow for selection on unobservables in that sense. Online Appendix C.2 details the imputation procedure. Online Appendix D.1 provides the results without imputation.

3. Procedure

The estimation procedure is divided into three stages. First, we estimate the censored quantile regression model (Equation 4) using the sample of employed individuals and impute the wages of individuals for whom we cannot observe wages. Second, we estimate the censored quantile regression model (Equation 4) using the sample of employed and nonemployed individuals and obtain the estimates for intercept and slope coefficients $\hat{\alpha}_{jst}(\tau)$ in the wage equation for $j = 0, 1,\ldots, 5$, $s = 1, 2,\ldots, 50$. $t = 1979, 1980,\ldots, 2012$, and $\tau = 0.04, 0.05,\ldots, 0.97$. Both in the first and second stages, we perform the separate regressions by state and year for each quantile. Finally, we estimate the linear regression model (Equation 2) of $\hat{\alpha}_{jst}(\tau)$ using the state-level panel data.

4. Inference

Chetverikov, Larsen, and Palmer (2016) derive the asymptotic properties of estimators for parameters in Equation 2. The authors show that estimation errors from the individual-level quantile regression are asymptotically negligible, if the size of the sample used in the individual-level quantile regression is sufficiently large relative to the size of the sample used in the state-level linear regression. Because the sample size may not be sufficiently large in the least populous states, we choose to report bootstrapped confidence intervals from 500,000 bootstrap estimates obtained by repeating the individual-level censored quantile regression 500 times and then repeating the state-level linear regression 1,000 times for each quantile regression estimate. We allow for heteroscedasticity and weak serial dependence.

5. Specification checks

As is common when estimating the impact of the minimum wage on the wage distribution (DiNardo, Fortin, and Lemieux 1996; Lee 1999; Teulings 2003; Autor, Manning, and Smith 2016), we focus primarily on the contemporaneous effect of the minimum wage. We estimate the following model in which we add the lag and lead variables, $m_{s,t-1}$ and $m_{s,t+1}$, to assess the validity of the model specification.

$$(5) \quad \alpha_{jst}(\tau) = m_{s,t-1}\beta_{j,-1}(\tau) + m_{st}\beta_{j,0}(\tau) + m_{s,t+1}\beta_{j,+1}(\tau) + x'_{st}\gamma_j(\tau)$$
$$+ \epsilon_{jst}(\tau) \text{ for } j = 0, \cdots, J$$

If Equation 2 is correctly specified, we expect two restrictions to be satisfied. First, the long-term effect, $\beta_{j,1}(\tau) + \beta_{j,0}(\tau)$, in Equation 5, would be the same as the contemporaneous effect, $\beta_j(\tau)$, in Equation 2. This restriction will be valid if the policy effect is well captured by the contemporaneous effect. Second, there would be no leading effect in

---

11. The results reported remain essentially unchanged if we assume that nonemployed individuals are less productive than 30 or 70 percent of employed individuals.
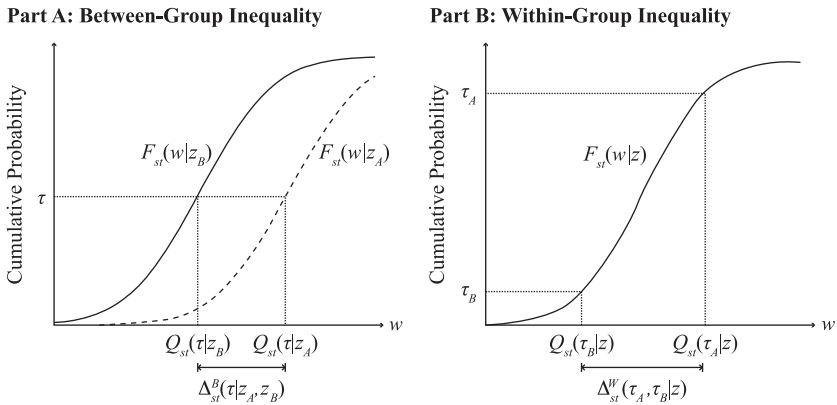
Part A: Between-Group Inequality   **Part B: Within-Group Inequality**

Figure 4

Inequality Measures

Notes: The conditional quantile function $Q_{st}(\tau|z)$ is an inverse of $F_{st}(w|z)$, where $F_{st}(\bullet|z)$ is the conditional distribution function of w_{ist} given $z_{ist} = z$ in state s and year t.

Equation 5; that is, $\beta_{j,+1}(\tau) = 0$. This restriction will not hold if changes in the real value of the minimum wage are driven by changes in unobserved state characteristics. We, thus, examine whether the long-term effect differs from the contemporaneous effect and whether the leading effect differs from zero.

C. Measures of Inequality

The aim of this work is to evaluate the quantitative contribution of the minimum wage to changes in between- and within-group inequality. Here, we define the two types of inequality and describe the way to measure the contribution of the minimum wage along the lines of the model described above.

Between-group inequality is the wage differential among workers with different observed characteristics. Consider two groups of workers—one consists of workers with observed characteristics, $z_{ist} = z_A$, and the other consists of workers with observed characteristics, $z_{ist} = z_B$. Between-group inequality can be defined as:

$$(6) \quad \Delta_{st}^{B}(\tau \,|\, z_A, z_B) := Q_{st}(\tau \,|\, z_A) - Q_{st}(\tau \,|\, z_B)$$

for a given quantile τ (see Figure 4A for a graphical description). Let $\tilde{\Delta}_{st}^{B}$ denote the counterfactual between-group wage differential if the real value of the minimum wage were kept constant at a certain level. The contribution of the minimum wage can be measured by taking the difference between the actual wage differential and the counterfactual wage differential:

$$(7) \quad \Delta_{st}^{B}(\tau \,|\, z_A, z_B) - \tilde{\Delta}_{st}^{B}(\tau \,|\, z_A, z_B).$$

Within-group inequality is the wage differential among workers with the same observed characteristics. Consider a range between two quantiles, τ_A and τ_B, as a measure of inequality. Within-group inequality can be defined as:

(8) $\Delta_{st}^{W}(\tau_A, \tau_B \mid z) := Q_{st}(\tau_A \mid z) - Q_{st}(\tau_B \mid z)$

for a group of workers with observed characteristics, $z_{ist} = z$ (see Figure 4B for graphical description). Let $\tilde{\Delta}_{st}^{W}$ denote the counterfactual within-group wage differential if the real value of the minimum wage is kept constant at a certain level. The contribution of the minimum wage can be measured by taking the difference between the actual wage differential and the counterfactual wage differential:

(9) $\Delta_{st}^{W}(\tau_A, \tau_B \mid z) - \tilde{\Delta}_{st}^{W}(\tau_A, \tau_B \mid z)$.

The real value of the minimum wage declined for the years 1979–1989, whereas it increased for the years 1989–2012, as described above. In the next section, we consider the counterfactual between- and within-group wage differentials in the year 2012 if the real value of the minimum wage were kept constant at the 1989 level. By doing so, we measure the contribution of the minimum wage to changes in between- and within-group inequality for the years 1989–2012. In the Online Appendix, we consider the counterfactual between- and within-group wage differentials in the year 1989 if the real value of the minimum wage were kept constant at the 1979 level.

