Online Appendices for
Effects of the Minimum Wage on Employment Dynamics

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Online Appendix 1. Results using additional data sets

In this appendix we provide empirical results similar to those in the main text, but using data from the Quarterly Census of Employment and Wages and the Quarterly Workforce Indicators, rather than from the Business Dynamics Statistics. The results are consonant with those in Section IV of the paper. Note that these data are quarterly rather than annual. As such, additional lags are included in the distributed lag models to cover the same temporal span as the annual specifications from the BDS.

A. Data

1. Quarterly Census of Employment and Wages (QCEW)

The *Quarterly Census of Employment and Wages* (QCEW), housed at the Bureau of Labor Statistics, is a program which originated in the 1930s to tabulate employment and wages of establishments which report to the Unemployment Insurance (UI) programs of the United States. Per the BLS, employment covered by these UI programs today represents about 99.7% of all wage and salary civilian employment in the country (including public sector employment). The BLS currently reports QCEW data by state for each quarter during 1975-2012, a span slightly longer than that of the BDS.[17] The data are disaggregated by NAICS industry codes for 1990-2012.

2. Quarterly Workforce Indicators

The *Quarterly Workforce Indicators* are data provided as part of the Longitudinal Employer-Household Dynamics (LEHD) program by the Bureau of the Census. Similar to the QCEW, these data originate from county employment insurance filings.[18]

Yet, for our research design, a major shortcoming of the QWI is the substantially shorter – and highly unbalanced – length of the panel. At its onset in 1990, only four states participated in the QWI program, and additional states gradually joined through 2004. From 2004 on, the QWI includes forty-nine states (Massachusetts and Washington, D.C. are never included). Thus, the starting date for QWI participation varies considerably across states, and many are relatively recent. In addition to the standard concerns with unbalanced panels, this is of particular concern for the distributed lag models, as including sixteen minimum wage terms reduces the sample size by over twenty percent.

[17] Employment levels – and therefore also quarterly job growth rates – are not available in the QCEW for Alaska and the District of Columbia for any quarters during 1978-1980. Employment data is not missing for any other states or periods.

[18] In fact, the QWI and QCEW originate identically from the same county unemployment insurance records. Thus, differences in the data stem from either the periods during which each state or county is included, or differing imputation methods employed by BLS versus Census [Abowd and Vilhuber, 2013].

B. Results

We follow the same pattern of specifications as in Section IV of the paper. As with the BDS, the classic state-panel fixed effects estimates in Table OA1.2 tend to have a negative and statistically significant estimate of the impact of the minimum wage on employment. Inclusion of leads in the QCEW raises some suspicions of pre-existing trends, though the contemporaneous effect is still sizable in magnitude and remains statistically significant (and statistically equivalent to the estimate without leading terms in Column (3)). It is also worth noting that because these are quarterly data, the leading periods are much closer in time to the "treatment period" in which the minimum wage actually changes; thus, we would expect leading terms in these data sets to be more likely to detect any anticipatory action on the part of firms with respect to the future change in minimum wage. As with the BDS, inclusion of state-specific time trends in Column (6) drives the estimated effect to zero. Turning to the long-difference estimates in Table OA1.3, we increase each lag by four quarters to match the timespan in the BDS. The general pattern of effects that increase in magnitude with the length of the difference is present, particularly in the QWI. Once again, the inclusion of trends eliminates this tendency.

Finally, the distributed lag first-differences estimates in Table OA1.4 also follow the same pattern as those in Table 4 of the paper. We include the contemporaneous value of the minimum wage, as well as fifteen lags, to match the same time frame as the BDS. For brevity, we present the sum of these effects rather than each individual coefficient, though full results with all coefficients are available on request (or in data and code provided by the authors online). In Column (1), we see that both the QCEW and the QWI produce a statistically significant total long-run elasticity of the minimum wage on employment of about -0.08, very similar in magnitude to that from the BDS. In Column (2), we add four lead terms and report their sum to test for pre-existing trends. This term is statistically insignificant and trivial in magnitude for both the QCEW and QWI, and the coefficients are jointly insignificantly different from zero. Moreover, the sum of the sixteen coefficients of interest is unaffected. In Column (3), we include eight lead terms and again find no evidence of pre-existing trends that would suggest that our results are being driven by confounding factors. Columns (4) through (6) follow the robustness checks in Table 4 of the paper and illustrate the stability of results.

Altogether, it is evident that our results are not driven by the choice of data set; each of the three sources produces the same conclusions.

