

The Many Effects of the Minimum Wage: New Evidence on Employment and Prices

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Economists disagree about the aggregate effects of the minimum wage and what they mean for basic economic theory. But, there is a mismatch between empirical evidence from policies that apply to entire markets and the textbook monopsony model that describes a single firm (Robinson, 1933). In this paper, we use new firm-level micro data on employment, wages, sales, and prices to study how low-wage employers adjust to minimum wage hikes. We find that firms paying just below the new minimum wage increase employment and lower prices relative to competitors, while firms already paying the old minimum do the opposite. This is new evidence that minimum wages increase employment and lower prices up to a threshold, above which the effects flip signs. Firms that are not directly affected also adjust because they compete with directly affected firms for both workers and customers. We interpret these results in a model of heterogeneous firms with both labor and product market power. We develop a general method to recover the model parameters from the difference-in-differences variation and find that unconstrained markups and markdowns are large. The market-level effects of the minimum wage depend on both the nature of firm-level heterogeneity and market-level spillovers. Spillovers, not reductions in firm-level monopsony markdowns, drive the bulk of employment and wage changes under the minimum wage policies we study.

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Economists disagree about the aggregate effects of the minimum wage and what they mean for basic economic theory. Many minimum wage hikes have small, or statistically zero, disemployment effects, but careful studies have found anything from large negative effects to modest positive ones.¹ Depending on the sign of the estimate, these employment effects are then used as evidence for, or against, monopsony in the labor market.

But, there is a mismatch between empirical evidence from policies that apply to entire markets and the textbook monopsony model that describes a single firm (Robinson, 1933). This model makes predictions about how a single firm jointly adjusts employment and prices in response to a minimum wage hike. However, market-level effects are driven by adjustments at many firms. Since these firms are different from each other and compete with each other, the market-level response to the policy need not be representative of the firm-level responses.

In this paper, we use new firm-level micro data on employment, wages, sales, and prices to study how low-wage employers adjust to minimum wage hikes, and we use these joint adjustments to directly estimate structural product and labor market parameters. In the first part, we use a new firm-level panel to estimate how firms jointly adjust their employment and prices, and how these adjustments vary based on initial exposure and market conditions. Then, in the second part, we interpret these results through a quantitative monopsony model. We develop a general method to recover parameters of an economic model from reduced-form difference-in-differences variation. We use this method to quantify markups and markdowns, the strength of spillovers, and the role of unobservable firm-level heterogeneity, and to extrapolate to new policy changes.

We use new microdata constructed from administrative payroll and point of sale records at thousands of small “counter-service” firms paying at or near the minimum wage to study firm-level responses.² These firms are small (on average ≈ 8 employees) and half of these firms hire minimum wage workers. This makes the sample well suited to understanding how highly exposed firms jointly adjust their employment and prices in response to binding minimum wage hikes. We use anonymized transaction records that link customers across

¹Recent reviews find that 29% (Neumark and Shirley, 2022) or 40% (Dube and Zipperer, 2024) of estimates are positive, and agree that the median policy effect is negative.

²Our data provider has provided an analytic sample that is a subset of total business volume. In particular, no statistics should be taken as representative of the business scope or composition of any products offered by the data provider.

stores to identify firms in our sample with customer overlap (Einav et al., 2026) and construct a competitor price index for each firm. These linked data allow us to measure joint firm-level responses and competitive spillovers, which have been difficult to study with the wage and price data typically available.³

To contextualize this sample, we begin by reproducing standard difference-in-differences (DiD) estimates of aggregate employment and price effects. We use five state-level minimum wage hikes between 2022 and 2025 to estimate reduced-form elasticities with respect to the minimum wage. We follow the literature in making a conditional common trends assumption: absent the change in the minimum wage, firms with the same covariates would have followed the same trends. We estimate that employment falls by 2.1 percent and prices increase by 1 percent for a 10 percent increase in the minimum wage. These estimates are broadly in line with the literature and unsurprising given our highly exposed sample.⁴

We start by reviewing the predictions of the Robinson monopsony model. This model shows that the effects of the minimum wage are heterogeneous: below some threshold minimum wage, a representative monopsonist increases employment and decreases prices, but above this threshold, it decreases employment and increases prices. We look for evidence of this kind of heterogeneity, which is challenging because the threshold is unobserved and varies across firms. We use the initial wage as a proxy for these unobserved thresholds: firms with higher initial wages should have higher thresholds.

We use our microdata to re-estimate the policy DiDs for employment and prices separately across firms with different initial wages. As the model predicts, we find that effects on employment and relative price both flip sign across initial wage groups. At firms paying just below the new minimum wage (higher thresholds), employment rises. These firms do not raise prices, but their competitors with different initial wages do, so their relative prices fall. At firms already paying the old minimum wage (lower thresholds), the signs flip: employment falls and prices rise.⁵ Firms paying above the new minimum wage also

³For example, Kline (2025) notes that “[t]o date, store level panels on wages and prices have only been available in relatively special settings, usually involving a single company” (p. 60).

⁴The employment estimate is at roughly the 35th percentile of estimates reviewed by Neumark and Shirley (2022). The price estimate is very close to estimates on restaurants in the CPI (Aaronson, 2001; Aaronson et al., 2008) and larger than grocery store estimates (Leung, 2021; Renkin et al., 2022), consistent with grocery stores having a lower labor share.

⁵Other papers that use exposure variation do not find that employment effects flip sign, but

adjust employment and prices, consistent with competitive spillovers.

To our knowledge, this is the first empirical evidence of the price cuts predicted by the basic monopsony model, the lack of which has been an “important puzzle” “long...recognized in the literature” (Kline, 2025, p. 61; Dube and Lindner, 2024, p. 58). The argument made famous by Card and Krueger (1994) that monopsony can explain employment increases was criticized almost immediately on the grounds that “if employment is expanding, so presumably is output, and prices should fall” (Brown, 1999, p. 2156).⁶ These results show that the dynamics predicted by Card and Krueger (employment can rise) and Brown (if it does, prices should fall) are present at the level of individual firms. Heterogeneity in initial wages and spillovers between firms obscure these dynamics in aggregate employment and price effects.

Motivated by these results, we develop a quantitative version of Robinson’s monopsony model with imperfect competition and spillovers in labor and product markets. In this model, each firm has its own threshold minimum wage that is generated by unobservable heterogeneity in labor supply, product demand, and productivity. Different mixes of firms above and below their threshold can give different aggregate responses. This model thus provides a way to allow for heterogeneity across policies, even in sign, while still imposing enough structure to extrapolate to new policies.

To take this model to the data, we develop a general method to identify supply and demand elasticities using variation from a single event study. Identification comes from the fact that the conditional common trends assumption is a conditional moment restriction: the DiD is valid within groups with the same covariates, which means there are many valid group-specific DiDs.⁷ For example, in a simple demand system where quantity depends only on the firm’s own price, we can use cross-group differences in price effects and in

they use this variation in a different way. Harasztosi and Lindner (2019) find an approximately linear relationship between employment changes and the fraction of a firm’s workers affected by a very large increase in Hungary, which they note is hard to reconcile with monopsony. Dustmann et al. (2021) find no disemployment effects for low-wage workers in Germany, though employment shrinks in smaller exposed establishments and expands in larger ones. Both papers use a single national policy and compare more and less exposed units, so effects that are common to all units are not identified. We instead compare firms to firms with the same initial wages in untreated markets, which lets us adjust for exposure-specific trends, and we measure spillovers directly.

⁶This argument is made perhaps most forcefully by Aaronson et al. (2008).

⁷Under a rank condition that policy effects differ sufficiently across these groups, we can identify multiple structural parameters from a single policy change.

quantity effects to estimate the demand elasticity with the ratio of triple differences.⁸ Our structural DiD estimator pools these moments to recover the structural parameters, which we estimate jointly using GMM.

We use this model to quantify the mechanisms of these policy effects and extrapolate to new policies. The structural estimates reveal that there are significant frictions in the labor and product markets. The estimated product-demand elasticity is 2.86 and the labor-supply elasticity is 5.44. In our model, and under the standard Lerner rule, this means that unconstrained markups (i.e. the inverse elasticity) are 35% and markdowns are just under 20%. Nevertheless, aggregate employment falls and aggregate prices rise.

This apparent contradiction arises because labor market spillovers are quantitatively significant and raise wages by shifting labor supply (through improving outside options), and not by moving monopsonists along their labor supply curve. When labor market spillovers are important, the minimum wage does a good job of raising wages and a bad job of reducing markdowns.⁹ In Robinson’s monopsony model, a binding minimum wage reduces markdowns by pushing firms above their unconstrained wage. In our model, the minimum wage also raises wages at competing firms, which raises firms’ unconstrained wages and reduces the direct bite of the policy.

These results help explain some of the apparent disagreement in the literature, clarify when minimum wages reduce the inefficiencies from monopsony, and inform the design of minimum wage policies. First, disagreement about policy effects need not imply disagreement about economic theory. Different aggregate estimates are often used as evidence for different theories. Our results show how different mixes of firms above and below their thresholds, together with competitive spillovers, can generate aggregate employment effects that differ in sign under the same economic model. Studying how firms jointly adjust employment and prices lets us identify consistent economic mechanisms across

⁸In this way, our approach is similar to the grouping estimator of Blundell et al. (1998), who use differences in how groups respond to tax reforms to identify labor supply parameters. In this example with a single endogenous variable, both our approach and theirs simplify to a Wald-DiD or “fuzzy” DiD (de Chaisemartin and D’Haultfœuille, 2018).

⁹These results help to explain the recent finding of Faia et al. (2026) that the German minimum wage decreased markdowns very little, if at all. Our results show that this finding is natural if minimum wages have large labor market spillovers. German Minimum Wage Commission (2018) and Dustmann et al. (2021) find evidence that the German minimum wage did cause wage spillovers to workers above the minimum wage.

policies, even when their aggregate effects differ.

Second, the efficiency argument for the minimum wage, going back to Robinson (1933), is that a binding minimum wage removes the incentive to decrease employment in order to cut wages. The more the minimum wage also shifts the labor supply curve, the less it operates through its direct effect and the worse it does at reducing markdowns. The employment effects depend on how much the minimum wage raises wages by moving firms along their labor supply curves and how much it raises wages through spillovers that shift those curves. Of course, the efficiency argument is only one argument for the minimum wage. These labor market spillovers amplify the effect of the minimum wage on wage growth. And so, though they do not reduce markdowns, minimum wage increases that cause disemployment can still increase total earnings for low wage workers.

Third, the design of minimum wage policies must account for competitive spillovers as well as differences in firms' thresholds. Minimum wages have the most scope to increase wages and employment when minimum wage firms are in distinct labor markets, such that the labor market spillover is small. This is distinct from the usual motivation for differentiated minimum wages, which is the worry that thresholds are different: the minimum wage exhausts markdowns at some firms before it can reach markdowns at higher wage firms.

Contribution to the Literature Our primary contribution is to the empirical literature that uses policy variation to estimate the effects of minimum wage increases. The modern literature began with Card and Krueger (1994), who famously found that a minimum wage increase in New Jersey increased employment and concluded that this was “inconsistent with the predictions of a conventional competitive model” (p. 790).¹⁰ This “high-stakes ‘theory-testing’” (Clemens, 2021, p. 51) continues to the present day, for example in the series of papers studying California’s recent \$20 minimum wage for fast-food workers. Sosinskiy and Reich (2026) find null employment effects and partial price pass-through, which they read as “consistent with a monopsony model” (p. 1), while Clemens et al. (2026)

¹⁰This result has itself been the subject of no small controversy. Neumark and Wascher (2000) re-analyze the same policy and find that employment decreases, which they read as “generally consistent with the prediction that raising the minimum wage reduces the demand for low-wage workers” (p. 1363).

read the price increases as “inconsistent with a strong monopsony interpretation” (p. 11).¹¹ We provide new evidence that Robinson’s monopsony model, appropriately applied to firms and not directly to markets, can explain much of the theoretical controversy: the policies we study have a mix of firms above their threshold (behaving like the competitive model) and firms below their threshold (behaving like monopsonists).

The closest papers to ours also use microdata to study how firms adjust to the minimum wage (Harasztosi and Lindner, 2019; Dustmann et al., 2021; Coviello et al., 2022; Rao and Risch, 2025). Relative to these papers, we estimate how firms jointly adjust their employment and prices, and we construct a network of firms that share customers.

We also contribute to the model-driven literature on the minimum wage, which has long highlighted the theoretical importance of heterogeneity and spillovers (Flinn, 2006; Engbom and Moser, 2022; Berger et al., 2025; Haanwinckel, 2025; Karabarbounis et al., 2025).¹² Papers in this literature largely discipline their key parameters with cross-sectional or market-level moments, or calibrate them to external estimates. Building on these theoretical insights, we use a model with these features to empirically analyze the effects of the minimum wage. We provide a set of new micro-moments and show how to use them to identify markups, markdowns, and the strength of spillovers from the policy variation.

More generally, we also contribute to the structural literature on labor market power and the smaller literature on “double” market power.¹³ Within this literature, we are most closely related to a series of recent working papers that use minimum wages to estimate structural features of labor markets. Faia et al. (2026) estimate markdowns by directly estimating the production function and test how markdowns respond to the introduction of a minimum wage; Bassier and Budlender (2025) and Bhuller et al. (2025) use demand shocks to look at how the bite of minimum wages and other wage floors (e.g. from unions) interacts with pass-through. We complement this work with estimates of both labor supply and product demand elasticities from minimum wage policy variation.

¹¹See Section 2.2 of Melo et al. (2026) for a more thorough review of the rapidly growing body of working papers estimating the aggregate effect of this policy.

¹²There is also a reduced form stream of this literature that estimates treatment effect heterogeneity suggestive of market structure (Harasztosi and Lindner, 2019; Okudaira et al., 2019; Gopalan et al., 2021; Azar et al., 2024; Popp, 2024; Jha et al., 2026, for example).

¹³Caldwell et al. (2026) provide a recent review of work on monopsony power. The literature integrating labor and product market frictions is smaller, but active; see for example Kroft et al. (2025), Deb et al. (2024), and Setzler (2025).

Finally, we contribute to the large literature using DiD by connecting its identifying assumptions to conditional moment restrictions in a structural model (Chamberlain, 1987; Chen and Pouzo, 2009; Chernozhukov et al., 2018). Chen et al. (2025) also show how to connect the common trends assumption to a conditional moment restriction, and use these restrictions to identify and efficiently estimate the reduced form dynamic effects. We further show how to combine the reduced form restrictions with an economic model (in this paper, the demand and supply equations) to identify structural parameters, in the spirit of the grouping estimator of Blundell et al. (1998). This gives researchers a way to use their DiD variation to estimate supply and demand elasticities and other structural parameters.

The paper proceeds as follows. First, we describe the data and setting and benchmark aggregate employment and price effects in our sample against the literature (Section 1). In the first part, we review the firm-level predictions of the Robinson monopsony model and explain how heterogeneity and competitive spillovers affect their interpretation (Section 2). We then show how firms jointly adjust their employment and prices, and how these adjustments vary based on initial exposure (Section 3). The second part presents the structural model (Section 4), establishes identification and introduces the structural DiD estimator (Section 5), and quantifies policy mechanisms and extrapolates to counterfactual policies (Section 6). We conclude by discussing implications for research and policy.

1. Data and Empirical Design

We construct a firm-level panel from administrative payroll and point-of-sale records at small counter-service firms and use five state-level minimum wage hikes to estimate policy effects. Although our sample is highly exposed to the minimum wage, our estimates of aggregate employment and price effects are broadly in line with the literature.

1.1. Estimation Sample

The sample contains roughly 2,000 firms in policy-change states and 10,000 firms in control states, observed from January 2019 through the end of 2025.

The estimation sample includes “counter-service” firms, including counter-service

restaurants and small retailers. These are two sectors with high minimum wage exposure.¹⁴ We keep firms with at least five employees in the pre-period. In the main analysis, we also require an average pre-period wage no more than \$5 above the state minimum wage. This allows us to keep focus on firms with high minimum wage exposure and firms paying close to the minimum wage.

Treated and control firms are similar in size: both average about eight employees, who each work about 19 to 20 hours a week. Treated firms pay more (\$13.80 an hour against \$11.30), and are in states with higher minimum wages by construction (\$11.09 against \$7.25). Our firms are quite a bit smaller even than the small businesses in Rao and Risch (2025), which average 40 to 50 workers and about \$1.75 million in annual revenue.

1.2. Data Construction

We use payroll records and point-of-sale transaction records.

Payroll records. Payroll records are pay-period observations containing a wage rate, hours worked, and gross earnings, as well as anonymized worker and firm identifiers. We aggregate these records to the store-month level. The three payroll outcomes are headcount, total hours, and average earnings.

Transaction records. Transaction records are itemized point-of-sale observations reporting the item, base price, and an anonymized payment identifier for each receipt. We aggregate these records to measure revenue at the store-month level.

1.3. Empirical Design

Our target parameters are reduced-form elasticities of outcomes with respect to the minimum wage. These are usually estimated with two-way fixed effects (TWFE) regressions of log outcomes on log minimum wages; we instead use a heterogeneity-robust DDML-based estimator. Because the design conditions on pre-period outcomes, we validate it with a rolling-origin placebo test rather than the usual pre-event coefficients.

¹⁴Rao and Risch (2025) find that restaurants alone employ over 40 percent of workers paid at or below the minimum wage and Cengiz et al. (2019) report that restaurants and retail together employ a majority of minimum wage workers. Dube et al. (2010) and Leung (2021) find that restaurants employ about 30 percent of minimum wage workers, more than any other industry.

TABLE 1. Treated and Control Firms in the Estimation Sample

	Treated	Control
Unique firms	$\approx 2k$	$\approx 10k$
Monthly revenue (\$)	$\approx 64k$	$\approx 53k$
Employees	8.3	8.5
Weekly hours per worker	19.80	18.96
Hourly Wage (\$)	13.80	11.30

Notes: This table reports averages over the pre-period (months -6 to -4) for firms in policy-change states (treated) and firms in control states, the 24 states whose nominal minimum wage did not change during the relevant window around each policy. The sample contains counter-service firms, including counter-service restaurants and small retailers, with at least five employees in the pre-period and an average pre-period wage no more than \$5 above the state minimum wage, observed from January 2019 through the end of 2025. Sample not indicative of business product usage.

1.3.1. Policy Variation

We study five state-level minimum wage policy changes that took effect between 2022 and 2025. We retain policy changes with a nominal increase greater than \$0.50 and a proportional increase of at least 5 percent, provided that the state’s minimum wage increased by no more than \$0.50 in total during the preceding 24 months. These restrictions limit contamination of the pre-period by earlier policies. We include both non-indexed increases and automatic adjustments tied to inflation when they satisfy the same criteria. We use the same five policies throughout the reduced-form and structural analyses. Table 2 lists these policies. The control group consists of firms in the 24 states whose nominal minimum wage did not change during the relevant window around each policy.

We use a stacked design to construct a slice for each policy change and we then pool across slices (Cengiz et al., 2019; Deshpande and Li, 2019; Dube et al., 2024). The Colorado slice, for example, contains firms in Colorado together with firms in states with no nominal minimum wage change during the Colorado event window.

1.3.2. A Heterogeneity-Robust Event-Study Estimator

Following the literature, we make a common trends assumption conditional on covariates X_{jk} . For each policy change, we compare changes in outcomes at treated firms with

TABLE 2. State-level minimum wage policy changes in the estimation sample

State	Date	Old MW	New MW	Increase (\$)	Increase (%)
Arizona	January 2022	\$12.15	\$12.80	\$0.65	5.35%
Colorado	January 2023	\$12.56	\$13.65	\$1.09	8.68%
Delaware	January 2022	\$9.25	\$10.50	\$1.25	13.51%
Hawaii	October 2022	\$10.10	\$12.00	\$1.90	18.81%
Michigan*	January 2025	\$10.33	\$12.48	\$2.15	20.81%

Notes: This table lists the five state minimum wage increases in the estimation sample. We retain policy changes with a nominal increase greater than \$0.50 and a proportional increase of at least 5 percent, provided that the state’s minimum wage increased by no more than \$0.50 in total during the preceding 24 months. The control group consists of firms in the 24 states whose nominal minimum wage did not change during the relevant window around each policy. *Michigan’s minimum wage increased from \$10.33 to \$10.56 on January 1, 2025, and then to \$12.48 on February 21, 2025. For the empirical analysis, we combine these adjacent increases (\$0.23 and \$1.92, respectively) into a single \$2.15 increase dated January 2025.

changes at control firms with the same covariates. We express these policy effects as elasticities with respect to the minimum wage. The workhorse estimator of these elasticities is a two-way fixed effects regression of log outcomes on the log minimum wage (Leung, 2021; Ashenfelter and Jurajda, 2022, for recent examples). Its coefficient is a weighted average of comparisons across policy changes of different sizes and different dates, and when effects are heterogeneous some of these weights can be negative (on different sizes: Callaway et al., 2025; on different dates: Sun and Abraham, 2020). Our framework supposes that these effects are heterogeneous. We therefore estimate the elasticities in two steps. We first fit the counterfactual trend y_0 with an ensemble of flexible machine learning models. Then we project the residualized outcome $Y_{jkt} - \hat{y}_0$ onto the dose in each relative time $r > 0$. The estimating equation is thus:

$$Y_{jkt} - \hat{y}_0(X_{jk}, t) = \sum_r \beta_r \Delta mw_k \times \mathbb{1} [treated_{jk}] \times \mathbb{1} [t = event_k + r] + U_{jkt} \quad (1)$$

where $\hat{y}_0$ is the estimated counterfactual outcome given covariates X_{jk} (which include the policy slice k) and calendar time t ; Δmw_k is the size of slice k ’s minimum wage increase; and r indexes time relative to the event.

The event studies plot the coefficient on the dose in a particular relative time. To recover the average post-event elasticity, we take the population-weighted average of the β_r over

the post-event relative times.

A Robust Pre-Trend Test Because the conditioning set includes lagged outcomes, the usual practice of simply reporting pre-event coefficients as a placebo test is not valid, in the sense that they will be zero even if the design is invalid.¹⁵ In general, when the lagged outcome is included in the conditioning set, the pre-event coefficients are a test of how well the estimator is able to achieve balance, not the usual test of “no treatment effect”.

We want an alternative designed to fail either if there is mean reversion induced by conditioning on the pre-period outcomes, or if the conditional common trends assumption is violated. We do that by adapting the rolling-origin forecast evaluation from time series and synthetic control (Kellogg et al., 2021). To validate the specification, we implement a series of rolling-origin placebo tests. At each time period s before the policy, we construct a counterfactual dataset in which the information set ends at $s - 1$. We then estimate the same specification as in the main analysis, controlling for the lagged outcomes through $s - 1$, and report the estimated “effect” at time s , relative to $t = -2$. We repeat this procedure for each pre-treatment period.

$$Y_{jkt} - \hat{y}_0^{(s)}(X_{jk}^{(s)}, t) = \beta_s^{placebo} \Delta mw_k \times \mathbb{1} [treated_{jk}] \times \mathbb{1} [t = event_k + s] + U_{jkt}^{(s)} \quad (2)$$

where both the outcome model $\hat{y}_0^{(s)}$ and the propensity score $\hat{p}^{(s)}$ are estimated using only data through $s - 1$, as are the covariates $X_{jk}^{(s)}$, and are cross-fit separately at each origin s .

In all event-study plots, we report the true dynamic path starting at $t = -1$ (to test for anticipation effects) and the rolling-origin placebo coefficients $\beta_s^{placebo}$ for all $t < -2$. We normalize the difference-in-differences by the $t = -2$ value, so the coefficient at $t = -2$ is always zero by construction.

Inference. We use a double/debiased machine learning estimator of the β_r . We estimate $y_0(X)$ and $p(X)$ with an ensemble of flexible ML models (Ahrens et al., 2025). We estimate

¹⁵Even though the practice of adjusting for pre-policy differences by regression adjustment (Dustmann et al., 2021; Karabarbounis et al., 2025; Rao and Risch, 2025; Faia et al., 2026), matching (Dustmann et al., 2021), and synthetic control (Wiltshire et al., 2025) is quite common, the implications for the standard pre-policy coefficients are often not fully developed. The usual practice is to choose a pre-period that is early enough so that mean reversion occurs as an “Ashenfelter dip” before the policy (Dustmann et al., 2021; Lamadon et al., 2022; Faia et al., 2026). Kellogg et al. (2021) make the general point for synthetic control.

β_r with a Neyman-orthogonal score for the ATT (Chernozhukov et al., 2018, eq. 5.4), so the error in estimating $\hat{y}_0(X)$ and $\hat{p}(X)$ does not affect the asymptotic variance of $\hat{\beta}_r$ to first order.¹⁶ This is a doubly-robust estimator of β_r , in the sense that it consistently recovers the target parameter if either the outcome model $\hat{y}_0(X)$ or the propensity score $\hat{p}(X)$ is correct (see, e.g., Sant’Anna and Zhao (2020) for doubly-robust estimation of the ATT in the canonical binary-treatment DiD).

We cluster standard errors by time, and allow for serial correlation in the residuals following Driscoll and Kraay (1998). This is not uniformly more or less conservative than two-way clustering by time and firm. In one dimension, we are more conservative than two-way clustering, which allows for correlation within a firm over time and across firms within a time period, but not across different firms in different time periods. We allow a shock at firm j in time t to affect the outcome of another firm k in time $t + 1$. The restriction implied by Driscoll and Kraay (1998) is that the correlation eventually decays to zero at sufficiently large time intervals. Along the other dimension, these standard errors are less conservative than two-way clustering, since we do not allow for arbitrary correlation within a firm across time.¹⁷

1.4. Wage and Price Measures

We construct firm-level wage and price indices from changes in worker-level earnings and item-level prices; in this way the initial composition of workers and the mix of goods are differenced out, like the firm fixed effect.

Prices. We construct a firm-level Laspeyres price index from the item-level prices, using lagged-month quantities as weights (Renkin et al., 2022). The index is computed only on items that appear in both the lagged and current month, so it reflects price changes on a constant basket. In this way, we abstract from the product composition; time-invariant differences in the mix of goods are differenced out, like the firm fixed effect. In the structural

¹⁶We cross fit the counterfactual trend $\hat{y}_0(X)$ and the propensity score $\hat{p}(X)$ and use a “short-stack” of learners to reduce sensitivity to the particular choice of machine learner. We normalize the propensity weights to sum to one following Hájek (1971).

¹⁷Driscoll and Kraay (1998) also allow for asymptotics with respect to time only. Two-way clustering requires both the number of time periods and the number of clusters to grow large. See Section III of Manski and Pepper (2018) for further discussion of some interpretative challenges with state-level clustering.

analysis, we use the changes in the minimum wage as an instrument for this firm-level average growth rate in prices, abstracting from changes in revenue that come from the changing mix of goods.

Wages. We construct a firm-level wage index¹⁸ from changes in worker-level earnings.¹⁹ We first compute month over month changes in total hourly earnings for each worker, average this to the firm-month level and then cumulate this month over month. We use “wages” to refer to the average cumulative change in wages at a particular firm; the choice of the level normalization falls out in the difference-in-differences analysis.

In our difference-in-differences design, the identifying variation comes from changes over time that difference out time-invariant heterogeneity. Though our difference-in-differences estimates will be at the firm level, we construct the wage measure from this initial worker-level differencing, which eliminates time-invariant worker-level heterogeneity. Wage levels enter only through their interaction with the minimum wage, which we discuss in Section 3.2.