The impact of the minimum wage on between- and within-group inequality defined above is measured using the estimated censored quantile regression model (Equation 4). As a result, the measured impact can vary across states. The reason for this is not only because there is a difference in changes in the minimum wage across states, but also because there is a difference in the proportion of workers who earn at or below the minimum wage across states. In the next section, we report not only the national mean, but also the maximum and minimum, of the impact. The contribution of the minimum wage to changes in between- and within-group inequality becomes greater in states where the minimum wage is more binding.

V. Results

Our results are divided into two parts. The first part is a collection of the results regarding the impact of the minimum wage on the wage structure. The second part is a collection of the results regarding the contribution of the minimum wage to changes in between- and within-group inequality.

A. Impact on the Wage Structure

We first present the results of estimating Equation 2. Figure 5 shows the impact of the minimum wage on the intercept and slope coefficients in the wage equation across quantiles. The four panels show the estimates for $\beta_0(\tau)$, $\beta_1(\tau) + 2\beta_2(\tau)\overline{educ}$, $\beta_3(\tau) + 2\beta_4(\tau)\overline{exper}$, and $\beta_5(\tau)$, respectively, where the bar represents the sample mean over all states and years. We summarize the impact of the minimum wage on the coefficients of linear and quadratic terms in education and experience as the impact on their marginal effects.

Both the intercept and slope coefficients in the wage equation are affected by the real value of the minimum wage. The intercept coefficient increases with a rise in the minimum
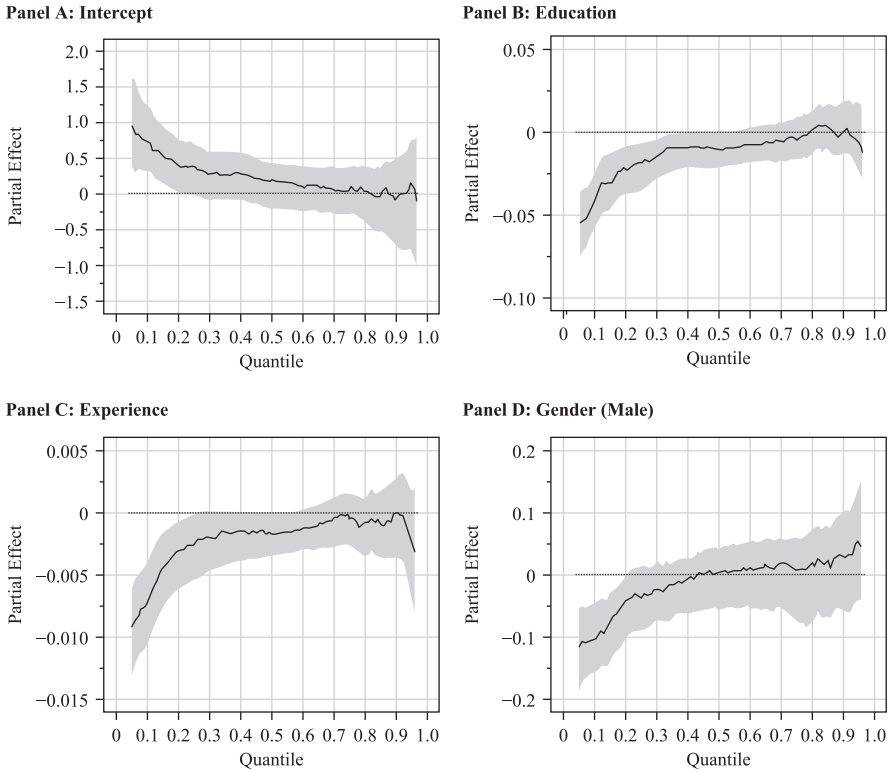
Panel A: Intercept

Panel B: Education

Panel C: Experience

Panel D: Gender (Male)

Figure 5

Impact of the Minimum Wage on the Wage Structure

Notes: Estimates of partial effects in Equation 2 are reported. The shaded area represents the 95 percent confidence interval. See Online Appendix Figure D2 for the uniform confidence band.

wage (Figure 5A), whereas the slope coefficients of education, experience, and gender decrease with a rise in the minimum wage (Figures 5B, 5C, and 5D). The former result implies that a rise in the minimum wage results in an increase in the lowest wages uniformly across workers. The latter result implies that a rise in the minimum wage weakens the relationship of hourly wages with education, experience, and gender. These results are consistent with the fact that less-educated, less-experienced, and female workers are more directly affected by a rise in the minimum wage than more-educated, more-experienced, and male workers. Furthermore, the magnitude of changes in the intercept and slope coefficients varies across quantiles. In all cases, the impact of the minimum wage is greatest at the lowest quantile and gradually declines in absolute value to zero by the 0.3 quantile. Spillover effects are present but limited mostly to the first quintile.

Before discussing the contribution of the minimum wage to changes in between- and within-group inequality, we present the results when estimating the augmented
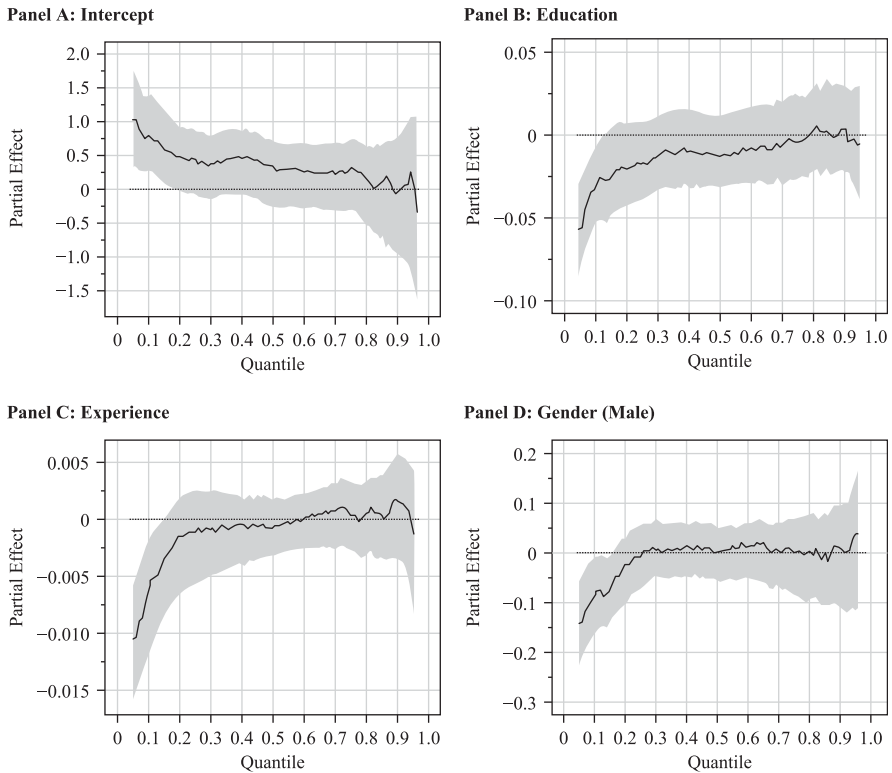
Panel A: Intercept

Panel B: Education

Panel C: Experience

Panel D: Gender (Male)

Figure 6

Long-Term Effect of the Minimum Wage on the Wage Structure

Notes: Estimates of the long-term effects in Equation 5 are reported. The shaded area represents the 95 percent confidence interval. See Online Appendix Figure D3 for the uniform confidence band.

model (Equation 5). The four panels in Figure 6 show the estimates of the long-term effects. All estimates remain essentially unchanged, although they become less precise. Indeed, the long-term effects fall inside the 95 percent confidence intervals of the contemporary effects. The four panels in Figure 7 illustrate the estimates of the leading (placebo) effects. All estimates are close to zero for virtually all quantiles, and virtually none of them are statistically significant. These results support our specification.