Table OA1.1: Summary statistics for state characteristics and employment outcomes in three administrative data sets

	BDS Annual, 1977 - 2011			**QCEW** Quarterly, 1975 - 2012			**QWI** Quarterly, varies - 2012*		
	Mean	Std. Dev.	Median	Mean	Std. Dev.	Median	Mean	Std. Dev.	Median
State minimum wage ($)	4.40	1.360	4.25	4.53	1.535	4.25	5.86	1.094	5.15
State minimum wage ($real)	7.09	0.916	6.89	7.28	0.975	7.05	6.89	0.729	6.85
Jobs (thousands)	1888.0	2103.8	1224.9	2167.9	2402.9	1441.7	2621.4	2794.2	1763.7
Job growth (thousands)	27.2	85.59	15.4	8.77	65.04	4.28	4.35	74.03	6.15
Job growth (log)	0.017	0.0348	0.019	0.0051	0.0256	0.0049	0.0019	0.0241	0.0061
Population (thousands)	5160.6	5725.6	3513.4	5138.0	5704.7	3502.0	6136.5	6784.5	4343.4
Share aged 15-59	0.62	0.0196	0.62	0.62	0.0199	0.62	0.62	0.0145	0.62
GSP/capita ($real)	41,592	16,310	38,447	41,302	16,334	38,148	45,345	8384	43,969
Observations	1785			7752			3029		

Notes: We define each state's minimum wage annually as of March 12 in the BDS, and as of the first date for each quarter in the QCEW and QWI. We use the maximum of the federal minimum wage and the state's minimum wage each period, drawn from state-level sources. Employment statistics are computed for the aggregate population of non-agricultural employees in each state for each of the three listed data sets. Job growth is the change in each state's employment level from one time period to the next. We use job growth and employment outcomes annually for the BDS and quarterly for the QCEW and QWI. All real dollar amounts are indexed to $2011 using the CPI-Urban. The QWI is a highly unbalanced panel, beginning with only four states in 1990 and gradually expanding until forty-nine states had joined by 2004. We include all available state-quarters of the QWI.

Table OA1.2: Classic state-panel fixed effect estimates for the effect of the minimum wage on log-employment

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: QCEW						
Log-MW	-0.1116	-0.1344***	-0.1391***	-0.0976***	-0.0923***	0.0010
	(0.1192)	(0.0458)	(0.0473)	(0.0345)	(0.0335)	(0.0171)
1st lead of log-MW				-0.0442*	0.0078	
				(0.0248)	(0.0131)	
2nd lead of log-MW					-0.0600***	
					(0.0220)	
Observations	7728	7728	7728	7677	7626	7728
Panel B: QWI						
Log-MW	-0.0384	-0.0165	-0.0447*	-0.0439***	-0.0443***	-0.0071
	(0.0441)	(0.0226)	(0.0231)	(0.0162)	(0.0163)	(0.0147)
1st lead of log-MW				-0.0014	0.0132	
				(0.0167)	(0.0175)	
2nd lead of log-MW					-0.0171	
					(0.0199)	
Observations	3029	3029	3029	2980	2931	3029
Time FE	National	National	Regional	Regional	Regional	Regional
Time-varying controls	No	Yes	Yes	Yes	Yes	Yes
Jurisdiction time trends	No	No	No	No	No	Yes

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$ Notes: Robust standard errors are clustered by state and reported in parentheses. All columns include state fixed effects. Where included, state-level annual time-varying controls are log-population, the share aged 15-59, and log real gross state product per capita.

Table OA1.3: Long difference estimates for the effect of the minimum wage on log-employment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of quarters:	4	8	12	16	20	24	28	32
Panel A: QCEW without trends								
Long difference in log-MW	-0.0028	-0.0091	-0.0152	-0.0079	-0.0071	-0.0136	-0.0276	-0.0356*
	(0.0069)	(0.0094)	(0.0118)	(0.0124)	(0.0136)	(0.0164)	(0.0184)	(0.0205)
Panel B: QCEW with trends								
Long difference in log-MW	-0.0024	-0.0080	-0.0127	-0.0028	0.0031	0.0058	0.0035	0.0039
	(0.0067)	(0.0089)	(0.0110)	(0.0113)	(0.0124)	(0.0146)	(0.0162)	(0.0177)
Observations	7516	7304	7092	6896	6700	6504	6300	6096
Panel C: QWI without trends								
Long difference in log-MW	-0.0067	-0.0092	-0.0165	-0.0208	-0.0242	-0.0337	-0.0430*	-0.0469*
	(0.0078)	(0.0105)	(0.0125)	(0.0152)	(0.0182)	(0.0209)	(0.0225)	(0.0265)
Panel D: QWI with trends								
Long difference in log-MW	-0.0044	-0.0072	-0.0128	-0.0145	-0.0133	-0.0164	-0.0196	-0.0102
	(0.0077)	(0.0096)	(0.0105)	(0.0124)	(0.0161)	(0.0194)	(0.0193)	(0.0203)
Observations	2833	2637	2441	2245	2049	1853	1657	1461

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$ Notes: Robust standard errors are clustered by state and reported in parentheses. The "number of quarters" row corresponds to the number of periods over which the long difference is taken. All columns include state fixed effects, quarterly-by-Region time fixed effects, and state-specific time-varying controls: log-population, the share aged 15-59, and log real gross state product per capita.