Competitor prices. The anonymized payment identifier links customers across firms whenever the same card is used at multiple stores in the data.²⁰ We use these links to construct a network of firms that share customers, which we use to construct our empirical competitor price index. For firms $j \neq k$, the customer-overlap weight is

$$s_{jk} \equiv \sum_i \frac{r_{ij}}{R_j} \cdot \frac{r_{ik}}{\sum_{k'} r_{ik'}} \quad (3)$$

where r_{ij} is customer i ’s total expenditure at firm j , $R_j \equiv \sum_i r_{ij}$ is firm j ’s total revenue, and the inner ratio is the share of customer i ’s expenditure at firm k relative to customer i ’s total expenditure across all firms in the data. The competitor price index is

$$\tilde{p}_j \equiv \frac{\sum_{k \neq j} s_{jk} p_k}{\sum_{k \neq j} s_{jk}} \quad (4)$$

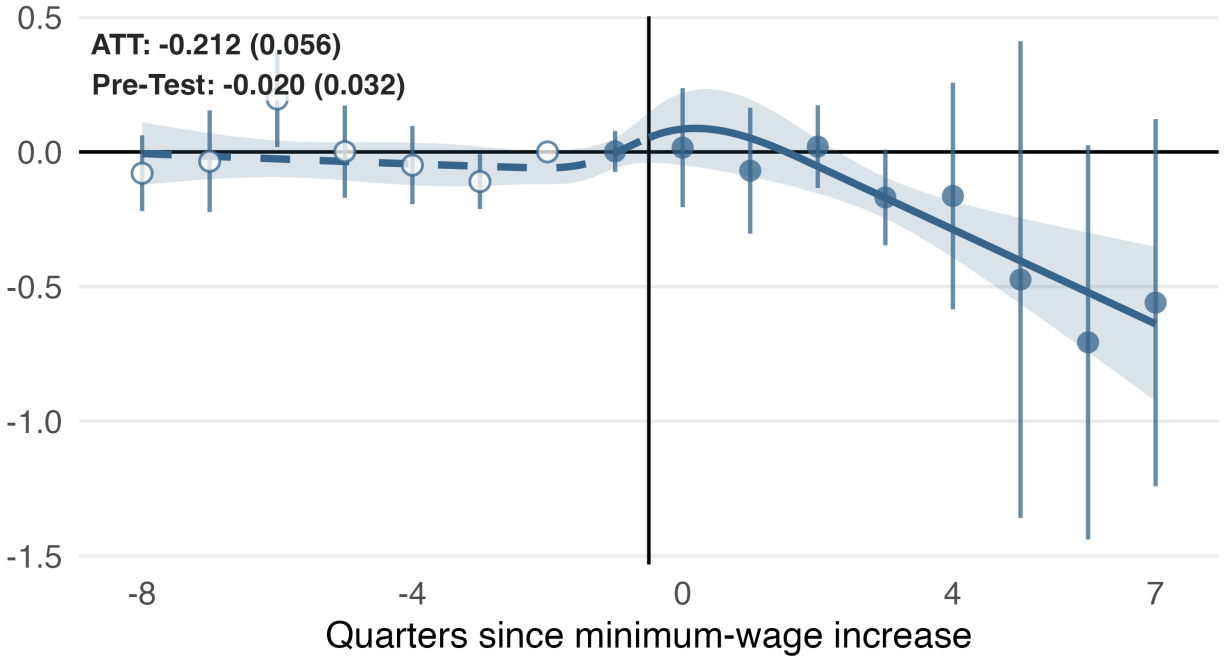
the empirical analog of competitors’ prices in Section 3.1. The relative price is $p_j - \tilde{p}_j$.

¹⁸We use hourly earnings, which include tips.

¹⁹In this way, the initial composition of workers is differenced out, like the firm fixed effect.

²⁰Card and firm identifiers are anonymized and encrypted; the only customer-level information we observe is that card i spent some amount at firm j and some amount at firm k .

FIGURE 1. Effect on Aggregate Employment



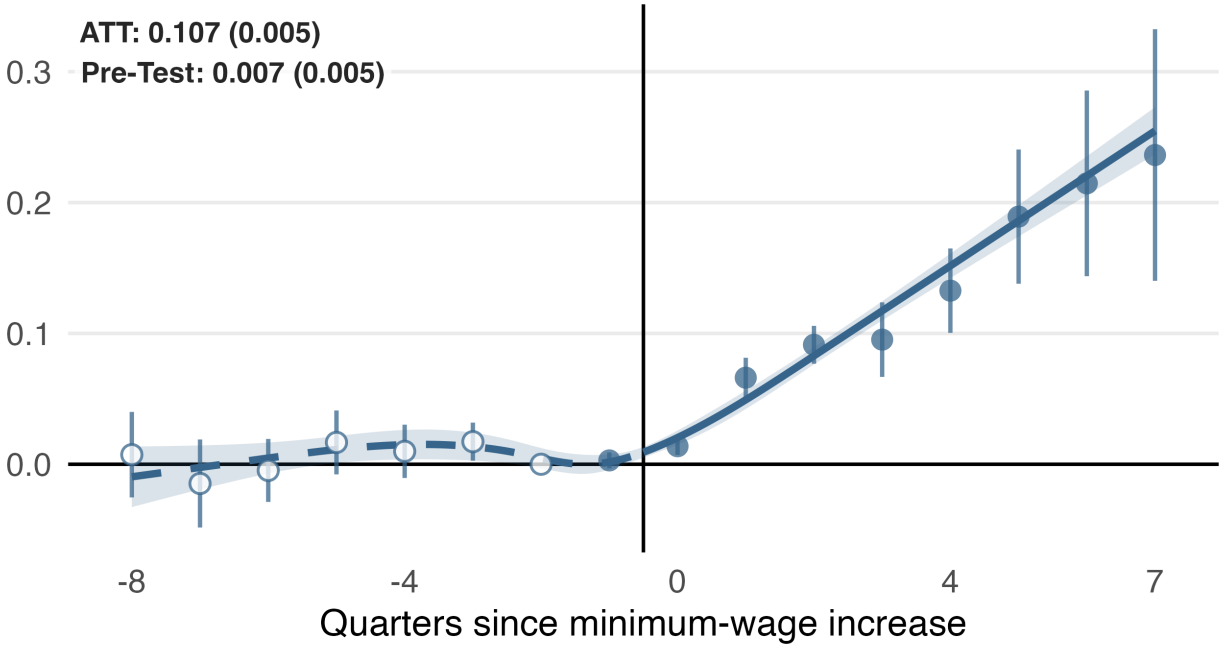
Notes: This figure plots event-study estimates of the effect of a minimum wage increase on firm employment. In each quarter, we report the percent change in employment for a 1 log point increase in the minimum wage, relative to two quarters before the increase. Hollow markers in the pre-period are rolling-origin placebo estimates: the estimate at quarter $s < -2$ re-estimates the specification using only information through quarter $s - 1$. Standard errors are clustered by calendar time and allow for serial correlation following Driscoll and Kraay (1998) (Section 1.3).

1.5. Representativeness

To contextualize our sample, we reproduce standard difference-in-differences (DiD) estimates of aggregate employment and price effects. Our sample is small counter-service firms. These firms are very exposed, which makes them ideal for studying how firms adjust to a binding minimum wage. We can use the sample of firms we observe to consistently estimate features of their markets, which are a subset of the whole economy; we do not see all small counter-service firms.

Our estimates are broadly consistent with the literature, though larger in magnitude than most. This is reasonable given that others have found effects tend to be stronger in restaurants and for low-wage workers.

FIGURE 2. Effects on Aggregate Prices



Notes: This figure plots event-study estimates of the effect of a minimum wage increase on firm prices. In each quarter, we report the change in a firm's log Laspeyres price index for a 1 log point increase in the minimum wage, relative to two quarters before the increase. The index cumulates month-over-month price changes of items sold in both months, weighted by the prior month's quantities (Section 1.4). Hollow markers in the pre-period are rolling-origin placebo estimates: the estimate at quarter $s < -2$ re-estimates the specification using only information through quarter $s - 1$. Standard errors are clustered by calendar time and allow for serial correlation following Driscoll and Kraay (1998) (Section 1.3).

1.5.1. Aggregate Effects on Employment

We show that the employment elasticity with respect to the minimum wage is -0.05 (0.055) in the first year, which is statistically indistinguishable from zero. Averaging over the first two years, the elasticity falls further to -0.21 (0.056), which is statistically significant at the 1% level. Figure 1 plots the dynamic path. The employment estimate is at roughly the 35th percentile of estimates reviewed by Neumark and Shirley (2022), who find a median elasticity of about -0.12 . Neumark and Shirley (2022) find that the average elasticity is stronger (-0.27) for studies of workers directly affected. The employment estimate is close to the large negative estimates from Clemens and Strain (2025) for large minimum wage increases (-0.15 to -0.48) and less negative than Karabarbounis et al. (2025) (-0.3 for restaurants).

1.5.2. Aggregate Effects on Prices

We estimate a price elasticity with respect to the minimum wage of about 0.1 (0.005). Figure 2 plots the dynamic path. This is consistent with recent estimates in the literature; Perez (2026) estimates an average pass-through of about 0.1 across 20 recent studies. The price estimate is very close to estimates on restaurants in the CPI (Aaronson, 2001; Aaronson et al., 2008), which find elasticities of about 0.07. Our estimates are somewhat larger than grocery store estimates (Leung, 2021; Renkin et al., 2022) of 0.058 and 0.036, consistent with grocery stores having a lower labor share.²¹ Ashenfelter and Jurajda (2022) study prices at McDonald’s and find a pass-through of about 0.2 log points, which is consistent with our estimates after about two years.

2. Monopsony and the Minimum Wage

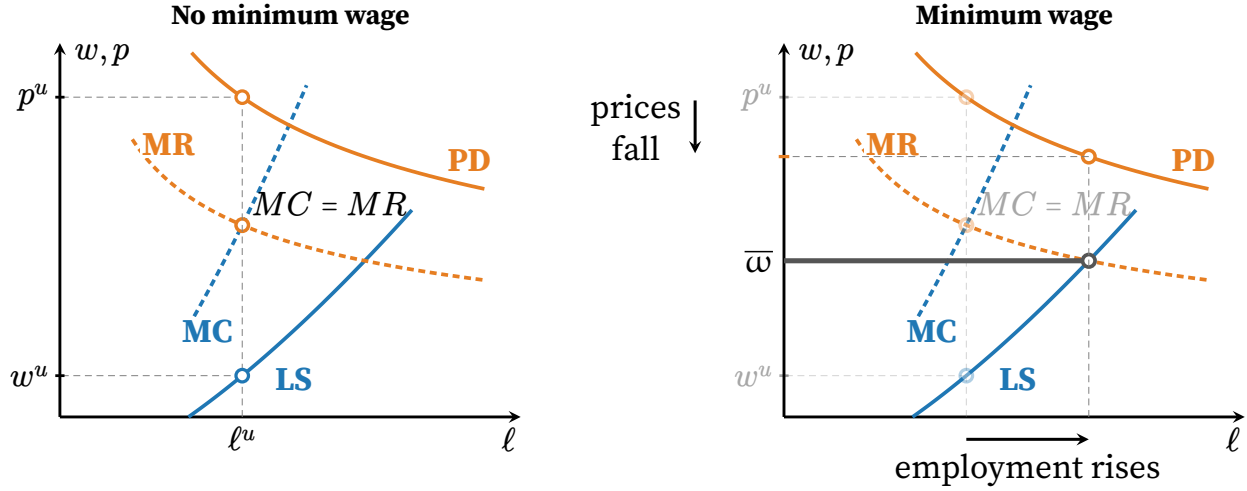
We review Robinson’s predictions for employment and prices at a single firm and explain why they need not hold at the market level when there is heterogeneity across firms and competitive spillovers (as in, e.g., Manning, 2003; Berger et al., 2025). Since these aggregate policy effects are a poor test of monopsony, Section 3.1 discusses tests based on firms’ joint adjustments of employment and prices.

2.1. The Robinson Monopsony Model

Robinson’s monopsony model shows that the effects of the minimum wage are heterogeneous: below some threshold minimum wage, a representative monopsonist increases employment and decreases prices (e.g., Card and Krueger, 1994; Manning, 2021; Kline, 2025). The minimum wage increases wages, but decreases marginal cost, since the firm no longer has to raise wages for everyone to hire the marginal worker. Since marginal cost has fallen, the firm increases its size until there are no more workers willing to work for the minimum wage (Figure 3). These predictions hold until the point where labor supply crosses marginal revenue: the threshold minimum wage ω^* (Figure 4). Above the threshold ω^* , the firm moves along marginal revenue, decreasing employment and increasing prices.

²¹Labor costs are about 16 percent of grocery stores’ variable costs (Renkin et al., 2022), against about 33 percent of restaurants’ total costs (Aaronson et al., 2008).

FIGURE 3. Robinson's Monopsony Model of the Minimum Wage



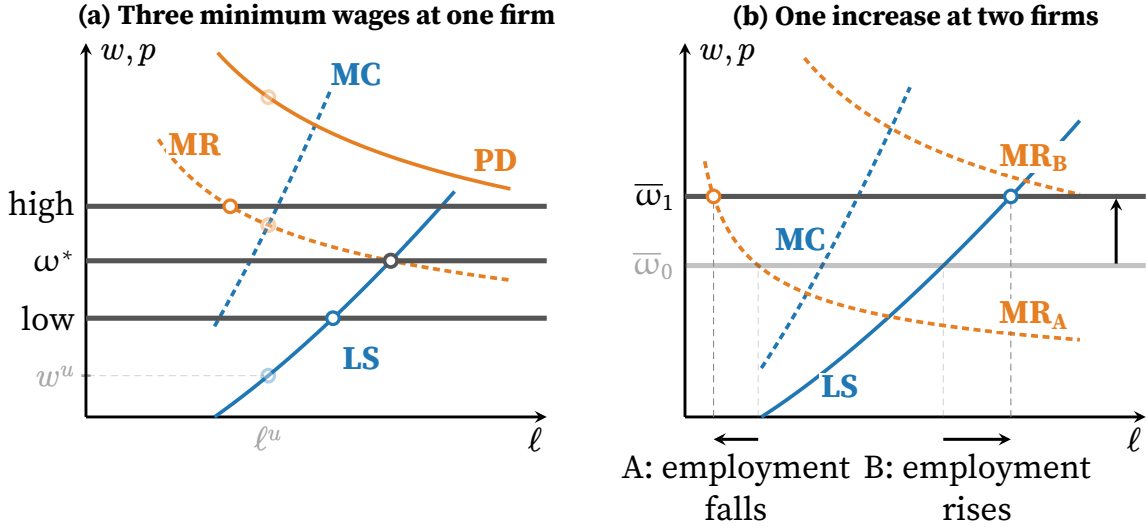
Notes: The left panel shows a monopsonist's choice without a minimum wage. The firm faces downward sloping marginal revenue (MR) and an upward sloping labor supply curve (LS), and sets its size ℓ^u so that marginal revenue equals marginal cost (MC), paying the wage w^u on its labor supply curve and charging the price p^u on its product demand curve (PD). The right panel adds a binding minimum wage $\bar{w}$ above w^u . Along the minimum wage, labor supply is perfectly elastic until there are no more workers willing to work for the minimum wage. The minimum wage increases wages, but decreases marginal cost, since the firm no longer has to raise wages for everyone to hire the marginal worker. Marginal cost is now the minimum wage up to the point where labor supply crosses it, and the firm's original marginal cost beyond. The firm sets its size where marginal revenue crosses this composite marginal cost curve: employment rises along labor supply and prices fall along product demand.

2.2. Why Firm-Level Predictions Need Not Hold in the Aggregate

Robinson's model can hold at every firm and not in the aggregate. Textbook monopsony has two features that are hard to take to data: effects vary across firms, and these effects depend on spillovers.

The standard argument in the literature is that evidence of employment increases is evidence for monopsony, going back to Card and Krueger (1994). On the other hand is the argument that price increases are evidence against monopsony (Brown, 1999; Aaronson and French, 2007). These arguments continue to the present day in working papers studying California's recent \$20 minimum wage for fast-food workers. Sosinskiy and Reich (2026) find null employment effects and partial price pass-through, which they read as "consistent with a monopsony model" (p. 1), while Clemens et al. (2026) read the price increases as "inconsistent with a strong monopsony interpretation" (p. 11).

FIGURE 4. The Threshold Minimum Wage



Notes: Panel (a) draws three minimum wages at the firm in Figure 3. The threshold minimum wage ω^* is the point where labor supply crosses marginal revenue. Below the threshold (low), a higher minimum wage moves the firm along labor supply and employment rises; above it (high), the firm moves along marginal revenue and employment falls. Panel (b) shows one increase in the minimum wage, from $\bar{\omega}_0$ to $\bar{\omega}_1$, at two firms with the same labor supply curve but different marginal revenue curves. Firm A pays the minimum wage, but the minimum wage is above its threshold, so the increase moves it along marginal revenue and employment falls. Firm B also pays the minimum wage, but the minimum wage is below its threshold, so the increase moves it along labor supply and employment rises.

But Manning (2003) points out two reasons why these aggregate policy effects are a poor test of market structure: effects vary across firms and depend on spillovers. Effects vary across firms depending on where the minimum wage crosses their supply and demand curves (Figure 4b). Different mixes of firms above and below their threshold can give different aggregate responses. These effects also depend on spillovers, which occur when the minimum wage changes the outside options of a firm's workers or customers, which are shifts in labor supply and product demand. If minimum wage firms disproportionately compete with other minimum wage firms, then spillovers among firms paying at or near the minimum wage could be important, even while these firms are a small share of the entire market.

2.3. How Heterogeneity and Spillovers Can Explain Conflicting Evidence

Firm heterogeneity and competitive spillovers have the potential to explain several long-standing disagreements and puzzles in the literature.

Disagreement about Employment Effects Different analyses contain different mixes of firms. For example, there are a series of papers disagreeing about the county-pair design (Dube et al., 2010, 2024; Jha et al., 2024). In our framework, these papers could disagree simply because they have different mixes of firms above and below their thresholds. Small changes in specifications or in contexts that change the relative weights of these groups could lead to substantively different estimates of policy effects.

Limited Evidence of Minimum Wage Thresholds One long-running question is why we don't see evidence of these thresholds in the data (Manning, 2021; Dube and Lindner, 2024). Different firms cross their thresholds at different minimum wages, so the aggregate need not contain a single threshold.

The Price Puzzle An open question in the literature is why we don't see prices fall, even though we often see employment rise (Card and Krueger, 1994; Kline, 2025). If employment increases, presumably quantities also increase, and so prices should fall (Brown, 1999). First, the model only requires price cuts at firms below their threshold, and the aggregate can also include price increases from firms above their threshold (see Kline, 2025, for a longer discussion). Second, with spillovers, prices can fall relative to competitors who increase prices, and need not fall in nominal terms.

Direct evidence of these patterns of firm heterogeneity and competitive spillovers remains limited. The challenge in finding this evidence is that the threshold is unobserved and varies across firms. We use the initial wage as a proxy for these unobserved thresholds: firms with higher initial wages should have higher thresholds. Any employment or price response at firms paying above the new minimum wage is direct evidence of spillovers.

3. Reduced-Form Evidence on Heterogeneity and Spillovers

We estimate employment and price policy DiDs across initial wage groups to test the firm-level predictions of the monopsony model, allowing for heterogeneity and competitive spillovers across firms. Employment and relative price effects flip signs across initial wage groups, and firms initially paying above the new minimum wage also adjust, providing direct evidence of spillovers.

3.1. Testing for Monopsony with Initial Wage Groups

We use the initial wage as a proxy for unobserved thresholds: firms with higher initial wages should have higher thresholds.

Initial Wages and Firm-Level Thresholds Heterogeneity depends on where the minimum wage is relative to each firm’s unobserved threshold ω^* .²² By optimization, firms either pay the minimum wage, or they pay their unconstrained wage w_j^u .

We construct proxies to identify firms at which the minimum wage is likely to be below or above their threshold. For a small increase in the minimum wage, from $\bar{w}_0$ to $\bar{w}_1$, we construct three groups of firms:

$$\bar{w}_0 < w_{j0} \leq \bar{w}_1 \quad (\text{Newly Binds}) \quad (5)$$

$$w_{j0} = \bar{w}_0 \quad (\text{Initially Binds}) \quad (6)$$

$$w_{j0} > \bar{w}_1 \quad (\text{Doesn't Bind}) \quad (7)$$

Newly Binds firms (higher thresholds) are initially paying their unconstrained wage, and so are on their labor supply curve. For a small change, a minimum wage slightly above their unconstrained wage keeps them on their labor supply curve. Initially Binds firms (lower thresholds) are already at the old minimum wage, so their w_j^u is at most the old minimum wage. The Initially Binds group is a mix. For small changes, all firms above ω^* are in the Initially Binds group. Finally, Doesn’t Bind firms pay above the new minimum wage and have no direct effects. In Section 4, we will formalize these groups using the

²²The literature has struggled to find enough variation in minimum wages to clearly see where the minimum wage is relative to ω^* (e.g., Manning, 2021, pp. 22–23).

additional structure of the model. At this stage, we simply need the Initially Binds firms to be more likely to be above their thresholds than the Newly Binds firms are.

Evidence on Heterogeneity Rising employment among Newly Binds firms shows that some firms are below their thresholds, and falling employment among Initially Binds firms shows that some firms are above their thresholds. Without spillovers, nominal prices move opposite to employment among Newly Binds and Initially Binds firms. Heterogeneity across these groups is then consistent with different mixes of firms above and below their thresholds.

Evidence on Spillovers The minimum wage has no direct effect on Doesn't Bind firms, so without spillovers their response is zero. Any employment or price response is direct evidence of spillovers. With spillovers, competitors' prices also change, so nominal price effects can shrink or disappear, but *relative prices* still move opposite to employment, holding fixed market demand conditions. We therefore also ask whether the aggregate effects differ across markets (Appendix A.1).

These groups are imperfect for several reasons: some minimum wage changes are large enough that even a firm starting below its threshold could move above it, wages could drift so that $w_{j1}^u \neq w_{j0}^u$, and spillovers could affect employment and prices at all three groups. The structural model is designed to address these concerns; at this stage we seek only suggestive evidence that Manning-style heterogeneity in thresholds or the presence of spillovers are important.

3.2. Constructing the Groups in the Data

The groups above treat each firm as paying a single wage. In the data, a firm pays its workers different wages, so we classify each firm using the lowest paid worker at the firm. When we classify firms by exposure, we compare hourly earnings including tips with the minimum wage, which allows firms to take the tip credit. We measure wages in the second quarter before the minimum wage increase (months -6 to -4). We assign a firm to Initially Binds if any worker is paid the old minimum. We assign a firm to Newly Binds if no worker is at the old minimum and any worker is at or below the new minimum. Finally, we assign

a firm to Doesn't Bind if no workers are at or below the new minimum.²³

When we construct groups from the time series of wages, mean reversion can generate spurious post-treatment differences that do not show up in the pre-period (Derenoncourt et al., 2021; Derenoncourt and Weil, 2025). We apply the same classification rule to treated and control firms and compare them within each group, so common mean reversion loads on common trends. The rolling-origin placebo test in Section 1.3.2 is designed to fail if the groups induce spurious patterns in the time series.

3.3. Results: Heterogeneity and Spillovers

Employment and relative price effects flip signs across initial wage groups. Firms initially paying above the new minimum wage also adjust, providing direct evidence of spillovers.

3.3.1. Heterogeneous Employment and Price Responses

Initially Binds firms decrease employment and raise prices, but Newly Binds firms increase employment holding nominal prices fixed.

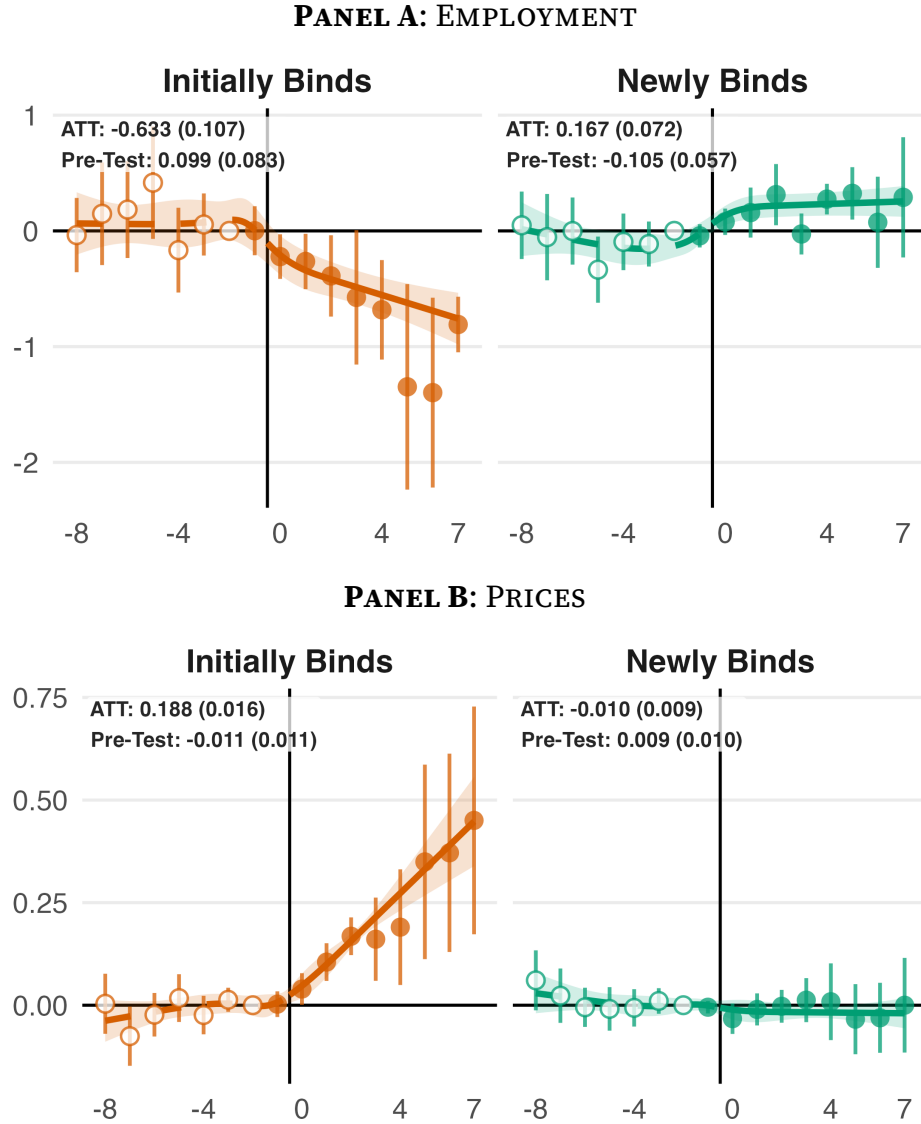
Employment and Prices by Group Figure 5 shows the grouped estimates. At Initially Binds firms, the employment elasticity is -0.633 (0.107) and the price elasticity is 0.188 (0.016). At Newly Binds firms, the employment elasticity is 0.167 (0.072). Consistent with the predictions of the monopsony models, we find this heterogeneity: employment flips sign between the two groups, and so does the relative price, which rises by 0.077 (0.021) at Initially Binds firms and falls by 0.090 (0.018) at Newly Binds firms (Figure 7).

The nominal price does not fall at the Newly Binds firms. The nominal price response is -0.010 (0.009) and statistically indistinguishable from zero.

Comparison with Estimates in the Literature Roughly 88% of the employment elasticity estimates in the Neumark review (Neumark and Shirley, 2022) fall between our estimates for Newly Binds and Initially Binds firms (Figure 6). A sample consisting entirely of Newly Binds firms would yield a positive employment elasticity, while a sample consisting entirely

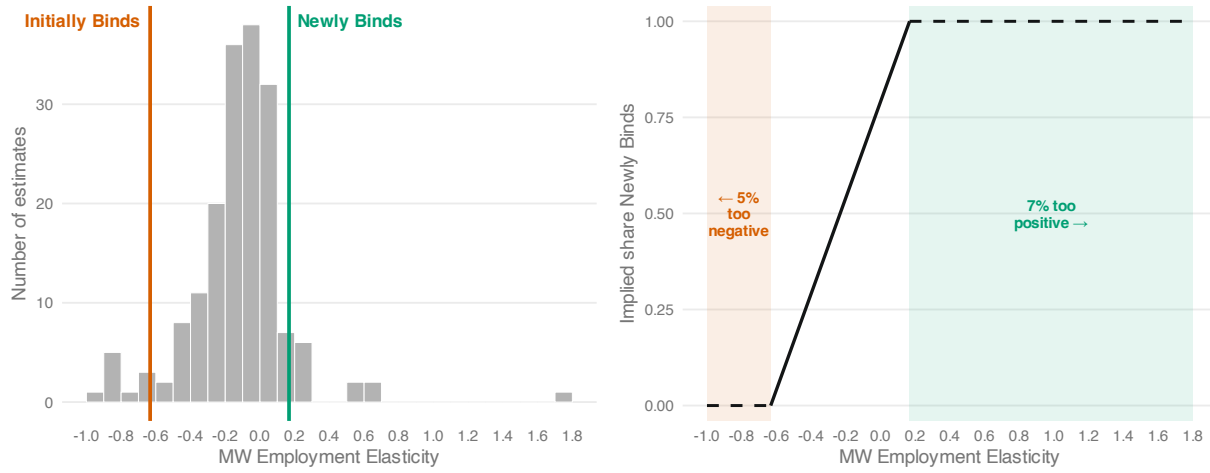
²³We study each increase one at a time, so control firms are assigned in the same way as treated firms. A control firm acting as a control in two different policies can be assigned to two different groups in those two policies.