B. Contribution to Changes in Between- and Within-Group Inequality

Finally, we discuss the quantitative contribution of the minimum wage to changes in between- and within-group inequality. As in Figure 3, the real value of the minimum wage declined by 30 log points due to inflation for the years 1979–1989 and subsequently increased by 28 log points due to increases in the statutory minimum wage for the years 1989–2012. Here, we provide the results for workers with ten years of
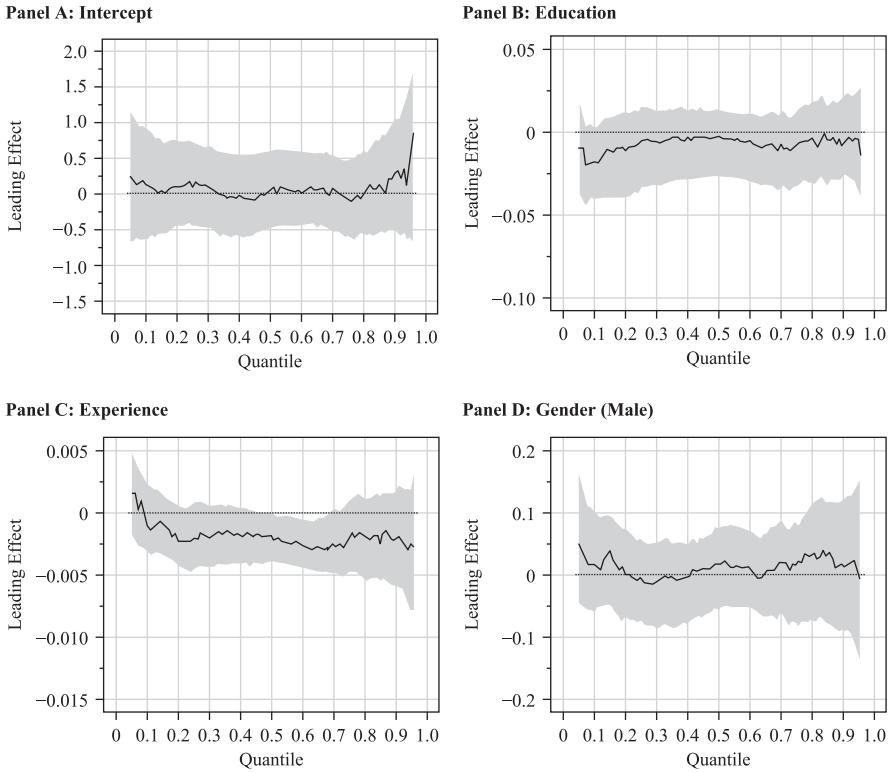
Panel A: Intercept

Panel B: Education

Panel C: Experience

Panel D: Gender (Male)

Figure 7

Placebo Effect on the Wage Structure

Notes: Estimates of the leading effects in Equation 5 are reported. The shaded area represents the 95 percent confidence interval. See Online Appendix Figure D4 for the uniform confidence band.

experience or fewer, who are subject to the influence of the minimum wage, for the latter period. Online Appendix D.2 shows the results for the former period.

1. Educational wage differential

We measure the educational wage differential by comparing workers with 16 years of education (equivalent to college graduates) and those with 12 years of education (equivalent to high school graduates), holding experience and gender constant. The four panels in Figure 8 show the national means of changes in the educational wage differential due to increases in the real value of the minimum wage for the years 1989–2012 by experience and gender for each decile $\tau = 0.05, 0.1, 0.2, \ldots, 0.9$. We also report the maximum and minimum values as error bars.

The minimum wage contributes to a reduction in the educational wage differential in the lower quantiles. The contribution of the minimum wage to a reduction in the
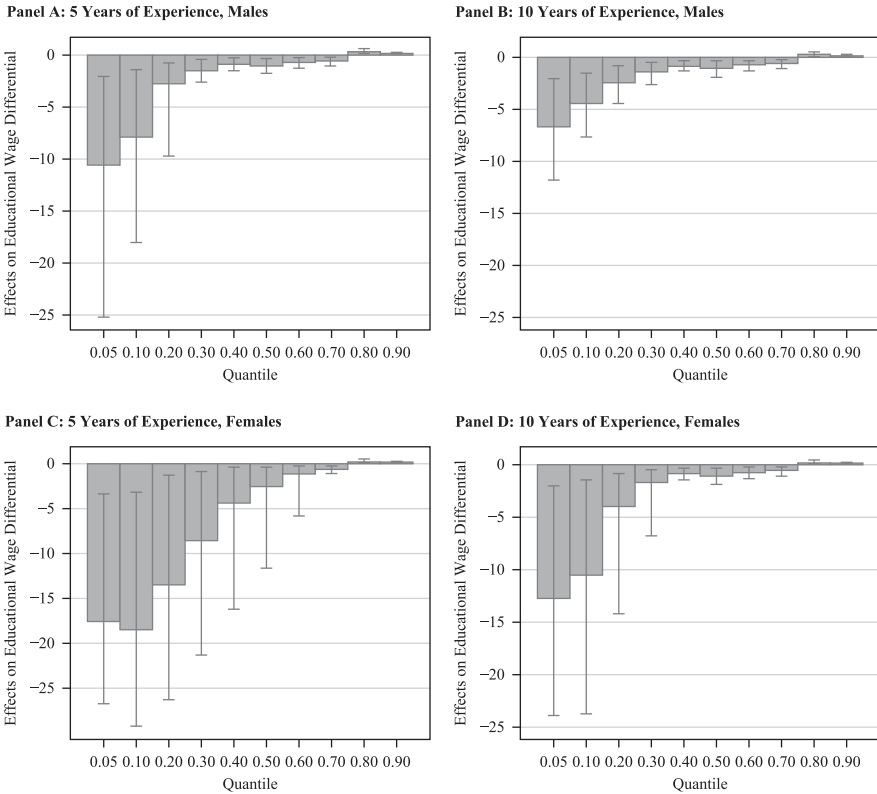
Panel A: 5 Years of Experience, Males

Panel B: 10 Years of Experience, Males

Panel C: 5 Years of Experience, Females

Panel D: 10 Years of Experience, Females
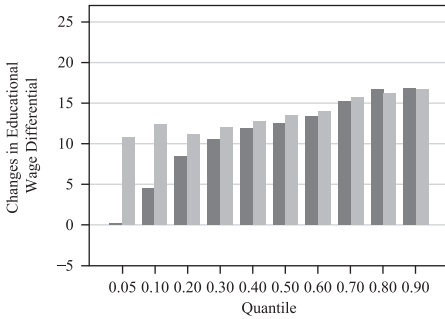

Figure 8

Changes in the Educational Wage Differential (16 vs. 12 Years of Education) Due to the Minimum Wage, 1989–2012

Notes: Bar charts represent national means. Error bars represent maximum and minimum values. The log-point changes in the educational wage differential due to the minimum wage are obtained from Equation 7.
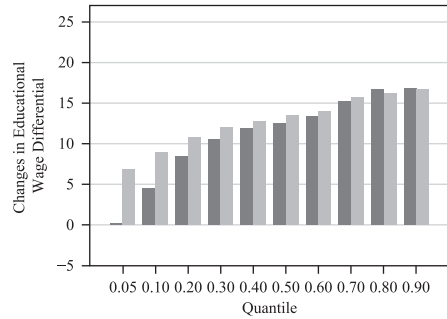
educational wage differential is greater for less-experienced, female workers than more-experienced, male workers. For each group of workers, the contribution of the minimum wage is greatest at the 0.05th quantile and gradually declines in absolute value to zero by the 0.2th to 0.5th quantiles. For female workers with five years of experience, however, it is slightly greater at the 0.1th quantile than the 0.05th quantile. The reason is that, at the 0.05th quantile in this group, both more- and less-educated workers are affected by a rise in the real value of the minimum wage.

