Minimum Wage and Individual Worker Productivity: Evidence from a Large US Retailer*

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Abstract

We study workers who are employed by a large US retailer, work in many store locations, and are paid based on performance. By means of a border-discontinuity analysis, we document that workers become more productive and are terminated less often after a minimum wage increase. These effects are stronger among workers whose pay is more often supported by the minimum wage. However, when workers are monitored less intensely, the minimum wage depresses productivity. We attribute these effects to an efficiency wage model. Profits decrease with the minimum wage, and a calibration exercise suggests that worker welfare increases.

Keywords: minimum wage, worker productivity, termination, efficiency-wage, payfor-performance.

JEL Classification: J24, J38, J63, J88, M52

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1 Introduction

Since the U.S. minimum wage was introduced in 1938, its effect on employment has been hotly debated. Much less attention has been paid to the effect of the minimum wage on the *productivity of employed workers*. This paper examines this "intensive margin," and shows that increasing the minimum wage causes the productivity of employed workers to increase through an efficiency wage mechanism.

Our evidence comes from salespeople who work at a large US retailer employing more than 10% of department store employees nationwide, and operating more than 2,000 stores across all fifty states.¹ Our workers' pay is, in part, based on performance (sales per hour) and their productivity is recorded administratively.² When our worker's average hourly pay falls below the minimum wage, the employer is required to make up the difference.

Our data cover 70 minimum wage increases at the state and local levels. Using a border-discontinuity research design, we compare the productivity of workers in "treated" vs "control" stores on the other side of the same border, in a specification that includes worker and county-pair \times month fixed effects.

We document that an increase in the minimum wage causes individual productivity to increase. This effect is stronger for workers whose pay is more often supported by the minimum wage (referred to herein as "low types"). These findings are not an artifact of selection and cross-border migration, nor are they explained by demand shifts, price changes, or other organizational changes. The effects persist in a "state-panel" research design. Interestingly, the effect of the minimum wage on worker productivity flips (becomes negative) when workers are relatively less monitored, as measured by a low supervisor-to-worker ratio within a store.

We interpret these findings through the lens of a model that features two sources of incentives. Workers are incentivized both by the threat of termination, which is based on the direct monitoring of effort; and by the variable component of pay, which reflects

 $^{^1\}mathrm{Employers}$ of comparable size employ 23% of the US workforce and roughly 20% of minimum wage workers. See Appendix C.1 for this computations.

²Among US workers with comparable hourly pay to our firm's, roughly 43% have some form of variable pay. See Appendix C.1 for these computations.

individual performance, which in turn is a noisy signal of effort.³ We refer to these channels as "efficiency wage" and "pay-for-performance," respectively.

In this model, a minimum wage increase has two opposite effects on incentives: it de-motivates effort provision because it flattens the pay schedule (pay-for-performance channel), but it motivates effort provision because of the fear of losing a now-higher paying job (efficiency wage channel). We infer that the efficiency wage channel dominates in our setting because, empirically, worker performance increases with the minimum wage. Consistent with the efficiency wage channel, we find that the workers whose performance increases the most with the minimum wage also have the largest drop in termination rates; according to efficiency wage theory, this decrease in terminations is the workers' reward for exerting more effort.

While the efficiency wage channel appears to dominate in the data, our theory predicts that this channel will vanish if effort is not monitored directly. In this scenario, the only source of incentives is the pay-for-performance channel, so the minimum wage is expected to de-motivate workers. We find empirical support for this prediction: when a store's workers are monitored less intensely, i.e., when the supervisor-to-worker ratio is low, a minimum wage increase is shown to decrease performance, contrary to that which we find on average.

Turning to store-level outcomes, we document that termination, hiring, and turnover rates all decrease with the minimum wage, and that the effect is increasing in the fraction of low types in a store, in line with the model's predictions. Meanwhile, employment does not change, store-level output increases, and average profits across all stores go down. This last result indicates that the endogenous increase in output is not large enough to offset the wage growth caused by the minimum wage.

Finally, we study the effect of the minimum wage on the welfare of employed and unemployed workers, under the assumption that the probability of exiting unemployment is a decreasing function of the minimum wage. Welfare could, in theory, be decreasing

³In our context, performance consists of the value of sales per hour, while effort consists of meeting and greeting the customer, explaining product features, up-selling to higher-margin products, and cross-selling (warranties, loans, credit cards, etc.).

if unemployment duration increases sharply in the minimum wage. Nevertheless, our calibration suggests that the welfare of employed and unemployed workers increases with the minimum wage.