FIGURE 5. Employment and price event studies by group.



Notes: This figure plots event-study estimates of the effect of a minimum wage increase on employment (Panel A) and log prices (Panel B), separately for Initially Binds and Newly Binds firms. Groups are assigned from hourly earnings in the second quarter before the increase: Initially Binds firms have at least one worker making the old minimum, and Newly Binds firms have no worker at the old minimum but at least one worker at or below the new minimum (Section 3.2). In each quarter, we report the change in the outcome for a 1 log point increase in the minimum wage, relative to two quarters before the increase. Hollow markers in the pre-period are rolling-origin placebo estimates: the estimate at quarter $s < -2$ re-estimates the specification using only information through quarter $s - 1$. The average post-period effect and the average placebo estimate are printed in each panel. Employment falls and prices rise at Initially Binds firms; employment rises and prices are flat at Newly Binds firms. Standard errors are clustered by calendar time and allow for serial correlation following Driscoll and Kraay (1998) (Section 1.3).

FIGURE 6. Comparison with published employment elasticities.



Notes: The left panel is a histogram of the minimum wage employment elasticities collected in Neumark and Shirley (2022). The vertical lines mark our estimates for Initially Binds and Newly Binds firms, the average post-period employment effects from Figure 5. A sample consisting entirely of Newly Binds firms would yield a positive employment elasticity, while a sample consisting entirely of Initially Binds firms would yield a negative elasticity. Different mixtures of these groups would yield elasticities between the two group-specific estimates. The right panel plots the share of Newly Binds firms a sample would need to produce each elasticity as a mixture of the two. Estimates to the left of the Initially Binds line (5%) are too negative for any mixture, and estimates to the right of the Newly Binds line (7%) are too positive; the remaining 88% fall between the two.

of Initially Binds firms would yield a negative elasticity. Different mixtures of these groups would yield elasticities between the two group-specific estimates. In a very reduced-form way, different compositions of these groups can generate much of the observed variation.

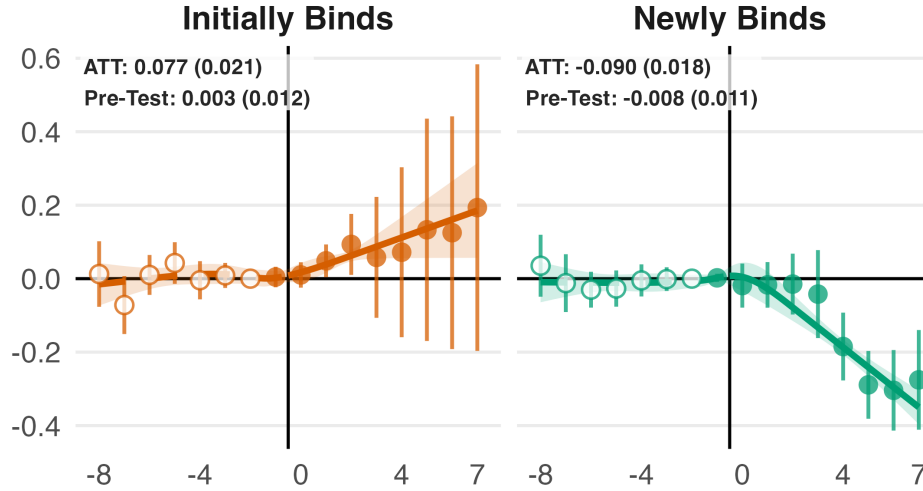
3.3.2. Competitive Spillovers

Relative prices fall at the firms that increase employment. Firms that are not bound by the minimum wage also adjust their employment and prices.

Relative Prices Newly Binds firms are competing with other firms that increase their prices, so the relative price of the Newly Binds firms falls (Figure 7). The relative price cuts for the Newly Binds firms are persistent through the event window and, if anything, are increasing over time.

The price cuts predicted by the monopsony model have eluded the empirical literature

FIGURE 7. Relative price event studies by group.

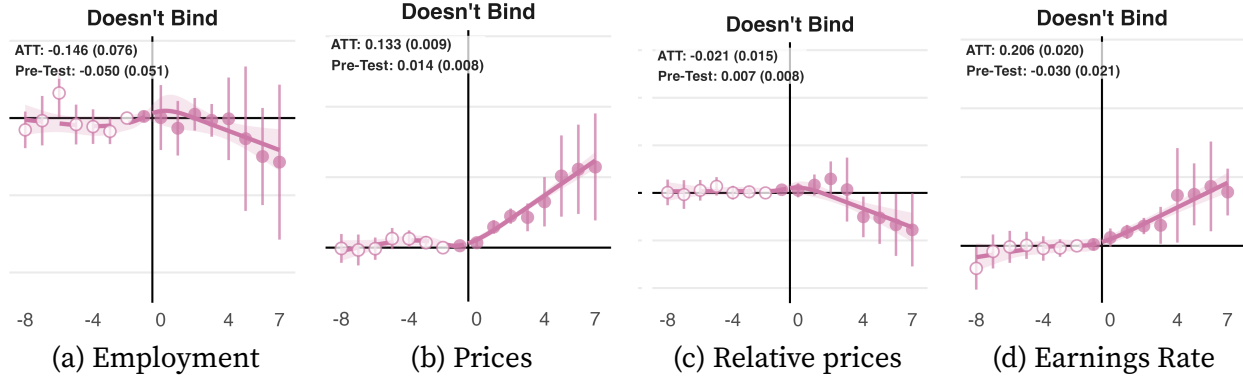


Notes: This figure plots event-study estimates of the effect of a minimum wage increase on relative log prices, separately for Initially Binds and Newly Binds firms. A firm's relative price is its log price index minus a weighted average of other firms' price indices. The weight on each competitor is proportional to the share of the firm's revenue that comes from customers it shares with that competitor (Section 1.4). Groups are assigned from hourly earnings in the second quarter before the increase: Initially Binds firms have at least one worker making the old minimum, and Newly Binds firms have no worker at the old minimum but at least one worker at or below the new minimum (Section 3.2). In each quarter, we report the change in relative log prices for a 1 log point increase in the minimum wage, relative to two quarters before the increase. Hollow markers in the pre-period are rolling-origin placebo estimates: the estimate at quarter $s < -2$ re-estimates the specification using only information through quarter $s - 1$. The average post-period effect and the average placebo estimate are printed in each panel. Relative prices fall at Newly Binds firms even though nominal prices do not. Standard errors are clustered by calendar time and allow for serial correlation following Driscoll and Kraay (1998) (Section 1.3).

for thirty years, since at least Card and Krueger (1994, p. 791).²⁴ Heterogeneity in initial wages and spillovers between firms obscure these price cuts in aggregate employment and price effects. First, the model only requires price cuts at firms below their threshold, and the aggregate can also include price increases from firms above their threshold (see Kline, 2025, for a longer discussion). Here the employment declines and price increases at the Initially Binds firms dominate in the aggregate, even though employment rises and

²⁴Card and Krueger (1994, p. 791) note that "One way to test a monopsony model is to identify stores that were initially 'supply-constrained' in the labor market and test for employment gains at these stores relative to other stores." In the same model, prices should have fallen "at low-wage stores in New Jersey relative to high-wage stores in New Jersey" (p. 791). They aim to identify supply-constrained firms through the use of recruitment bonuses, but find no differential employment growth at these stores (p. 792).

FIGURE 8. Employment and price event studies at Doesn't Bind firms.



Notes: This figure plots event-study estimates of the effect of a minimum wage increase on employment (Panel a), log prices (Panel b), relative log prices (Panel c), and log hourly earnings (Panel d) at Doesn't Bind firms, which pay above the new minimum wage at baseline (months -6 to -4). A firm's relative price is its log price index minus a weighted average of other firms' price indices. The weight on each competitor is proportional to the share of the firm's revenue that comes from customers it shares with that competitor (Section 1.4). In each quarter, we report the change in the outcome for a 1 log point increase in the minimum wage, relative to two quarters before the increase. Hollow markers in the pre-period are rolling-origin placebo estimates: the estimate at quarter $s < -2$ re-estimates the specification using only information through quarter $s - 1$. The average post-period effect and the average placebo estimate are printed in each panel. Standard errors are clustered by calendar time and allow for serial correlation following Driscoll and Kraay (1998) (Section 1.3).

relative prices fall at the Newly Binds firms. Second, with spillovers, prices can fall relative to competitors who increase prices, and need not fall in nominal terms.

The results support heterogeneity together with product-market spillovers. In principle, the demand shift alone can explain the quantity response at Newly Binds firms. But a demand shift alone would also raise nominal prices at these firms; the estimated price response is -0.010 (s.e. 0.009), statistically indistinguishable from zero. We use the quantitative model (Section 4) to quantify how much these firms grow because the minimum wage moves them along their labor supply curve or because demand shifts toward them.

Firms Not Bound by the Minimum Wage The Doesn't Bind group has an employment elasticity of -0.146 (0.076), a nominal price elasticity of 0.133 (0.009), and a relative price elasticity of -0.021 (0.015) (Figure 8). These firms pay above the new minimum wage at baseline (months -6 to -4); these responses are therefore direct evidence that spillovers through labor and product markets are qualitatively important.

Quantifying these different channels and extrapolating to counterfactual policy interventions require knowing the market structure. Motivated by these facts, we build a structural model that features unobservable firm heterogeneity and rich market spillovers (Flinn, 2006; Berger et al., 2025; Karabarbounis et al., 2025), and we show how to identify it using heterogeneous effects of the minimum wage across firms and markets.

4. The Model

We develop a quantitative monopsony model in which firms differ in their minimum wage thresholds and compete in labor and product markets. Minimum wage hikes move firms along their supply and demand curves and shift those curves through competitive spillovers, so aggregate policy effects depend on both firm heterogeneity and competitive spillovers.

4.1. Heterogeneity and Spillovers through Demand and Supply

In our model, firms have their own quality (product), amenity (labor), and productivity shifters. These shifters allow each firm to have its own demand and supply curves, and therefore every firm can have its own minimum wage threshold. The minimum wage can shift demand and supply by shifting market-level indices and aggregates.

4.1.1. Firms and Markets

Our model features firms in local labor and product markets that share state-level outside options. The minimum wage affects outcomes at an individual firm by changing its own price and wage, and by changing local product and labor market conditions. In the main text, we assume that the outside option does not change. Appendix C.4 allows the outside option to change.

In each local market there is a single nest, which separates our focal “counter-service” firms from the outside option. The outside option is whatever happens outside our data, and so is a composite of unemployment and employment in, e.g., the warehouse sector. The local markets within a state share an outside option, but otherwise don’t directly interact. On the product side, a firm’s local market is the network of firms sharing customers, and customers in the same state share a common outside option of shopping at a large chain.

Policies are assigned at the level of the state $s(j)$; each state contains multiple markets $m(j)$, which in turn contain many firms j , and t indexes time. Each firm takes all market indices and aggregates as given when choosing its wage, employment, and price, and so the minimum wage effect combines both direct effects (through the direct constraint) and indirect effects through these aggregates. Lowercase variables denote logs of their uppercase counterparts.

4.1.2. Market Structure and Production

Without the minimum wage, we have constant-elasticity demand and labor supply, as in Kroft et al. (2025), linked by a decreasing returns to scale, labor-only production technology.

Product demand. This model captures two primary ways that the minimum wage affects firm-level demand, directly through prices and indirectly by shifting the demand curve.

The log product demand curve takes the following form:

$$q_{jt} = g_{jt} - \epsilon (p_{jt} - \tilde{p}_{jt}) - \eta_p (\tilde{p}_{jt} - \hat{p}_{s(j)}) + \eta_e \tilde{e}_{m(j)t} \quad (8)$$

where g_{jt} is firm quality, p_{jt} is the own price, $\tilde{p}_{jt}$ is the competitor price index, $\hat{p}_{s(j)}$ is the price at the outside option, and $\tilde{e}_{m(j)t}$ is aggregate market earnings. The competitor price index $\tilde{p}_{jt}$ is the customer-overlap weighted price index (Section 1), which plays the role of the standard market-level price index. Aggregate earnings $\tilde{e}_{m(j)t}$ are the total labor earnings in market $m(j)$. This term enters explicitly to allow the minimum wage to shift demand by shifting aggregate earnings, in addition to the direct effects on prices. Finally, the price at the outside option $\hat{p}_{s(j)}$ enters additively as a common state effect.

Labor supply. From the perspective of the firm, this is a standard isoelastic labor supply curve. However, we need to adapt the market level terms to account for the fact that the minimum wage can cause rationing (i.e. a wedge between labor supply and realized employment at firms above their threshold). We adapt the workhorse model to allow minimum wage increases that both 1) increase the market-level wage rate and 2) increase market-level rationing to have an ex-ante ambiguous effect on the firm-level labor supply curve, which we discuss in more detail below. The log labor supply curve takes the following form:

$$\ell_{jt}^S = a_{jt} + \phi (w_{jt} - \tilde{w}_{m(j)t}) + \eta_w (\tilde{w}_{m(j)t} - \hat{w}_{s(j)}) - \eta_\ell \tilde{\ell}_{m(j)t} \quad (9)$$

where a_{jt} is firm amenity, w_{jt} is the own wage, $\tilde{w}_{m(j)t}$ is the market wage index,²⁵ $\hat{w}_{s(j)}$ is the wage-equivalent value of the outside option, and $\tilde{\ell}_{m(j)t}$ is realized aggregate market employment. The outside option $\hat{w}_{s(j)}$ enters additively as a common state effect.

Realized aggregate employment $\tilde{\ell}_{m(j)t}$ is the total employment in market $m(j)$. This term enters explicitly to allow the minimum wage to shift labor supply by increasing market-level rationing, in addition to the direct effects on wages. Labor supply ℓ_{jt}^S equals realized employment at firms on their labor supply curve, but at firms above their threshold it exceeds realized employment. We discuss the substance of the rationing mechanism below and show how this labor supply curve arises from a modified nested logit model in Appendix C.

Rationing. Increasing a binding minimum wage at one firm affects labor supply to other firms in two ways. First, increasing the binding minimum wage increases wages at firms paying the minimum wage, which makes it harder for other firms to hire when $\eta_w < \phi$ (as in our estimates; Table 3). However, if some firms decrease employment as the minimum wage increases, some of these workers may be able to work at other firms, which makes it easier for these firms to hire. This would show up as reallocation as in Dustmann et al. (2021). By explicitly including both channels, we allow the data to determine the direction of the spillover onto firms paying above the minimum wage. In contrast, the theoretically elegant “shadow wage” rationing mechanism proposed by Berger et al. (2025), and the related expected-wage mechanism in Bhuller et al. (2025), imply that employment is a sufficient statistic for the direction of the spillover.²⁶ If rationing decreases employment,

²⁵The market wage index is $\tilde{W}_{m(j)t} = (\sum_{k \in m(j)} A_{kt} W_{kt}^\phi)^{1/\phi}$, where A_{kt} is the amenity weight of Appendix C.2, with $\tilde{w}_{m(j)t} = \log \tilde{W}_{m(j)t}$.

²⁶Berger et al. (2025) choose “shadow wages” at rationed firms that rationalize the observed allocations. If a rationed firm increases wages but rations workers such that employment falls, this means the shadow wage has also fallen. A key advantage of the shadow wage is that it allows for a direct comparison between distortions to the allocation of workers due to monopsony (lower wages) and distortions from rationing (lower shadow wages), which highlights the conceptual tradeoff between setting the minimum wage “too low” or “too high”. However, since the shadow wage rationalizes observed quantities, a change in employment due to a cut in wages and a change in employment of the same size due to an increase in the minimum enter the wage index identically and have the same spillover effects.

it decreases the shadow wage, which can cause firms paying above the minimum wage to decrease their wages. Since our model is designed to quantify competitive spillovers, we preserve both the wage channel and the rationing channel for the sake of the empirical analysis.

Production. The product and labor markets are linked by a simple production technology that depends only on labor. Production has returns to scale α and firm productivity ρ_{jt} and so log output is:

$$q_{jt} = \rho_{jt} + \alpha \ell_{jt} \quad (10)$$

We abstract from adjustments in capital in response to the minimum wage. Productivity ρ_{jt} could reflect differences in capital, among other things, but we will need to assume that the policy has no direct effect on productivity, though it can change over time.

4.1.3. Model Features

This model contains three unobservable sources of firm-level heterogeneity:

$$\xi_{jt} \equiv (a_{jt}, g_{jt}, \rho_{jt}) \quad (11)$$

It also contains seven common structural parameters:

$$\theta = (\epsilon, \eta_p, \eta_e, \alpha, \phi, \eta_w, \eta_\ell)' \quad (12)$$

The first three govern product demand, α governs production, and the last three govern labor supply. We maintain $\epsilon > 1$, $\phi > 0$, and $0 < \alpha < 1$. These restrictions make revenue strictly concave in employment and inverse labor supply increasing. The rationing mechanism in Appendix C.2 gives $\eta_w \geq 0$ and $\eta_\ell \geq 0$. Let $\mathcal{A}_{jt}$ collect the aggregates:

$$\mathcal{A}_{jt} \equiv \{\tilde{p}_{jt}, \hat{p}_{s(j)}, \tilde{e}_{m(j)t}, \tilde{w}_{m(j)t}, \hat{w}_{s(j)}, \tilde{\ell}_{m(j)t}\} \quad (13)$$

4.2. The Firm's Problem

Firms take their product demand, labor supply and production as given and maximize profits subject to the minimum wage. We can invert demand and labor supply so that the firm's problem is a choice of optimal size. Let $\bar{w} \equiv \log \bar{W}$ denote the log minimum wage.

$$\max_{\ell} \underbrace{\exp(p_{jt}(\ell) + q_{jt}(\ell))}_{\text{Revenue}} - \underbrace{\exp(\max\{\bar{w}, w_{jt}(\ell)\} + \ell)}_{\text{Wage bill}} \quad (14)$$

where $q_{jt}(\ell) = \rho_{jt} + \alpha\ell$, and $w_{jt}(\ell)$ is inverse labor supply and $p_{jt}(\ell)$ is inverse demand.²⁷

Write MR for marginal revenue with respect to employment and MC for marginal labor cost. The firm would like to increase size as long as $MR > MC$ and decrease when $MC > MR$. The marginal cost structure differs depending on whether the firm is paying the minimum wage or is unconstrained and moving along its labor supply curve. There is a single point of discontinuity where the minimum wage crosses the labor supply curve.²⁸ The FOC therefore has three cases: above the threshold, where the firm moves along marginal revenue; below the threshold, where the firm pays the minimum wage and moves along labor supply; and unconstrained, where the minimum wage is slack. Appendix C.3 proves that these conditions are necessary and sufficient for a unique firm optimum.

$$\log MR_{jt}(\ell^*) \begin{cases} = \bar{w}, & \ell^* < \bar{\ell}_{jt} \quad (\text{above threshold}), \\ \in [\bar{w}, \bar{w} + \nu], & \ell^* = \bar{\ell}_{jt} \quad (\text{below threshold}), \\ = w_{jt}(\ell^*) + \nu, & \ell^* > \bar{\ell}_{jt} \quad (\text{unconstrained}) \end{cases} \quad (15)$$

where $\log MR_{jt}(\ell) = \log[\alpha(1 - \epsilon^{-1})] + p_{jt}(\ell) + q_{jt}(\ell) - \ell$, $\nu \equiv \log(1 + \phi^{-1})$, and $\bar{\ell}_{jt}$ is labor supply if firm j paid the minimum wage. We can rearrange these conditions to write log employment as a piecewise linear function of the log minimum wage, holding primitives and aggregates fixed.

²⁷The inverse labor supply comes from rearranging the labor supply curve to solve for w_{jt} given ℓ . This is given by $w_{jt}(\ell) = \phi^{-1}(\ell - a_{jt}) + (1 - \eta_w \phi^{-1}) \tilde{w}_{m(j)t} + \eta_w \phi^{-1} \hat{w}_{s(j)} + \eta_\ell \phi^{-1} \tilde{\ell}_{m(j)t}$. The inverse demand comes from using the production function (10) to write quantity in terms of employment ℓ and then rearranging demand to solve for p_{jt} given $q_{jt}(\ell)$. This is given by $p_{jt}(\ell) = \epsilon^{-1}(g_{jt} - q_{jt}(\ell)) + (1 - \eta_p \epsilon^{-1}) \tilde{p}_{jt} + \eta_p \epsilon^{-1} \hat{p}_{s(j)} + \eta_e \epsilon^{-1} \tilde{e}_{m(j)t}$.

²⁸At this point, decreasing employment decreases costs by exactly the minimum wage, since wages don't adjust. However, to increase employment, the firm must increase wages for all workers, so the marginal cost jumps up to $\bar{W} + W'(L)L = \bar{W}(1 + \phi^{-1})$, or $\bar{w} + \nu$ in logs. Therefore the FOC is that the firm sets $MR_- \geq MC_-$ and $MR_+ \leq MC_+$, which collapses to $MR = MC$ whenever $MC_- = MC_+$, which holds everywhere except for this single point of discontinuity.

4.3. Optimal Employment and Minimum Wage Thresholds

We can rearrange these FOCs to eliminate the firm's choice and write the optimal employment as a function of the firm-specific heterogeneity ξ_{jt} , the aggregates that the firm takes as given, and the minimum wage.

To do this, it is convenient to collect the firm's demand and supply shifters:

$$\mathcal{D}_{jt} \equiv (1 - \eta_p \epsilon^{-1}) \tilde{p}_{jt} + \eta_p \epsilon^{-1} \hat{p}_{s(j)} + \eta_e \epsilon^{-1} \tilde{e}_{m(j)t} \quad (16)$$

$$\mathcal{S}_{m(j)t} \equiv (1 - \eta_w \phi^{-1}) \tilde{w}_{m(j)t} + \eta_w \phi^{-1} \hat{w}_{s(j)} + \eta_\ell \phi^{-1} \tilde{\ell}_{m(j)t} \quad (17)$$

Additionally, since revenue depends on curvature in both production and in the final output demand, we collect those terms into the elasticity of labor demand:

$$\gamma \equiv [1 - \alpha (1 - \epsilon^{-1})]^{-1} \quad (18)$$

We can use these expressions to write the unconstrained wage (ignoring the minimum wage) as

$$w_{jt}^u \equiv \frac{\gamma (\xi_{jt}^D + \mathcal{D}_{jt} - \nu) + \phi \mathcal{S}_{m(j)t} - a_{jt}}{\gamma + \phi} \quad (19)$$

where ξ_{jt}^D is a firm-specific demand intercept that depends on the ξ_{jt} .²⁹

The threshold minimum wage is a constant wedge above the unconstrained wage w_{jt}^u :

$$\omega_{jt}^* - w_{jt}^u = \frac{\gamma \nu}{\gamma + \phi} > 0 \quad (20)$$

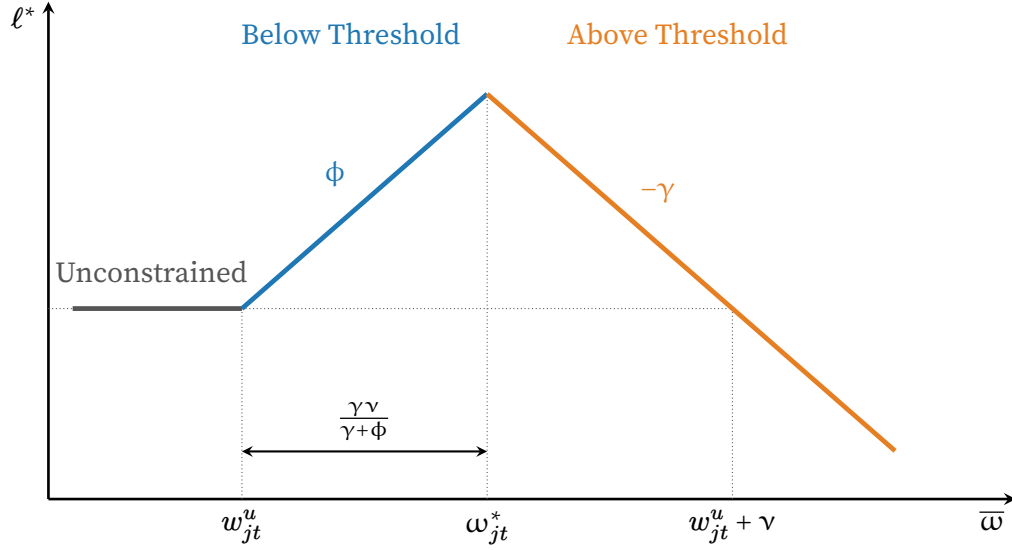
The threshold is therefore

$$\omega_{jt}^* \equiv \frac{\gamma (\xi_{jt}^D + \mathcal{D}_{jt}) + \phi \mathcal{S}_{m(j)t} - a_{jt}}{\gamma + \phi} \quad (21)$$

Given these thresholds, we can write the firm's choice of employment as a structural function f^ℓ of the minimum wage $\bar{w}$, the firm-level heterogeneity ξ_{jt} , the aggregate state $\mathcal{A}_{jt}$, and the model parameters as:

²⁹ $\xi_{jt}^D \equiv \log[\alpha (1 - \epsilon^{-1})] + \epsilon^{-1} g_{jt} + (1 - \epsilon^{-1}) \rho_{jt}$ and $\xi_{jt}^U \equiv \xi_{jt}^D + \phi^{-1} a_{jt} - \nu$.

FIGURE 9. Optimal Employment and the Minimum Wage



Notes: This figure plots a firm's optimal log employment ℓ^* against the log minimum wage $\bar{w}$, holding fixed the firm's shifters and the market aggregates. The function mapping the minimum wage into optimal employment is piecewise linear in the minimum wage. For low values of the minimum wage below the unconstrained wage w_{jt}^u , the slope is zero, then for $\bar{w}$ between w_{jt}^u and ω_{jt}^* , the slope is ϕ (along the labor supply curve), and then finally for $\bar{w} > \omega_{jt}^*$, the slope is $-\gamma$ (along the labor demand curve). The threshold ω_{jt}^* is a constant wedge $\gamma v / (\gamma + \phi)$ above the unconstrained wage, where $v \equiv \log(1 + \phi^{-1})$ is the log markdown, and employment returns to its unconstrained level at $w_{jt}^u + v$. The figure is drawn with $\phi = 2$, $\gamma = 2$, and $v = \log 1.5$.

$$f^\ell(\bar{w}; \xi_{jt}, \mathcal{A}_{jt}, \theta) \equiv \begin{cases} \gamma (\xi_{jt}^D + \mathcal{D}_{jt} - \bar{w}), & \bar{w} > \omega_{jt}^* \quad (\text{above threshold}), \\ a_{jt} + \phi (\bar{w} - \mathcal{S}_{m(j)t}), & w_{jt}^u \leq \bar{w} \leq \omega_{jt}^* \quad (\text{below threshold}), \\ \frac{\phi\gamma}{\phi + \gamma} (\xi_{jt}^U + \mathcal{D}_{jt} - \mathcal{S}_{m(j)t}), & \bar{w} < w_{jt}^u \quad (\text{unconstrained}) \end{cases} \quad (22)$$

Figure 9 illustrates that, holding fixed the aggregates, the function mapping the minimum wage into optimal employment is piecewise linear in the minimum wage. In particular, for low values of the minimum wage below the unconstrained wage w_{jt}^u , the slope is zero, then for $\bar{w}$ between w_{jt}^u and ω_{jt}^* , the slope is ϕ (along the labor supply curve), and then finally for $\bar{w} > \omega_{jt}^*$, the slope is $-\gamma$ (along the labor demand curve). Appendix C.3 derives w_{jt}^u , ω_{jt}^* , and the other outcomes at the optimum. Both the unconstrained wage w_{jt}^u and the threshold ω_{jt}^* move when the minimum wage changes the market aggregates.