The educational wage differential increased during the period (Figure 9). The trend in the educational wage differential is known to be important in accounting for the rise in wage inequality in the United States (Autor, Katz, and Kearney 2008). The increase in the educational wage differential is typically attributed in the literature to skill-biased technological change and compositional changes in the workforce (Bound and Johnson
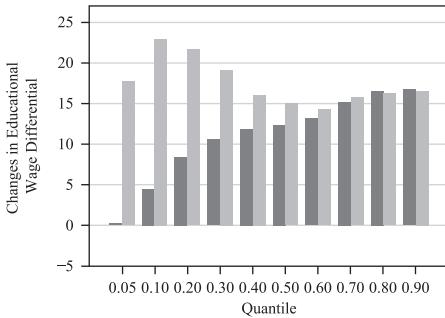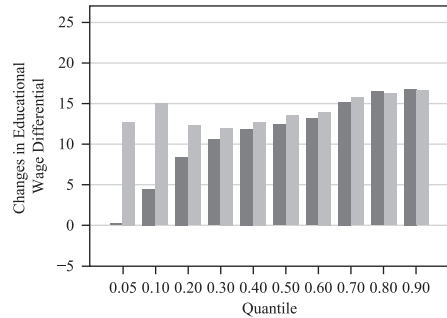
Figure 9

Actual and Counterfactual Changes in the Educational Wage Differential (16 vs. 12 Years of Education), 1989–2012

Notes: National means are reported. Counterfactual log-point changes in the educational wage differential are obtained using Equations 6 and 7.

1992; Katz and Murphy 1992; Autor, Katz, and Kearney 2008). The magnitude of the increase in the educational wage differential is greater in the higher quantiles than the lower quantiles during the period, as also shown by Buchinsky (1994) and Angrist, Chernozhukov, and Fernández-Val (2006). The educational wage differential did not increase at the 0.05 quantile and increased only moderately at the 0.1 quantile, whereas it increased more in the higher quantiles. If there were no increase in the real value of the minimum wage, however, the educational wage differential would increase at the 0.05 quantile and more than double at the 0.1 quantile for all groups. Consequently, in the counterfactual case in which the real value of the minimum wage is kept constant, the increase in the educational wage differential is more uniform across quantiles. Our results indicate that the minimum wage is another factor in accounting for the patterns of changes in the educational wage differential.
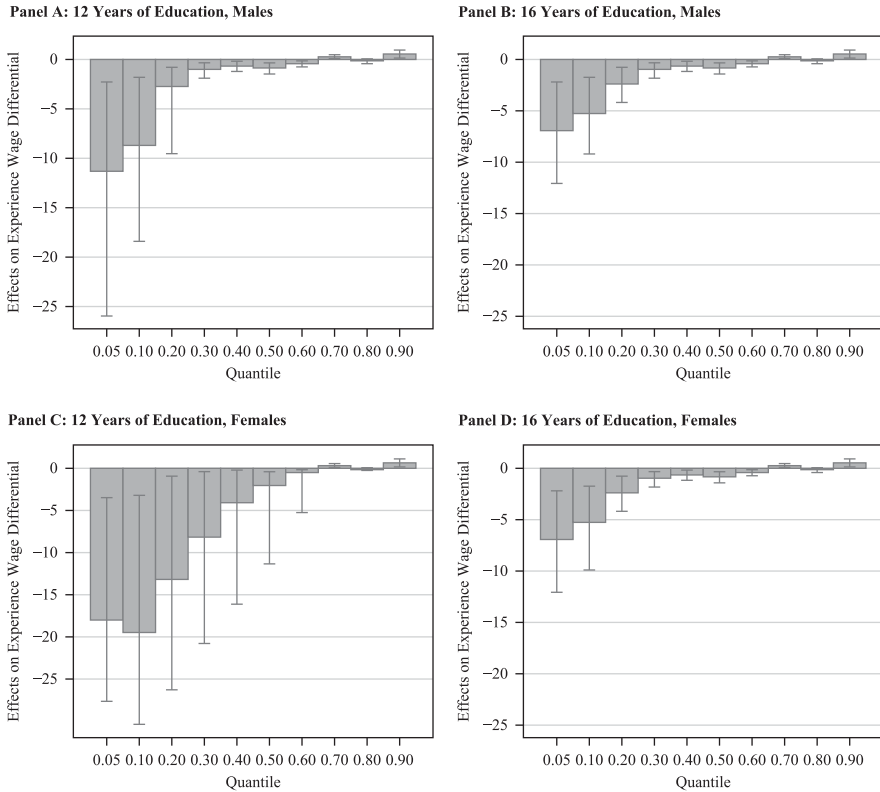
Panel A: 12 Years of Education, Males

Panel B: 16 Years of Education, Males

Panel C: 12 Years of Education, Females

Panel D: 16 Years of Education, Females

Figure 10

Changes in the Experience Wage Differential (25 vs. 5 Years of Experience) Due to the Minimum Wage, 1989–2012

Notes: Bar charts represent national means. Error bars represent maximum and minimum values. The log-point changes in the experience wage differential due to the minimum wage are obtained from Equation 7.

2. Experience wage differential

We measure the experience wage differential by comparing workers with 25 years of experience and those with five years of experience, holding education and gender constant. The four panels in Figure 10 show the national means of changes in the experience wage differential due to increases in the real value of the minimum wage for the years 1989–2012 by education and gender. We also report the maximum and minimum values as error bars.