Our paper contributes to different strands of the literature. First, it contributes to the literature on the individual productivity effects of the minimum wage. To our knowledge, this literature consists of Ku (2018) and Hill (2018), who study tomato and strawberry pickers, respectively, in a single farm around one or two minimum wage events. They reach apparently conflicting results: Ku (2018) finds that increasing the minimum wage increases individual productivity, while Hill (2018) finds the opposite. As they both use relatively more productive workers as the control group, their research designs only allow relative estimates (low vs. high types) of the productivity gain. In contrast, we observe workers in nearby establishments experiencing no minimum wage increase, permitting an estimation of the absolute productivity gains for low and high types. Moreover, our model and our empirical findings reconcile Ku's (2018) and Hill's (2018) apparently opposing findings by appealing to variation in monitoring intensity.

Second, our paper contributes to the minimum wage literature on aggregate flows of low-paid workers and employment.⁴ This literature tends to find a reduction in worker turnover and, in the county border-discontinuity strand of this literature, a lack of disemployment effect after a minimum wage increase. We replicate these effects but, whereas the existing studies are based on county- and state-level aggregates, our study is based on individual worker data and links these effects to an endogenous increase in worker productivity.

Third, our study is related to the recent and growing empirical literature studying the effects of the minimum wage on firm-level profits.⁵ These studies tend to find non-positive effects of the minimum wage on profits, as do we. Our paper adds to this literature by showing that the rising labor costs associated with a minimum wage increase can be partially offset by an increase in worker productivity, which presumably attenuates the

⁴For the literature on aggregate flows, see Portugal and Cardoso (2006), Brochu and Green (2003), Dube et al. (2016), Gittings and Schmutte (2016), Jardim et al. (2018). For the literature on employment, see Manning (2021) for a recent review.

⁵For the literature on profits, see Draca et al. (2011), Harasztosi and Lindner (2019), Riley and Bondibene (2017), Mayneris et al. (2018), Hau et al. (2020), and Clemens (2021) for a review.

negative effect of the minimum wage on profits.

Finally, we contribute to the empirical literature on efficiency wages, which has mostly interpreted efficiency wages as gift exchange or reciprocity.⁶ Within this literature, perhaps the closest paper is Jayaraman et al. (2016) which shows that an increase in the minimum daily wage payable to Indian plantation workers increases output. This effect is attributed to reciprocity because the plantation workers cannot be fired, so an efficiency-wage channel à la Shapiro and Stiglitz (1984) or Rebitzer and Taylor (1995) cannot be invoked. Our paper, in contrast, provides evidence for the incentive effect provided by termination.

Overall, this paper contributes to the minimum wage literature by documenting the endogenous effort response of low-paid workers. This is another channel through which the minimum wage may affect firm productivity and worker welfare, separately from the conventional channel that labor becomes more expensive, causing profits to shrink and workers to lose their job. In addition, the paper suggests that the efficiency wage model can be a useful organizing framework for understanding the workers' response to the minimum wage.

The paper proceeds as follows. Section 2 presents the model while Section 3 describes the data, the institutional context, and the identification strategy. Section 4 discusses our core results: the effect of the minimum wage on worker productivity. Section 5 examines the heterogeneous effects of the minimum wage on worker productivity by monitoring intensity. Section 6 presents the store-level results on turnover, employment, output, and profits. Section 7 discusses two alternative channels: demand and organizational adjustments. Section 8 calibrates the effect of a minimum wage increase on worker welfare. Section 9 discusses the external validity of our findings and concludes.

2 Model

In this section we model the effort choice of a worker (in our empirical setting, a salesperson whose job is to interact with a customer) who has two sources of incentives: the probability

⁶See, for example, Gneezy and List (2006), Della Vigna et al. (2016).

of being terminated, and the wage. The probability of termination is decreasing in worker effort and depends on the firm's monitoring intensity. The expected wage is based on individual performance (in our setting, sales per hour) and is increasing in effort. By law, the wage cannot fall below the minimum wage. The model generalizes the efficiency wage model of Rebitzer and Taylor (1995, henceforth RT). The model is used to characterize the relationship between the minimum wage and optimal worker effort, how this relationship changes as a function of the firm's monitoring intensity, and how firm-level turnover is affected by the minimum wage.

