Technical Annex A: Evidence from Seven US States on the Impact of High Minimum Wages

In this Annex, we describe the analysis underlying the estimates in Charts 4.B and Chart 4.E for the seven states in the U.S. that have implemented high levels of minimum wages. The analysis here closely follows Cengiz, Dube, Lindner and Zipperer (2019), but updates the results to include recent increases in the minimum wage that are higher (especially in terms of coverage).

The seven states were selected based on the following criteria: namely that they had instituted a new minimum wage of at least $10.50 by 2018. These states are New York, California, Maine, Washington, Vermont, Oregon, and Arizona. Of these seven states, Arizona, Oregon, Vermont and Washington index their minimum wages to inflation, creating incremental changes in the minimum wage prior to the major minimum wage hikes. The total change in the minimum wage is large for all states, ranging from Vermont which raised its minimum wage from $8.15 to $10.50 between 2012 and 2018 to New York which raised the state minimum wage from the federal minimum of $7.25 to $11.10 between 2013 and 2018. These increases are substantial: on average, this group of states increased their minimum wage by 30% without using population weights, and 38% when weighted by population. On average, around 17% of existing jobs paid below the new minimum wage one year prior to the policy, when averaged without population weights (or 20% using population weights). These are much larger changes than prior minimum wage increases in the U.S. For example, the sample of Cengiz et al., which included all minimum wage increases above $0.25, had an average increase in the minimum wage of 10% that put around 9% of employment below the new MW. To emphasize, the sample of minimum wage changes considered here affects a share of the workforce that is twice as large as what was considered in Cengiz et al.

For each treatment event (i.e. a minimum wage rise), the control group includes the 21 states that didn't increase their minimum wage in the 2010-2018 period except New Mexico, which is excluded due to a large and persistent increase in the minimum wage in its largest city, Albuquerque. To clarify, all the states in the control sample have a minimum wage of $7.25 throughout the entire sample, which is the federal minimum wage.

The analysis in this report closely follows the methodology used by Cengiz et al. Our primary source of data is the Consumer Population Survey Outgoing Rotation Group (CPS-ORG) for 2011-2018. The CPS-ORG provides individual level data that is used to estimate the quarterly distribution of hourly wages and employment for each state. We estimate this distribution using only observations with non-imputed earnings. The CPS-ORG provides a direct measurement of the hourly wage for hourly workers. For non-hourly workers, we estimate the hourly earnings as the respondent's usual weekly earnings divided by their usual hours worked per week. We next deflate the hourly wages to 2018 dollars using the monthly consumer price index. We create seven different datasets—one for each event—that includes all observations from the treated state, as well as the 21 control states. In each dataset, each worker is assigned to one of four \$1 wage bins below the new minimum (where the bottom bin includes all workers employed for less than \$4 below the new minimum), or one of 18 \$1 bins at or above the new minimum wage.[1] The individual level data is then collapsed into an employment count measuring total number of workers in each quarterly, state-level wage bin for each event. This employment count is benchmarked against administrative data from the Quarterly Census of Employment and Wages (QCEW) to reduce measurement error following Cengiz et al. The seven event-specific datasets are then "stacked" to obtain a single dataset of event-state-quarter-\$1 wage bin employment counts and hourly wage estimates.

The regression specification used here is a stacked difference-in-difference as follows:

$$\frac{E_{hsjt}}{N_{hst}} = \sum_{\tau=-3}^{2} \sum_{k=-4}^{17} \alpha_{\tau k} I_{hsjt}^{\tau k} + \mu_{hsj} + \Omega_{hsjt} + u_{hsjt} \qquad (1)$$