Table OA1.4: Distributed lag first-differences estimates for the effect of the minimum wage on log-employment

	Baseline	Leading values		Division FE	Non-indexed	Pre-2008
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: QCEW						
Current + Lags	-0.0820**	-0.0875***	-0.0880**	-0.0559	-0.0729**	-0.0869***
	(0.0313)	(0.0305)	(0.0334)	(0.0345)	(0.0311)	(0.0302)
Leads		-0.0059	0.0069			
		(0.0070)	(0.0138)			
Observations	6918	6714	6510	6918	6698	5898
Panel B: QWI						
Current + Lags	-0.0863**	-0.1114***	-0.0873	-0.0702**	-0.0612*	-0.1023**
	(0.0333)	(0.0384)	(0.0532)	(0.0342)	(0.0310)	(0.0413)
Leads		-0.0038	0.0034			
		(0.0152)	(0.0251)			
Observations	2245	2049	1853	2245	2026	1366

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$ Notes: Robust standard errors are clustered by state and reported in parentheses. All columns include state fixed effects, quarterly-by-Region time fixed effects, and state-specific time-varying controls: log-population, the share aged 15-59, and log real gross state product per capita. Columns (2) - (3) include, respectively, the leading values of the log minimum wage during the preceding year or preceding two years (4 or 8 leading terms, respectively). Column (4) uses Division-by-time fixed effects, rather than Region-by-time. Column (5) drops the observations with an inflation-indexed state minimum wage, and Column (6) uses only pre-2008 data.

Online Appendix 2. Results by industry

In the main body of the paper, we present results for virtually the entire workforce, including workers in all industries. In this appendix, we disaggregate the effect on job growth rates by industry. The BDS does not report separate employment outcomes by state and industry, but these are disaggregated in the QCEW and QWI. In Table OA2.1, we estimate the effects of the minimum wage in different industries (two-digit NAICS code), focusing on the distributed lag model.[19] Much of the literature focuses on one or several industries that are conjectured to be more responsive to changes in the minimum wage. Echoing points made in Clemens and Wither [2014] and Neumark et al. [2004], we choose to show all industries as it is not necessarily clear which particular *industry codes* ought not to be sensitive to the minimum wage. That said, industries that tend to have a higher concentration of low-wage jobs show more deleterious effects on job growth from higher minimum wages, and the results appear consistent between the QCEW and QWI.[20]

[19] See http://www.naics.com/search.htm for a full list of the component industries of each category.

[20] It may seem anomalous that professional services would be negatively affected, but firms in this category span a broad array, from lawyers' offices to direct mail advertising. The large negative effect on the offices of holding companies ("management") is perhaps stranger; note, though, that the effect is only present in the QCEW, that the estimates are quite noisy, and that this category has among the fewest firms of any industry.

Table OA2.1: Distributed lag first-differences estimates for the effect of the minimum wage on log-employment by industry

	QCEW		**QWI**	
	coef.	s.e.	coef.	s.e.
All: NAICS available (1990-)	-0.0815***	(0.0285)	-0.0863**	(0.0333)
11: Agriculture and wildlife	-0.1618	(0.1744)	-0.0546	(0.1266)
21: Mining	0.2011	(0.1941)	0.2638	(0.2389)
22: Utilities	-0.0043	(0.1488)	0.0625	(0.1366)
23: Construction	-0.2107	(0.1438)	-0.2003	(0.1333)
31-33: Manufacturing	-0.0957	(0.0646)	-0.0852	(0.0569)
42: Wholesale trade	-0.0073	(0.0431)	-0.0803	(0.0577)
44-45: Retail trade	-0.0253	(0.0312)	-0.0710	(0.0439)
48-49: Transportation and warehouse	-0.1010	(0.0799)	-0.0195	(0.0670)
51: Information service	0.1654	(0.2316)	-0.0086	(0.0762)
52: Finance and insurance	-0.0137	(0.0451)	-0.1410	(0.0858)
53: Real estate	-0.0639	(0.0561)	-0.0327	(0.0749)
54: Professional service	-0.2021***	(0.0614)	-0.2713***	(0.0629)
55: Management	-0.6041*	(0.3381)	-0.1628	(0.7198)
56: Administrative support	-0.1575**	(0.0595)	-0.2162**	(0.0825)
61: Education related	0.6623*	(0.3501)	0.0234	(0.0975)
62: Health care	-0.0287	(0.0320)	0.0408	(0.0689)
71: Arts and entertainment	-0.1098	(0.1452)	-0.1486	(0.0989)
72: Accommodation and food	-0.0669***	(0.0226)	-0.1098*	(0.0648)
81: Other service	-0.1235	(0.3323)	-0.0004	(0.0573)
92: Public administration	-0.0346	(0.0767)	-0.0760	(0.1075)
Observations	3825		2245	

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$ Notes: Robust standard errors are clustered by state and reported in parentheses. All columns include state fixed effects, quarterly-by-Region time fixed effects, and state-specific time-varying controls: log-population, the share aged 15-59, and log real gross state product per capita. Each coefficient represents a separate regression of the distributed lags in first differences model, using lags over 16 quarters.