Each worker has a firm- (or match-) specific type $x \ge 0$ and chooses a continuous effort level $e \in [0,1]$. Type x's cost of effort c(x,e) is strictly increasing in effort. We assume that the marginal cost of effort vanishes at zero and is infinite at 1; these assumptions will help ensure that optimal effort is interior to [0,1].

Worker performance (i.e., value of output: in our case, sales revenue per hour) is a non-negative random variable Y(x,e) that is uniformly bounded from above across all (x,e). Its density $f_Y(y;x,e)$ has interval support, is twice continuously differentiable in all its arguments, and enjoys the strict monotone likelihood ratio property (MLRP) in x and x and x Intuitively, the MLRP means that higher types and greater effort levels produce stochastically higher output. The MLRP implies first-order stochastic dominance.

Consider any continuous nondecreasing compensation scheme $\overline{w}(\cdot)$ that transforms performance into pay. For example, $\overline{w}(Y) = b + cY$ where b represents the base salary and c the commission rate. The expected wage is denoted by:

$$w(x, e) = \mathbb{E}(\overline{w}(Y(x, e))).$$

The function w is nondecreasing in each of its arguments due to the MLRP.

⁷The model generalizes RT in three ways. First, worker effort is continuous rather than binary. Second, workers differ by type – in this case, by productivity and cost of effort. Third, pay is allowed to depend on performance as well as on the minimum wage. The third feature implies that effort provision will follow a mixture of efficiency wage logic and pay-for-performance logic.

⁸This means that the ratio $f_Y(y;x,e)/F_Y(y;x,e)$ is strictly increasing in x and in e whenever f>0.

Type x's effort choice problem is:

$$V^{E}(x) = \max_{e} w(x, e) - c(x, e) + \frac{1}{(1+r)} \left[\pi(e) V^{E}(x) + (1 - \pi(e)) V^{A} \right]. \tag{1}$$

The function $V^E(x)$ represents type x's discounted value of being employed. The numbers r>0 and V^A represent, respectively, the discount rate and the lifetime value of becoming unemployed. Note that V^A is not a function of x, consistent with the assumption that types are firm- (or match-) specific. The function $\pi(e)$ represents the probability of continued employment, which is assumed to be nondecreasing and continuously differentiable over [0,1]. We interpret the magnitude of $\pi'(e)$ as reflecting the firm's monitoring intensity; the limit case where $\pi'(e) \equiv 0$ for all e will be referred to as the "no monitoring" case.⁹

To simplify the worker's problem, subtract the equation $\left[r/\left(1+r\right)\right]V^{A}=u^{A}$ from (1). We get:

$$V(x) = \max_{e} u(x, e) + \frac{1}{(1+r)} \pi(e) V(x), \tag{2}$$

where $V(x) = V^{E}(x) - V^{A}$ represents the additional discounted value of being employed relative to being unemployed, and

$$u(x,e) = w(x,e) - c(x,e) - u^{A}$$
(3)

represents the flow value of employment, net of flow opportunity cost u^A , of a type x who is currently employed and exerts effort e.

Problem (2) shows that the worker maximizes the sum of two terms: the flow value of employment, which is the source of standard "pay for performance" incentives; and the value from continued employment, which is the "efficiency wage" incentive channel. If $\pi(\cdot)$ is a strictly increasing function, the efficiency wage channel motivates the worker to exert more effort than is justified solely by pay-for-performance.

We assume that u is continuously differentiable over its domain, and make the following

⁹ Equation (1) is a continuous-effort counterpart of RT's equations (2-4). In keeping with RT, equation (1) says that the worker is fired *after* receiving the period's pay, and that firing decisions are made based on effort provision, not on realized performance.

intuitive assumption.

Assumption 1. $u_x > 0$, $u_{xe} > 0$, and $u_{ee} < 0$.