4.4. The Identification Problem

Firm-specific quality, amenity, and productivity shifters mean that differences in wages and employment across firms do not trace out a single supply or demand curve. These shifters can also change over time, so changes in wages and employment within firms need not trace out either curve. We therefore use minimum wage hikes as a source of policy variation to identify supply and demand.

Minimum wage hikes move constrained firms along labor supply below their thresholds and along labor demand above them. But they also shift these curves by changing market-level indices and aggregates. One aggregate policy DiD cannot separate movements along these curves from shifts in the curves. In the next section, we show how the underlying DiD variation across firms and markets identifies the model's parameters.

5. Identification and Estimation

We show how heterogeneous policy responses across firms and markets identify the structural parameters from a single source of policy variation, and estimate the model by GMM.

5.1. Recovering Structural Parameters from DiD Variation

The Conditional DiD. Recall we motivated the DiD design with a conditional common trends assumption (Section 1.3), which we maintain here. For the sake of exposition, consider a pre increase period 0 and post increase period t . Write the change in an outcome y as $\Delta y_{jt} \equiv y_{jt} - y_{j0}$ and let T_j indicate firms in states that increase their minimum wage. The underlying covariate-specific DiDs are

$$\text{DiD}(y, X) \equiv \mathbb{E}[\Delta y_{jt} \mid X, T_j = 1] - \mathbb{E}[\Delta y_{jt} \mid X, T_j = 0] \quad (23)$$

For any outcome y , let $\mu^y(X) \equiv \mathbb{E}[\Delta y_{jt} \mid X_j = X, T_j = 0]$ be the control trend, and write the change net of the control trend as $\Delta^0 y_{jt} \equiv \Delta y_{jt} - \mu^y(X_j)$. By construction $\mathbb{E}[\Delta^0 y_{jt} \mid X, T_j = 0] = 0$ and $\mathbb{E}[\Delta^0 y_{jt} \mid X, T_j = 1] = \text{DiD}(y, X)$.

A Structural Equation in DiDs. To build intuition for identification, consider initially unconstrained firms and a minimum wage hike small enough that they remain on their labor supply curves under both policy states. Taking conditional DiDs of the labor supply equation (9) gives:

$$\text{DiD}(\ell, X) = \phi \text{DiD}(w - \tilde{w}, X) + \eta_w \text{DiD}(\tilde{w}, X) - \eta_\ell \text{DiD}(\tilde{\ell}, X) \quad (24)$$

The firm's fixed amenity differences out, and its amenity trend is common to treated and control firms with the same X under the appropriate common trends assumption (Assumption 1, Section 5.2).

Many Conditional DiDs. When we report the canonical aggregate DiD in Section 1.5, this is simply an average over many of these valid X -specific DiDs. Those X -specific DiDs provide the identifying variation we need to recover our structural parameters. Blundell et al. (1998) make a similar argument and use differences across groups following a tax reform to identify labor supply parameters. Identification then depends on whether the policy effects across X provide enough independent first-stage variation (Appendix D.3). Because the right-hand-side DiDs are reduced-form policy effects that we estimate, we can test whether this rank condition holds. Section 3.3.1 shows that these policy effects differ across groups.

5.2. Identification of the Minimum Wage Model

5.2.1. Connecting Common Trends to the Structural Model

We connect the static model to the reduced form DiDs by restricting how unobservable firm heterogeneity and market-level aggregates change over time.

Panel Data from a Static Model. To do this, we need to connect the static model to panel data. To generate the panel data, we apply the structural function to the realized minimum wage, the realized aggregates, and the unobservable firm heterogeneity in every period.

Structural Common Trends. We first consider what conditional common trends means for unobservable firm heterogeneity, holding market-level aggregates fixed.

ASSUMPTION 1 (Structural common trends).

$$a_{jt} = a_j + u_t^a(X_j), \quad g_{jt} = g_j + u_t^g(X_j), \quad \rho_{jt} = \rho_j + u_t^\rho(X_j) \quad (25)$$

We assume that (for example) the amenity a_{jt} has a time-invariant firm-specific component a_j and a time trend $u_t^a(X_j)$ that does not depend on j , except through observables X_j . These $u_t^a(X_j)$ are the structural common trends, and similarly for quality g_{jt} and productivity ρ_{jt} . The trends do not depend on T_j , so the policy has no direct effect on amenities, quality or productivity.

X_j includes time invariant observables (industry, population density) as well as initial conditions at the firm (employment, revenue, wage) and market (K lags of all the aggregates in $\mathcal{A}_{jt}$: the price, wage, earnings and employment indices).

Market Aggregates. Two firms with the same individual observables can have different effects if they are in markets with different market-level effects. In principle, we could condition on the whole distribution of observables for all the firms in the market, but that would be too high dimensional. Instead, we include the history of the aggregates (e.g. the market-level wage index) in X to control for the differences in composition. We make this assumption directly:

ASSUMPTION 2 (Aggregates are functions of their history).

$$\mathcal{A}_{jt}(\bar{\omega}) = \mathcal{A}_t\left(\bar{\omega}; \left\{\mathcal{A}_{j,-k}\right\}_{k=0}^{K-1}\right) \quad (26)$$

This implies

$$\Delta \mathcal{D}_{jt} = \Delta \mathcal{D}_t(X_j, T_j), \quad \Delta \mathcal{S}_{m(j)t} = \Delta \mathcal{S}_t(X_j, T_j) \quad (27)$$

We also maintain the assumption of Section 4.1 that the state outside options $\hat{w}_{s(j)}$ and $\hat{p}_{s(j)}$ do not respond to the policy. If they did, treated states would have policy-driven intercept shifts in demand and labor supply that the comparison with control states does not remove. In Appendix C.4, we show how to accommodate unobservable shifts in the state-level outside option.

For small changes in the minimum wage such that initially unconstrained firms remain below their thresholds under both policy states, the optimal employment expression in Proposition 1 reduces to labor supply. We now extend this argument to firms that cross their thresholds.

5.2.2. Structural DiDs and Firm-Level Primitives

Employment Changes without Unobservables. We can eliminate the firm-specific heterogeneity by conditioning on firms that are initially unconstrained (the Newly Binds and Doesn't Bind groups from Section 3.3.1). For an initially unconstrained firm, the labor supply equation holds in the first period and we observe the unconstrained wage w_{j0}^u . Proposition 1 shows that we can then eliminate the unobservable heterogeneity and write changes in employment and wages as functions only of observables and structural parameters.

PROPOSITION 1. *Consider initially unconstrained firms in initial-wage cells whose control group does not mean revert down to the minimum wage in period t .³⁰ Under Assumption 1, the changes in employment and in wages, net of their control trends, can be written as functions of only the observables and the parameters of interest. In particular:*

(i) $\Delta^0 \ell_{jt} = f^{\Delta \ell}(\Delta^0 w_{jt}, \Delta^0 \mathcal{A}_{jt}; \theta)$, where

$$f^{\Delta \ell}(\Delta^0 w_{jt}, \Delta^0 \mathcal{A}_{jt}; \theta) = f^{LS}(\Delta^0 w_{jt}, \Delta^0 \mathcal{A}_{jt}; \theta) - \psi_{jt}(\theta) \quad (28)$$

$$f^{LS}(\Delta^0 w_{jt}, \Delta^0 \mathcal{A}_{jt}; \theta) = \phi \left(\Delta^0 w_{jt} - \Delta^0 \tilde{w}_{m(j)t} \right) + \eta_w \Delta^0 \tilde{w}_{m(j)t} - \eta_\ell \Delta^0 \tilde{\ell}_{m(j)t} \quad (29)$$

$$\psi_{jt}(\theta) = (\phi + \gamma) \max \left\{ 0, \Delta^0 w_{jt} - f^{\Delta w^u}(\Delta^0 \mathcal{A}_{jt}; \theta) - \frac{\gamma^v}{\gamma + \phi} \right\} \quad (30)$$

Here, f^{LS} is the change in labor supply. $\psi_{jt}(\theta)$ is the rationing wedge, the gap between labor supply and realized employment. Below the threshold this wedge is zero; above the threshold, employment follows the marginal revenue curve, as in the optimal employment function (22).

(ii) $\Delta^0 w_{jt} = f^{\Delta w}(\bar{w}_1, \Delta^0 \mathcal{A}_{jt}, X_j; \theta)$, where

$$f^{\Delta w}(\bar{w}_1, \Delta^0 \mathcal{A}_{jt}, X_j; \theta) = \max \left\{ f^{\Delta w^u}(\Delta^0 \mathcal{A}_{jt}; \theta), \bar{w}_1 - w_{j0} - \mu^w(X_j) \right\} \quad (31)$$

where the initial wage w_{j0} is an element of X_j and the change in the unconstrained

³⁰Because the initial wage is in X_j , these are restrictions on X_j . We observe if the minimum wage is binding, so both are sample restrictions rather than assumptions. On this sample no control firm binds, so $\mu^w(X_j)$ is the control trend in the unconstrained wage and no control firm is above its threshold. The control trends are taken on these cells. In practice, wage growth is strong in this period, so this restriction on the control group wage growth never applies.

wage, net of its control trend, is

$$f^{\Delta w^u}(\Delta^0 \mathcal{A}_{jt}; \theta) = \frac{\gamma \Delta^0 \mathcal{D}_{jt} + \phi \Delta^0 \mathcal{S}_{m(j)t}}{\gamma + \phi} \quad (32)$$

The trends in the amenity, quality and productivity (u_t^a , u_t^g and u_t^p in Assumption 1) drop out because the same trends enter the control firms' labor supply and unconstrained wage, so they are absorbed by $\mu^\ell(X_j)$ and $\mu^w(X_j)$. With the outside options fixed, $\Delta^0 \mathcal{D}_{jt}$ and $\Delta^0 \mathcal{S}_{m(j)t}$ are linear combinations of $\Delta^0 \mathcal{A}_{jt}$. Appendix D.1 proves Proposition 1.

We compose $f^{\Delta \ell}$ and $f^{\Delta w}$ to write the employment change as a function of the minimum wage. Below the threshold, the firm is on its labor supply curve and there is no rationing wedge, so this is the labor supply equation from the example in Section 5.1.

The Structural DiD Equation. Applying Proposition 1 to the conditional DiD gives

$$\text{DiD}(\ell, X) = \phi \text{DiD}(w - \tilde{w}, X) + \eta_w \text{DiD}(\tilde{w}, X) - \eta_\ell \text{DiD}(\tilde{\ell}, X) - \mathbb{E}[\psi_{jt}(\theta) \mid X, T_j = 1] \quad (33)$$

The final term is the expected rationing wedge among treated firms with the same X ; it is zero for control firms on our sample (see Appendix D.1). Under Assumption 2, $\Delta^0 \mathcal{A}_{jt}$, and hence $\Delta^0 w_{jt}$ and $\psi_{jt}(\theta)$, are functions of X and T_j alone, so the wedge is a known function of the cell and the parameters.

Assumption 1 rules out idiosyncratic shocks to firm primitives within an X cell. Conditionally mean-zero shocks leave the demand, production and labor supply moments unchanged, but can move firms across their thresholds and change the expected rationing wedge. The stronger assumption lets us calculate this wedge from observables and structural parameters. For firms far enough from the threshold under both policy states that shocks do not move them across it, the same residual equations hold under the standard common trends assumption allowing conditionally mean-zero shocks (Appendix D.6). The stronger structural common trends assumption is therefore needed only to deal with threshold crossings.

Once the demand and production parameters are identified, the labor parameters are globally identified when $\text{DiD}(w - \tilde{w}, X)$, $\text{DiD}(\tilde{w}, X)$ and $\text{DiD}(\tilde{\ell}, X)$ are linearly independent across the cells whose treated firms remain below their threshold, leaving out the cells closest to it (Proposition 3).

Firm-Level Primitives. Given the estimated parameters, we recover initial firm-level primitives as residuals of the model's equations. Demand and production hold for every firm, so we recover quality g_{j0} and productivity ρ_{j0} from (8) and (10), respectively. For firms on their labor supply curve, we also recover amenity a_{j0} from (9). For firms at or above their threshold, labor supply need not hold, and we know only an upper bound on w_{j0}^u .

We use these primitives to recover firms' initial unconstrained wages for the counterfactuals in Section 6.3.1 (Appendix D.4).

5.3. GMM Estimation

Moment Conditions. These assumptions imply conditional moment restrictions for demand, production and employment. We apply the same argument as in (33) to the demand and production curves. For each equation, let $\zeta_{jt}(\theta)$ denote the residual from the model equation in changes, net of control trends (Appendix D.2). We use all firms for demand and production, and initially unconstrained firms (the Newly Binds and Doesn't Bind groups) for employment. The conditional moments imply

$$\mathbb{E}[h(X_j)\zeta_{jt}(\theta)] = 0 \quad (34)$$

The expectation is taken over the corresponding estimation sample, and the moment holds for any function $h(X)$ with a finite second moment. One candidate is the group indicator using the Newly Binds, Initially Binds, and Doesn't Bind groups of Section 3.2. However, these group indicators use only part of the variation in X . We estimate a pilot from the group indicators and the conditional first stages and then use the Chamberlain instruments, which make efficient use of this variation (Chamberlain, 1987). Constructed at the pilot estimate, they give one instrument per parameter, so the final step is exactly identified (Appendix D.5.3).

Estimator and Inference. With one Chamberlain instrument per parameter, the estimator solves the sample moments exactly:

$$\widehat{\mathbf{g}}(\widehat{\theta}) = 0 \quad (35)$$

where $\widehat{\mathbf{g}}(\theta)$ stacks the sample analogs of (34). The appendix multiplies each instrument by the treatment residual $T_j - p(X_j)$, where $p(X)$ is the propensity score of Section 1.3; the moment stays valid because $\zeta_{jt}(\theta)$ has mean zero given X_j and T_j , and it is Neyman orthogonal (Chernozhukov et al., 2018), so first-order error in the estimated control trends, propensity and DiDs in the rationing wedge does not move it (Appendix D.5.2). We cluster standard errors by calendar time and allow for serial correlation following Driscoll and Kraay (1998), using moments stacked by calendar time. Appendix D.5 describes how we construct the control trends and the instruments.

5.4. Addressing Unmodeled Channels: Firm Exit and Worker Heterogeneity

The model abstracts from firm exit and worker heterogeneity, but these dynamics are present to varying degrees in the data (Lamadon et al., 2022; Karabarbounis et al., 2025; Rao and Risch, 2025; Volpe, 2026). While these channels are unmodeled, we take the model to the data in a way that can partially accommodate them.

Employment, with exit. Although the model does not explicitly model exit, our empirical employment measure pools extensive and intensive margin responses. For initially unconstrained firms, Proposition 1 shows that changes in log employment are functions only of observables and structural parameters. Firms with the same X under the same policy state therefore have a common proportional employment response. Taking conditional means preserves this common proportional response, so the model has a representative-firm interpretation in changes.

Employment at this representative firm is mean establishment headcount conditional on X and the policy state, which importantly includes observations with zero employment. Log employment is the logarithm of this conditional mean, which is defined whenever the mean is positive. Conditioning on survival (i.e. dropping these zeros) would conceptually change the economic object. We maintain the conditional employment moments for this zero-inclusive mean; the model does not separately specify an exit decision. Our empirical employment outcome measures headcount relative to the establishment’s average in months -6 through -4 , minus one. We interpret percentage-change contrasts as first-order approximations to the model’s log responses.³¹ Revenue and quantity are constructed the

³¹If the baseline denominator B_j is held fixed within X , the conditional mean of $H_{jt}/B_j - 1$

same way.

Wages with Heterogeneous Workers. We construct the firm’s wage response from within-worker changes, which difference out time-invariant worker wage heterogeneity. We use headcount to measure labor input because the monopsony friction arises when firms hire additional workers. To attract those workers, firms must raise pay for incumbents; our wage index captures these within-worker pay changes.

Wage levels do enter when constructing groups and exposure to the minimum wage. We use differences in minimum wage exposure to generate variation in wage-index growth and identify the labor-supply elasticity under the structural DiD restrictions. Differences in the share of workers affected by the policy can generate different first-stage wage responses. For this purpose, the exposure groups need not contain homogeneous workers, perfectly measure policy bite, or classify every firm as above or below its threshold. Identification requires sufficiently independent policy responses across X , together with the structural moment restrictions above.

6. Structural Results

We use the structural estimates to quantify market frictions and spillovers and compare firm-level and aggregate responses to minimum wage hikes. We estimate substantial mark-downs (0.18) and markups (0.35), yet aggregate employment falls. This is because labor market spillovers affect employment negatively by contracting labor supply at unconstrained firms and reducing the direct bite of the minimum wage at firms paying the minimum wage.³²

6.1. Structural Parameters

Table 3 reports the parameter estimates. Product demand is less elastic than labor supply. equals the proportional change in conditional mean headcount. This holds here because baseline employment is in X . Writing these changes as $g_d(X)$ for policy state d , the exact log contrast is $\log\{1 + g_1(X)\} - \log\{1 + g_0(X)\}$, approximated by $g_1(X) - g_0(X)$ for small changes.

³²We use *direct bite* for the gap between a firm’s wage and its unconstrained wage, $w_{jt} - w_{jt}^u$. The effect of the minimum wage on wages decomposes into a spillover, Δw_{jt}^u , and a direct bite, $\Delta w_{jt} - \Delta w_{jt}^u$; for unconstrained firms, $\Delta w_{jt} = \Delta w_{jt}^u$.

TABLE 3. Structural parameter estimates

		Estimate	S.E.
<i>Product Demand</i>			
Firm-level Demand Elasticity	ϵ	2.86	(0.14)
Markup	$1/\epsilon$	0.35	(0.02)
Market-level Demand Elasticity	η_p	2.26	(0.22)
Market Earnings Elasticity	η_e	0.33	(0.06)
<i>Labor Supply</i>			
Firm-level Labor Supply Elasticity	ϕ	5.44	(0.11)
Markdown	$1/\phi$	0.18	(0.004)
Market-level Labor Supply Elasticity	η_w	2.42	(0.15)
Market Rationing Elasticity	η_ℓ	0.06	(0.03)

Notes: This table reports GMM estimates of the structural parameters from the moments in Section 5.3. All parameters are jointly estimated. The markup and markdown are $1/\epsilon$ and $1/\phi$, with standard errors by the delta method. Returns to scale, α , are 0.36, and so the labor demand elasticity is $\gamma = [1 - \alpha(1 - \epsilon^{-1})]^{-1} = 1.31$ (0.05). Standard errors, in parentheses, are clustered by calendar time and allow for serial correlation following Driscoll and Kraay (1998) (Section 1.3).

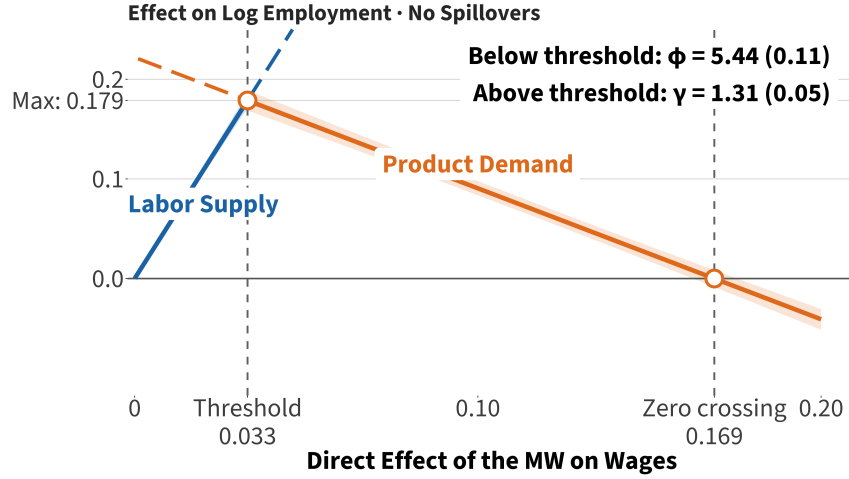
Labor Supply Estimates. The labor supply elasticity is 5.44, which implies an unconstrained markdown of 0.18 ($1/\phi$). This is larger than Kroft et al. (2025) (3.5 to 4.1) and the median of the 91 studies reviewed by Caldwell et al. (2026) (2.1), but smaller than Lamadon et al. (2022) (6.0 to 6.5) and roughly similar to the long-run estimate of Bassier and Manning (2026) (5.2).

Demand Estimates. The demand elasticity is 2.86, with a markup of 0.35. This is smaller than Kroft et al. (2025) (7.3, in construction) and Hottman et al. (2016) (median 3.9) and similar to the store-level elasticities of DellaVigna and Gentzkow (2019) (2.2 to 2.8, 10th to 90th percentile within the typical chain).

Returns to scale, α , are 0.36, and so the labor demand elasticity is 1.31 (γ , s.e. 0.05), which implies a labor share of revenue of about 0.20.

We defer discussion of the market elasticities until Section 6.4, where we turn off different channels in the counterfactual; that makes it clearer to see how these contribute.

FIGURE 10. The direct employment response at a single firm



Notes: This figure plots the direct effect of the minimum wage on log employment at a single firm, holding market aggregates fixed, against the direct bite of the minimum wage on its wage, $w_j - w_j^u$, at the estimates in Table 3. Below the threshold, the firm moves along its labor supply curve with slope ϕ ; above it, along its labor demand curve with slope $-\gamma$. Dashed segments extend each curve beyond the range where it governs employment, and the shaded band is the confidence interval. The employment-maximizing direct bite of the minimum wage is small (0.03 log points), but increases employment by roughly 0.18 log points. Employment returns to its unconstrained level at the zero crossing, $\approx 0.17 = \log(1 + \phi^{-1})$.

6.2. The Direct Effect at a Single Firm

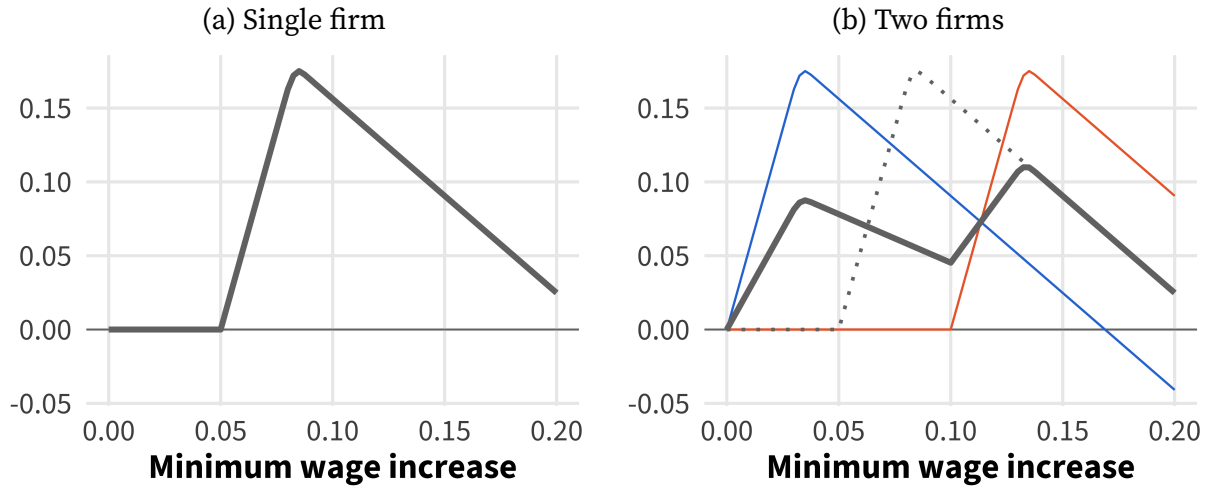
Figure 10 plots the direct effect of the minimum wage on log employment at a single firm. The employment-maximizing direct bite of the minimum wage is small (0.03 log points), but increases employment by roughly 0.18 log points.

The minimum wage eliminates markdowns at the threshold, about a 0.03 increase,³³ but on net increases employment and decreases prices up to the zero crossing at roughly $0.17 = \log(1 + \phi^{-1}) \approx \phi^{-1}$ (the difference between percent and logs).

The demand slope makes the optimal minimum wage small, but makes overshooting less costly. For example, a direct bite of 0.10 log points still increases employment relative to the unconstrained level, even though further increases reduce employment.

³³Even though the unconstrained log markdown is $v = \log(1 + \phi^{-1}) \approx 0.17$, the markdown is eliminated when the direct bite reaches $\gamma v / (\gamma + \phi) \approx 0.03$ log points, holding market conditions fixed. The remaining reduction in markdowns comes from falling marginal revenue product of labor as employment expands. In this way, small wage growth can accompany a complete reduction in markdowns.

FIGURE 11. Aggregating direct effects across firms.



Notes: The left panel plots the direct employment response at a single firm at 1.05 against the size of the minimum wage increase; the right panel plots the responses at two firms at 1.00 (blue) and 1.10 (orange) (thin lines) and their aggregate (thick line), with the single-firm response repeated as the dotted line. Wages are unconstrained wages relative to the initial minimum wage, so a firm at 1.10 is unaffected until the minimum wage has risen 0.10 log points. Dispersion makes it harder to target both firms with one minimum wage, reducing the maximum employment gain. In this example, it also raises the employment-maximizing minimum wage because employment rises more steeply below the threshold than it falls above it.

6.3. Aggregate Effects

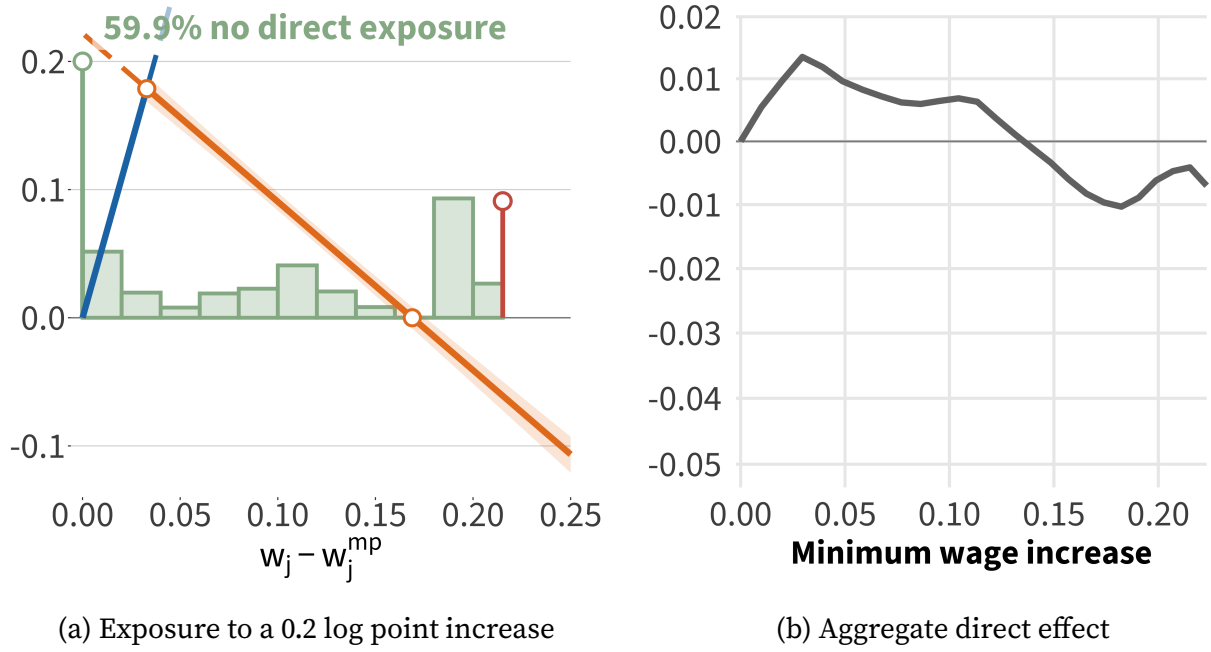
The simple direct effect function we estimated doesn't describe the aggregates, since we have to account for both heterogeneity and spillovers.³⁴ The spillovers have a net negative effect, relative to the direct effects.