Online Appendix 3. Dynamic panel estimates

An alternative approach to estimating the short- and long-run effects of the minimum wage on employment, at the cost of imposing a stricter assumption on the nature of this relationship, is to use a dynamic panel specification (e.g. Arellano and Bond, 1991). The specification takes the form:

$$\text{emp}_{it} = \mu \cdot \text{emp}_{it-1} + \alpha_i + \tau_t + \gamma_i \cdot t \ + \sum_{r=0}^{s} \beta_r \text{mw}_{it-r} + \psi \cdot \text{controls}_{it} + \epsilon_{it}$$

which differs from the specifications discussed in Section IV of the paper in that the lag of employment is included on the right hand side. This can be first-differenced to eliminate the α_i jurisdiction fixed effects:

$$\Delta\text{emp}_{it} = \mu \cdot \Delta\text{emp}_{it-1} + \theta_t + \gamma_i \ + \sum_{r=0}^{s} \beta_r \Delta\text{mw}_{it-r} + \psi \cdot \Delta\text{controls}_{it} + \Delta\epsilon_{it} \tag{1}$$

In this dynamic panel model, the short run marginal effect of the minimum wage on employment is β_0, and the effect after one year of a sustained change is captured by $\beta_1 + (1+\mu) * \beta_0$. The long run effect on employment is determined by $(\beta_0 + \beta_1)/(1-\mu)$, following the properties of a geometric series. Importantly, this long run effect (in fact, the specific time path of the effect) can be identified using only a single lag term for the minimum wage. Thus, a dynamic panel specification skirts much – although not all – of the concern about constantly changing treatment intensities.

However, in solving one identification problem, the dynamic panel approach introduces another, as the Δemp terms are autocorrelated. The standard practice, as in Holtz-Eakin et al. [1988] and Arellano and Bond [1991], is to create "GMM-style" instruments using deeper lags of employment and substituting zeroes for the missing observations resulting from the lags. It is important to note that these instruments may be problematic as well, depending on the degree of autocorrelation. An alternative approach is to use deeper lags of the *minimum wage* rather than employment as instruments. A further alternative is to use a traditional two-stage least squares approach in which deeper lags of the minimum wage are used as instruments, without the GMM-style substitution of missing observations, similar in spirit to Anderson and Hsiao [1982].[21]

In Table OA3.1, we estimate Equation 1 using both GMM-style and standard instruments. Columns (1) and (2) use Roodman's (2009) Stata module, which allows for flexible estimation of dynamic panel models.[22] In Column (1), the contemporaneous elasticity of

[21] We are grateful to an anonymous referee for both of these suggestions. See Roodman [2009] for an extensive discussion of these issues.

[22] In all cases, we use deeper minimum wage lags as instruments rather than deeper lags of employment. In both specifications, results are qualitatively similar when using deeper lags of employment or when using both employment and minimum wage variables as instruments.

a minimum wage increase is -0.031 (s.e. = 0.017), with the lag term (-0.054, s.e. = 0.02) implying that the impact after one year at the same treatment intensity would be -0.10 (s.e. = 0.033) and after two years, -0.14 (s.e. = 0.049); the long-run impact of a permanent real increase in the minimum wage effect is -0.20 (s.e. = 0.088). Adding additional lags in Column (2) does not dramatically change the effect, with the impact after one year at the same treatment intensity being -0.096 and after two years, -0.13, with the long-run elasticity being -0.27 (s.e. = 0.13). In Column (3), we use standard rather than GMM instruments and find somewhat smaller effects than in Column (1), with a statistically-significant long-run elasticity of around -0.08.[23] The result in Column (4) is similar; note that the magnitude here is very close to that from the distributed lag model in first differences.

Altogether, the results from the dynamic panel models also suggest that the impacts of the minimum wage on employment are dynamic rather than discrete.

[23]For these specifications, we use four lags of the minimum wage as instruments, beginning with the first period not included in the primary equation. The magnitude of the overall effect of the minimum wage tends to be fairly stable based on the choice of instrument sets, though for some sets, the lagged employment coefficient is imprecise and sometimes implausible. The first stage estimates are strong, with an overall F-statistic of 142.6 in Column (3) and 241.6 in Column (4); the four instruments are jointly significant with p = 0.009 and p = 0.071 for Columns (3) and (4), respectively.

Table OA3.1: Dynamic panel estimates for the effect of the minimum wage on log-employment (BDS)

	GMM Instruments		**Standard Instruments**	
	(1)	(2)	(3)	(4)
Log-MW	-0.0309*	-0.0390**	-0.0159	-0.0153
	(0.0171)	(0.0165)	(0.0136)	(0.0150)
1st lag of log-MW	-0.0543***	-0.0310*	-0.0379***	-0.0309**
	(0.0204)	(0.0167)	(0.0094)	(0.0153)
2nd lag of log-MW		-0.0095		-0.0051
		(0.0121)		(0.0239)
3rd lag of log-MW		-0.0146		0.0136
		(0.0227)		(0.0172)
1st lag of employment	0.5772***	0.6539***	0.3256	0.5301
	(0.0960)	(0.0846)	(0.2437)	(0.6678)
Estimated Permanent Effect	-0.2015**	-0.2720**	-0.0799**	-0.0802*
	(0.0884)	(0.1323)	(0.0316)	(0.0428)
Observations	1683	1581	1428	1326

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$ Notes: Robust standard errors are clustered by state and reported in parentheses. Columns (1) and (2) use Roodman [2009]'s difference GMM estimator with lags of the minimum wage as instruments. Columns (3) and (4) use two-stage least squares with four lagged minimum wage values as instruments.