The minimum wage contributes to a reduction in the experience wage differential in the lower quantiles. The contribution of the minimum wage to a reduction in the experience wage differential is greater for less-educated, female workers than more-educated, male workers. For each group of workers, the contribution of the minimum wage is greatest at the 0.05th quantile and gradually declines in absolute value to zero by the 0.2th to 0.5th quantiles. For female workers with 12 years of education, however, it is slightly
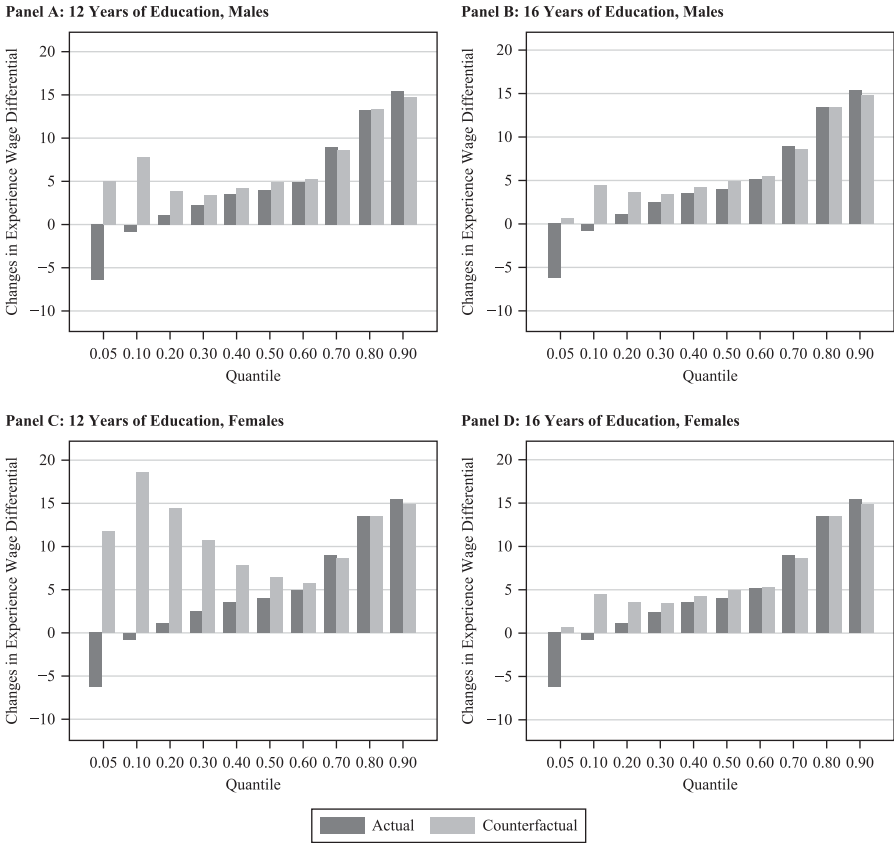
Panel A: 12 Years of Education, Males

Panel B: 16 Years of Education, Males

Panel C: 12 Years of Education, Females

Panel D: 16 Years of Education, Females

Actual   Counterfactual

Figure 11

Actual and Counterfactual Changes in the Experience Wage Differential (25 vs. 5 Years of Experience), 1989–2012

Notes: National means are reported. Counterfactual log-point changes in the experience wage differential are obtained using Equations 6 and 7.

greater at the 0.1th quantile than the 0.05th quantile. The reason is that, at the 0.05th quantile in this group, both more- and less-experienced workers are affected by a rise in the real value of the minimum wage.

The experience wage differential increased during the period with the exception of the lowest quantile (Figure 11). Changes in the experience wage differential are typically attributed in the literature to compositional changes in the workforce (Welch 1979; Jeong, Kim, and Manovskii 2015). The magnitude of the increase in the experience wage differential is greater in the higher quantiles than the lower quantiles during the period. The experience wage differential declined at the 0.05th quantile and increased only moderately at the median, whereas it increased more at the 0.7th and higher
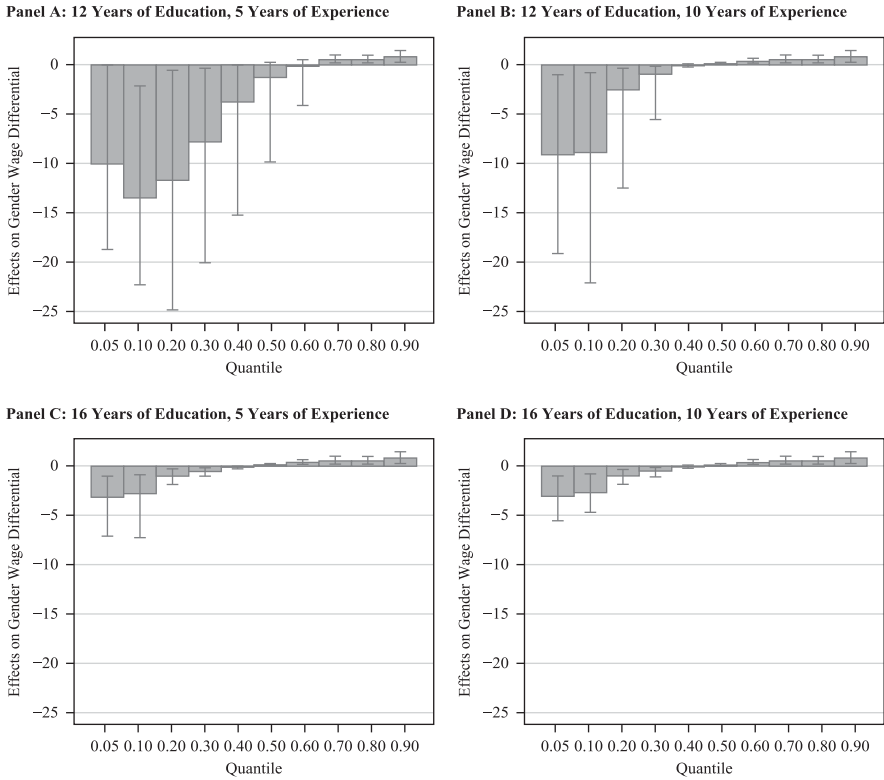
Panel A: 12 Years of Education, 5 Years of Experience

Panel B: 12 Years of Education, 10 Years of Experience

Panel C: 16 Years of Education, 5 Years of Experience

Panel D: 16 Years of Education, 10 Years of Experience

Figure 12

Changes in the Gender Wage Differential (Males vs. Females) Due to the Minimum Wage, 1989–2012

Notes: Bar charts represent national means. Error bars represent maximum and minimum values. The log-point changes in the gender wage differential due to the minimum wage are obtained from Equation 7.

quantiles. If there were no increase in the real value of the minimum wage, however, the experience wage differential would increase in the lower as well as higher quantiles. Consequently, in the counterfactual case in which the real value of the minimum wage is kept constant, the increase in the educational wage differential at the 0.1th quantile is at least as high as the increase in the median for all groups. Our results indicate that the minimum wage is another factor in accounting for the patterns of changes in the experience wage differential.

3. Gender wage differential

We measure the gender wage differential by comparing male workers and female workers, holding education and experience constant. The four panels in Figure 12 show

the national means of changes in the gender wage differential due to increases in the real value of the minimum wage for the years 1989–2012 by education and experience. We also report the maximum and minimum values as error bars.

The minimum wage contributes to a reduction in the gender wage differential in the lower quantiles. The contribution of the minimum wage to a reduction in the gender wage differential is greater for less-educated, less-experienced workers than more-educated, more-experienced workers. For each group of workers, the contribution of the minimum wage is greatest at the 0.05th quantile and gradually declines in absolute value to zero by the 0.2th to 0.5th quantiles. For workers with 12 years of education and five years of experience, however, it is slightly greater at the 0.1th quantile than the 0.05th quantile. The reason is that, at the 0.05th quantile in this group, both male and female workers are affected by a rise in the real value of the minimum wage. For workers with 16 years of education, however, the contribution of the minimum wage is only modest across quantiles.

The gender wage differential declined during the period (Figure 13). Changes in the gender wage differential are typically attributed in the literature to changes in workforce composition and gender discrimination (Blau and Kahn 2017). Differently from the education and experience wage differentials, the magnitude of the change in the gender wage differential is almost uniform across quantiles. If there were no increase in the real value of the minimum wage, however, the gender wage differential would decline less in the lower quantiles. For workers with 12 years of education, the gender wage differential would not decline but could increase in the lower quantiles. Consequently, in the counterfactual case in which the real value of the minimum wage is kept constant, the decline in the gender wage differential is less in the lower quantiles than the higher quantiles for all groups. Our results indicate that the minimum wage is another factor in accounting for the patterns of changes in the gender wage differential.