The first two properties signify that higher types have higher payoffs and higher marginal return on effort. The third property, concavity of u in e, helps identify the optimal effort level. The required properties may be imparted to u by either of its components, w and c. For example, Assumption 1 holds if the wage w is identically equal to the minimum wage, provided that the cost function is strictly convex in e, and higher types have lower effort cost and lower marginal cost of effort, which are standard assumptions.

To avoid trivialities, we assume that it is strictly optimal for all types to show up for work. Formally, we assume that the set of *individually rational effort levels*, defined as the set of effort levels e such that u(x,e) > 0, is non-empty for all x. Then, expression (2) implies that V(x) > 0 for all x.

Assumption 2. $\pi(e)$ is weakly concave in e.

This assumption helps ensure that problem (2) is strictly concave in e. Assumption 2 is trivially satisfied in the no monitoring case, because then $\pi'(e) \equiv 0$ for all e.

Under Assumptions 1 and 2, the maximization problem in (2) is strictly concave in e and so type x's optimal effort, if positive, is the unique solution to the first-order condition:

$$u_e(x,e) + \frac{1}{(1+r)}\pi'(e)V(x) = 0.$$
(4)

The next lemma says that the model behaves "nicely."

Lemma 1. Suppose Assumptions 1 and 2 hold.

- 1. Fix x. The worker's maximization problem (2) is concave in e and has a unique solution $e^*(x)$.
- 2. $e^*(x)$ is nondecreasing in x, and it is strictly increasing if $e^*(x)$ is interior to [0,1].
- 3. If $\pi'(e) > 0$ for all e then $e^*(x)$ is interior to [0,1] for all x.

Linking the Model to Our Empirical Setting

We study a single firm with many store locations across the U.S., and the above model describes the problem of a worker operating in a specific store.

Compensation scheme Since in our firm all workers nationwide are subject to the same compensation scheme, the compensation scheme cannot be optimally adapted to the local conditions of most stores. At best, it is optimal on average. Hence, in our model, we cannot assume that the compensation scheme $\overline{w}(\cdot)$ is optimally adapted to the local parameters, including the minimum wage M. We assume, instead, that when a locality increases M, \overline{w} does not change.¹⁰ Thus, in a store that is subject to a local minimum wage M, the expected wage is:

$$w(x, e; M) = \mathbb{E}\left(\max\left[M, \overline{w}\left(Y(x, e)\right)\right]\right). \tag{5}$$

The function w(x, e; M) is bounded below by M and is nondecreasing in all its arguments.¹¹

Henceforth w(x, e; M) will replace w(x, e), and we assume that Assumption 1 continues to hold after this replacement.

The worker's optimal effort $e^*(x; M)$ will henceforth be indexed by the minimum wage level.

Low types

Definition 1 (MMW, or low type). Type x is MMW (i.e., "motivated by the minimum wage") or a "low type" if w(x, e; M) = M for all $e \in [0, 1]$.

 $^{^{10}}$ This assumption is validated empirically in Table 2, where we show that when a locality increases M, base pay and commission rates in the store do not change.

¹¹It is obviously nondecreasing in M. It is nondecreasing in x and in e by stochastic dominance, because the function max [M, w(Y)] is nondecreasing in Y.

MMW types cannot increase their wage by exerting more effort, so their only incentive to exert effort is the fear of losing their job. In this respect, MMW types behave exactly as the workers in the RT model. The set of MMW types, if nonempty, is an interval including zero; this is because the function w(x, e; M) is nondecreasing in x. It is therefore appropriate to refer to MMW types as "low types." Empirically, we will define a "low type" as a worker whose pay is often determined by the minimum wage and, therefore, has incentives similar to the MMW types in the theory.

Three cases nested by the model The model nests two polar cases and a "hybrid" one.

Special Cases Nested by the Model

Polar case: pure efficiency wages If $w(x, e; M) \equiv M$, pay does not depend on performance and all incentives to exert effort in the worker's problem (2) come from reducing the probability of being terminated. This is the pure efficiency-wage model.

Polar case: pure pay-for-performance If $\pi'(e) \equiv 0$ (no monitoring case), the worker's maximization problem (2) reduces to maximizing the per-period value of the worker's utility from employment. In this case exerting effort does not alter the probability of being fired, so all incentives to exert effort come from performance pay.

Hybrid case (our preferred model): When $\pi'(e) > 0$ and M is not too high, the model is a hybrid of pure efficiency wages and pure pay-for-performance, meaning that some types (MMW types) will be motivated by efficiency wages only, and others (higher types) will in part be motivated by performance pay.