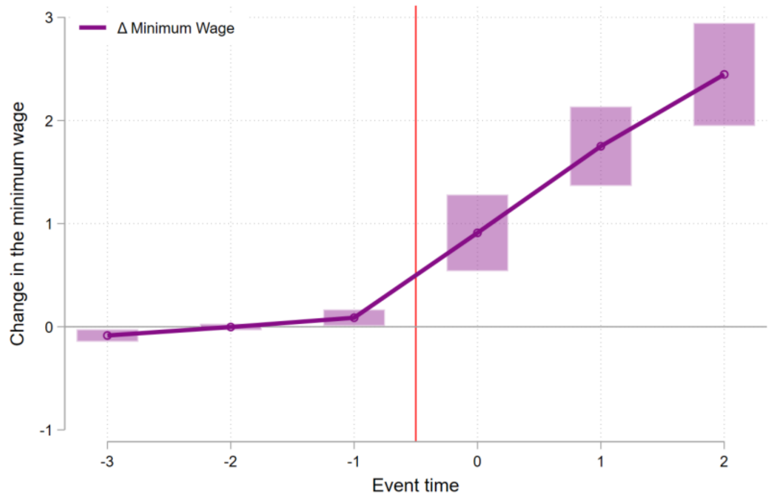
where E_{hsjt} is the employment count in \$1 wage bin j in state s for event h and during quarter t and N_{hst} is the population of state s during quarter t for event h. The wage bins are constructed relative to the new minimum wage for each event. $I_{hsjt}^{\tau k}$ is a treatment dummy variable taking value one if the minimum wage was raised in state s, τ time periods from date t for each dollar group k. Here τ represents event time in years relative to the minimum wage change for $\tau < 1$. For example, $\tau = 0$ represents the first full year following the first minimum wage increase. The $\tau = 1$ category includes all intermediate periods between the first and the penultimate year of the post-treatment period, while $\tau = 2$ represents the last full year of the post treatment period (i.e., 2018). This slightly non-standard way of delineating event time allows us to look at the effect in the most recent period in calendar time (2018), which is of particular interest given the phased-in nature of the minimum wage increases we are studying (more on this below). Indeed, the key estimate of interest is the most recent period effect, where the minimum wage is the highest.

This specification produces estimates for the impact of the minimum wage $\alpha_{\tau k}$ to vary by dollar group k and by event-time period τ. This specification also controls for event-state-wage bin fixed effects and event-time-wage bins fixed effects. Standard errors are clustered by state, which is the level policy is assigned. In the same manner as the benchmark estimates, we then find changes in the excess jobs above (Δa), missing jobs below (Δb) and the percentage change in affected wages ($\%\Delta w = \frac{\%\Delta \text{wb} - \%\Delta e}{1 + \%\Delta e}$) where the percentage

[1] The wage bins are defined for each event as (0.00, $MW_{2018q4}^{Treated}$-3), [$MW_{2018q4}^{Treated}$-3, $MW_{2018q4}^{Treated}$-2), [$MW_{2018q4}^{Treated}$-2, MW-1), … , [$MW_{2018q4}^{Treated}$+17, ∞).

change in the affected wage bill is the product of sample average wages for each dollar group with the change in employment for the dollar group.

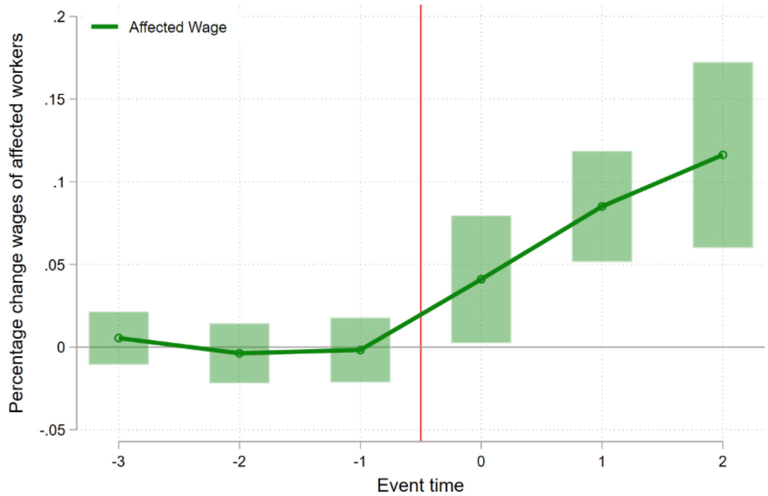
Figure A1— Evolution of the Minimum Wage in Treated Versus Control States