6.3.1. Aggregating Direct Effects

Figure 11 compares the direct employment response at a single firm at 1.05 with the aggregate response at two firms at 1.00 and 1.10. Dispersion makes it harder to target both firms with one minimum wage, reducing the maximum employment gain. In this example, it also raises the employment-maximizing minimum wage because employment rises more steeply below the threshold than it falls above it. The implications of dispersion for

³⁴This is essentially a linearization around the original equilibrium, analogous to keeping the shares fixed in a standard logit price index. In principle, the shares also change as the prices change; for simplicity we abstract from changes to the shares or to the aggregate elasticities due to changes in these equilibrium quantities.

FIGURE 12. From the direct effect at each firm to the aggregate direct effect.



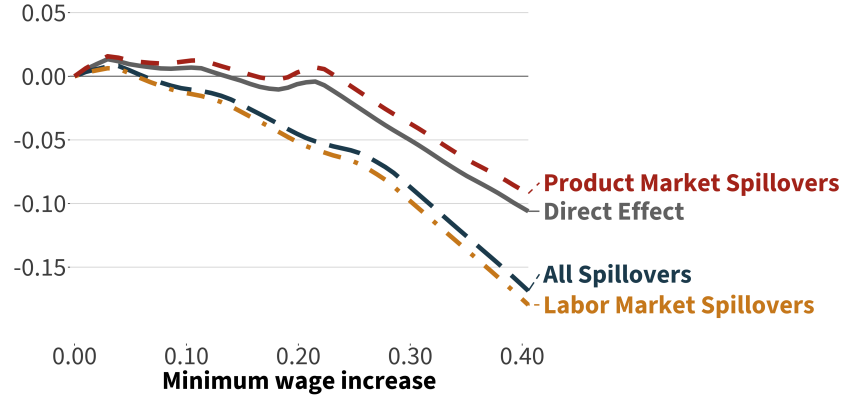
Notes: Panel (a) plots the distribution of baseline employment by direct bite, $w_j - w_j^u$, after a minimum wage increase of 0.2 log points, with the direct employment response from Figure 10 overlaid. Firms initially paying their unconstrained wage start with zero direct bite; firms paying the minimum wage start with a direct bite of $w_{j0} - w_{j0}^u$. The red dot marks firms already above their thresholds. The mass to the right of 0.2 represents Initially Binds firms with positive initial direct bite; 59.9% of employment has no direct exposure. Panel (b) applies the direct employment response to the initial wage distribution, which gives the aggregate direct effect on log employment for each size of minimum wage increase, holding market aggregates fixed. The estimate at 0.2 corresponds to the scenario illustrated in Panel (a). This effect is nonlinear and non-monotonic because employment rises at firms newly bound by the minimum wage.

the employment-maximizing minimum wage therefore depend on the relative slopes of labor supply and labor demand, ϕ and γ .

In order to connect the direct effects to policy effects, we apply this to the wage distribution. As long as $w_0 > \bar{w}$, there is no direct effect. For Newly Binds firms, we see $w_0 = w_0^u$, and we can apply $w_0^u - \bar{w}$ as we increase $\bar{w}$. For Initially Binds firms, we recover their unconstrained wages or establish that they start above their thresholds. Once $w_0^u < \bar{w}_0 - \frac{\gamma v}{\gamma + \phi}$, the firm is already above its threshold at the old minimum wage, and further increases move it along marginal revenue.

As described in Section 5.2, we recover firms' unconstrained wages or establish that they start above their thresholds. Firms initially paying their unconstrained wage start

FIGURE 13. Aggregate employment response to the minimum wage.



Notes: This figure plots the aggregate response of log employment to a minimum wage increase of each size. The direct effect holds market aggregates fixed, as in Figure 12(b). We then add spillovers to the product demand curve (competitor prices and market earnings), to the labor supply curve (the market wage and rationing), or to both. Product market spillovers increase employment. Labor market spillovers, however, have a strong negative effect.

with zero direct bite; firms paying the minimum wage start with a direct bite of $w_{j0} - w_{j0}^u$. The red dot marks firms already above their thresholds. The mass to the right of 0.2 in Figure 12(a) represents Initially Binds firms with positive initial direct bite.

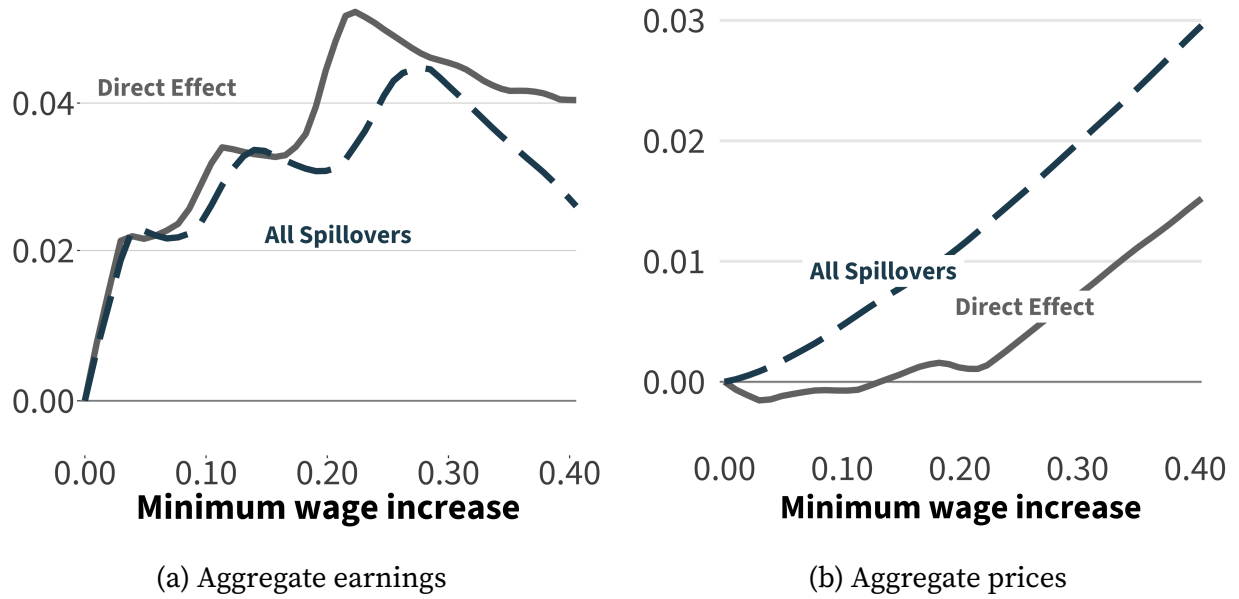
Applying the direct employment response to the initial wage distribution gives the aggregate direct effect in Figure 12(b). This effect is nonlinear and non-monotonic because employment rises at firms newly bound by the minimum wage. When the minimum wage crosses a round-number wage paid by many firms, these employment gains can cause the aggregate direct effect to increase.

6.3.2. Effect of Spillovers on Aggregate Outcomes

Firm composition matters because the minimum wage applies to firms “who would otherwise choose very different wages” (Manning, 2003, p. 340). It determines both the aggregate direct effect and the competitive spillovers. Responses at firms paying the minimum wage shift labor supply and product demand at other firms, so changing the mix of firms changes the effects at each firm, in addition to directly changing the aggregate effect.

Figure 13 plots policy effects without spillovers, as in Figure 12(b), and with spillovers. We show separately the effects of product market spillovers and labor market spillovers. To turn off a spillover channel, we remove the corresponding market index from the

FIGURE 14. Aggregate earnings and price responses to the minimum wage.



Notes: This figure plots the aggregate response of log earnings (Panel a) and log prices (Panel b) to a minimum wage increase of each size. The direct effect holds market aggregates fixed; the response with all spillovers adds market shifts to both the product demand and labor supply curves, as in Figure 13. Aggregate employment falls, but earnings rise. Spillovers also amplify price increases relative to the direct effects alone.

firm's demand or labor supply equation.³⁵ Product market spillovers increase employment. Labor market spillovers, however, have a strong negative effect. Aggregate employment falls, but earnings rise (Figure 14). Spillovers also amplify price increases relative to the direct effects alone. In the next section, we explain why product market spillovers dampen employment losses while labor market spillovers magnify them.

6.4. Mechanics of Spillovers

Product market spillovers shift demand out. Labor market spillovers contract labor supply at unconstrained firms and reduce the direct bite of the minimum wage at firms paying the minimum wage. Reducing markdowns accounts for only a small share of wage growth.

Figure 15 decomposes wage growth into spillover effects, wage gains from reducing markdowns, and wage increases above the threshold. At a 0.40 log point increase in the

³⁵ Removing competitor prices sets $\eta_p = \epsilon$, removing market earnings sets $\eta_e = 0$, removing the market wage sets $\eta_w = \phi$, and removing rationing sets $\eta_\ell = 0$.

minimum wage, wages rise by 0.20 log points: about 0.09 comes from spillovers, 0.01 from reducing markdowns, and 0.10 from increases above the threshold.³⁶ Wage increases above the threshold do not reduce markdowns because markdowns have already been eliminated.

6.4.1. Product Market Spillovers

Product market spillovers have two channels. First, increasing prices at competitors shifts demand out. Second, increasing earnings also shifts demand out. Both of these channels increase demand and so mute disemployment at rationed firms. Product market spillovers therefore make it easier to pass through to customers, enough to push employment effects from slightly negative to slightly positive at +0.20 log points.

The firm-level and market-level demand elasticities are similar, so changes in competitor prices have a small effect on demand holding the firm's own price fixed. Demand shifts come primarily from increases in market earnings, with an estimated elasticity of 0.33.

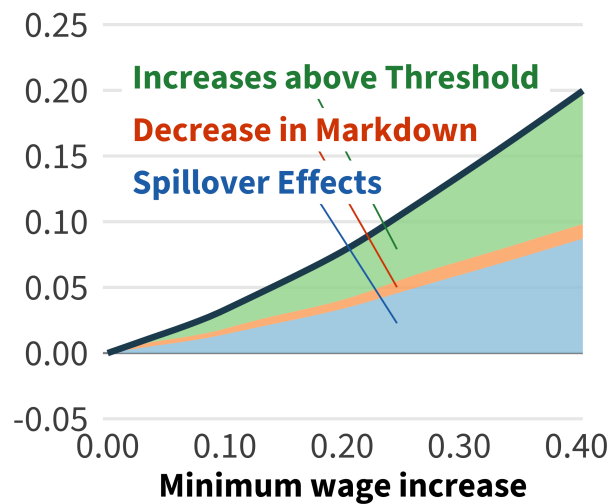
6.4.2. Labor Market Spillovers: Wage Levels versus Rationing

The firm-level labor supply elasticity exceeds the market-level elasticity, so higher wages at competing firms shift labor supply away from the firm. We also estimate a small but statistically significant rationing elasticity. While rationing to unconstrained firms would be good for aggregate employment, it would push down aggregate wages. In the data, wages rise, and firms behave as if the combined increase in wages and rationing makes it harder to hire. The wage index channel dominates the rationing channel.

Labor market wage spillovers affect employment through two channels. First, higher wages at competing firms improve workers' outside options and contract labor supply. Unconstrained firms optimally respond by raising wages and decreasing employment, consistent with the reduced form evidence in Section 3.3.2. Second, labor market spillovers reduce the direct bite of the minimum wage at firms paying the minimum wage. The direct bite pushes wages above firms' unconstrained wages; below their thresholds, this increases

³⁶How much of the wage growth comes from eliminating markdowns and how much markdowns are eliminated are different questions. A small contribution to wage growth can nevertheless accompany a large markdown reduction (see footnote 33).

FIGURE 15. Decomposition of the aggregate wage response.



Notes: This figure decomposes the aggregate wage response to a minimum wage increase of each size into spillover effects, wage gains from reducing markdowns, and wage increases above the threshold. The dark line is the total effect on wages, including all spillovers. At a 0.40 log point increase in the minimum wage, wages rise by 0.20 log points: about 0.09 comes from spillovers, 0.01 from reducing markdowns, and 0.10 from increases above the threshold. Wage increases above the threshold do not reduce markdowns because markdowns have already been eliminated.

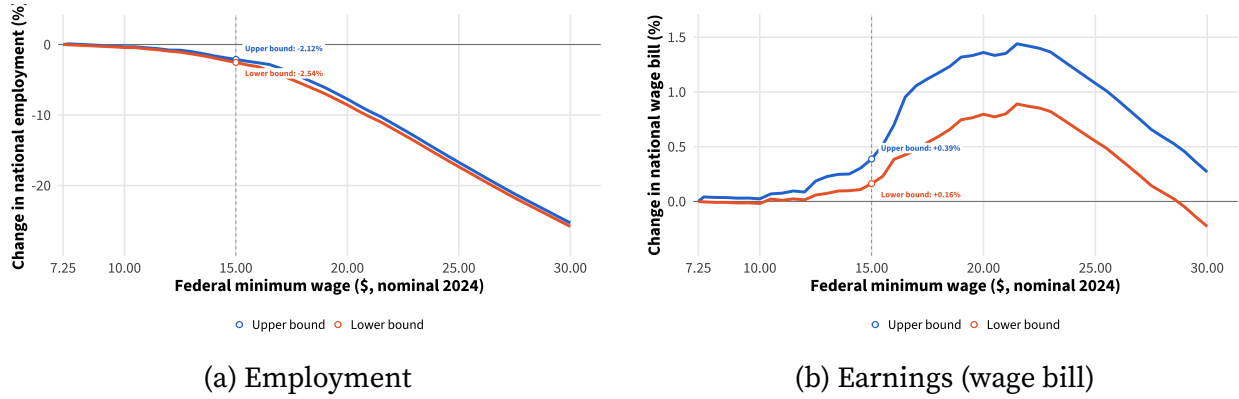
employment and reduces markdowns. By raising firms' unconstrained wages, spillovers reduce this direct bite and limit these employment gains.

We can split the direct bite and spillover components at a firm paying the minimum wage with a simple thought experiment. Suppose we increased the minimum wage at every firm except one. The exempt firm's wage would rise through spillovers from its competitors. If the new minimum wage also applied to this firm and was binding, its direct bite would be the gap between the new minimum wage and this counterfactual wage. By raising the counterfactual wage, spillovers reduce the direct bite of the minimum wage.

6.5. Implied Effects of a Counterfactual Federal Minimum Wage Hike

We use the model to simulate the effects of federal minimum wage hikes. We extend the analysis beyond our low-wage estimation sample by applying the model to the national wage distribution from the CPS.

FIGURE 16. Counterfactual effects of a federal minimum wage.



Notes: This figure plots the simulated effect of a federal minimum wage, in nominal 2024 dollars, on national employment (Panel a) and the national wage bill (Panel b), in percent. We apply the model to the 2024 wage distribution of hourly workers, following the definition of Cengiz et al. (2019). We treat each worker as a separate job and each state as a local market. We do not recover firm-level unobservables in these data, so we do not know whether workers initially paid the minimum wage are above or below their thresholds. We therefore consider two extreme scenarios: one in which all workers initially paid the minimum wage are above their thresholds, and another in which all are below their thresholds and the minimum wage “just binds”. The just-binds scenario is the upper bound. The dashed line marks \$15, where the labeled effects are printed.

We apply the model to the 2024 wage distribution of hourly workers, following the definition of Cengiz et al. (2019). We treat each worker as a separate job and each state as a local market. We do not recover firm-level unobservables in these data, so we do not know whether workers initially paid the minimum wage are above or below their thresholds. We therefore consider two extreme scenarios in these simulations: one in which all workers initially paid the minimum wage are above their thresholds, and another in which all are below their thresholds and the minimum wage “just binds”, with $w_{jt}^u = w_{jt} = \bar{w}_t$.

Employment effects are small but negative through about \$15; by \$20, employment falls approximately linearly with further minimum wage hikes. Total earnings initially rise because wage gains outweigh employment losses, and peak at a minimum wage of about \$21.50. By \$30, employment effects are negative enough to offset wage growth in one of the two scenarios, and nearly offset it in the other. The majority of wage growth comes from spillovers. As in the estimation sample, even high minimum wages do little to reduce markdowns.

7. Conclusion

We use new microdata constructed from administrative payroll and point of sale records at thousands of small counter-service firms to study firm-level responses to minimum wage hikes. As the monopsony model predicts, we find that effects on employment and relative price both flip sign across initial wage groups. We then provide a general method to use DiD variation to estimate supply and demand elasticities and other structural parameters. These estimates reconcile evidence of monopsony with aggregate employment losses. Minimum wage hikes raise wages at competing firms, which raises firms' unconstrained wages and reduces the direct bite of the policy. When labor market spillovers are important, the minimum wage does a good job of raising wages and a bad job of reducing markdowns.

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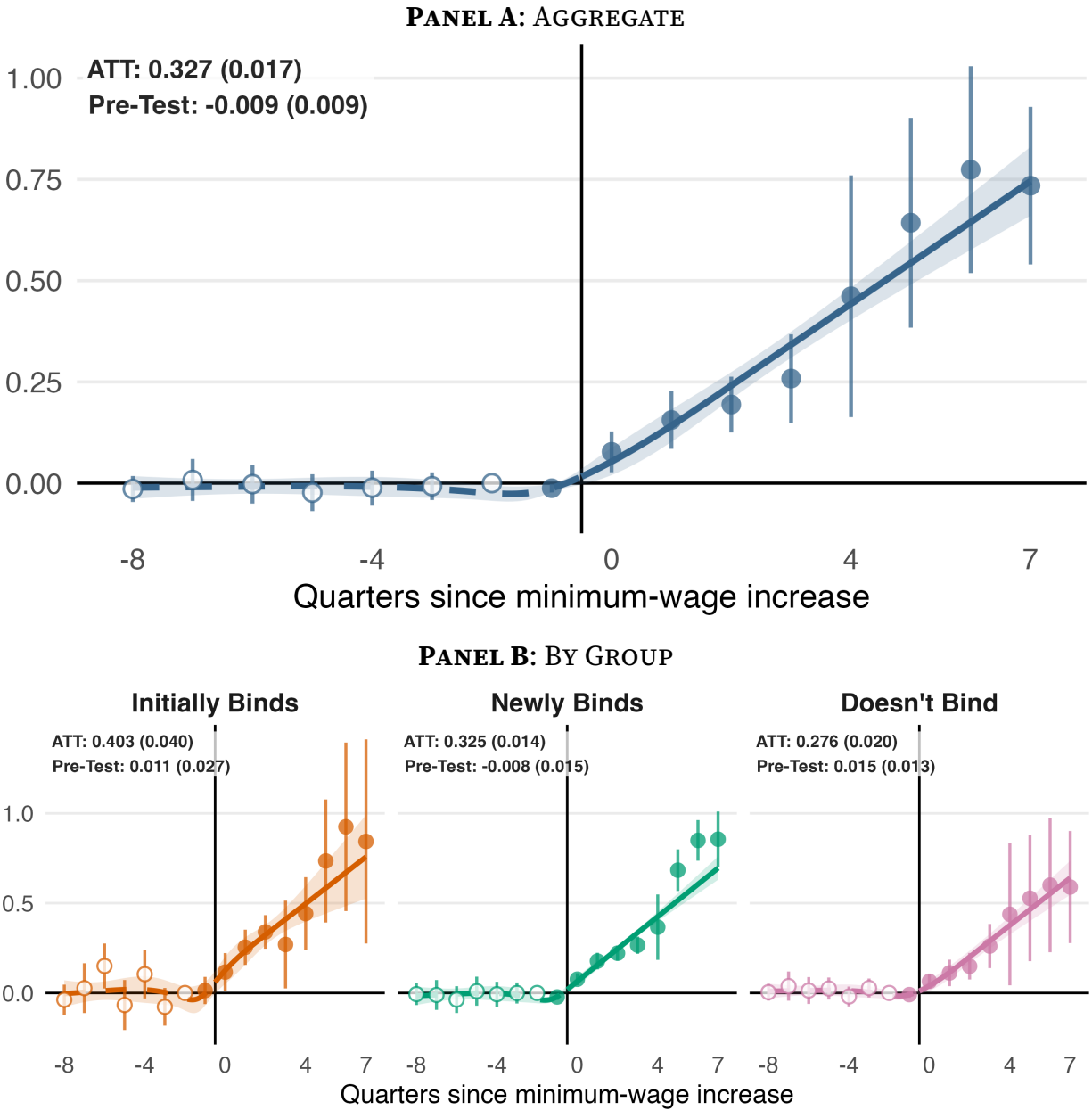
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Appendix

A. Event Studies for Additional Outcomes

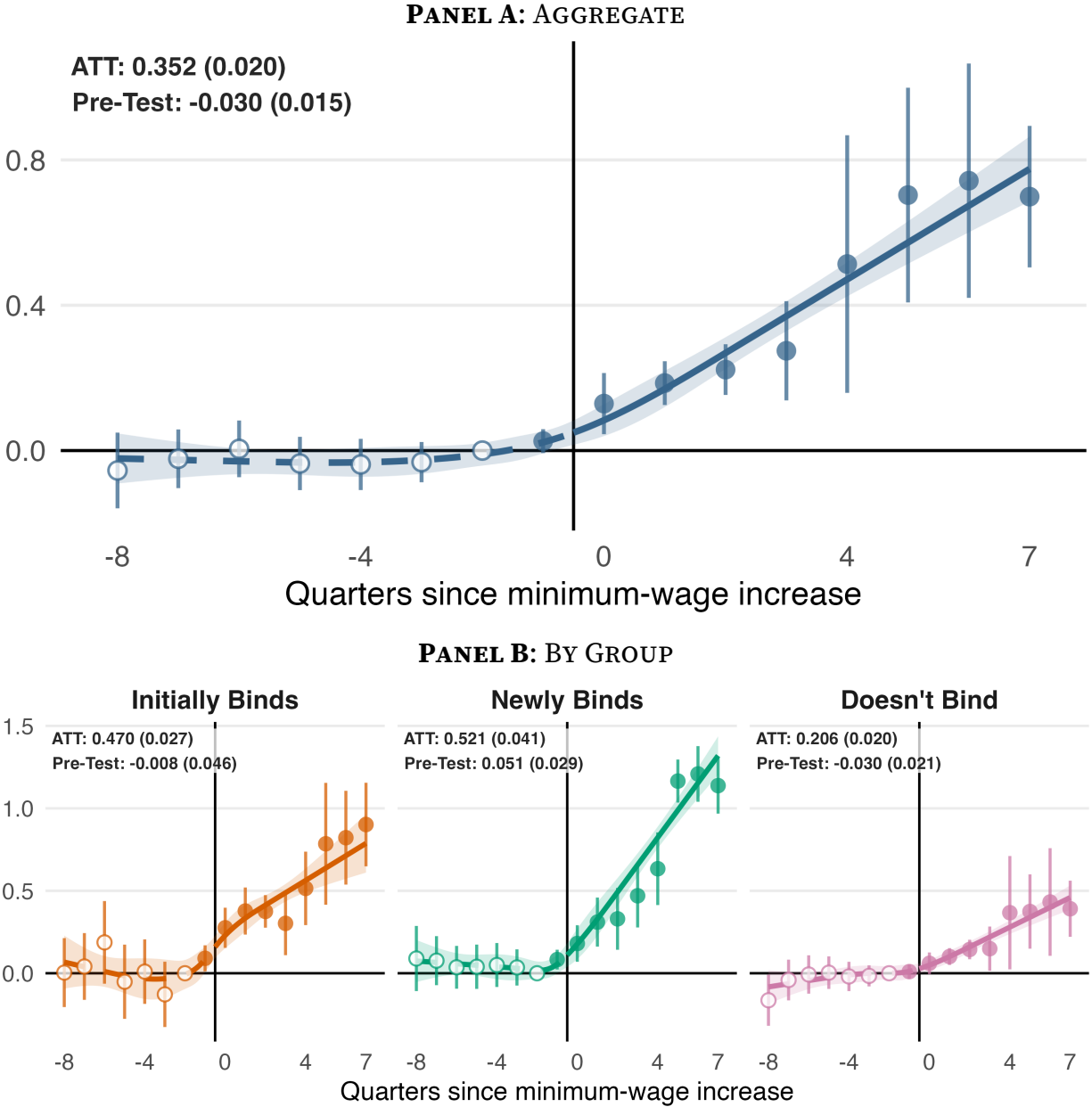
This appendix reports event studies for the remaining payroll and transaction outcomes, estimated with the specification of Figures 1 and 5.

FIGURE A.1. Lowest Base Wage at the Firm



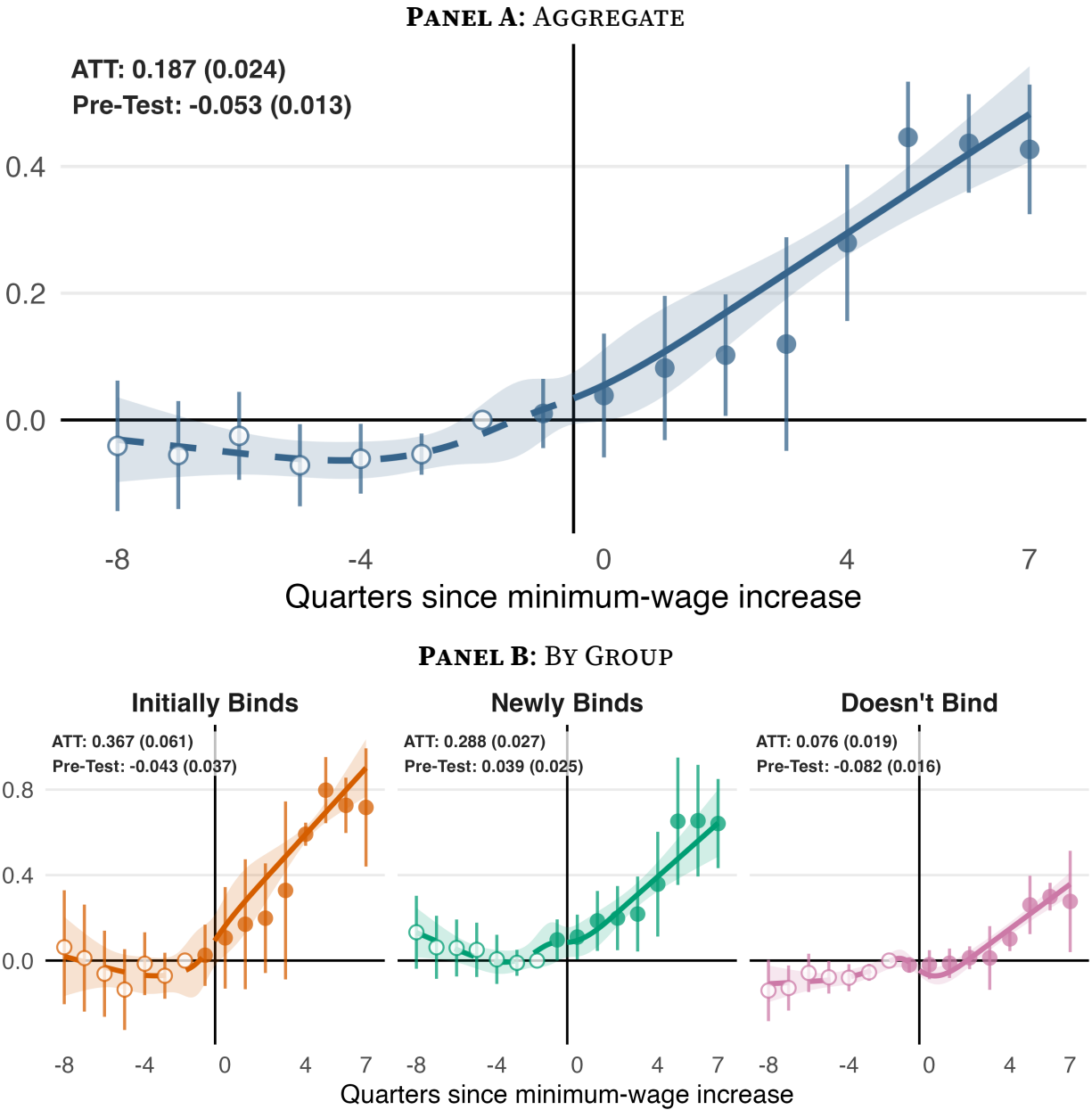
Notes: This figure plots event-study estimates of the effect of a minimum wage increase on the lowest base hourly wage paid at the firm, pooling all firms (Panel A) and separately for Initially Binds, Newly Binds, and Doesn't Bind firms (Panel B). Groups are assigned from hourly earnings in the second quarter before the increase: Initially Binds firms have at least one worker making the old minimum, Newly Binds firms have no worker at the old minimum but at least one worker below the new minimum, and Doesn't Bind firms have all their workers above the new minimum (Section 3.2). In each quarter, we report the change in the log of the lowest base hourly wage paid at the firm for a 1 log point increase in the minimum wage, relative to two quarters before the increase. Hollow markers in the pre-period are rolling-origin placebo estimates: the estimate at quarter $s < -2$ re-estimates the specification using only information through quarter $s - 1$. The average post-period effect and the average placebo estimate are printed in each panel. Standard errors are clustered by calendar time and allow for serial correlation following Driscoll and Kraay (1998) (Section 1.3).