Online Appendix 4. Historical Minimum Wage Increases and Erosion

Historically, minimum wages have been set in nominal dollars and not adjusted for inflation, so any nominal wage differential between two jurisdictions will become economically less meaningful over time. This appendix section presents some figures depicting the frequency and magnitude of minimum wage changes – and their subsequent erosion due to inflation. Looking first only within-state, Figure OA4.4 shows that the mean real state minimum wage increase during 1976-2012 was 55 cents (the median was also 55 cents). By the time the same state next increased its real minimum wage, which took 54 months on average, the previous increase in minimum wage had eroded – via inflation – to an average cumulative real *decrease* of 11 cents (median -12 cents, see Figure OA4.5). In fact, Figure OA4.6 shows that the 62 percent of state-year real minimum wage increases that were eventually fully eroded by inflation did so in, on average, twenty-two months, and the median time elapsed was only sixteen months. Turning instead to comparisons within Census Region, the mean *relative* real increase in state minimum wage was 25 cents (median 13 cents, Figure OA4.7). By the time of the next within-state increase, the prior increase had eroded – both via inflation and from other regional neighbors changing their minimum wages – to an average decrease of 1 cents (median +2 cents, Figure OA4.8). For those 47 percent of state-year increases which fully eroded relative to regional states, this took only 17 months on average (median 12 months, Figure OA4.9). This exercise demonstrates that there is a relatively short duration of time during which a state difference-in-differences estimation can identify the effects of the minimum wage on employment levels.

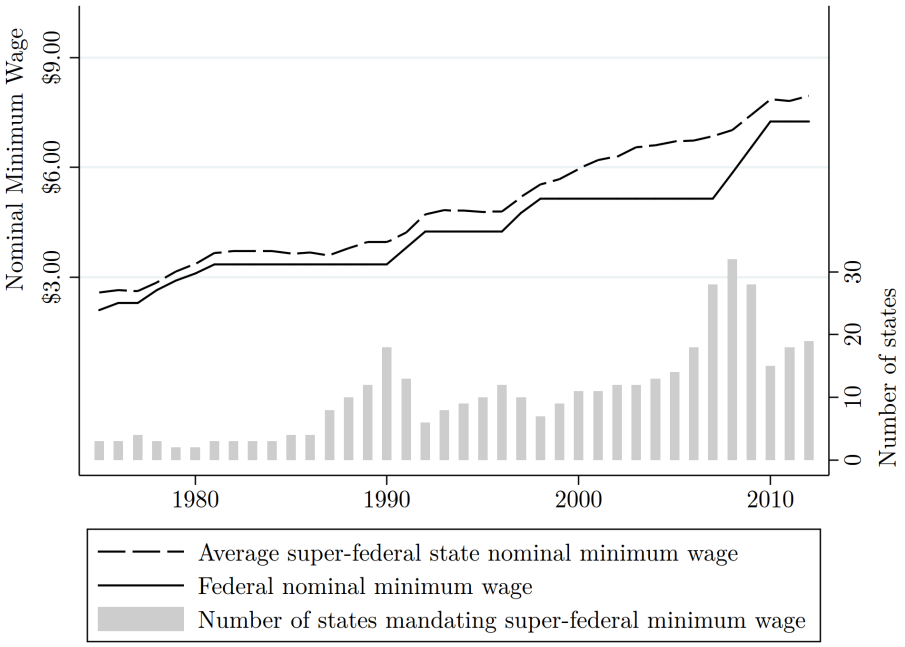

Figure OA4.1: Comparison of federal to state nominal minimum wages (January, 1975-2012)