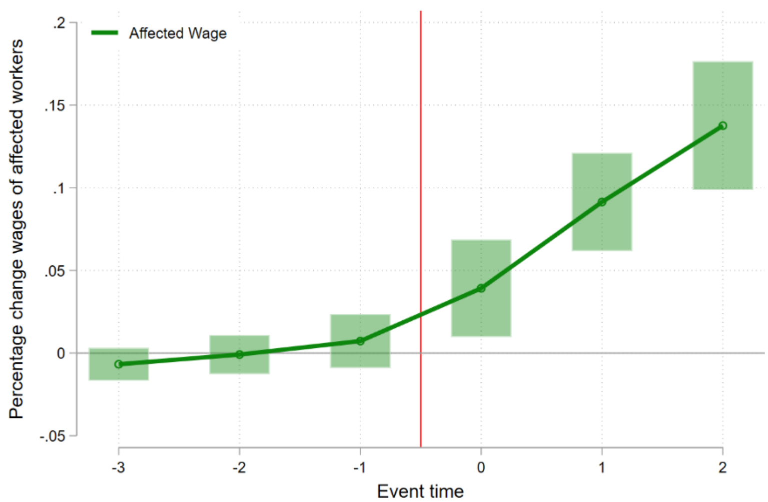
Notes: This figure shows the evolution of the minimum wage in treated versus control states. The estimates are found from a stacked difference-in-difference model that is similar to Equation (1) but doesn't estimate the change across the wage distribution. Specifically, we regress the quarterly, state minimum wage on treatment indicators I_{hst}^{τ} that value one if the minimum wage was raised in state s τ time periods from date t of event h. Here τ represents event-time in years relative to the minimum wage change for $\tau < 1$. The event-time $\tau = 1$ includes all time periods after one year of the minimum wage change but before the last year of the minimum wage change, while $\tau = 2$ represents the last full year of post treatment period (i.e., 2018). The purple line depicts the average change in the minimum wage in the treated group relative to the control group. The shaded area is the 95% confidence interval based on standard errors that are clustered by state.

Figure A1 shows the evolution of the minimum wage for states with minimum wages over $10.50. Minimum wage policies tend to be implemented gradually. The average policy has increased the minimum wage by 1 dollar in the first year and by approximately $2.50 during the post-treatment sample. The figure also shows a slight positive pre-trend in the minimum wage indicating that the treated states are more likely to index their minimum wages to inflation than the control states, resulting in very small increases in the treated minimum wage prior to treatment.