4. Within-group differential

The four panels in Figure 14 show the national means of changes in the 90/10 and 50/10 within-group wage differentials due to increases in the real value of the minimum wage for the years 1989–2012 by education, experience, and gender. We also report the maximum and minimum values as error bars.

The minimum wage contributes to a reduction in the 90/10 and 50/10 within-group wage differentials among workers with lower levels of education and experience. The contribution of the minimum wage is the same for changes in the 90/10 and 50/10 within-group wage differentials except for female workers with 12 years of education and no experience. The results reflect the fact that changes in the real value of the minimum wage have no effect at the median or higher quantiles for almost all groups. The minimum wage also contributes to a reduction in the 50/20 within-group wage differential, but only moderately for fewer groups. The contribution of the minimum wage to changes in within-group wage differentials is greater for less-educated, less-experienced, female workers than more-educated, more-experienced, male workers. For workers with 16 years of education and five or more years of experience, the contribution of the minimum wage is close to zero.
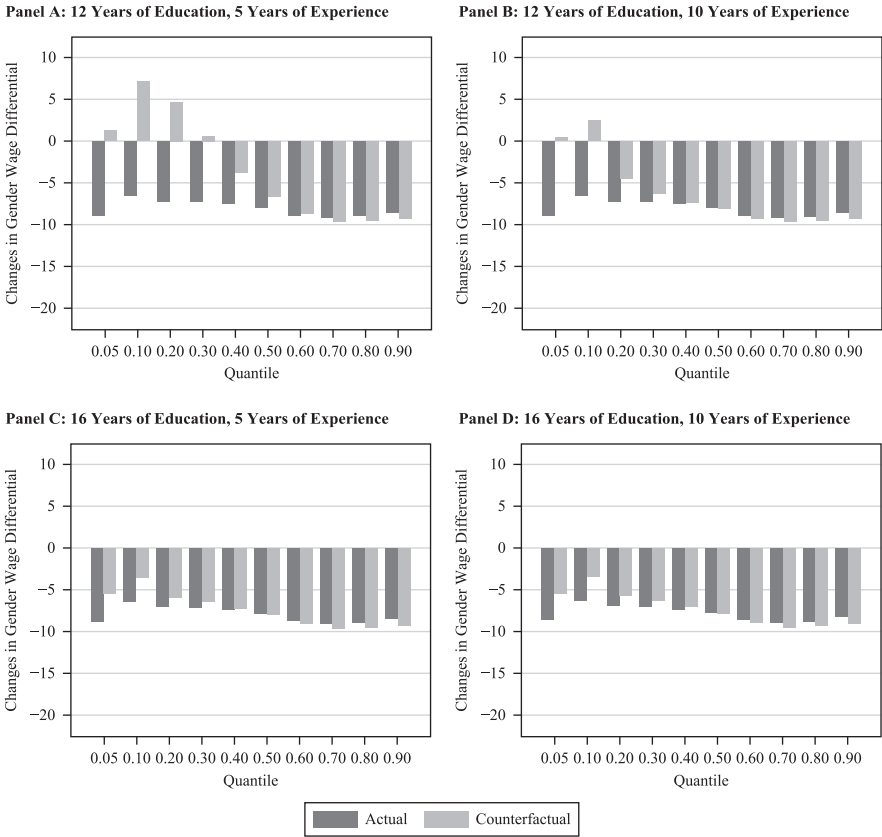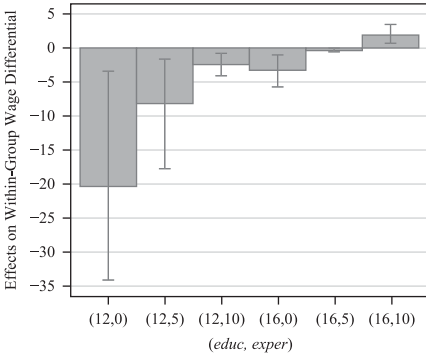
Panel A: 12 Years of Education, 5 Years of Experience

Panel B: 12 Years of Education, 10 Years of Experience

Panel C: 16 Years of Education, 5 Years of Experience

Panel D: 16 Years of Education, 10 Years of Experience

Figure 13

Actual and Counterfactual Changes in the Gender Wage Differential (Males vs. Females), 1989–2012
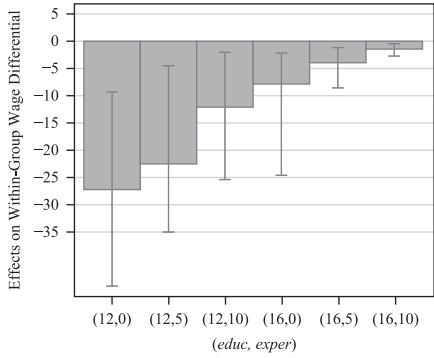
Notes: National means are reported. Counterfactual log-point changes in the gender wage differential are obtained using Equations 6 and 7.

The 90/10, 50/10, and 50/20 within-group wage differentials declined during the period (Figure 15). The 50/10 wage differential declined more than the 50/20 wage differential. The magnitude of the decline in within-group wage differentials is similar for male and female workers, but it is greater for less-educated, less-experienced workers than more-educated, more-experienced workers. If there were no increase in the minimum wage, however, the 50/10 and 50/20 wage differentials would change roughly equally. Furthermore, within-group wage differentials would decline similarly for less-educated, less-experienced workers and more-educated, more-experienced workers, whereas they would decline less for male workers and would not decline but could increase for female workers. Our results indicate that the minimum wage accounts for most of the changes in within-group wage differentials.
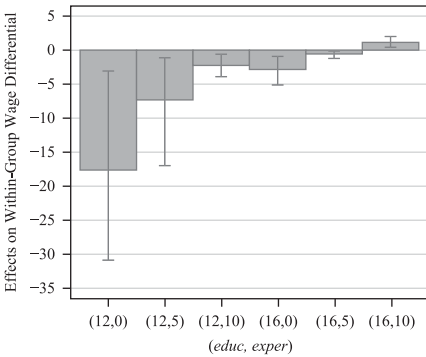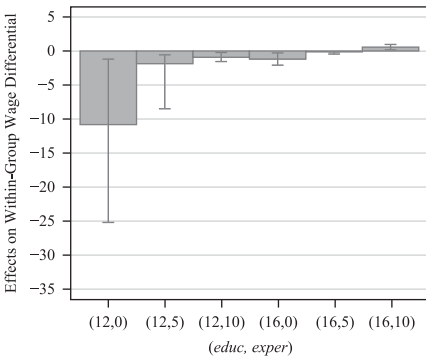
Figure 14

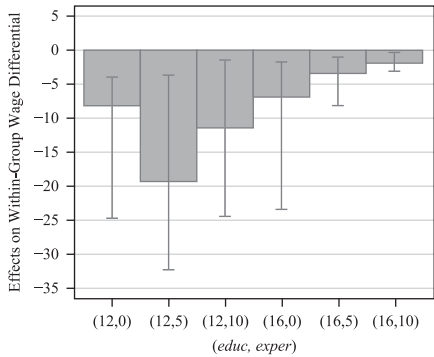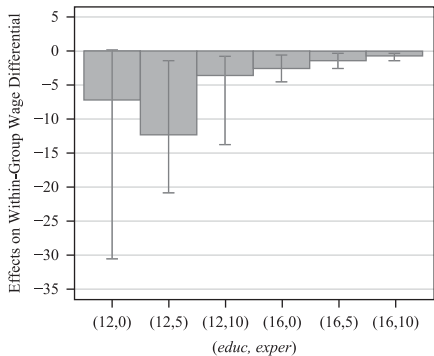*Changes in the 90/10, 50/10, and 50/20 Within-Group Differentials Due to the Minimum Wage, 1989–2012*