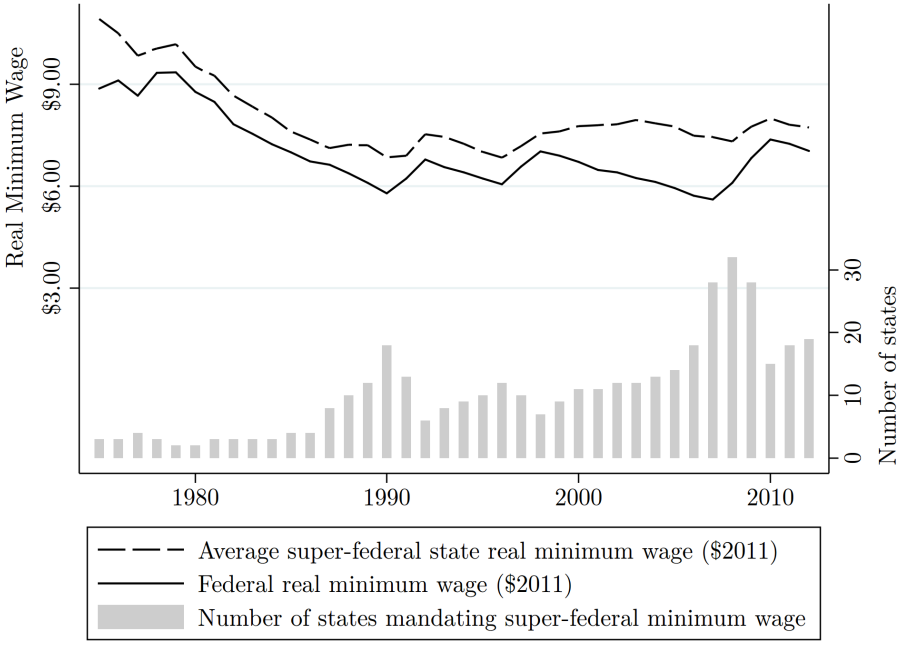

Figure OA4.2: Comparison of federal to state real minimum wages (January, 1975-2012)

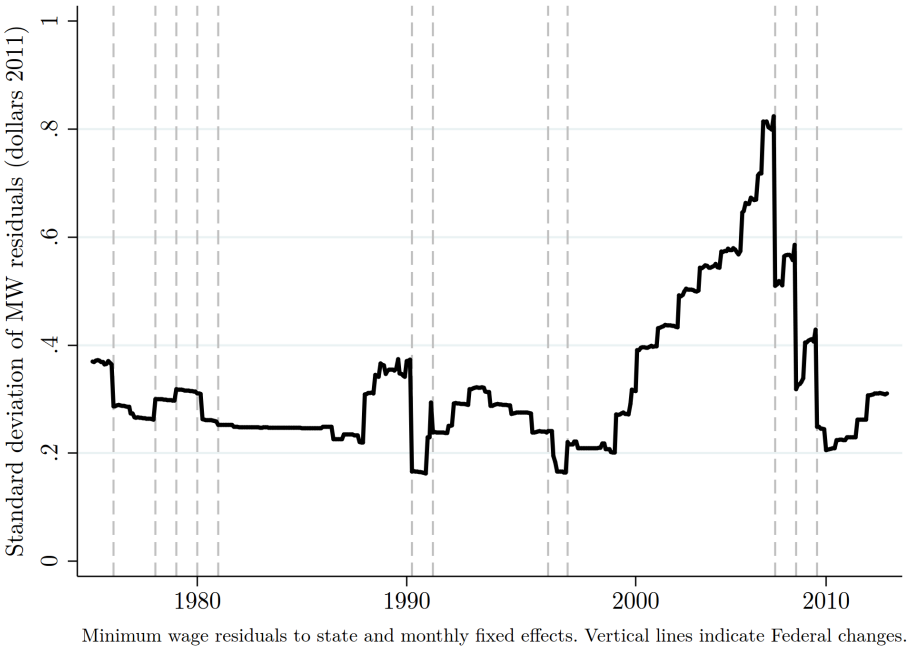

Figure OA4.3: Standard deviation of residual state real minimum wages (1975-2012)