Figure A2— Impact of Minimum Wage Changes on Affected Wages Over Time



(a) Unweighted

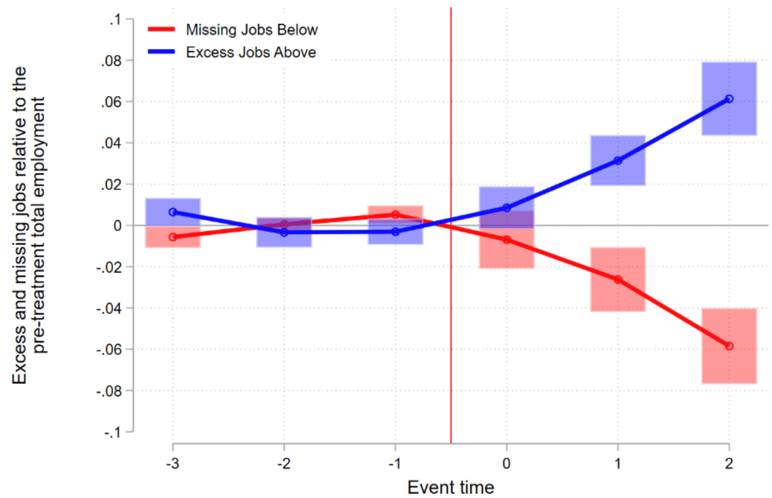


(b) Weighted by population size

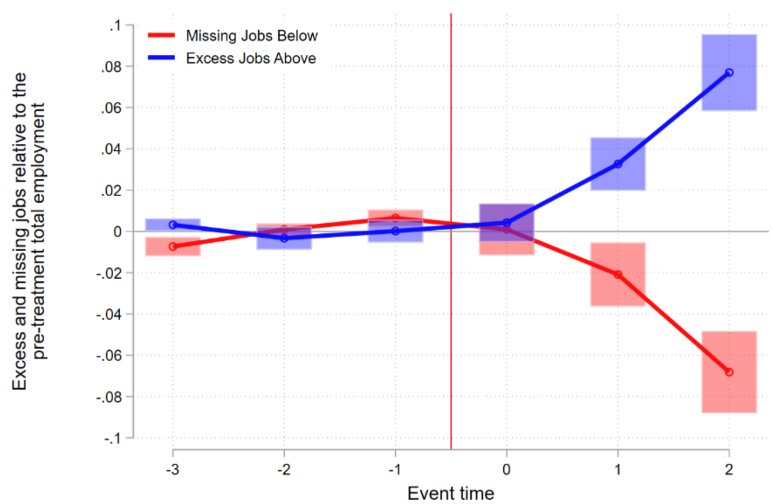
Notes: These figures show the effect of high minimum increases on affected wages with and without population weights. The green line depicts the average percentage change in wages for affected workers relative to the average wage of affected workers in states that increased their minimum wage above $10.50, over the three years prior to the initial raise. Workers are "affected" if their wage is less than five dollars above the new minimum wage. The shaded area is the 95% confidence interval based on standard errors that are clustered by the state, calculated using the delta method. Here τ represents event-time in years relative to the minimum wage change for $\tau < 1$. The event-time $\tau = 1$ includes all time periods after one year of the minimum wage change but before the last year of the minimum wage change, while $\tau = 2$ represents the last full year of post treatment period (i.e., 2018).

Figure A2 depicts the evolution of wages for workers affected by minimum wage changes, with and without population weights. The figures show a large wage increase of approximately 12.5% during the last year of the post-treatment period. The figures show that the policy has an immediate, positive impact on the wages of affected workers of approximately 4% in the first year of the policy, but grows considerably over time, and exceeds 12% in the last year out ($\tau = 2$). The gradual impact on average wages of affected workers reflects the fact that these increases are phased in, as shown in Figure A1. The use of population weights seems to have little impact on the estimated effect on affected wages but does increase the precision.

Figure A3— Impact of Minimum Wage Changes on Missing and Excess Jobs Over Time



(a) Unweighted



(b) Weighted by population

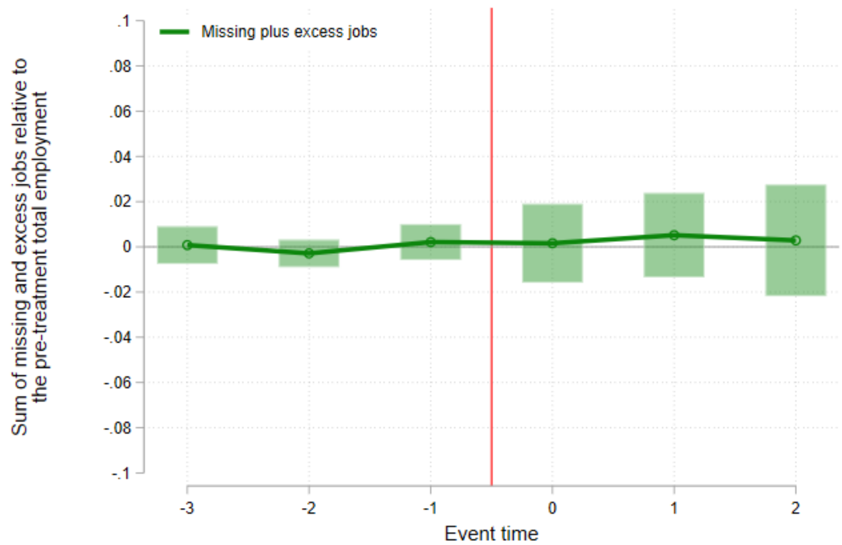
Notes: These figures show the effect of high minimum increases on missing and excess jobs with and without population weights. The regression specification is given in equation (1) and includes state-event-dollar group fixed effects and event-time-dollar group fixed effects. The specification estimates the employment effect for every dollar group.