FIGURE A.2. Lowest Hourly Earnings at the Firm



Notes: This figure plots event-study estimates of the effect of a minimum wage increase on the lowest hourly earnings paid at the firm, including tips, pooling all firms (Panel A) and separately for Initially Binds, Newly Binds, and Doesn't Bind firms (Panel B). Groups are assigned from hourly earnings in the second quarter before the increase: Initially Binds firms have at least one worker making the old minimum, Newly Binds firms have no worker at the old minimum but at least one worker below the new minimum, and Doesn't Bind firms have all their workers above the new minimum (Section 3.2). In each quarter, we report the change in the log of the lowest hourly earnings paid at the firm for a 1 log point increase in the minimum wage, relative to two quarters before the increase. Hollow markers in the pre-period are rolling-origin placebo estimates: the estimate at quarter $s < -2$ re-estimates the specification using only information through quarter $s - 1$. The average post-period effect and the average placebo estimate are printed in each panel. Standard errors are clustered by calendar time and allow for serial correlation following Driscoll and Kraay (1998) (Section 1.3).

FIGURE A.3. Wage Index



Notes: This figure plots event-study estimates of the effect of a minimum wage increase on the firm-level wage index, pooling all firms (Panel A) and separately for Initially Binds, Newly Binds, and Doesn't Bind firms (Panel B). Groups are assigned from hourly earnings in the second quarter before the increase: Initially Binds firms have at least one worker making the old minimum, Newly Binds firms have no worker at the old minimum but at least one worker below the new minimum, and Doesn't Bind firms have all their workers above the new minimum (Section 3.2). In each quarter, we report the change in the wage index, the average cumulative change in workers' total hourly earnings at the firm (Section 1.4), for a 1 log point increase in the minimum wage, relative to two quarters before the increase. Hollow markers in the pre-period are rolling-origin placebo estimates: the estimate at quarter $s < -2$ re-estimates the specification using only information through quarter $s - 1$. The average post-period effect and the average placebo estimate are printed in each panel. Standard errors are clustered by calendar time and allow for serial correlation following Driscoll and Kraay (1998) (Section 1.3).

FIGURE A.4. Aggregate Responses by Market Population Density



Notes: Each panel shows how the employment, wage, or earnings response to the minimum wage varies with population density. The double/debiased machine learning estimator of Section 1.3 produces a doubly-robust score for each firm, whose average is the average post-period effect for a 1 log point increase in the minimum wage. The conditional average effect at each density is estimated by projecting these scores onto population density (log scale) in two ways: onto indicators for density bins, which gives the points, and onto a spline basis, which gives the curve and its pointwise confidence band. Employment effects are positive in the sparsest markets and turn negative in the densest; wage effects are flat across the density range; earnings responses largely track employment.

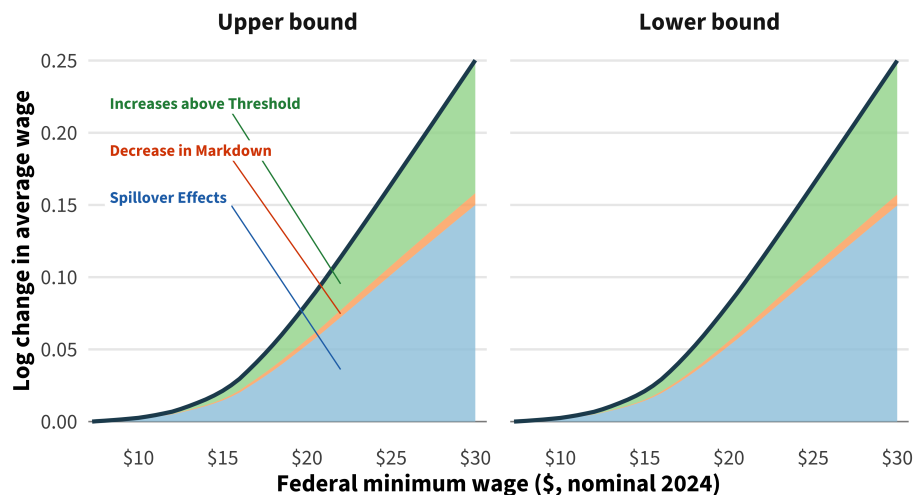
A.1. Variation Across Markets

Spillovers make firm and market responses jointly determined. Each firm's choices depend on the market around it, and market outcomes are themselves aggregates of individual firms' responses. Cross-market variation in aggregate responses therefore changes the environment in which firms respond. We use population density as a simple way to organize this variation. Figure A.4 plots the aggregate employment, wage, and earnings responses by market density.

Aggregate employment effects fall with density: employment rises in the sparsest markets and falls sharply in the densest. Wage effects are flat by comparison, and earnings largely follow employment. While these patterns show that aggregate market conditions change differently across markets, they do not reveal whether this variation reflects differences in market composition, in the types of spillovers, or both.

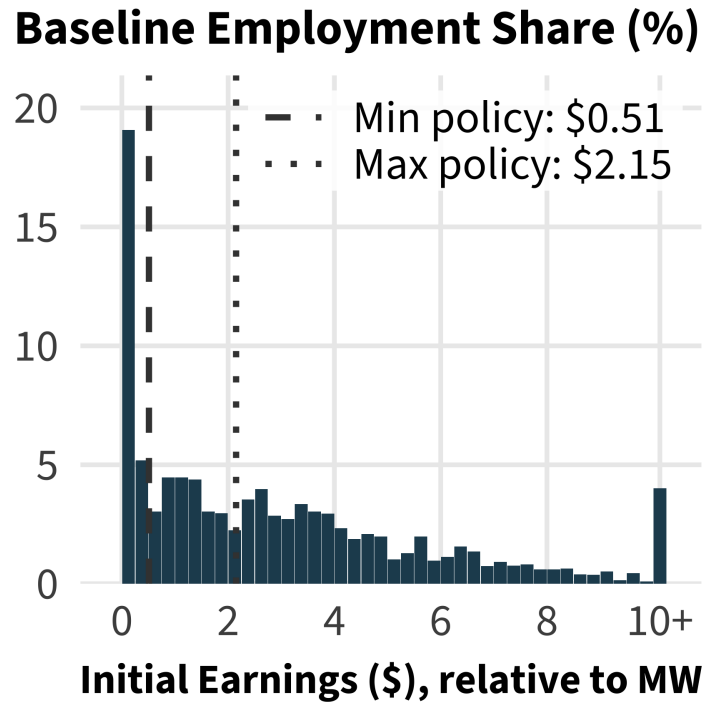
A.2. Federal Minimum Wage Counterfactuals

FIGURE A.5. Decomposition of the National Average Wage Response



Notes: This figure decomposes the change in the log national average wage under a federal minimum wage into spillover effects, wage gains from reducing markdowns, and wage increases above the threshold, for the two scenarios in Figure 16. The dark line is the total effect on wages, including all spillovers. The majority of wage growth comes from spillovers. As in the estimation sample, even high minimum wages do little to reduce markdowns.

FIGURE B.1. Exposure to the Minimum Wage



Notes: This figure plots the share of baseline employment (months –6 to –4) by workers’ initial hourly earnings relative to the state minimum wage, in dollars, pooled across the treated firms in the five policies in Table 2. Hourly earnings include tips. The dashed and dotted lines mark the smallest and largest minimum wage increases among these policies.

B. Additional Descriptive Statistics

This appendix reports the distribution of baseline employment by exposure to the minimum wage, and summary statistics for the national sample and the estimation sample.

TABLE B.1. Broader Sample: All Firms

	Mean	SD	P25	P50	P75
Panel: Aggregate					
<i>Worker characteristics</i>					
Monthly total earnings, including tips	1353.76	1281.87	444.87	961.20	1882.14
Monthly tips	271.88	523.84	0.00	42.98	331.59
Hourly total earnings / total hours	15.96	8.63	11.41	14.65	18.55
Monthly hours	80.77	56.98	33.77	68.87	119.95
Months observed per worker-job in baseline	2.63	0.65	2.00	3.00	3.00
Full time (>130 hours/month)	21.0				
Unique worker-jobs (event-stacked)	623,629				
<i>Firm characteristics</i>					
Monthly revenue	55,795	63,712	22,157	37,192	65,947
Revenue per hour	145.85	594.99	45.56	66.68	107.52
Workers	8.64	6.68	4.00	7.00	11.00
Within-firm hourly wage SD	3.36	5.70	1.27	2.36	4.08
Unweighted mean worker hourly wage	15.62	5.97	11.83	14.63	18.14
Unique location-firms (event-stacked)	67,079				

Notes: This table reports summary statistics for firms in all fifty states, before eliminating states with policy changes in the pre-period that are excluded from both treatment and control. Statistics are computed over the pre-period (months –6 to –4), with each worker-month or firm-month observation weighted equally. Total earnings include tips, and hourly earnings divide total earnings by total hours. Full time is the percentage of worker-months above 130 hours. A firm is a single business location. Sample not indicative of business product usage.

TABLE B.2. Broader Sample: By Group

	Mean	SD	P25	P50	P75
Panel: Initially Binds					
<i>Worker characteristics</i>					
Monthly total earnings, including tips	1272.98	1219.03	419.91	896.55	1750.49
Monthly tips	274.38	528.11	0.00	53.50	331.09
Hourly total earnings / total hours	15.26	8.58	10.80	13.88	17.71
Monthly hours	79.48	56.44	33.35	67.29	117.13
Months observed per worker-job in baseline	2.62	0.65	2.00	3.00	3.00
Full time (>130 hours/month)	20.1				
Unique worker-jobs (event-stacked)	463,594				
<i>Firm characteristics</i>					
Monthly revenue	53,074	59,930	21,342	35,489	62,717
Revenue per hour	122.43	453.54	43.16	62.14	96.66
Workers	9.14	6.97	5.00	7.00	11.00
Within-firm hourly wage SD	3.42	5.79	1.33	2.43	4.15
Unweighted mean worker hourly wage	14.77	5.64	11.16	13.76	17.15
Unique location-firms (event-stacked)	42,161				
Panel: Newly Binds					
<i>Worker characteristics</i>					
Monthly total earnings, including tips	1461.37	1331.83	494.39	1072.50	2062.32
Monthly tips	257.83	493.53	0.00	30.10	328.88
Hourly total earnings / total hours	16.92	7.40	12.50	15.26	19.40
Monthly hours	82.38	57.35	34.17	71.00	122.99
Months observed per worker-job in baseline	2.64	0.64	2.00	3.00	3.00
Full time (>130 hours/month)	22.3				
Unique worker-jobs (event-stacked)	53,242				
<i>Firm characteristics</i>					
Monthly revenue	58,849	72,785	22,983	38,451	67,534
Revenue per hour	147.55	444.71	50.80	74.01	122.22
Workers	7.86	5.87	4.00	6.00	10.00
Within-firm hourly wage SD	3.15	4.30	1.21	2.20	3.78
Unweighted mean worker hourly wage	16.24	5.18	12.70	15.15	18.55
Unique location-firms (event-stacked)	5,709				
Panel: Doesn't Bind					
<i>Worker characteristics</i>					
Monthly total earnings, including tips	1781.16	1521.74	639.62	1392.39	2536.00
Monthly tips	253.72	493.98	0.00	0.00	316.14
Hourly total earnings / total hours	19.46	9.19	15.00	17.75	21.96
Monthly hours	88.46	59.33	37.50	79.42	133.89
Months observed per worker-job in baseline	2.65	0.64	2.00	3.00	3.00
Full time (>130 hours/month)	26.5				
Unique worker-jobs (event-stacked)	66,207				
<i>Firm characteristics</i>					
Monthly revenue	65,214	73,629	25,842	44,275	78,103
Revenue per hour	244.16	829.01	59.46	90.67	164.19
Workers	6.56	5.01	4.00	5.00	8.00
Within-firm hourly wage SD	3.33	6.04	1.15	2.22	3.97
Unweighted mean worker hourly wage	19.06	6.52	15.18	17.71	21.44
Unique location-firms (event-stacked)	8,819				

Notes: This table reports the statistics in Table B.1 by group, for the national sample. Groups are assigned from hourly earnings in the second quarter before the increase: Initially Binds firms have at least one worker making the old minimum, Newly Binds firms have no worker at the old minimum but at least one worker below the new minimum, and Doesn't Bind firms have all their workers above the new minimum (Section 3.2). Statistics are computed over the pre-period (months -6 to -4), with each worker-month or firm-month observation weighted equally. Total earnings include tips, and hourly earnings divide total earnings by total hours. Full time is the percentage of worker-months above 130 hours. A firm is a single business location. Sample not indicative of business product usage.

TABLE B.3. Firm Size: All Firms

Firm-size bin	Workers (%)	Firms (%)
Panel: Aggregate		
1-4	10.2	27.4
5-9	33.8	42.7
10-14	23.5	17.1
15-19	13.4	6.9
20-24	7.4	2.9
25-49	10.5	2.8
50+	1.2	0.2

Notes: This table reports the firm size distribution for the national sample in Table B.1. Firm size is the median monthly headcount over the pre-period (months –6 to –4), among months with positive headcount. Worker shares count worker-jobs and firm shares count firm-slices. A firm is a single business location. Sample not indicative of business product usage.

TABLE B.4. Firm Size: By Group

Firm-size bin	Workers (%)	Firms (%)
Panel: Initially Binds		
1-4	8.7	23.8
5-9	32.5	43.3
10-14	23.8	18.5
15-19	14.0	7.6
20-24	8.0	3.3
25-49	11.7	3.3
50+	1.3	0.2
Panel: Newly Binds		
1-4	13.0	31.3
5-9	37.2	43.3
10-14	23.0	15.4
15-19	12.6	5.8
20-24	6.4	2.3
25-49	7.1	1.8
50+	0.8	0.1
Panel: Doesn't Bind		
1-4	19.3	42.7
5-9	41.3	40.2
10-14	20.5	11.2
15-19	9.3	3.5
20-24	4.5	1.3
25-49	4.6	1.0
50+	0.4	0.0

Notes: This table reports the firm size distribution in Table B.3 by group, for the national sample. Groups are assigned from hourly earnings in the second quarter before the increase: Initially Binds firms have at least one worker making the old minimum, Newly Binds firms have no worker at the old minimum but at least one worker below the new minimum, and Doesn't Bind firms have all their workers above the new minimum (Section 3.2). Firm size is the median monthly headcount over the pre-period (months -6 to -4), among months with positive headcount. Worker shares count worker-jobs and firm shares count firm-slices. A firm is a single business location. Sample not indicative of business product usage.

TABLE B.5. Estimation Sample: All Firms

	Mean	SD	P25	P50	P75
Panel: Aggregate					
<i>Worker characteristics</i>					
Monthly total earnings, including tips	1297.29	1241.34	424.91	912.72	1794.54
Monthly tips	260.49	497.16	0.00	45.81	320.45
Hourly total earnings / total hours	15.26	8.74	10.87	13.99	17.80
Monthly hours	80.73	57.09	33.82	68.60	119.82
Months observed per worker-job in baseline	2.62	0.65	2.00	3.00	3.00
Full time (>130 hours/month)	21.0				
Unique worker-jobs (event-stacked)	432,093				
<i>Firm characteristics</i>					
Monthly revenue	54,641	65,655	21,330	35,742	63,310
Revenue per hour	141.83	551.87	43.93	64.38	104.48
Workers	8.63	6.77	4.00	7.00	11.00
Within-firm hourly wage SD	3.32	5.79	1.28	2.36	4.02
Unweighted mean worker hourly wage	14.91	5.65	11.29	13.97	17.33
Unique location-firms (event-stacked)	40,968				

Notes: This table reports summary statistics for the estimation sample: counter-service firms with at least five employees in the pre-period and an average pre-period wage no more than \$5 above the state minimum wage (Section 1.1). Statistics are computed over the pre-period (months –6 to –4), with each worker-month or firm-month observation weighted equally. Total earnings include tips, and hourly earnings divide total earnings by total hours. Full time is the percentage of worker-months above 130 hours. A firm is a single business location. Sample not indicative of business product usage.

TABLE B.6. Estimation Sample: By Group

	Mean	SD	P25	P50	P75
Panel: Initially Binds					
<i>Worker characteristics</i>					
Monthly total earnings, including tips	1241.37	1196.55	408.51	870.01	1702.44
Monthly tips	265.09	505.49	0.00	53.53	322.96
Hourly total earnings / total hours	14.82	8.66	10.38	13.42	17.23
Monthly hours	79.59	56.56	33.43	67.35	117.30
Months observed per worker-job in baseline	2.62	0.65	2.00	3.00	3.00
Full time (>130 hours/month)	20.2				
Unique worker-jobs (event-stacked)	371,470				
<i>Firm characteristics</i>					
Monthly revenue	52,503	61,229	20,874	34,801	61,548
Revenue per hour	122.29	469.90	42.28	60.93	95.38
Workers	9.09	7.00	5.00	7.00	11.00
Within-firm hourly wage SD	3.34	5.88	1.29	2.39	4.06
Unweighted mean worker hourly wage	14.33	5.42	10.88	13.39	16.64
Unique location-firms (event-stacked)	33,172				
Panel: Newly Binds					
<i>Worker characteristics</i>					
Monthly total earnings, including tips	1475.36	1333.74	503.14	1104.64	2089.16
Monthly tips	232.63	409.78	0.00	22.42	324.15
Hourly total earnings / total hours	16.54	7.02	12.12	15.09	19.17
Monthly hours	84.92	58.26	35.48	74.41	127.53
Months observed per worker-job in baseline	2.64	0.64	2.00	3.00	3.00
Full time (>130 hours/month)	24.0				
Unique worker-jobs (event-stacked)	32,024				
<i>Firm characteristics</i>					
Monthly revenue	59,705	76,741	22,624	37,649	65,732
Revenue per hour	158.39	483.77	50.60	75.36	126.75
Workers	7.32	5.40	4.00	6.00	9.00
Within-firm hourly wage SD	3.02	4.00	1.21	2.18	3.64
Unweighted mean worker hourly wage	15.89	4.75	12.60	14.96	18.20
Unique location-firms (event-stacked)	3,643				
Panel: Doesn't Bind					
<i>Worker characteristics</i>					
Monthly total earnings, including tips	1811.48	1525.63	630.43	1434.16	2607.25
Monthly tips	232.84	476.56	0.00	0.00	274.95
Hourly total earnings / total hours	19.39	10.18	15.00	17.57	22.00
Monthly hours	90.60	61.18	37.45	80.22	139.05
Months observed per worker-job in baseline	2.65	0.63	2.00	3.00	3.00
Full time (>130 hours/month)	28.6				
Unique worker-jobs (event-stacked)	28,599				
<i>Firm characteristics</i>					
Monthly revenue	68,124	85,922	25,153	42,603	76,219
Revenue per hour	292.25	1026.13	60.62	98.55	190.49
Workers	5.93	4.83	3.00	5.00	7.00
Within-firm hourly wage SD	3.37	6.40	1.22	2.30	4.02
Unweighted mean worker hourly wage	18.82	6.57	15.11	17.56	21.20
Unique location-firms (event-stacked)	4,153				

Notes: This table reports the statistics in Table B.5 by group, for the same estimation sample. Groups are assigned from hourly earnings in the second quarter before the increase: Initially Binds firms have at least one worker making the old minimum, Newly Binds firms have no worker at the old minimum but at least one worker below the new minimum, and Doesn't Bind firms have all their workers above the new minimum (Section 3.2). Statistics are computed over the pre-period (months -6 to -4), with each worker-month or firm-month observation weighted equally. Total earnings include tips, and hourly earnings divide total earnings by total hours. Full time is the percentage of worker-months above 130 hours. A firm is a single business location. Sample not indicative of business product usage.

C. Microfoundations and Derivations

This appendix derives the product demand and labor supply curves of Section 4 from customer and worker choice and characterizes the firm optimum. The choice and application equations below are exact under their stated assumptions. The main text holds the resulting local elasticities constant over the policy changes we study. We use the notation of the main text and suppress time subscripts where they are unnecessary.

C.1. Product Demand and the Competitor Price Index

Customer i allocates purchases within the modeled product nest using a CES quantity index with elasticity $\epsilon > 1$. Customer i 's quantity and price indices are

$$\begin{aligned} Q_i &= \left(\sum_j G_{ij}^{1/\epsilon} Q_{ij}^{(\epsilon-1)/\epsilon} \right)^{\epsilon/(\epsilon-1)} \\ P_i &= \left(\sum_j G_{ij} P_j^{1-\epsilon} \right)^{1/(1-\epsilon)} \end{aligned} \quad (36)$$

where G_{ij} is customer i 's taste weight on firm j , zero for firms the customer does not visit. Conditional cost minimization gives $Q_{ij} = G_{ij} (P_j/P_i)^{-\epsilon} Q_i$. Total demand depends on market earnings and the price at the outside option:

$$Q_i = G_i \tilde{E}_m^{\eta_e} (P_i/\hat{P}_s)^{-\eta_p} \quad (37)$$

where $\tilde{E}_m = \sum_{k \in m} W_k L_k$ and $G_i > 0$ is a customer shifter.

Let $Q_j = \int Q_{ij} di$. Holding tastes fixed, define the baseline spending shares and overlap weights by

$$\begin{aligned} \sigma_{ij} &= \frac{G_{ij} P_j^{1-\epsilon}}{\sum_k G_{ik} P_k^{1-\epsilon}} \\ s_{jk} &= \int \frac{Q_{ij}}{Q_j} \sigma_{ik} di \end{aligned} \quad (38)$$

Differentiating the price index gives $d \log P_i = \sum_k \sigma_{ik} dp_k$. Differentiating individual de-

mand and weighting by Q_{ij}/Q_j therefore gives

$$dq_j = -\epsilon dp_j + (\epsilon - \eta_p) \sum_k s_{jk} dp_k + \eta_p d\hat{p}_s + \eta_e d\tilde{e}_m \quad (39)$$

Thus $d\tilde{p}_j = \sum_k s_{jk} dp_k$ yields the local form of (8). At a common price for firm j 's product, Q_{ij}/Q_j also equals customer i 's share of that firm's sales, r_{ij}/R_j , and σ_{ik} is customer i 's spending share at firm k , so s_{jk} is the customer-overlap weight (3) of Section 1.4. The weights sum to one by construction. The empirical index in Section 1.4 leaves out firm j 's own price and rescales the remaining weights to sum to one, which treats the own share s_{jj} as negligible; this holds when firm j is a small share of its customers' spending.

If all customers face the same within-nest price index, aggregating (37) gives the main-text log demand equation exactly, with $g_j = \log \int G_{ij} G_i di$. With heterogeneous customer sets, fixed baseline overlap weights implement the differential (39), and finite changes use a first-order approximation.

C.2. Labor Supply with Rationing

Choice of firm and entry. A finite positive mass of potential workers each supplies one unit of labor if hired. Worker i has utility U_{ij} at firm j and U_{i0} at the outside option:

$$U_{ij} = \bar{a}_j + \phi w_j + v_{ij} \quad (40)$$

$$U_{i0} = o_i + \phi \hat{w}_s + v_{i0}$$

with $\phi > 0$ and independent Type I extreme-value shocks. Relative firm amenities $\bar{a}_j$ are common across workers. The index $\hat{w}_s$ expresses the outside option in wage-equivalent units, but o_i allows workers to differ in their taste for that option.

Let $A_j = \exp(\bar{a}_j)$. Conditional on choosing work in market m , the firm share and wage index are

$$F_{jm}(\mathbf{W}_m) = \frac{A_j W_j^\phi}{\sum_{k \in m} A_k W_k^\phi} \quad (41)$$

$$\widetilde{W}_m = \left(\sum_{k \in m} A_k W_k^\phi \right)^{1/\phi} \quad (42)$$

The mass of first-time applicants is

$$N_m = \int \pi_i di \quad (43)$$

$$\pi_i = \frac{\exp\{\phi(\tilde{w}_m - \hat{w}_s)\}}{\exp(o_i) + \exp\{\phi(\tilde{w}_m - \hat{w}_s)\}}$$

Because outside utility loads on $\phi\hat{w}_s$, entry depends on the difference between the market wage index and the outside option $\hat{w}_s$.

Without the minimum wage, every applicant is hired, so $L_j = N_m F_{jm}$ and log labor supply is thus

$$\ell_j = \bar{a}_j + \log N_m + \phi(w_j - \tilde{w}_m)$$

Let F_{jm0} be F_{jm} at the baseline. The wage index then changes by

$$\Delta\tilde{w}_m = \frac{1}{\phi} \log \left[\sum_{j \in m} F_{jm0} \exp\{\phi \Delta w_j\} \right] \quad (44)$$

This formula holds amenities and the set of firms fixed. If amenities change, the differential also includes $\phi^{-1} \sum_j F_{jm} d\bar{a}_j$.

Rationing. With a binding minimum wage, firms can ration workers by hiring fewer workers than are willing to work at the given wage, so that $\ell_j < \ell_j^S$. A rationed worker exits with probability $1 - \lambda$, and with probability λ draws new iid v_{ij} , with $0 \leq \lambda < 1$. Thus, the probability that a given firm maximizes utility, given that the worker is rationed, is the same as the unconditional probability in (41). Workers do not internalize the probability that they will be rationed; they see only the wage, the amenity, and their taste shock.

Let N_m^S count all applications, including re-draws from rationed workers, and let $\tilde{L}_m = \sum_j L_j$ count realized employment. The number of rationed applications is $N_m^S - \tilde{L}_m$. Total applications are therefore first-time applicants plus re-draws:³⁷

$$N_m^S = N_m + \lambda(N_m^S - \tilde{L}_m) \quad (45)$$

$$N_m^S = \frac{N_m - \lambda\tilde{L}_m}{1 - \lambda}$$

Independent redraws imply labor supply $L_j^S = N_m^S F_{jm}$, so the exact conditional supply

³⁷Because each firm hires the smaller of its capacity and its applicants, total applications solve a single equation with a strictly increasing left side, and so have a unique solution.

equation is

$$\ell_j^S = \bar{a}_j + \log N_m^S + \phi(w_j - \tilde{w}_m) \quad (46)$$

The aggregate elasticities. Take a baseline with $0 < \tilde{L}_{m0} < N_{m0}$ and hold λ and the population's participation tastes fixed. Differentiating (45) gives

$$d \log N_m^S = \eta_w (d\tilde{w}_m - d\hat{w}_s) - \eta_\ell d\tilde{\ell}_m \quad (47)$$

$$\eta_w = \frac{\partial \log N_m / \partial (\tilde{w}_m - \hat{w}_s)|_0}{1 - \lambda \tilde{L}_{m0} / N_{m0}} \quad (48)$$

$$\eta_\ell = \frac{\lambda \tilde{L}_{m0} / N_{m0}}{1 - \lambda \tilde{L}_{m0} / N_{m0}} \geq 0$$

For (43), $\partial \log N_m / \partial (\tilde{w}_m - \hat{w}_s)|_0 = \phi \int \pi_{i0} (1 - \pi_{i0}) di / \int \pi_{i0} di$. Thus $0 \leq \eta_w \leq \phi(1 + \eta_\ell)$; the stronger inequality $\eta_w < \phi$ does not follow. Combining (46) and (47) yields

$$d\ell_j^S = d\bar{a}_j + \phi(dw_j - d\tilde{w}_m) + \eta_w (d\tilde{w}_m - d\hat{w}_s) - \eta_\ell d\tilde{\ell}_m \quad (49)$$

At fixed wages and entry, lower employment generates more re-draws and increases supply to each firm. This effect vanishes when $\lambda = 0$. At a fixed own wage and market employment, the wage-index effect is $\eta_w - \phi$: entry offsets part, and potentially all, of the substitution toward higher-paying competitors.