The pure efficiency wage case may be disregarded for empirical purposes: the great majority of our workers receive a substantial amount of variable pay. Therefore, only two cases can possibly match our setting: pure pay-for-performance, and the hybrid case.

Value of outside option The model can be extended to allow the lifetime value of a job in the local economy to depend on the minimum wage, so that $V^A = V^A(M)$. All the results go through if the function $V^A(\cdot)$ is decreasing, as would be the case if the

main effect of a minimum wage increase is to slow the movement out of unemployment. If, conversely, the function $V^A(\cdot)$ rises too steeply, a minimum wage increase will be demotivating. This is not the case in our setting because, empirically, we find that increasing the minimum wage promotes worker effort (see Section 4).

2.1 Core Theoretical Results: Effect of Minimum Wage on Individual Productivity

Assumption 3. $\overline{w}(\cdot)$ is a strictly increasing function, $w_M(x, 1; M) > 0$, and $|w_{eM}(x, e; M)| < \infty$ for all $x \geq 0, e \in [0, 1]$.

The assumption that $\overline{w}(\cdot)$ is strictly increasing is made for convenience of exposition. Note that it does *not* imply that w(x, e; M) is strictly increasing in e, and indeed this is not the case for MMW types. The assumption $w_M(x, 1; M) > 0$ says that even a worker who exerts maximum effort (e = 1) earns the minimum wage with a positive probability, however small. The assumption that $|w_{eM}(x, e; M)| < \infty$ is purely technical.

Proposition 1. (Effect of the minimum wage on productivity) Suppose Assumptions 1-3 hold and, in addition, $\pi'(e) > 0$ for all e.

- 1. Effort is strictly increasing in M for MMW types ("low types").
- 2. The set of types whose effort increases with M, grows with M.
- 3. For M large enough, all types' effort increases with M.
- 4. Increasing M has a negligible effect on the effort of types whose wage is negligibly affected by the minimum wage.

Proof. See Appendix B.1.

It is worth emphasizing that part 1 requires the assumption that $\pi'(e) > 0$ for all e. This assumption fails in the no monitoring case, in which case increasing M does not increase the low types' effort (Proposition 2 part 2 below). Empirically, the "low types"

in part 1 will correspond to the workers who, at a given point in time, most benefit from the minimum wage while the "negligibly affected" in part 4 will correspond to "high types" – see page 18. We will show that, in the average store, these types show the response predicted by Proposition 1. The medium types' response will depend on the monitoring intensity, as discussed in the next section.

2.2 Role of Monitoring in Effort Exertion

Monitoring intensity must, intuitively, enter the model through the sensitivity to effort of the probability of being fired. We now make this idea precise.

Definition 2. (Monitoring intensity) Monitoring is more intense under $\widetilde{\pi}(e)$ than under $\pi(e)$ if, for every e, the elasticity of $[1 + r - \widetilde{\pi}(e)]$ is larger in absolute value than that of $[1 + r - \pi(e)]$.

Definition 2 establishes a partial order on the functions $\pi(\cdot)$.¹² In general, the constant function is the smallest element in this partial order – this is the previously-mentioned "no monitoring case" where $\pi'(e) \equiv 0$. At the opposite end of the spectrum, $\pi(\cdot)$ may be chosen so that $[1 + r - \pi(e)]$ has arbitrarily large elasticity (in absolute value), provided that r is small enough, i.e., that the worker is sufficiently patient.¹³ The next result describes how effort response to the minimum wage varies by monitoring intensity and by type.

Proposition 2. (Role of monitoring in effort exertion)

- 1. (Effect of increasing monitoring) When monitoring becomes more intense, all types exert more effort.
- 2. (Effect of increasing M, no monitoring case) Suppose $\pi'(e) \equiv 0$. Then MMW types ("low types") exert zero effort. Increasing M does not increase their effort, and it decreases the effort of any type who exerts positive effort.

For example, in the parametric family $\pi(e; a) = a \frac{e}{e+1}$ monitoring is more intense when a is larger: see Appendix B.2.

¹³Refer to the proof of Proposition 2 part 3 in Appendix B.1.