The red line depicts the average change in missing jobs. Jobs are "missing" if their wage is less than the new minimum wage. The missing jobs below the new minimum wage are estimated as the averaged effects for the dollar-groups below the new minimum wage. The red shaded area is the 95% confidence interval for the missing jobs below the new minimum wage based on standard errors that are clustered by state.

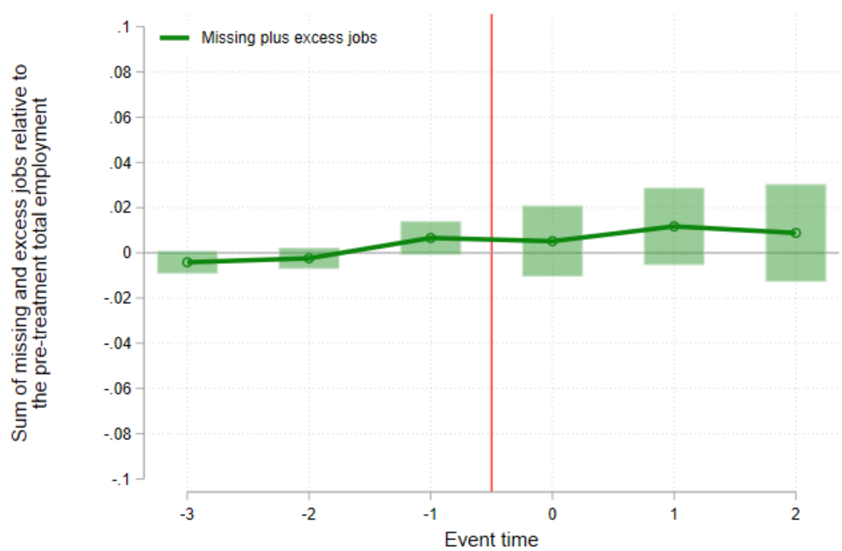
The blue line depicts the average change in excess jobs. Jobs are "excess" if their wage is at least the new minimum wage but less than five dollars above the new minimum wage. The excess jobs above the new minimum wage are estimated as the averaged effects for the dollar-groups between the new minimum wage and five dollars above the new minimum wage. The blue shaded area is the 95% confidence interval for the excess jobs above the new minimum wage based on standard errors that are clustered by state. Here τ represents event-time in years relative to the minimum wage change for $\tau < 1$. The event-time $\tau = 1$ includes all time periods after one year of the minimum wage change but before the last year of the minimum wage change, while $\tau = 2$ represents the last full year of post treatment period (i.e., 2018).

Figure A3 shows the evolution of the impact of the policy on missing and excess jobs with and without population weights. Recall that missing jobs is the number of fewer jobs paying below the new (last period) minimum wage, while excess jobs is the additional jobs paying at or up to $4 above the new minimum wage. The impact of the policy is large, and again grows over time reflecting the phase-in. During the first year after the policy, there is no significant change in the missing or excess jobs suggesting the first phase was not very binding. In contrast, by the last year of the post-treatment period, the missing jobs estimates are between 6 and 8 percent across specifications. Importantly, however, the excess jobs are of a similar magnitude. The use of population weights has limited influence on the estimates, and there doesn't seem to be a substantive difference in the pretreatment trends of both missing and excess jobs between the control and treated states. The figure does show a statistically significant difference in the missing jobs three years prior to the policy; however, the estimate is small in magnitude and very precise.