Notes: Bar charts represent national means. Error bars represent maximum and minimum values. The log-point changes in the within-group wage differentials due to the minimum wage are obtained from Equation 9.
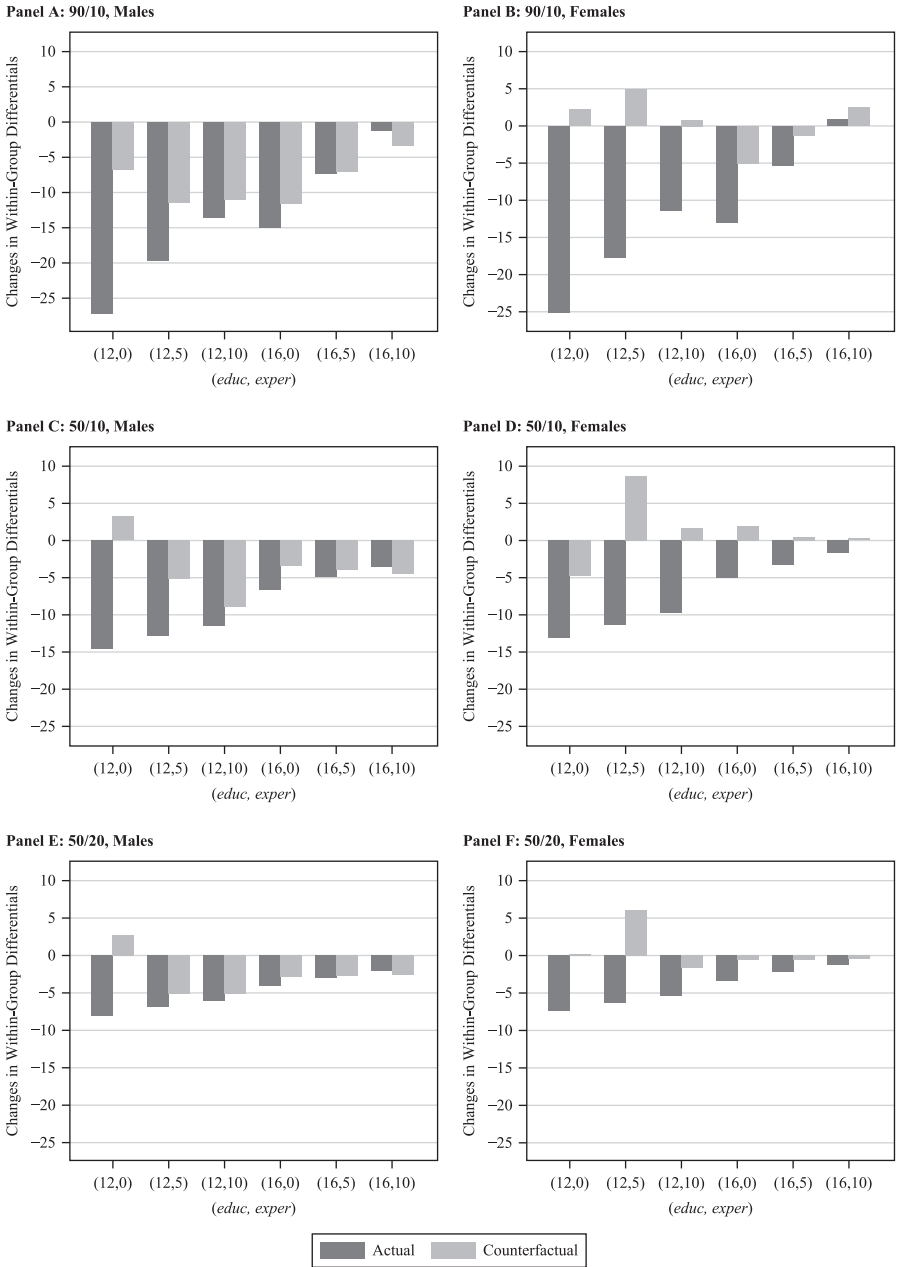
Figure 15

Actual and Counterfactual Changes in the 90/10, 50/10, and 50/20 Within-Group Differentials, 1989–2012

Notes: National means are reported. Counterfactual log-point changes in the within-group wage differentials are obtained using Equations 8 and 9.

VI. Conclusion

We examined the impact of the minimum wage on wage structure and evaluated the contribution of the minimum wage to changes in between- and within-group inequality in the United States. We employed quantile regression approaches to address the issues of heterogeneity, censoring, and missing wages.

We have shown that changes in the real value of the minimum wage over recent decades have affected the relationship of hourly wages with education, experience, and gender. In the literature, changes in between-group wage differentials are typically attributed to skill-biased technological change, compositional changes in the workforce, and changes related to gender discrimination. Our results indicate that changes in the real value of the minimum wage account in part for the patterns of changes in the education, experience, and gender wage differentials. If there were no increase in the real value of the minimum wage in the 1990s and 2000s, the education and experience wage differentials would increase more uniformly across quantiles, whereas the gender wage differential would decline less uniformly across quantiles.

We have further shown that the impact of the minimum wage is heterogeneous across quantiles of workers' productivity not attributable to their observed characteristics. In the literature, the sources of changes in within-group wage differentials are less conclusive than those of changes in between-group wage differentials. Our results indicate that changes in the real value of the minimum wage account for most of the changes in within-group wage differentials for workers with ten or fewer years of experience. In particular, the decline in the 50/10 and 50/20 within-group wage differential among female workers for the years 1989–2012 is attributed almost entirely to a rise in the real value of the minimum wage.

Overall, our results reveal that changes in the real value of the minimum wage influence between- and within-group wage differentials in the United States. Basically, it is not only supply and demand factors but also institutional factors that determine wage differentials among workers. Therefore, when we interpret the patterns of changes in wage differentials through the lens of economic models, there is a need to adjust the data taking into account the influence of the minimum wage. In addition, our results confirm that spillover effects are present, though limited to the first quintile for most of the demographic groups. A rise in the minimum wage increases actual wages paid to workers who earn slightly more than the minimum wage, as well as those who earn at the minimum wage. Therefore, there is a need to take into account spillover effects, as well as censoring effects, when we evaluate the distributional impact of the minimum wage.

References

Aaronson, Daniel, and Eric French. 2007. "Product Market Evidence on the Employment Effects of the Minimum Wage." *Journal of Labor Economics* 25(1):167–200.

Aaronson, Daniel, Eric French, Isaac Sorkin, and Ted To. 2018. "Industry Dynamics and the Minimum Wage: A Putty–Clay Approach." *International Economic Review* 59(1):51–84.

Angrist, Joshua, Victor Chernozhukov, and Iván Fernández-Val. 2006. "Quantile Regression under Misspecification, with an Application to the U.S. Wage Structure." *Econometrica* 74(2):539–63.

Autor, David H., Lawrence F. Katz, and Melissa S. Kearney. 2008. "Trends in U.S. Wage Inequality: Revising the Revisionists." *Review of Economics and Statistics* 90(2):300–323.

Autor, David H., Alan Manning, and Christopher L. Smith. 2016. "The Contribution of the Minimum Wage to US Wage Inequality over Three Decades: A Reassessment." *American Economic Journal: Applied Economics* 8(1):58–99.