3. (Effect of increasing M, high monitoring case) If Assumption 3 holds, increasing M increases any type's equilibrium effort if monitoring is sufficiently intense. Functions $\pi(\cdot)$ exist under which monitoring is arbitrarily intense if r is small enough.

Proof. See Appendix B.1.

Part 1 is intuitive because it confirms that increasing monitoring raises equilibrium effort. Parts 2 and 3 are instructive: increasing the minimum wage promotes effort when monitoring is high, but it promotes shirking when monitoring is low. In addition, parts 2 and 3 yield testable predictions by type. Among the non-monitored workers, the low types do not change their effort as the minimum wage increases (because non-monitored MMW types shirk regardless of the minimum wage level), whereas higher types decrease their effort due to the attenuated pay-for-performance incentive. Among the highly monitored workers, an increase in M causes all types to exert more effort. Taken together, these predictions are a strong empirical test of the dual nature (efficiency wage and pay-for-performance) of the model.

Proposition 2 suggests that a store's workers should respond differently to a minimum wage increase depending on whether monitoring is low or high in that store. To make this idea precise, let us extend the model such that a fraction $(1 - \mu)$ of workers in a store, chosen at random independently of their type, is "not monitored." That is, a shirking worker is detected with probability $\underline{\pi}$ independent of effort. The remaining fraction μ of workers is "highly monitored," meaning that shirking workers are detected with a highly elastic probability $\pi(e)$, as described in Proposition 2 part $3.^{14}$ We think of μ as a continuous measure of monitoring coverage and, for now, take μ as given. It helps to think of the store as being partitioned into two divisions. In the non-monitored division, workers effectively operate on a "pure pay-for-performance" basis: they are never terminated for lack of effort. Workers in the highly monitored division behave as in the previous sections.

¹⁴In the context of optimal monitoring, it may seem ad-hoc to split the workers into only two groups monitored with different probabilities. Yet, in a general monitoring game, only two strategies can ever attain maximal deterrence. One is to monitor all agents with the same probability. The other is to create exactly two groups of agents (and never more than two) who are monitored with different intensities. See Lazear (2006), Eeckhout et al. (2010).

Proposition 2 characterizes how effort, and therefore individual performance, changes in either division. Empirically, we expect a store to behave as described in part 2 when monitoring coverage μ is low and to behave as in part 3 when μ is high. Both predictions are found to hold in the data (see Section 5). Empirically, we find that *on average* a store behaves as a high-monitoring store.

Thus far, we have assumed that the monitoring coverage μ is not endogenous to M. In Appendix B.3 we work out a theory where μ is endogenous, and can be purchased by the firm at a cost $K(\mu)$. The theory predicts that if store profits are non-decreasing in M (as indeed is the case empirically in our main sample)¹⁵, then μ should increase with M. However, the increase could be small depending on the shape of the function $K(\mu)$. This prediction is tested empirically in Section 5. The coefficient on M has the expected sign, but its magnitude is small and statistical significance is lacking. Overall, we believe that the evidence is consistent with the theory of endogenous coverage μ , but points to a degree of endogeneity small enough to be ignored for practical purposes. We therefore proceed under the assumption that μ is exogenous.

2.3 Effect of Minimum Wage on Turnover in a Store's Steady State

In this section, we characterize the steady state turnover rate in a store where a fraction μ of workers are highly monitored and the rest are not monitored. Steady state means that, given M and the termination policy given by $\pi(\cdot)$, replacement workers are randomly drawn from the pool of the unemployed such that the fraction of employees terminated and hired are equal, and in the next period the type distribution in the store is reproduced identically. Note that in this definition, the absolute size of the labor force in the store is left unspecified.