Figure A3— Impact of Minimum Wage Changes on Employment (Missing plus Excess Jobs)



(a) Unweighted



(b) Weighted by Population

Notes: These figures show the effect of high minimum wage increases on affected employment with and without population weights. The red line depicts the average percentage change in wages for affected workers relative to the average employment of affected workers in states that increased their minimum wage above $10.50 over the three years prior to the initial raise. Workers are "affected" if their wage is less than five dollars above the new minimum wage. The shaded area is the 95% confidence interval based on standard errors that are clustered by the state. The regression specification is given in equation (1) and includes state-event-dollar group fixed effects and event-time-dollar group fixed effects. The specification estimates the employment effect for every dollar group. The figure displays the total effects for the dollar-groups up to five dollars above the new minimum wage. Here τ represents event-time in years relative to the minimum wage change for $\tau < 1$. The event-time $\tau = 1$ includes all time periods after one year of the minimum wage change but before the last year of the minimum wage change, while $\tau = 2$ represents the last full year of post treatment period (i.e., 2018).

Figure 4A displays the evolution of the policy's impact on low-wage employment by summing the excess and missing jobs estimates. The estimates highlight that while the excess and missing jobs estimates are quite large in magnitude (especially in the last year of treatment), the change in the overall number of low wage jobs is quite small, and statistically indistinguishable from zero. The figure also does not indicate major differences in the employment trends between the treated and control states based on weighting.

Table A1 explores the robustness of the estimates to the use of weights, as well as the definition of the baseline (pre-treatment) period. Column (2) of Table A1 (the estimate used in the main report) uses population weights, and compares the last year out ($\tau = 2$) to the 3-year pre-treatment period $\tau \in [-3, -1]$. The estimates suggests that these high minimum wage increases have led to a reduction of jobs paying below the new minimum wage by 6.8%, while increasing the number of excess jobs at-or-just-above the minimum wage by 7.7%. These results are large relative to prior research on the impact of minimum wage changes in general that uses a comparable specification, suggesting the bite of the policy increases with the magnitude of the new minimum wage.[2] While the percentage change in employment is small and statistically insignificant, the wage gains seem to be large. We find a precise 13.8% increase in wages paid to affected workers. Our results also suggest most of these wage gains are due to spillovers, meaning most of the wage gains are not directly attributable to wage increases for workers who were paid below the new MW prior to the increase.

Columns (1) through (8) of Table A1 assess the variability in the estimates by the post-treatment window length, the use of population weights and the baseline pretreatment length used to construct the percentage change. Overall, the effect on missing and excess jobs (and wages) is much larger in the last year of the sample than the average post-treatment effect and the gap is larger when population weights are applied. Comparing Columns (1) and (2) to Columns (3) and (4) and Columns (5) and (6) to columns (7) and (8) gives the robustness of the findings to the use of population weights. Population weights tend to increase the magnitude of the estimates, but the increase is small and statistically indistinguishable; use of population weights does typically tend to increase precision. Similarly, the use of a one-year versus 3-year baseline to construct the percentage change estimates has only modest effect, slightly increasing the

[2] For comparison, the pooled stacked analysis given by Dube et al (2019) reported in column (2) of Table (D.1) found the missing jobs below new minimum wage to be -1.8% (0.004) and excess jobs above the new minimum wage of 2.1% (.004), resulting in a 2.8% (.029) increase in affected employment.

estimated missing jobs below the new minimum wage, which decreases both estimated wage and employment gains for affected workers. Again, this decrease is small.

The spillover share of the wage increase is somewhat larger here than found in Cengiz et al. Across specifications, the last year out spillover share of wage increase ranges between 41% and 69%, with 3 out of the 4 specifications being above 50%; in contrast Cengiz et al. found it to be around 40%.