Linearizing around the baseline yields the main-text labor supply equation (9) with intercept

$$a_j = \bar{a}_j + \log N_{m0}^S - \eta_w (\tilde{w}_{m0} - \hat{w}_{s0}) + \eta_\ell \tilde{\ell}_{m0} \quad (50)$$

This suppresses the second-order effect of the rationed share $(N_{m0} - \tilde{L}_{m0})/N_{m0}$ on the coefficients on the aggregates. Common coefficients across markets additionally impose common local slopes. When every firm is on its labor supply curve, $\tilde{L}_m = N_m$ and so $N_m^S = N_m$: re-draws do not affect that allocation. Derivatives that move a firm above its threshold from this point are one-sided.

C.3. Optimal Employment and Minimum Wage Thresholds

Fix the firm primitives and aggregate state, and suppress firm and time subscripts. By (18), $1 - \gamma^{-1} = \alpha(1 - \epsilon^{-1}) \in (0, 1)$. With $L = e^\ell$, inverse demand and labor supply write the revenue

and the wage bill in (14) in levels as

$$\begin{aligned}\exp\{p(\ell) + q(\ell)\} &= \exp\{\epsilon^{-1}g + (1 - \epsilon^{-1})\rho + \mathcal{D}\}L^{1-1/\gamma} \\ \exp\{\max\{\bar{w}, w(\ell)\} + \ell\} &= \max\{\bar{W}L, \exp(\mathcal{S} - a/\phi)L^{1+1/\phi}\}\end{aligned}\tag{51}$$

The second expression is the least wage bill that attracts L workers and respects the minimum wage. It permits the firm to ration workers when the minimum wage exceeds inverse labor supply.

PROPOSITION 2 (Conditional firm optimum). *For $\epsilon > 1$, $\phi > 0$, $0 < \alpha < 1$, and finite primitives and aggregates, the firm has a unique positive optimal employment level. The conditions in (15) characterize this optimum, and its log is (22).*

PROOF. Revenue in (51) is strictly concave in L . The wage bill is the maximum of two convex functions, so profit is strictly concave. Profit is positive for sufficiently small $L > 0$, because $L^{1-1/\gamma}$ dominates L near zero, and tends to minus infinity as $L \rightarrow \infty$. Thus a unique positive optimum exists. At a smooth point it equates marginal revenue and marginal cost; where the minimum wage crosses labor supply it places marginal revenue between the two one-sided marginal costs. These are precisely (15). $\square$

To solve the conditions, write log marginal revenue (defined after (15)) and inverse labor supply as

$$\begin{aligned}\log \text{MR}(\ell) &= \xi^D + \mathcal{D} - \ell/\gamma \\ w(\ell) &= (\ell - a)/\phi + \mathcal{S}\end{aligned}\tag{52}$$

An unconstrained firm solves $\log \text{MR}(\ell) = w(\ell) + \nu$, a firm above its threshold solves $\log \text{MR}(\ell) = \bar{w}$, and a firm below its threshold chooses $\bar{\ell} = a + \phi(\bar{w} - \mathcal{S})$, labor supply at the minimum wage. These equations give the three cases of (22). The conditions at $\bar{\ell}$ hold with equality at the two ends of the below-threshold range: $\log \text{MR}(\bar{\ell}) = \bar{w} + \nu$ at $\bar{w} = w^u$, and $\log \text{MR}(\bar{\ell}) = \bar{w}$ at $\bar{w} = \omega^*$. Hence

$$\begin{aligned}(\gamma + \phi)w^u &= \gamma(\xi^D + \mathcal{D} - \nu) + \phi\mathcal{S} - a \\ (\gamma + \phi)\omega^* &= \gamma(\xi^D + \mathcal{D}) + \phi\mathcal{S} - a\end{aligned}\tag{53}$$

Subtracting proves the constant gap $\omega^* - w^u = \gamma\nu/(\gamma + \phi)$ in (20). Here $\nu = \log(1 + 1/\phi)$ is the log markdown of an unconstrained firm: $\text{MR}/W = 1 + 1/\phi$.

Given $\ell^* = f^\ell(\bar{\omega}; \xi, \mathcal{A}, \theta)$, the remaining outcomes, including log revenue $r = p + q$, are

$$\begin{aligned} w &= \max\{\bar{\omega}, w^u\} \\ q &= \rho + \alpha\ell^* \\ p &= \epsilon^{-1}(g - \rho - \alpha\ell^*) + \mathcal{D} \\ r &= \epsilon^{-1}g + (1 - \epsilon^{-1})\rho + \mathcal{D} + (1 - \gamma^{-1})\ell^* \end{aligned} \tag{54}$$

Adjacent employment cases agree at w^u and ω^* , so all outcomes are continuous in $\bar{\omega}$. With primitives and aggregates fixed, employment slopes are 0, ϕ , and $-\gamma$ in the unconstrained, below-threshold, and above-threshold cases; price slopes are 0, $-\alpha\phi/\epsilon$, and $\alpha\gamma/\epsilon$. Employment is maximized at ω^* and returns to its unconstrained level at $\bar{\omega} = w^u + \nu$, since $\log \text{MR}(\ell^u) = w^u + \nu$ is then the above-threshold firm's first-order condition. Both w^u and ω^* move when the minimum wage changes the aggregates.

The rationing wedge. For every optimal allocation, the rationing wedge between labor supply and realized employment is Ψ :

$$\begin{aligned} \ell &= a + \phi(w - \mathcal{S}) - \Psi \\ \Psi &= (\phi + \gamma) \max\{0, w - \omega^*\} \end{aligned} \tag{55}$$

For unconstrained and below-threshold firms, $w \leq \omega^*$ and $\Psi = 0$. For an initially unconstrained firm on the sample of Proposition 1, $\Psi_{j0} = 0$ and $w_{j0} = w_{j0}^u$, so the period- t rationing wedge is $\psi_{jt}(\theta)$ in that proposition. Above the threshold, $w = \bar{\omega}$ and subtracting labor demand from labor supply gives

$$a + \phi(w - \mathcal{S}) - \gamma(\xi^D + \mathcal{D} - w) = (\phi + \gamma)(w - \omega^*)$$

which proves (55).

C.4. Policy-Dependent Outside Options

This subsection shows that it is straightforward to extend the model to allow for shifts in the product and labor market outside options. These shifts are identified from the effects

at firms in treated states paying above the minimum wage, in local product and labor markets with zero shift in the local market indices. Allow the outside options to respond to policy and write them as $\hat{p}_{st}$ and $\hat{w}_{st}$. The demand and labor supply equations, their shifters, and all closed-form policies retain their form. Common coefficients η_p and η_w make the resulting intercept shifts common within a state. A common outside option with market-specific loadings would instead shift intercepts differently across markets.

Under no anticipation and conditional common trends, which must also cover the untreated outside-option trends, write $\text{DiD}_{st}(y, X)$ for the conditional DiD (23) of outcome y for the policy event in state s at time t . For a given policy event, define the outside shifts from the DiDs of the outside options, which are common within the state:

$$\begin{aligned}\beta_{st}^p &= \eta_p \text{DiD}_{st}(\hat{p}, X) \\ \beta_{st}^w &= \eta_w \text{DiD}_{st}(\hat{w}, X)\end{aligned}\tag{56}$$

Holding the minimum wage, firm primitives, and market aggregates fixed, $\mathcal{D}_{jt}$ rises by β_{st}^p/ϵ and $\mathcal{S}_{m(j)t}$ by β_{st}^w/ϕ , so w_{jt}^u and ω_{jt}^* both rise by

$$\frac{\gamma\beta_{st}^p/\epsilon + \beta_{st}^w}{\gamma + \phi}\tag{57}$$

Thus the constant wedge in (20) is unchanged at each aggregate state. Holding the firm in the same case, the contribution to the employment change is

$$\begin{cases} \gamma\beta_{st}^p/\epsilon, & \bar{\omega}_t > \omega_{jt}^*, \\ -\beta_{st}^w, & w_{jt}^u \leq \bar{\omega}_t \leq \omega_{jt}^*, \\ \frac{\gamma}{\gamma + \phi} (\phi\beta_{st}^p/\epsilon - \beta_{st}^w), & \bar{\omega}_t < w_{jt}^u \end{cases}\tag{58}$$

For a change of case, evaluate the full policy at both states. Total policy effects also include induced movements in local prices, wages, earnings, and employment.

Implications for the structural moments. If the firm primitives a , g , and ρ do not respond directly to policy, their conditional DiDs are zero. Demand and (55) imply

$$\text{DiD}_{st}(r, X) - (1 - \epsilon) \text{DiD}_{st}(p, X) - (\epsilon - \eta_p) \text{DiD}_{st}(\tilde{p}, X) - \eta_e \text{DiD}_{st}(\tilde{e}, X) = \beta_{st}^p\tag{59}$$

$$\text{DiD}_{st}(\ell, X) + \text{DiD}_{st}(\Psi, X) - \phi \text{DiD}_{st}(w - \tilde{w}, X) - \eta_w \text{DiD}_{st}(\tilde{w}, X) + \eta_\ell \text{DiD}_{st}(\tilde{\ell}, X) = -\beta_{st}^w \quad (60)$$

The term $\text{DiD}_{st}(\Psi, X)$ is the DiD of the individual wedge Ψ , not the positive part of a conditional mean. It is zero on a sample that lies on labor supply under both policy states. Otherwise, constructing it requires the identification restrictions that recover w^u for initially unconstrained firms. Equation (57) must enter *inside* the positive part in (55).

Allowing slice-by-period intercepts uses up common variation. For the linear demand moment, the pooled second-moment matrix of the regressors $(\text{DiD}_{st}(p, X), \text{DiD}_{st}(\tilde{p}, X), \text{DiD}_{st}(\tilde{e}, X))$, centered within slice and period, must have full column rank. The analogous requirement for the linear supply moment uses $(\text{DiD}_{st}(w - \tilde{w}, X), \text{DiD}_{st}(\tilde{w}, X), -\text{DiD}_{st}(\tilde{\ell}, X))$. These rank conditions concern variation in conditional DiDs across X after removing the slice-by-period means. With an active wedge, centering removes the additive intercept but leaves the outside shifts inside Ψ . The shifts must then be estimated jointly with the structural parameters. Where the population moments are differentiable, full column rank of the augmented moment Jacobian is a sufficient condition for local identification.

The demand shift β_{st}^p can use firms in every case. Given the slopes and $\text{DiD}_{st}(\Psi, X)$, residuals averaged within slice and period recover the intercepts. If η_p and η_w are nonzero, division recovers $\text{DiD}_{st}(\hat{p}, X)$ and $\text{DiD}_{st}(\hat{w}, X)$; small loadings make this recovery weak. Interpreting these as pure outside-price and outside-wage changes also excludes other policy-induced state demand or amenity shifts, including outside-income changes not captured by modeled earnings. Without that exclusion, the intercepts identify net state shifts.

D. Identification and Estimation Derivations

This appendix collects the derivations behind Section 5. It uses the notation of Section 5.1: a pre increase period 0 and a post increase period t , changes $\Delta y_{jt} \equiv y_{jt} - y_{j0}$, the indicator T_j for firms in states that increase their minimum wage, and the conditional DiD $\text{DiD}(y, X)$ in (23).

We observe each change with measurement error, $Y_{jt}^y = \Delta y_{jt} + u_{jt}^y$, where the measurement error u_{jt}^y satisfies $\mathbb{E}[u_{jt}^y \mid X_j, T_j = 1] = \mathbb{E}[u_{jt}^y \mid X_j, T_j = 0]$. The error adds nothing to any conditional DiD, so we write every equation in terms of Δy_{jt} .

The control trend $\mu^y(X)$ and the change net of the control trend $\Delta^0 y_{jt} \equiv \Delta y_{jt} - \mu^y(X_j)$ are defined in Section 5.1. By (23),

$$\mathbb{E}[\Delta y_{jt} \mid X_j = X, T_j] = \mu^y(X) + T_j \text{DiD}(y, X) \quad (61)$$

D.1. From Proposition 1 to the Structural DiD Equation

We prove Proposition 1 and derive the structural DiD equation (33).

Proof of Proposition 1. By (9) and (17), labor supply is $\ell_{jt}^S = a_{jt} + \phi(w_{jt} - \mathcal{S}_{m(j)t})$, and the unconstrained wage w_{jt}^u is (19). By Assumption 1, the changes $\Delta a_{jt} = \Delta u_t^a(X_j)$ and $\Delta \xi_{jt}^D = \epsilon^{-1} \Delta u_t^g(X_j) + (1 - \epsilon^{-1}) \Delta u_t^p(X_j)$ are the same for every firm with the same X_j . An initially unconstrained firm has $w_{j0} = w_{j0}^u$ and $\ell_{j0} = \ell_{j0}^S$, and on the sample of the proposition every control firm also has $w_{jt} = w_{jt}^u$ and $\ell_{jt} = \ell_{jt}^S$. Every control firm with the same X_j has the same changes in its primitives, so $\mu^w(X_j)$ and $\mu^\ell(X_j)$ contain the same primitive trends as Δw_{jt}^u and $\Delta \ell_{jt}^S$. Subtracting $\mu^w(X_j)$ from Δw_{jt}^u cancels the primitive trends and leaves $\Delta^0 \mathcal{D}_{jt}$ and $\Delta^0 \mathcal{S}_{m(j)t}$, which is (32). By (22) and (20), employment is labor supply less the rationing wedge, $\ell_{jt} = \ell_{jt}^S - (\phi + \gamma) \max\{0, w_{jt} - w_{jt}^u - \gamma v / (\gamma + \phi)\}$ with $w_{jt} = \max\{w_{jt}^u, \bar{w}_1\}$, and the wedge is zero in period 0. Since $w_{j0} = w_{j0}^u$, $w_{jt} - w_{jt}^u = \Delta w_{jt} - \Delta w_{jt}^u = \Delta^0 w_{jt} - f^{\Delta w^u}(\Delta^0 \mathcal{A}_{jt}; \theta)$, so the period- t rationing wedge is $\psi_{jt}(\theta)$ in (30). Differencing employment and subtracting $\mu^\ell(X_j)$ gives $\Delta^0 \ell_{jt} = \phi(\Delta^0 w_{jt} - \Delta^0 \mathcal{S}_{m(j)t}) - \psi_{jt}(\theta)$; with the outside options fixed, the first term is f^{LS} in (29), which proves (i). Subtracting $w_{j0} + \mu^w(X_j)$ from $w_{jt} = \max\{w_{jt}^u, \bar{w}_1\}$ proves (ii). The proof does not use Assumption 2. $\square$

For initially unconstrained firms with a given X , on the sample of Proposition 1, the rationing wedge (30) is

$$\psi_{jt}(\theta) = (\phi + \gamma) \left[\Delta^0 w_{jt} - f^{\Delta w^u}(\Delta^0 \mathcal{A}_{jt}; \theta) - \frac{\gamma v}{\gamma + \phi} \right]_+ \quad (62)$$

$$\Delta w_{jt}^u - \mu^w(X_j) = f^{\Delta w^u}(\Delta^0 \mathcal{A}_{jt}; \theta)$$

with $[z]_+ \equiv \max\{z, 0\}$. Since $\mu^w(X_j)$ cancels, the argument of the positive part is $\Delta w_{jt} - \Delta w_{jt}^u - \gamma v / (\gamma + \phi)$, which is $w_{jt} - \omega_{jt}^*$ because $w_{j0} = w_{j0}^u$ and by (20). By Proposition 1, $\Delta^0 \ell_{jt} = f^{LS}(\Delta^0 w_{jt}, \Delta^0 \mathcal{A}_{jt}; \theta) - \psi_{jt}(\theta)$. The function f^{LS} in (29) is linear in the detrended changes, and $\mathbb{E}[\Delta^0 y_{jt} \mid X, T_j = 1] = \text{DiD}(y, X)$, so taking expectations over treated firms

with the same X gives

$$\text{DiD}(\ell, X) = \phi \text{DiD}(w - \tilde{w}, X) + \eta_w \text{DiD}(\tilde{w}, X) - \eta_\ell \text{DiD}(\tilde{\ell}, X) - \mathbb{E}[\psi_{jt}(\theta) \mid X, T_j = 1] \quad (63)$$

The expected rationing wedge among control firms, $\mathbb{E}[\psi_{jt}(\theta) \mid X, T_j = 0]$, is zero on the sample of Proposition 1, because no control firm is above its threshold.

We can write the last term as a function of the cell in three steps. First, Proposition 1(ii) gives $\Delta^0 w_{jt} = \max \{ f^{\Delta w^u}(\Delta^0 \mathcal{A}_{jt}; \theta), \bar{w}_1 - w_{j0} - \mu^w(X_j) \}$, so

$$\Delta^0 w_{jt} - f^{\Delta w^u}(\Delta^0 \mathcal{A}_{jt}; \theta) = [\bar{w}_1 - w_{j0} - \mu^w(X_j) - f^{\Delta w^u}(\Delta^0 \mathcal{A}_{jt}; \theta)]_+ \quad (64)$$

Second, the structural trends of Assumption 1 do not appear: they enter the control firms' wages in the same way, so they are absorbed by $\mu^w(X_j)$. With the outside options fixed, (16) and (17) make (32) linear in the detrended aggregates,

$$f^{\Delta w^u}(\Delta^0 \mathcal{A}_{jt}; \theta) = \frac{\gamma}{\gamma + \phi} \left[(1 - \eta_p \epsilon^{-1}) \Delta^0 \tilde{p}_{jt} + \eta_e \epsilon^{-1} \Delta^0 \tilde{e}_{m(j)t} \right] + \frac{\phi}{\gamma + \phi} \left[(1 - \eta_w \phi^{-1}) \Delta^0 \tilde{w}_{m(j)t} + \eta_\ell \phi^{-1} \Delta^0 \tilde{\ell}_{m(j)t} \right] \quad (65)$$

Third, by Assumption 2 in the form (27), $\Delta \mathcal{D}_{jt}$ and $\Delta \mathcal{S}_{m(j)t}$ are functions of (X_j, T_j) , and so are their detrended versions. The initial wage w_{j0} and the control trend $\mu^w(X_j)$ are functions of X_j , and the new minimum wage $\bar{w}_1$ is set by T_j within a slice. So the argument of the positive part is a function of (X_j, T_j) , and the expectation passes through the positive part.

For control firms, $\bar{w}_1 = \bar{w}_0$ and, on the sample of Proposition 1, the firm does not bind, so the positive part in (64) is zero and $\Delta^0 w_{jt} = f^{\Delta w^u}(\Delta^0 \mathcal{A}_{jt}; \theta_0)$ for every control firm. At θ_0 the argument of the positive part is then $-\gamma\psi/(\gamma + \phi) < 0$ and the control wedge is zero, which does not use Assumption 2; under that assumption the detrended wage and aggregates of control firms are zero, so the control wedge is zero at every θ . A detrended change that is a function of (X_j, T_j) equals its conditional mean: zero for control firms and the DiD for treated firms. For treated firms, $\Delta^0 w_{jt} = \text{DiD}(w, X)$, and by (65) the unconstrained wage of firms with $X_j = X$ drifts across policy states by

$$f^{\Delta w^u}(\Delta^0 \mathcal{A}_{jt}; \theta)|_{T_j=1} = \frac{\gamma \text{DiD}(\mathcal{D}, X) + \phi \text{DiD}(\mathcal{S}, X)}{\gamma + \phi} \quad (66)$$

so the expected rationing wedge among treated firms is

$$\mathbb{E} [\psi_{jt}(\theta) \mid X, T_j = 1] = (\phi + \gamma) \left[\text{DiD}(w, X) - \frac{\gamma \text{DiD}(\mathcal{D}, X) + \phi \text{DiD}(\mathcal{S}, X)}{\gamma + \phi} - \frac{\gamma v}{\gamma + \phi} \right]_+ \quad (67)$$

where, with the outside options fixed, $\text{DiD}(\mathcal{D}, X) = (1 - \eta_p \epsilon^{-1}) \text{DiD}(\tilde{p}, X) + \eta_e \epsilon^{-1} \text{DiD}(\tilde{e}, X)$ and $\text{DiD}(\mathcal{S}, X) = (1 - \eta_w \phi^{-1}) \text{DiD}(\tilde{w}, X) + \eta_\ell \phi^{-1} \text{DiD}(\tilde{\ell}, X)$ by (16) and (17). Substituting (67) into (63) gives (33). The argument of the positive part, times $\phi + \gamma$, is $(\phi + \gamma) \text{DiD}(w, X) - \gamma \text{DiD}(\mathcal{D}, X) - \phi \text{DiD}(\mathcal{S}, X) - \gamma v$.

If a cell's control group did bind in period t , $\mu^w(X)$ would no longer be the control trend of the unconstrained wage and the control wedge could also enter the DiD. The sample restriction in Appendix D.2.3 excludes these cells.

D.2. Conditional Moments by Equation

Each equation gives a conditional moment restriction.

D.2.1. Product Demand

Demand holds for every firm, so we use all firms. Log revenue is $r_{jt} = p_{jt} + q_{jt}$. Substituting the product demand curve (8) and differencing, with the outside option price fixed and quality $g_{jt} = g_j + u_t^g(X_j)$ from Assumption 1,

$$\Delta r_{jt} = \Delta u_t^g(X_j) + (1 - \epsilon) \Delta p_{jt} + (\epsilon - \eta_p) \Delta \tilde{p}_{jt} + \eta_e \Delta \tilde{e}_{m(j)t} \quad (68)$$

For revenue, (61) reads

$$\mathbb{E} [\Delta r_{jt} \mid X_j = X, T_j] = \mu^r(X) + T_j \text{DiD}(r, X) \quad (69)$$

Taking conditional DiDs of (68), the quality trend cancels:

$$\text{DiD}(r, X) = (1 - \epsilon) \text{DiD}(p, X) + (\epsilon - \eta_p) \text{DiD}(\tilde{p}, X) + \eta_e \text{DiD}(\tilde{e}, X) \quad (70)$$

Combining (70) with (61) for $r, p, \tilde{p}$ and $\tilde{e}$ gives the demand moment

$$\mathbb{E} [\zeta_{jt}^R(\theta) \mid X_j] = 0 \quad (71)$$

with ζ_{jt}^R as in (74).

D.2.2. Production

The output DiD is α times the employment DiD. Output is $q_{jt} = r_{jt} - p_{jt}$. The production function (10) with $\rho_{jt} = \rho_j + u_t^p(X_j)$ gives $\Delta q_{jt} = \Delta u_t^p(X_j) + \alpha \Delta \ell_{jt}$, so $\text{DiD}(q, X) = \alpha \text{DiD}(\ell, X)$ and

$$\mathbb{E} [\zeta_{jt}^Q(\theta) \mid X_j] = 0 \quad (72)$$

D.2.3. Labor Supply and Employment

Employment follows labor supply below the threshold. Let $R^L(X) = 1$ for cells in the sample of Proposition 1: firms have no worker paid the old minimum wage (the Newly Binds and Doesn't Bind groups of Section 3.2), and no control firm in the cell pays it in period t . The first restriction is on X because w_{j0} is in X_j , and the second is defined cell by cell, so R^L is a function of X ; because we observe whether the minimum wage is binding, both are sample restrictions rather than assumptions. For these firms, the initial wage equals the unconstrained wage w_{j0}^u , and Appendix D.1 gives the labor DiD equation (33). The expected rationing wedge (67) is a function of X and θ . The function is nonlinear *across* X , but not *within* X , and so we can still construct a valid (nonlinear) conditional moment. On these cells every control firm is initially unconstrained and remains unconstrained in period t , so conditioning on that adds nothing and the control trends are the $\mu^y(X)$ of Section 5.1. The labor moment is

$$\mathbb{E} [\zeta_{jt}^L(\theta) \mid X_j, R^L(X_j) = 1] = 0 \quad (73)$$

Residuals and Instruments. These assumptions gave us a series of conditional moment restrictions, that we can also express as a relationship between many DiDs. To take this to data, we work with the conditional moment restriction form. The product side is easy because demand always holds. For $b \in \{R, Q, L\}$, let $\zeta_{jt}^b(\theta)$ denote the residual of equation b :

$$\begin{aligned} \zeta_{jt}^R(\theta) &= [\Delta r_{jt} - \mu^r(X_j)] - (1 - \epsilon) [\Delta p_{jt} - \mu^p(X_j)] - (\epsilon - \eta_p) [\Delta \tilde{p}_{jt} - \mu^{\tilde{p}}(X_j)] - \eta_e [\Delta \tilde{e}_{m(j)t} - \mu^{\tilde{e}}(X_j)] \\ \zeta_{jt}^Q(\theta) &= [\Delta q_{jt} - \mu^q(X_j)] - \alpha [\Delta \ell_{jt} - \mu^\ell(X_j)] \\ \zeta_{jt}^L(\theta) &= [\Delta \ell_{jt} - \mu^\ell(X_j)] - \phi [\Delta (w_{jt} - \tilde{w}_{m(j)t}) - \mu^{w-\tilde{w}}(X_j)] - \eta_w [\Delta \tilde{w}_{m(j)t} - \mu^{\tilde{w}}(X_j)] \\ &\quad + \eta_\ell [\Delta \tilde{\ell}_{m(j)t} - \mu^{\tilde{\ell}}(X_j)] + T_j \mathbb{E} [\psi_{jt}(\theta) \mid X_j, T_j = 1] \end{aligned} \quad (74)$$

where each bracket is the change net of its control trend, $\Delta^0 y_{jt} = \Delta y_{jt} - \mu^y(X_j)$, as defined in Section 5.1. The labor residual is the cell-level form of $\Delta^0 \ell_{jt} - f^{\Delta \ell}(\Delta^0 w_{jt}, \Delta^0 \mathcal{A}_{jt}; \theta)$: $\zeta_{jt}^L(\theta) = \Delta^0 \ell_{jt} - f^{LS}(\Delta^0 w_{jt}, \Delta^0 \mathcal{A}_{jt}; \theta) + T_j \mathbb{E}[\psi_{jt}(\theta) \mid X_j, T_j = 1]$. Appendix D.2 derives each residual. We use all firms for demand and production, and the cells with $R^L(X_j) = 1$ for employment. This keeps the treated firms and the control trends on the same X . The conditional moments imply

$$\mathbb{E} \left[h(X_j) \zeta_{jt}^b(\theta) \right] = 0, \quad b \in \{R, Q, L\} \quad (75)$$

for any function $h(X)$ with a finite second moment, with the expectation taken over the equation's sample. Assumptions 1 and 2 therefore imply instrument validity; identification also requires a rank condition that different groups have sufficiently different policy effects (Section 5.1).³⁸ One candidate $h(\cdot)$ is the group indicator using the Newly Binds, Initially Binds, and Doesn't Bind groups of Section 3.2. The groups are functions of X , and their relative-price first stages differ: Newly Binds firms cut relative prices while Initially Binds firms raise them. Comparing revenue responses across the groups would identify the coefficient on relative price. However, these group indicators use only part of the variation in X . We estimate a pilot from the group indicators and the conditional first stages and then use the Chamberlain instruments, which make efficient use of this variation (Chamberlain, 1987). Constructed at the pilot estimate, they give one instrument per parameter, so the final step is exactly identified (Appendix D.5.3).