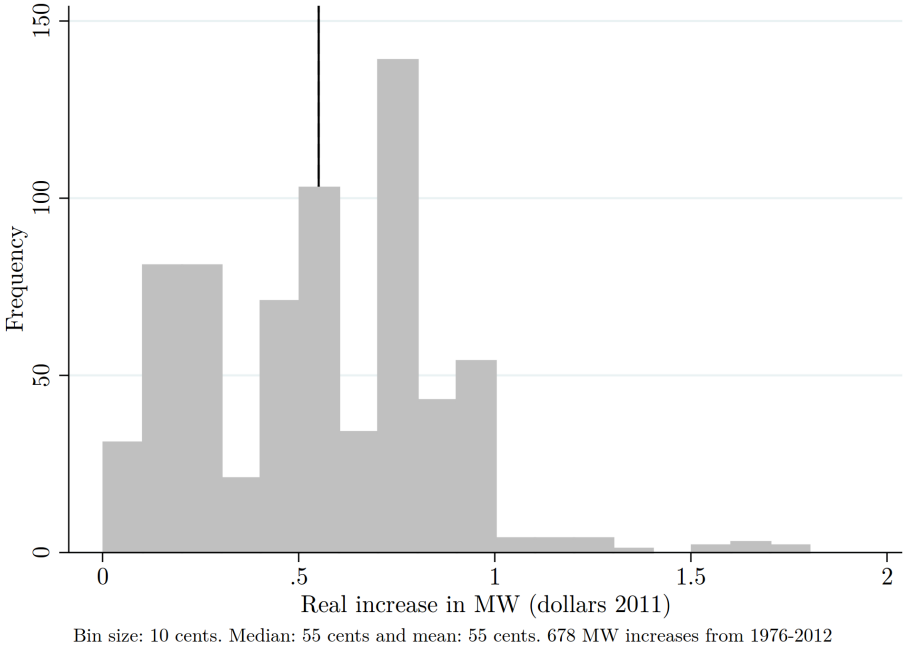

Figure OA4.4: Distribution of real minimum wage increases

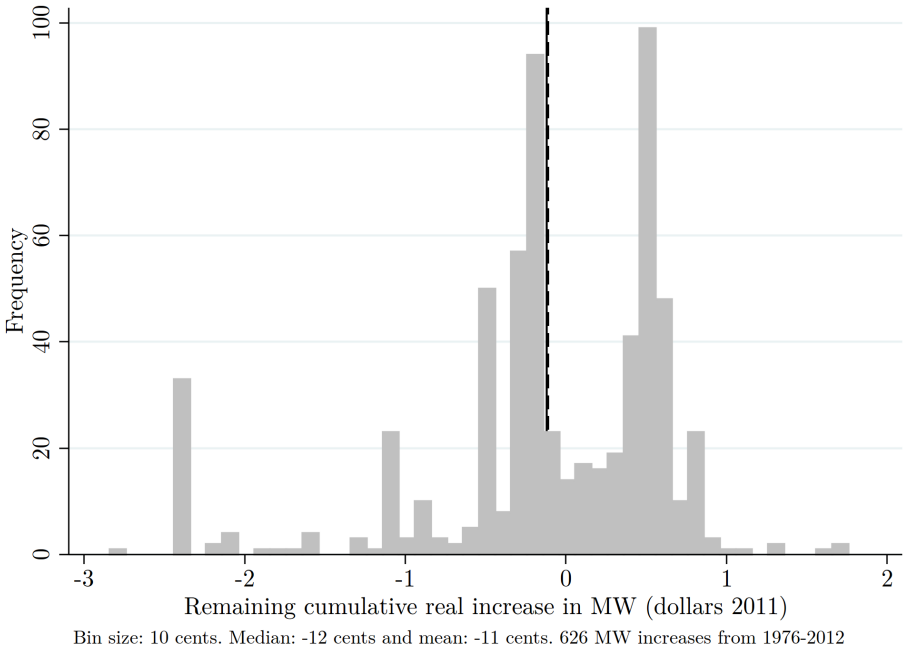

Figure OA4.5: Cumulative difference in real minimum wage prior to a new increase

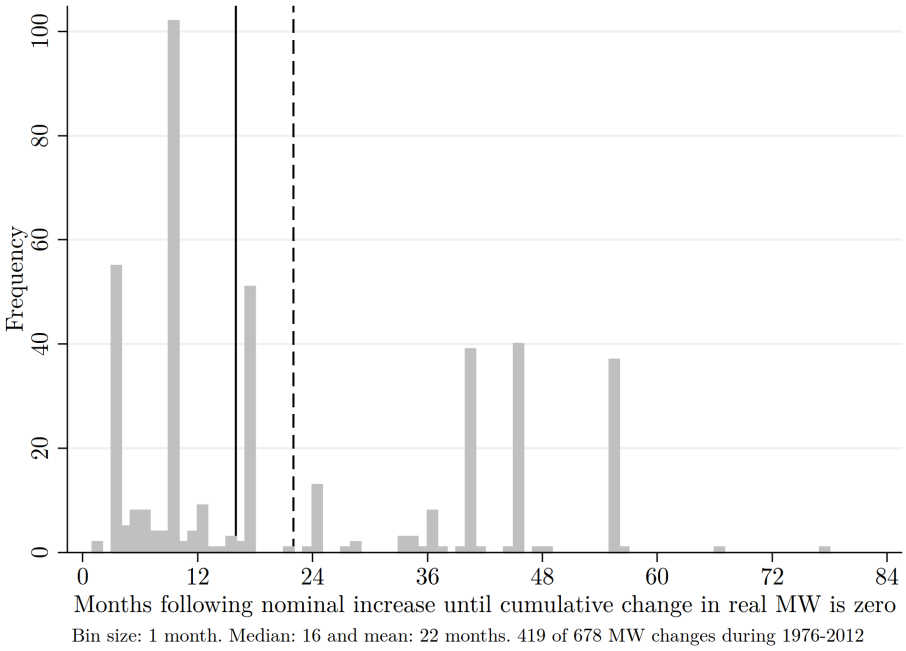

Figure OA4.6: Erosion of real increases in minimum wage

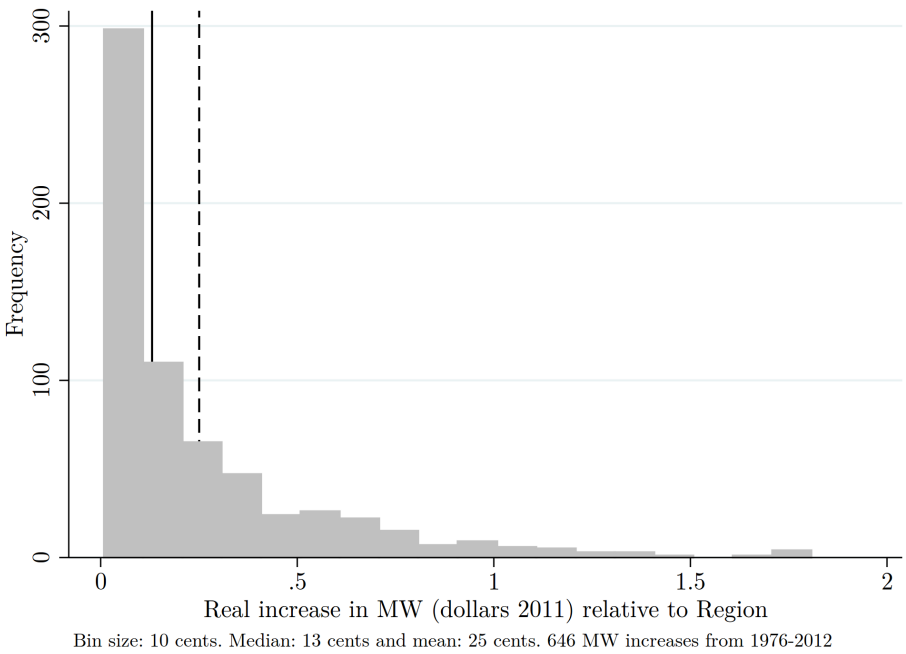