Table A1—Impact of Minimum Wages on Employment and Wages and the Influence of Population Weights, the Treatment Window and the Baseline Length

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Missing jobs below new MW (Δb)	-0.027***	-0.068***	-0.029***	-0.058***	-0.033***	-0.074***	-0.034***	-0.063***
	(0.007)	(0.010)	(0.007)	(0.009)	(0.006)	(0.010)	(0.006)	(0.009)
Excess jobs above new MW (Δa)	0.037***	0.077***	0.033***	0.061***	0.036***	0.076***	0.036***	0.064***
	(0.006)	(0.010)	(0.005)	(0.009)	(0.005)	(0.008)	(0.006)	(0.010)
%Δ affected wages	0.090***	0.138***	0.081***	0.116***	0.080***	0.125***	0.082***	0.116***
	(0.013)	(0.020)	(0.017)	(0.029)	(0.010)	(0.019)	(0.018)	(0.029)
%Δ affected employment	0.049	0.044	0.024	0.017	0.015	0.010	0.012	0.004
	(0.040)	(0.055)	(0.054)	(0.073)	(0.028)	(0.046)	(0.051)	(0.074)
Employment elasticity w.r.t. MW	0.129	0.116	0.081	0.055	0.040	0.027	0.039	0.014
	(0.104)	(0.145)	(0.180)	(0.242)	(0.073)	(0.121)	(0.169)	(0.244)
Emp. Elasticity w.r.t. affected wage	0.543	0.320	0.300	0.142	0.188	0.083	0.144	0.037
	(0.406)	(0.365)	(0.631)	(0.609)	(0.339)	(0.357)	(0.606)	(0.627)
%Δ affected wage no spillover		0.058***		0.066***		0.061***		0.072***
		(0.013)		(0.013)		(0.012)		(0.011)
Spillover share of wage increase		0.692***		0.512		0.556*		0.410
		(0.187)		(0.444)		(0.291)		(0.573)
Jobs below new MW $(\bar{b}_{-1})$		0.200		0.172		0.200		0.172
%Δ MW		0.381		0.301		0.381		0.301
Min-to-Med Wage (Treated)		0.527		0.527		0.527		0.527
Number of events	7	7		7		7		7
Number of observations	5544	5544	5544	5544	5544	5544	5544	5544
Population weights	Yes	Yes	No	No	Yes	Yes	No	No
Treatment window	Full	Last Year	Full	Last Year	Full	Last Year	Full	Last Year
Baseline pretreatment length	3	3	3	3	1	1	1	1

Notes: This table reports the effects of minimum wage increases above $10.50 from 2011-2018 using the stacked difference-in-difference model given in Equation (1). This model reports the average effect for the 7 events. The table reports estimates with and without population weights to gauge the influence of weighting. The table reports both baselines to assess how the baseline choice influences the estimates. Last, the table also reports the estimates averaged over the entire post-treatment period and averaged over only the last post-treatment year. The regression includes event-state-wage bin and event-time-wage bin fixed effects. Standard errors are clustered by state. Significance levels are * 0.10, ** 0.05, *** 0.01.

Line-by-line description. Row one displays the missing jobs below the new minimum wage (Δb) which is the estimated effect on wage bins below the new MW relative to pretreatment total employment during. Row two reports the excess jobs above the new minimum wage (Δa) which is the estimated effect on wage bins at or above the new minimum wage but less than five dollars above the new minimum wage. Row three reports the percentage change in the average wages of affects workers $\left(\frac{\%\Delta wb - \%\Delta e}{1+\%\Delta e}\right)$. Row four reports the percentage change in employment for affected workers $\left(\frac{\Delta a+\Delta b}{\bar{b}_{-1}}\right)$. Row five reports the employment elasticity with respect to the minimum wage $\left(\frac{1}{\%\Delta MW}\frac{\Delta a+\Delta b}{\bar{b}_{-1}}\right)$. Row six reports the employment elasticity with respect to the affected wage $\left(\frac{1}{\%\Delta w}\frac{\Delta a+\Delta b}{\bar{b}_{-1}}\right)$; the standard error is found using the delta method. Row seven gives the percentage change in the affected wage without spillover, which is the percentage change in wages had all of the missing jobs been paid the new minimum wage $\left(\frac{\sum_{k=-4}^{-1} k(\alpha_k - \alpha_{-1k})}{\overline{wb}_{-1}}\right)$. Row eight reports the spillover share of the total wage increase $\left(\frac{\%\Delta w - \%\Delta w_{no\ spillover}}{\$\Delta w}\right)$; the standard error is estimated using the delta method.