D.3. Heterogeneous Policy Effects as Identifying Variation

The preceding moment conditions hold conditional on X . That means we can use the heterogeneous policy effects to identify the structural parameters.

We use the fact that the initial conditions and controls in X predict heterogeneous responses to the minimum wage, in addition to being the source of confounding in the time trends (e.g. common trends holds only after conditioning on X). And so, given the fact that we made a conditional common trends assumption in the reduced form analysis, the thought experiment is that when we report the aggregate DiD, we are really reporting the average over many valid X -specific DiDs. Those X -specific DiDs provide the identifying

³⁸If increases are small enough that responses are linear around each firm's initial state, conditional common trends alone gives instrument validity.

variation we need to recover our structural parameters.

The tools developed in this section are quite general; though we only have a single source of policy variation, we are able to recover multiple supply and demand parameters. For example, in a simple demand system where quantity depends only on the firm's own price, we can use cross-group differences in price effects and in quantity effects to estimate the demand elasticity.

D.3.1. Counting Equations and Parameters

Conditioning on X gives many valid DiDs. If we average the restrictions over X , the production equation contains one parameter and one moment, so a nonzero employment response identifies α . The product-demand equation contains three endogenous channels, Δp_{jt} , $\Delta \tilde{p}_{jt}$, and $\Delta \tilde{e}_{m(j)t}$, but supplies only one unconditional moment. The labor equation contains three endogenous channels, $\Delta (w_{jt} - \tilde{w}_{m(j)t})$, $\Delta \tilde{w}_{m(j)t}$, and $\Delta \tilde{\ell}_{m(j)t}$, but supplies only one unconditional moment.

The conditional first stages are the DiDs of the endogenous channels. For demand and labor supply, stack them as

$$Z^R(X) \equiv \left(\text{DiD}(p, X), \text{DiD}(\tilde{p}, X), \text{DiD}(\tilde{e}, X) \right)' \quad (76)$$

$$Z^L(X) \equiv \left(\text{DiD}(w, X), \text{DiD}(\tilde{w}, X), \text{DiD}(\tilde{\ell}, X) \right)' \quad (77)$$

with $Z^L(X)$ defined on the cells with $R^L(X) = 1$ and set to zero elsewhere; the production first stage is $\text{DiD}(\ell, X)$. The entries of $Z^L(X)$ span the same space as the labor DiDs above because $\text{DiD}(w - \tilde{w}, X) = \text{DiD}(w, X) - \text{DiD}(\tilde{w}, X)$.

D.3.2. Firm-Level and Market-Level Variation

We combine firm-level variation with variation in market conditions. A firm's initial conditions supply first-stage variation in its own price and wage; the market indices and their trends supply first-stage variation in market employment and the competitor price and wage indices.

D.3.3. Global Identification

The model is globally identified under a suitable rank condition. On the sample of Proposition 1 and under Assumption 2, the structural DiD equation (33) is the minimum of two terms. The first is the labor supply term $\phi \text{DiD}(w - \tilde{w}, X) + \eta_w \text{DiD}(\tilde{w}, X) - \eta_\ell \text{DiD}(\tilde{\ell}, X)$. By the sentence after (67), the labor supply term less $(\phi + \gamma)$ times the argument of the positive part in the expected rationing wedge is the marginal revenue term $\gamma [\text{DiD}(\mathcal{D}, X) - \text{DiD}(w, X) + v]$, the employment response along the marginal revenue curve. The parameter space Θ is a compact subset of the region where $\epsilon > 1$, $\phi > 0$, $\alpha > 0$, and $1 - \alpha(1 - \epsilon^{-1}) > 0$, with θ_0 in its interior. Since $\phi + \gamma > 0$ on Θ , the expected rationing wedge is zero when the labor supply term is the smaller of the two and equals their difference otherwise, so

$$\text{DiD}(\ell, X) = \min \left\{ \phi \text{DiD}(w - \tilde{w}, X) + \eta_w \text{DiD}(\tilde{w}, X) - \eta_\ell \text{DiD}(\tilde{\ell}, X), \gamma [\text{DiD}(\mathcal{D}, X) - \text{DiD}(w, X) + v] \right\} \quad (78)$$

Given $(\epsilon, \eta_p, \eta_e, \alpha)$, the marginal revenue term depends on ϕ only through $v = \log(1 + \phi^{-1})$, which falls as ϕ rises.

At the true parameter value θ_0 , the argument of the positive part is the treated firms' gap to their threshold. On the sample, control firms have $\Delta w_{jt} = \Delta w_{jt}^u$ and every firm has $w_{j0} = w_{j0}^u$, so $\text{DiD}(w - w^u, X) = \mathbb{E} [w_{jt} - w_{jt}^u \mid X, T_j = 1]$ and the argument is $\text{DiD}(w - w^u, X) - \gamma v / (\gamma + \phi)$. A treated cell is below its threshold when $\text{DiD}(w - w^u, X) < \gamma v / (\gamma + \phi)$ and at or above it otherwise. Below, $\text{DiD}(w - w^u, X)$ is always this object at θ_0 , and the parameters in any expression containing it are at θ_0 as well; the indicator in Appendix D.5.2 varies with θ and is written out there.

PROPOSITION 3 (Global identification). *Let θ_0 be the true parameter value, and treat the DiDs of the market indices as data, so that they do not vary with θ . Suppose that*

$$\mathbb{E} [Z^R(X_j) Z^R(X_j)' \mid T_j = 1] > 0 \quad (79)$$

$$\Pr(\text{DiD}(\ell, X_j) \neq 0 \mid T_j = 1) > 0$$

$$\begin{aligned} & \mathbb{E} \left[\mathbb{1} \left\{ \text{DiD}(w - w^u, X_j) < \frac{\gamma v}{\gamma + \phi} \right\} \mathbb{1} \left\{ \Pr(\text{DiD}(w - w^u, X_{j'}) \right. \right. \\ & \quad \left. \left. > \text{DiD}(w - w^u, X_j) \mid X_j, T_{j'} = 1, R^L(X_{j'}) = 1) > 0 \right\} \right. \\ & \quad \left. \times Z^L(X_j) Z^L(X_j)' \mid T_j = 1, R^L(X_j) = 1 \right] > 0 \end{aligned} \quad (80)$$

where firm j' is drawn independently of firm j . The first indicator keeps the cells whose treated firms are below their threshold, and the second drops the cells closest to it: those with no positive share of treated cells in the labor sample ($R^L(X_j) = 1$) closer to the threshold. Then θ_0 is the only $\theta \in \Theta$ that satisfies (70) and $\text{DiD}(q, X) = \alpha \text{DiD}(\ell, X)$ for almost every treated X , and (78) for almost every treated X in the labor sample.

PROOF. Let $\theta \in \Theta$ satisfy the three equations. Subtracting (70) at θ_0 from the same equation at θ shows that, for almost every treated X , $Z^R(X)$ is orthogonal to the change in the coefficient vector $(1 - \epsilon, \epsilon - \eta_p, \eta_e)'$ from θ_0 to θ . The expectation in (79), taken as a quadratic form in that change, is then zero, so the change is zero and $(\epsilon, \eta_p, \eta_e)$ takes its value at θ_0 . The production equation holds at θ and at θ_0 , so $\alpha \text{DiD}(\ell, X)$ equals its value at θ_0 for almost every treated X ; since $\text{DiD}(\ell, X) \neq 0$ with positive probability, α takes its value at θ_0 . By (18) and (16), γ and $\text{DiD}(\mathcal{D}, X)$ also take their values at θ_0 .

The marginal revenue term at θ therefore exceeds its value at θ_0 by γ times the change in v , the same amount in every cell; this amount is nonnegative if ϕ is at most its value at θ_0 and negative otherwise. The labor supply term equals $Z^L(X)'(\phi, \eta_w - \phi, -\eta_\ell)'$. So if the labor supply term at θ equals its value at θ_0 for almost every cell kept by the indicators in (80), the argument used for demand gives $(\phi, \eta_w, \eta_\ell)$ at its value at θ_0 , and $\theta = \theta_0$. At θ_0 , the labor supply term less the marginal revenue term is $(\phi + \gamma) \text{DiD}(w - w^u, X) - \gamma v$. By (78) at θ_0 , a cell below its threshold has $\text{DiD}(\ell, X)$ equal to the labor supply term at θ_0 and strictly below the marginal revenue term at θ_0 , and a cell at or above its threshold has $\text{DiD}(\ell, X)$ equal to the marginal revenue term at θ_0 .

Suppose first that ϕ is at most its value at θ_0 . In every cell below its threshold, $\text{DiD}(\ell, X)$ is strictly below the marginal revenue term at θ_0 , which is at most the marginal revenue term at θ . The minimum in (78) at θ is therefore the labor supply term, which equals $\text{DiD}(\ell, X)$ and hence its value at θ_0 . The cells kept by the indicators in (80) are all below their threshold, so $\theta = \theta_0$.

Suppose instead that ϕ exceeds its value at θ_0 , so that the marginal revenue term at θ is below its value at θ_0 by the same positive amount in every cell. Equation (78) at θ requires $\text{DiD}(\ell, X)$ to be at most the marginal revenue term at θ in almost every treated cell of the labor sample. This fails in every cell at or above its threshold, where $\text{DiD}(\ell, X)$ is the marginal revenue term at θ_0 . In a cell below its threshold, it holds if and only if $(\phi + \gamma) \text{DiD}(w - w^u, X) - \gamma v$ is at most minus that amount. So, almost surely,

$(\phi + \gamma) \text{DiD}(w - w^u, X_j) - \gamma v$ is at most minus that amount, a bound that does not depend on X_j . Take a cell kept by the indicators in (80). A positive share of treated cells in the labor sample has a larger value of $\text{DiD}(w - w^u, \cdot)$, and almost all of them satisfy the bound, so the cell's $(\phi + \gamma) \text{DiD}(w - w^u, X) - \gamma v$ is strictly below minus that amount. Then $\text{DiD}(\ell, X)$ is strictly below the marginal revenue term at θ , so the minimum in (78) at θ is the labor supply term, which equals $\text{DiD}(\ell, X)$ and hence its value at θ_0 . This holds in almost every cell kept by the indicators, so $\theta = \theta_0$, which contradicts ϕ exceeding its value at θ_0 . $\square$

Treated cells at or above the threshold are sufficient but not needed: when they have positive probability, no cell below the threshold is closest to it, so (80) becomes the rank condition across all cells below the threshold.

D.4. Firm-Level Primitives

Given θ , the three structural equations in the initial period give the primitives as residuals. Demand (8) and production (10) hold for every firm, and labor supply (9) holds for firms on their labor supply curve (unconstrained firms and firms below their threshold):

$$\begin{aligned} g_{j0} &= q_{j0} + \epsilon (p_{j0} - \tilde{p}_{j0}) + \eta_p (\tilde{p}_{j0} - \hat{p}_{s(j)}) - \eta_e \tilde{e}_{m(j)0} \\ \rho_{j0} &= q_{j0} - \alpha \ell_{j0} \\ a_{j0} &= \ell_{j0} - \phi (w_{j0} - \tilde{w}_{m(j)0}) - \eta_w (\tilde{w}_{m(j)0} - \hat{w}_{s(j)}) + \eta_\ell \tilde{\ell}_{m(j)0} \end{aligned} \quad (81)$$

The outside options are common state effects, so g_{j0} and a_{j0} are recovered up to a state constant. These constants cancel from the unconstrained wage. Substituting (81) into (16), (17) and the definition of ξ_{jt}^D gives $\xi_{j0}^D + \mathcal{D}_{j0} = \log[\alpha(1 - \epsilon^{-1})] + r_{j0} - \alpha(1 - \epsilon^{-1})\ell_{j0}$ and $\phi \mathcal{S}_{m(j)0} - a_{j0} = \phi w_{j0} - \ell_{j0}$, so, using $\log \text{MR}_{j0}$ from (83) and $\gamma^{-1} = 1 - \alpha(1 - \epsilon^{-1})$, (19) becomes

$$w_{j0}^u = \frac{\gamma (\log \text{MR}_{j0} - v) + \phi w_{j0}}{\gamma + \phi} \quad (82)$$

For an unconstrained firm the first-order condition (15) gives $\log \text{MR}_{j0} = w_{j0} + v$, so (82) returns $w_{j0}^u = w_{j0}$. For a firm paying the minimum wage, $w_{j0} = \bar{w}_0$ and (82) becomes (84). By (15), $\log \text{MR}_{j0} \in [\bar{w}_0, \bar{w}_0 + v]$. If $\log \text{MR}_{j0} \in (\bar{w}_0, \bar{w}_0 + v]$, the firm is below its threshold and on its labor supply curve, so (81) and (82) hold, and $w_{j0}^u \in (\bar{w}_0 - \gamma v / (\gamma + \phi), \bar{w}_0]$. If $\log \text{MR}_{j0} = \bar{w}_0$, the firm is at or above its threshold: labor supply need not hold, a_{j0} is not

recovered, and we know only that $w_{j0}^u \leq \bar{\omega}_0 - \gamma\upsilon/(\gamma + \phi)$.

For Newly Binds firms, we observe $w_{j0} = w_{j0}^u$. For Initially Binds firms, we first calculate log marginal revenue from observed revenue and employment:

$$\log \text{MR}_{j0} = \log \left[\alpha \left(1 - \epsilon^{-1} \right) \right] + r_{j0} - \ell_{j0} \quad (83)$$

If the firm is below its threshold, its unconstrained wage is

$$w_{j0}^u = \frac{\gamma (\log \text{MR}_{j0} - \upsilon) + \phi \bar{\omega}_0}{\gamma + \phi} \quad (84)$$

For firms at or above their threshold, $\log \text{MR}_{j0} = \bar{\omega}_0$, and we recover only the bound

$$w_{j0}^u \leq \bar{\omega}_0 - \frac{\gamma\upsilon}{\gamma + \phi} \quad (85)$$

D.5. GMM Implementation

We stack the moments (34) across policy slices and calendar periods, giving each calendar period equal weight. The control trends $\mu^y(X)$ are cross-fit at the firm level, as in the reduced-form estimator of Section 1.3, and the market indices each firm faces leave that firm out.

From here on we restore the policy slice. An observation is firm j in slice k of the stacked design, and its covariates X_{jk} include the slice (Section 1.3), so the control trends, propensity and first stages are functions of X_{jk} with no slice index. Δy_{jk} , Y_{jk}^y , T_{jk} , $\psi_{jk}(\theta)$, ζ_{jk}^b and $R^L(X_{jk})$ are the slice versions of the objects above, with the residuals written in observed outcomes (Appendix D.5.2). The true parameter value is θ_0 .

D.5.1. Stacked Residuals

We stack the three equations on their own samples. Because $R^L(X_{jk})$ is a function of X_{jk} , given X_{jk} either all three equations are present or only demand and production are. Stack the residuals with the labor entry switched off outside its sample,

$$\begin{aligned} \zeta_{jk}(\theta) &\equiv \left(\zeta_{jk}^R(\theta), \zeta_{jk}^Q(\theta), R^L(X_{jk}) \zeta_{jk}^L(\theta) \right)' \\ \mathbb{E} \left[\zeta_{jk}(\theta_0) \mid X_{jk} \right] &= 0 \end{aligned} \quad (86)$$

where ζ_{jk}^b are the residuals (74) written in observed outcomes (Appendix D.5.2). At θ_0 , the residuals equal the measurement errors net of their control-group means,

$$\zeta_{jk}(\theta_0) = \mathbf{u}_{jk} - \mathbb{E}[\mathbf{u}_{jk} \mid X_{jk}, T_{jk} = 0] \quad (87)$$

where $\mathbf{u}_{jk} = (u_{jk}^r, u_{jk}^q, R^L(X_{jk})u_{jk}^\ell)'$ collects the errors in the three outcomes. The centered errors have conditional mean zero under both policy states because $\mathbb{E}[\mathbf{u}_{jk} \mid X_{jk}, T_{jk} = 1] = \mathbb{E}[\mathbf{u}_{jk} \mid X_{jk}, T_{jk} = 0]$, which gives (86). Let $p(X) = \Pr(T_{jk} = 1 \mid X_{jk} = X)$ be the propensity score of Section 1.3, which we assume is bounded away from zero and one.

D.5.2. Orthogonal Scores

Our scores are insensitive to first-order error in the estimated control trends, the propensity and the DiDs in the rationing wedge.

Cross-Fitted Trends and Market Indices. The residuals use the observed change net of its control trend, $\Delta^0 Y_{jk}^y \equiv Y_{jk}^y - \mu^{Y^y}(X_{jk})$ with $\mu^{Y^y}(X) \equiv \mathbb{E}[Y_{jk}^y \mid X_{jk} = X, T_{jk} = 0]$, in place of the structural change $\Delta^0 y_{jk}$. The two control trends differ by the control-group mean of the measurement error, so the residual at θ_0 is the centered error in (87). Folds are defined at the firm level: firm j 's entire time series is assigned to one fold, so the control trends used for firm j are estimated on the other folds. Hats on μ denote these cross-fitted estimates. Each market index a firm faces is estimated from other firms with the same market entries of X .

Residuals. The product demand and production residuals are

$$\zeta_{jk}^R(\theta) \equiv \Delta^0 Y_{jk}^r - (1 - \epsilon) \Delta^0 p_{jk} - (\epsilon - \eta_p) \Delta^0 \tilde{p}_{jk} - \eta_e \Delta^0 \tilde{e}_{m(j)k} \quad (88)$$

$$\zeta_{jk}^Q(\theta) \equiv \Delta^0 Y_{jk}^q - \alpha \Delta^0 \ell_{jk} \quad (89)$$

which are the residuals of (74) with the observed outcome in place of the structural outcome change. The labor residual uses the detrended shifters $\Delta^0 \mathcal{D}_{jk}$ and $\Delta^0 \mathcal{S}_{m(j)k}$, the detrended market indices combined with the coefficients of (16) and (17), which therefore depend on

θ :

$$\begin{aligned} \zeta_{jk}^L(\theta) \equiv & \Delta^0 Y_{jk}^\ell - \phi \Delta^0 w_{jk} - (\eta_w - \phi) \Delta^0 \tilde{w}_{m(j)k} + \eta_\ell \Delta^0 \tilde{\ell}_{m(j)k} \\ & + (\phi + \gamma) \mathbb{1} \left\{ \text{DiD}(w, X_{jk}) - \frac{\gamma \text{DiD}(\mathcal{D}, X_{jk}) + \phi \text{DiD}(\mathcal{S}, X_{jk})}{\gamma + \phi} > \frac{\gamma v}{\gamma + \phi} \right\} \\ & \times \left[\Delta^0 w_{jk} - \frac{\gamma \Delta^0 \mathcal{D}_{jk} + \phi \Delta^0 \mathcal{S}_{m(j)k}}{\gamma + \phi} - T_{jk} \frac{\gamma v}{\gamma + \phi} \right] \end{aligned} \quad (90)$$

The indicator is the treated cell's position relative to its threshold in (67), applied to every firm in the cell. At θ_0 the detrended wage and shifters are functions of X_{jk} and T_{jk} , so the bracket is zero for control firms and, for treated firms, the argument of the positive part in (67); the last term is therefore T_{jk} times the expected rationing wedge, as in (74). When we take this to data, we replace the max with a softplus to avoid technical issues with the kink. Let sp be the softplus, a smooth function that equals $[z]_+$ outside a small window around zero, and sp' its derivative. The last two lines of (90) become

$$\begin{aligned} & (\phi + \gamma) \text{sp}'(z) \left[\Delta^0 w_{jk} - \frac{\gamma \Delta^0 \mathcal{D}_{jk} + \phi \Delta^0 \mathcal{S}_{m(j)k}}{\gamma + \phi} - T_{jk} \frac{\gamma v}{\gamma + \phi} \right] \\ & + (\phi + \gamma) T_{jk} [\text{sp}(z) - z \text{sp}'(z)] \end{aligned} \quad (91)$$

where z is the argument of the positive part in (67) at X_{jk} . With the max, sp' is the indicator and the second line is zero. In the sample, the trends, the propensity and the DiDs in z are their cross-fitted estimates. The orthogonal score weights the stacked residual by the treatment residual, where $p(X)$ is the propensity score (not the price):

$$[T_{jk} - p(X_{jk})] \zeta_{jk}(\theta) \quad (92)$$

Orthogonality. Following Theorem 3.3 of Chernozhukov et al. (2018), we show that the moment is Neyman orthogonal.

PROPOSITION 4 (Neyman orthogonality). *Use the labor term (91), and ignore the bias from smoothing at a fixed width, so that $\zeta_{jk}(\theta_0)$ has mean zero given X_{jk} and T_{jk} . Perturb the instrument h , the propensity p , the control trends μ and, through the DiDs in the rationing wedge, z , in bounded directions that are functions of X_{jk} . Then*

$$\frac{\partial}{\partial \tau} \mathbb{E} \left[(h + \tau \dot{h})(X_{jk}) [T_{jk} - (p + \tau \dot{p})(X_{jk})] \zeta_{jk}(\theta_0; \mu + \tau \dot{\mu}, z + \tau \dot{z}) \right] \Big|_{\tau=0} = 0 \quad (93)$$

PROOF. This is condition (2.3) of Chernozhukov et al. (2018). A control-trend perturbation changes each residual by a function of X_{jk} , and $T_{jk} - p(X_{jk})$ has mean zero given X_{jk} . Perturbing p or h gives $-h(X_{jk})\dot{p}(X_{jk})\zeta_{jk}$ or $\dot{h}(X_{jk})[T_{jk} - p(X_{jk})]\zeta_{jk}$, which have mean zero because $\zeta_{jk}(\theta_0)$ has mean zero given X_{jk} and T_{jk} . Perturbing z gives $(\phi + \gamma) \text{sp}''(z) \dot{z}(X_{jk})$ times the bracket less $T_{jk}z$, which has mean zero given X_{jk} and T_{jk} because the bracket has mean z among treated firms and zero among control firms. $\square$

D.5.3. Pilot and Chamberlain Instruments

We construct the Chamberlain instruments from a pilot estimate and hold them fixed.

The pilot instruments $\mathbf{h}_{jk}^{\text{pilot}}$ stack the conditional first stages $Z^R(X_{jk})$, DiD(ℓ , X_{jk}) and $R^L(X_{jk})Z^L(X_{jk})$ with an indicator for each slice and group of Section 3.2. The pilot estimate minimizes the GMM criterion formed from $\text{vec}[\mathbf{h}_{jk}^{\text{pilot}}[T_{jk} - p(X_{jk})]\zeta_{jk}(\theta)']$:

$$\widehat{\theta}^{\text{pilot}} \in \arg \min_{\theta \in \Theta} \widehat{\mathbf{g}}^{\text{pilot}}(\theta)' \widehat{\mathbf{W}}^{\text{pilot}} \widehat{\mathbf{g}}^{\text{pilot}}(\theta) \quad (94)$$

Thus $\widehat{\theta}^{\text{pilot}} \xrightarrow{p} \theta_0$.

Following Chamberlain (1987), define

$$\mathcal{G}(X; \theta) \equiv \mathbb{E} \left[[T_{jk} - p(X_{jk})] \frac{\partial \zeta_{jk}(\theta)}{\partial \theta'} \mid X_{jk} = X \right] \in \mathbb{R}^{3 \times 7} \quad (95)$$

$$\mathcal{V}(X; \theta) \equiv \mathbb{E} \left[[T_{jk} - p(X_{jk})]^2 \zeta_{jk}(\theta) \zeta_{jk}(\theta)' \mid X_{jk} = X \right] \in \mathbb{R}^{3 \times 3} \quad (96)$$

$$\mathcal{H}^*(X; \theta) \equiv \mathcal{G}(X; \theta)' \mathcal{V}(X; \theta)^{-1} \in \mathbb{R}^{7 \times 3} \quad (97)$$

with the labor row and column dropped where $R^L(X) = 0$ (the labor entry of ζ_{jk} is zero there). Given X , $\mathcal{H}^*$ is the optimal instrument for the conditional moment under the covariance $\mathcal{V}$, which we assume is positive definite. The final step uses $\widehat{\mathcal{H}}^*$ evaluated at $\widehat{\theta}^{\text{pilot}}$, one instrument per parameter.

D.5.4. Stacked GMM and Inference

The sample moment gives equal weight to each calendar period:

$$\widehat{\mathbf{g}}(\theta) \equiv \frac{1}{\mathcal{T}} \sum_{t=1}^{\mathcal{T}} \frac{1}{|\mathcal{O}_t|} \sum_{(j,k) \in \mathcal{O}_t} \widehat{\mathcal{H}}^*(X_{jk}) [T_{jk} - \widehat{p}(X_{jk})] \widehat{\zeta}_{jk}(\theta) \quad (98)$$

Here $\mathcal{O}_t$ is the set of firm-slice observations in calendar period t . With one Chamberlain instrument per parameter, the final estimator $\hat{\theta}$ solves $\widehat{\mathbf{g}}(\hat{\theta}) = 0$, which is (35). Local identification requires the Jacobian of the population moment at θ_0 to have rank seven. Let $\widehat{S}(\theta)$ be a consistent positive-semidefinite estimator of the long-run covariance of the calendar-time moment sequence in (98). With the control trends, the propensity and the DiDs in the rationing wedge held fixed, define

$$\widehat{J} \equiv \left. \frac{\partial \widehat{\mathbf{g}}(\theta)}{\partial \theta'} \right|_{\theta=\hat{\theta}} \quad (99)$$

The variance estimator is

$$\widehat{\text{Var}}(\hat{\theta}) \equiv \frac{1}{J} \widehat{J}^{-1} \widehat{S}(\hat{\theta}) \widehat{J}^{-1'} \quad (100)$$

D.6. Extension: Shocks within X Away from the Threshold

This subsection shows that the moments extend to shocks within X for firms far enough from their threshold that the shocks do not move them across it. Although the indicator for being above the threshold is a function of X , it is not locally stable when a firm is exactly at its threshold.

Allowing variation within X . Suppose the gap $w_{jk} - \omega_{jk}^*$ varies within X among treated firms, by a shock with mean zero given X_{jk} and T_{jk} , so that its conditional mean is $\text{DiD}(w - w^u, X_{jk}) - \gamma v / (\gamma + \phi)$ (Appendix D.3.3). Suppose the shock is smaller in absolute value than this mean, almost surely, so that it never moves a firm across its threshold. Then every treated firm in the cell is on the same side of its threshold as the cell, where the positive part is affine, and the expectation passes through it:

$$\mathbb{E} [\psi_{jk}(\theta_0) \mid X_{jk}, T_{jk} = 1, R^L(X_{jk}) = 1] = (\phi + \gamma) \left[\text{DiD}(w - w^u, X_{jk}) - \frac{\gamma v}{\gamma + \phi} \right]_+ \quad (101)$$

The expected rationing wedge (67) therefore keeps its form, and the labor residual is unchanged. A control firm that a shock moved across its threshold would pay the minimum wage in period t , and the sample restriction R^L drops its cell.

Far-from-threshold estimates. We can cross-fit the structural parameters and the threshold indicator, holding out each firm across all periods and slices, and predict each held-out

firm's distance to its threshold, $\widehat{\text{DiD}}(w - w^u, X_{jk}) - \gamma\nu/(\gamma + \phi)$ with the parameters at their cross-fitted estimates, from pre-treatment X_{jk} . For a grid of buffers c in log-wage units, we keep firms whose predicted distance exceeds c in absolute value. The rule is frozen before estimation and uses only X_{jk} , so the indicator for keeping a firm is a function of X_{jk} . We reestimate with the same residual equations, so that on the retained support

$$\mathbb{E} \left[\mathbb{1} \left\{ \left| \widehat{\text{DiD}}(w - w^u, X_{jk}) - \frac{\gamma\nu}{\gamma + \phi} \right| > c \right\} h(X_{jk}) \zeta_{jk}(\theta_0) \mid R^L(X_{jk}) = 1 \right] = 0 \quad (102)$$