Bell, Brian, and Stephen Machin. 2018. "Minimum Wages and Firm Value." *Journal of Labor Economics* 36(1):159–95.

Blau, Francine D., and Lawrence M. Kahn. 2017. "The Gender Wage Gap: Extent, Trends, and Explanations." *Journal of Economic Literature* 55(3):789–865.

Bosch, Mariano, and Marco Manacorda. 2010. "Minimum Wages and Earnings Inequality in Urban Mexico." *American Economic Journal: Applied Economics* 2(4):128–49.

Bound, John, and George Johnson. 1992. "Changes in the Structure of Wages in the 1980's: An Evaluation of Alternative Explanations." *American Economic Review* 82(3):371–92.

Buchinsky, Moshe. 1994. "Changes in the U.S. Wage Structure 1963–1987: Application of Quantile Regression." *Econometrica* 62(2):405–58.

Card, David, and John E. DiNardo. 2002. "Skill-Biased Technological Change and Rising Wage Inequality: Some Problems and Puzzles." *Journal of Labor Economics* 20(4):733–83.

Card, David, and Alan B. Krueger. 1995. *Myth and Measurement*. Princeton, NJ: Princeton University Press.

———. 2017. "Book Review: Myth and Measurement and the Theory and Practice of Labor Economics." *Industrial and Labor Relations Review* 70(3):826–31.

Chernozhukov, Victor, Iván Fernández-Val, and Amanda E. Kowalski. 2015. "Quantile Regression with Censoring and Endogeneity." *Journal of Econometrics* 186(1):201–21.

Chernozhukov, Victor, Iván Fernández-Val, and Blaise Melly. 2013. "Inference on Counterfactual Distributions." *Econometrica* 81(6):2205–68.

Chernozhukov, Victor, and Han Hong. 2002. "Three-Step Censored Quantile Regression and Extramarital Affairs." *Journal of the American Statistical Association* 97(459):872–88.

Chetverikov, Denis, Bradley Larsen, and Christopher Palmer. 2016. "IV Quantile Regression for Group-Level Treatments, with an Application to the Distributional Effects of Trade." *Econometrica* 84(2):809–33.

DiNardo, John, Nicole M. Fortin, and Thomas Lemieux. 1996. "Labor Market Institutions and the Distribution of Wages, 1973–1992: A Semiparametric Approach." *Econometrica* 64(5): 1001–44.

Draca, Mirko, Stephen Machin, and John Van Reenen. 2011. "Minimum Wages and Firm Profitability." *American Economic Journal: Applied Economics* 3(1):129–51.

Dube, Arindrajit. 2019. "Minimum Wages and the Distribution of Family Incomes." *American Economic Journal: Applied Economics* 11(4):268–304.

Dube, Arindrajit, Suresh Naidu, and Michael Reich. 2007. "The Economic Effects of a Citywide Minimum Wage." *Industrial and Labor Relations Review* 60(4):522–43.

Flinn, Christopher J. 2006. "Minimum Wage Effects on Labor Market Outcomes under Search, Matching, and Endogenous Contact Rates." *Econometrica* 74(4):1013–62.

Fortin, Nicole, and Thomas Lemieux. 2015. "Changes in Wage Inequality in Canada: An Interprovincial Perspective." *Canadian Journal of Economics* 48(2):682–713.

Giuliano, Laura. 2013. "Minimum Wage Effects on Employment, Substitution, and the Teenage Labor Supply: Evidence from Personnel Data." *Journal of Labor Economics* 31(1):155–94.

Hirsch, Barry T., Bruce E. Kaufman, and Tetyana Zelenska. 2015. "Minimum Wage Channels of Adjustment" *Industrial Relations* 54(2):199–239.

Hubbard, William H.J. 2011. "The Phantom Gender Difference in the College Wage Premium." *Journal of Human Resources* 46(3):568–86.

Jeong, Hyeok, Yong Kim, and Iourii Manovskii. 2015. "The Price of Experience." *American Economic Review* 105(2):784–815.

Johnson, William, Yuichi Kitamura, and Derek Neal. 2000. "Evaluating a Simple Method for Estimating Black–White Gaps in Median Wages." *American Economic Review Papers and Proceedings* 90(2):339–43.

Juhn, Chinhui, Kevin M. Murphy, and Brooks Pierce. 1993. "Wage Inequality and the Rise in Returns to Skill." *Journal of Political Economy* 101(3):410–42.

Kambayashi, Ryo, Daiji Kawaguchi, and Ken Yamada. 2013. "Minimum Wage in a Deflationary Economy: The Japanese Experience, 1994–2003." *Labour Economics* 24:264–76.

Katz, Lawrence, and David Autor. 1999. "Changes in the Wage Structure and Earnings Inequality." In *Handbook of Labor Economics*, Volume 3, Part A, ed. Orley C. Ashenfelter and David Card, 1463–555. New York: Elsevier.

Katz, Lawrence F., and Kevin M. Murphy. 1992. "Changes in Relative Wages, 1963–1987: Supply and Demand Factors." *Quarterly Journal of Economics* 107(1):35–78.

Koenker, Roger. 2017. "Quantile Regression: 40 Years On." *Annual Review of Economics* 9:155–176.

Koenker, Roger, and Gilbert Bassett. 1978. "Regression Quantiles." *Econometrica* 46(1):33–50.

Lazear, Edward P., and Sherwin Rosen. 1981. "Rank-Order Tournaments as Optimum Labor Contracts." *Journal of Political Economy* 89(5):841–64.

Lee, David S. 1999. "Wage Inequality in the United States During the 1980s: Rising Dispersion or Falling Minimum Wage?" *Quarterly Journal of Economics* 114(3):977–1023.

Lemieux, Thomas. 2006. "Increasing Residual Wage Inequality: Composition Effects, Noisy Data, or Rising Demand for Skill?" *American Economic Review* 96(3):461–98.

Machado, José A.F., and José Mata. 2005. "Counterfactual Decomposition of Changes in Wage Distributions Using Quantile Regression." *Journal of Applied Econometrics* 20(4):445–65.

Neumark, David, Mark Schweitzer, and William Wascher. 2004. "Minimum Wage Effects throughout the Wage Distribution." *Journal of Human Resources* 39(2):425–50.

Neumark, David, and William L. Wascher. 2008. *Minimum Wages*. Cambridge, MA: MIT Press.

Phelan, Brian J. 2019. "Hedonic-Based Labor Supply Substitution and the Ripple Effect of Minimum Wages." *Journal of Labor Economics* 37(3):905–47.

Powell, James L. 1986. "Censored Regression Quantiles." *Journal of Econometrics* 32(1):143–55.

Teulings, Coen N. 2003. "The Contribution of Minimum Wages to Increasing Wage Inequality." *Economic Journal* 113(490):801–3.

Wei, Ying. 2017. "Quantile Regression with Measurement Errors and Missing Data." In *Handbook of Quantile Regression*, ed. Roger Koenker, Victor Chernozhukov, Xuming He, and Limin Peng, 165–83. Boca Raton, FL: Chapman and Hall/CRC.

Welch, Finis. 1979. "Effects of Cohort Size on Earnings: The Baby Boom Babies' Financial Bust." *Journal of Political Economy* 87(5):S65–S97.

Yoon, Jungmo. 2010. "Quantile Regression Analysis with Missing Response with Applications to Inequality Measures and Data Combination." http://dx.doi.org/10.2139/ssrn.2952579