Table A2—Impact of Minimum Wages on Employment and Wages by Demographic Groups

	(1)	(2)	(3)	(4)
Missing jobs below new MW (Δb)	-0.070*	-0.094***	-0.108***	-0.120***
	(0.040)	(0.034)	(0.037)	(0.034)
Excess jobs above new MW (Δa)	0.090***	0.108***	0.125***	0.153***
	(0.020)	(0.026)	(0.039)	(0.043)
%Δ affected wages	0.111***	0.106***	0.094***	0.089***
	(0.016)	(0.016)	(0.013)	(0.015)
%Δ affected employment	0.040	0.029	0.024	0.049
	(0.083)	(0.062)	(0.057)	(0.059)
Employment elasticity w.r.t. MW	0.105	0.095	0.062	0.161
	(0.216)	(0.206)	(0.150)	(0.196)
Emp. Elasticity w.r.t. affected wage	0.362	0.270	0.250	0.546
	(0.788)	(0.583)	(0.617)	(0.642)
Jobs below new MW $(\bar{b}_{-1})$	0.513	0.505	0.713	0.688
%Δ MW	0.384	0.301	0.380	0.301
Min-to-Med Wage (Treated)	0.877	0.886	0.944	0.951
Min-to-Med Wage (All)	0.981	1.008	1.120	1.126
Number of events	7	7	7	7
Number of observations	5544	5544	5544	5544
Population weights	Yes	No	Yes	No
Post period	Full	Full	Full	Full
Sample	Less than high school	Less than high school	High probabilit y	High probabilit y

Notes: This table reports the effects of minimum wage increases above $10.50 from 2011-2018 using the stacked difference-in-difference model given in Equation (1) for three demographic groups: workers with less than a high school education, and those predicted to have a high probability of being minimum wage workers (based on the Card and Krueger approach). This model reports the average effect for the 7 events. The table reports estimates with and without population weights to gauge the influence of weighting. The population weights are the quarterly, state level demographic group population. The regression includes event-state-wage bin and event-time-wage bin fixed effects. Standard errors are clustered by state. Significance levels are * 0.10, ** 0.05, *** 0.01.

Line-by-line description. Row one displays the missing jobs below the new minimum wage (Δb) which is the estimated effect on wage bins below the new MW relative to pretreatment total employment during. Row two reports the excess jobs above the new minimum wage (Δa) which is the estimated effect on wage bins at or above the new minimum wage but less than five dollars above the new minimum wage. Row three reports the percentage change in the average wages of affects workers $\left(\frac{\%\Delta wb - \%\Delta e}{1+\%\Delta e}\right)$. Row four reports the percentage change in employment for affected workers $\left(\frac{\Delta a+\Delta b}{\bar{b}_{-1}}\right)$. Row five reports the employment elasticity with respect to the minimum wage $\left(\frac{1}{\%\Delta MW}\frac{\Delta a+\Delta b}{\bar{b}_{-1}}\right)$. Row six reports the employment elasticity with respect to the affected wage $\left(\frac{1}{\%\Delta w}\frac{\Delta a+\Delta b}{\bar{b}_{-1}}\right)$; the standard error is calculated using the delta method.

Table A2 reports estimates of the impact of the minimum wage for demographic groups that are particularly likely to be low-wage workers. This includes those without a high school degree, and a "high probability group" using the method proposed by Card and Krueger (1995), and also implemented in Cengiz et al. The bite of the minimum wage is larger for these groups, as indicated by the larger magnitude of missing jobs below (Δb) than in Table A1. For all groups, there is a small, but not statistically significant, increase in employment for affected workers. While the own-wage elasticities of these subgroups are somewhat imprecise compared to the overall low-wage employment in Table A1, they rule out *OWE*'s more negative than -0.93 (less than HS) or -0.77 (high probability group) at the 90 percent confidence level.