Figure OA4.7: Distribution of relative minimum wage increases

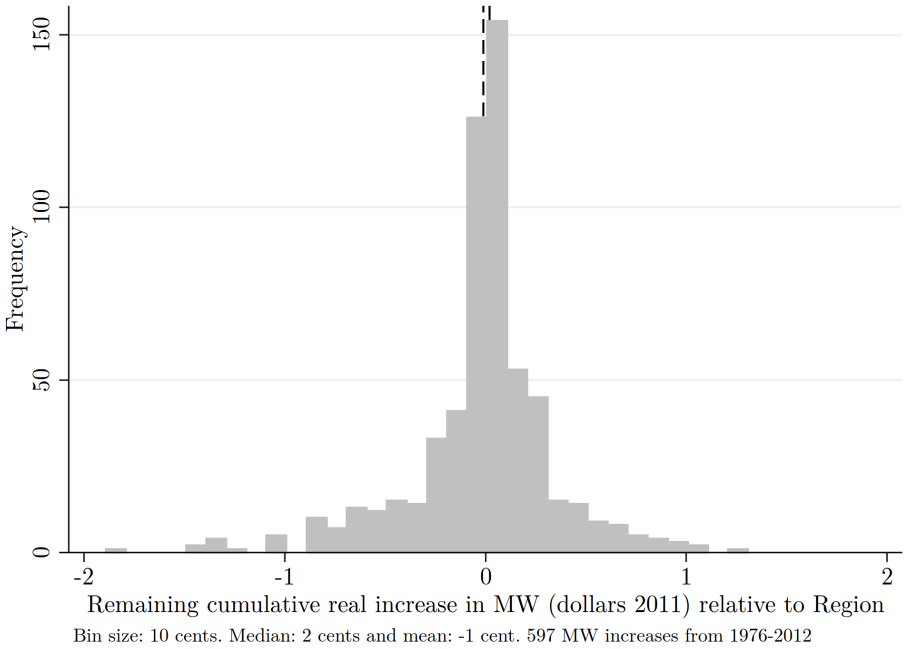

Figure OA4.8: Cumulative difference in relative minimum wage prior to a new increase

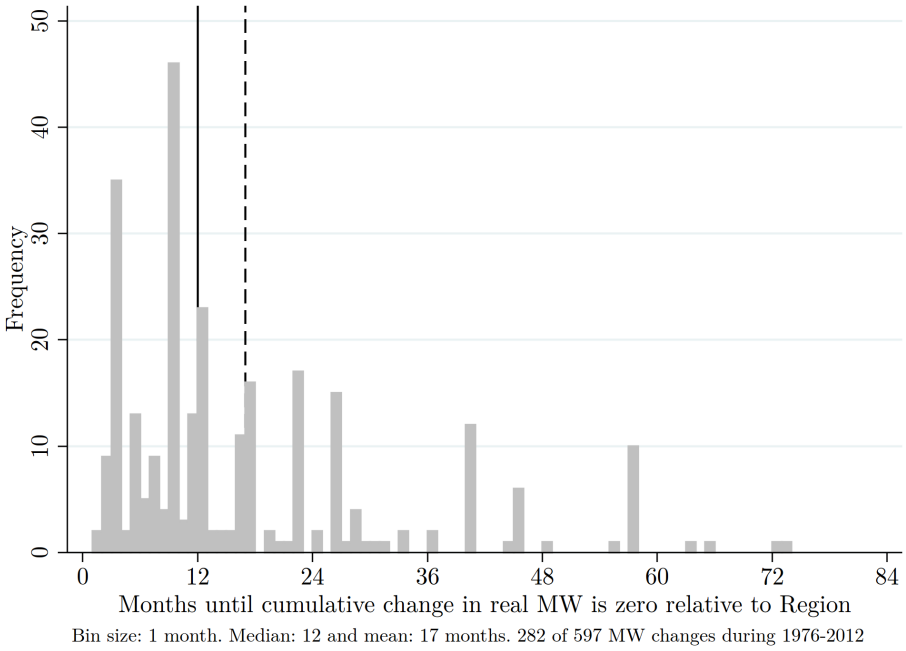

Figure OA4.9: Erosion of relative increases in minimum wage

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