Denote by H the c.d.f. of the type distribution that our firm can expect upon hiring a random worker from the unemployment pool, and let h be its density. Since types are firm-(or match-) specific, unemployed workers are not negatively (or positively) selected from

¹⁵This is the "border sample" defined in section 3.1, see Table 8.

a hiring firm's perspective, hence H is not a function of any of the model's parameters.¹⁶

Denote by $g^{M}(x)$ the density of the steady state type distribution in a highly monitored division given a certain M. The density $g^{M}(x)$ must solve:

$$g^{M}(x) = \pi (e^{*}(x; M)) g^{M}(x) + \lambda (M) h(x),$$

where $\lambda(M)$ denotes the per capita inflow of workers (which, in steady state, coincides with the outflow) in a highly monitored division. Isolating $g^{M}(x)$ yields:

$$g^{M}(x) = \frac{\lambda(M)}{1 - \pi(e^{*}(x; M))} h(x).$$

$$(6)$$

Because g^M must integrate to 1 we get, for all M:

$$1 = \lambda (M) \int_0^\infty \frac{1}{1 - \pi (e^*(x; M))} dH(x).$$

Since in a highly monitored store $e^*(x; M)$ is increasing in M for all x (Proposition 2 part 3), $\lambda(M)$ is decreasing in M.

Turning to the non-monitored division, recall that $\underline{\pi}$ is the constant probability of retention under no monitoring. In a non-monitored division the turnover is $(1-\underline{\pi})$ independent of type, and the steady state type distribution in that division coincides with H(x).

The steady state turnover rate for the entire store, averaging across the highly-monitored and non-monitored divisions, is:

$$\mu\lambda\left(M\right)+\left(1-\mu\right)\left(1-\underline{\pi}\right).$$

This expression is decreasing in M because $\lambda(M)$ is decreasing in M. This proves the following result.

Proposition 3. (Impact of minimum wage on steady-state turnover and tenure in a store) In steady state, the average turnover rate in a store is decreasing, and therefore average tenure is increasing, in the level of the minimum wage. Both effects are driven by

¹⁶Without this assumption, the problem would be much less tractable analytically.

increased effort.

Intuitively, the decrease in turnover results from the fraction of highly monitored workers who, after an increase in the minimum wage, exert more effort and thus are terminated less frequently. Among non-monitored workers, effort decreases after a minimum wage increase (Proposition 2 part 2), but their turnover remains unchanged as their probability of termination is independent of effort.

2.4 Effect of Minimum Wage on Store Output, Profits, and Employment

The minimum wage has two opposite effects on store-level output: workers exert more effort (at least, highly monitored workers), but g^M changes in a way that may increase the representation of low types. Section 6.3 calibrates the size of these two effects.

Let us now turn to profits. In our empirical setting, the compensation scheme \overline{w} is set uniformly for all workers nationally, and is thus not adapted to local store conditions. Therefore, increasing the local minimum wage may possibly cause profits to increase in some stores but to decrease in others.¹⁷ However, the average effect across all stores could never be positive if \overline{w} is set to maximize aggregate profits at the national level. The above discussion is summarized in the following result.

Lemma 2 (Impact of minimum wage on store-level profits). If \overline{w} is set to maximize nationwide profits, increasing M cannot increase nationwide profits.

This lemma says that, on average across all stores, profits must decrease with the minimum wage. Section 6.3 explores this prediction.

Next, we address store size, which we denote by L. Given a certain M, the optimal

¹⁷Increasing the minimum wage may increase profits in a store if the compensation scheme \overline{w} is not profit-maximizing given local store conditions. Take the following example. Suppose $\pi(e) \equiv \overline{\pi}$ so that there is no monitoring, and $\overline{w}(Y) < M$ so that all workers are paid the minimum wage. Suppose the cost of effort is $c(x,e) \equiv M + \epsilon$ independent of type and effort, with ϵ an arbitrarily small number. Then no worker exerts effort. Increasing M by a finite but small amount causes all workers to switch to exerting effort, and the wage bill increases only a little. Hence profits increase with M.

store size solves:

$$\max_{L} L \cdot \Pi(F_{M}, M) - \kappa(L), \qquad (7)$$

where $\Pi(F_M, M)$ denotes gross store profits per worker, ¹⁸ and the convex function $\kappa(\cdot)$ captures the amortization or capital cost of operating at a given size. The solution to problem (7) depends on the value of the term $\Pi(F_M, M)$, with higher values yielding a larger optimal store size. If, however, the function $\kappa(\cdot)$ is very convex around some \hat{L} , such that it resembles a step function, optimal store size will approximately equal \hat{L} irrespective of the value of $\Pi(F_M, M)$. Section 6.2 explores the empirical effect of the minimum wage on employment.

3 Data and Empirical Strategy

3.1 Data and Institutional Background

We match the firm's bi-weekly worker-level payroll data with monthly personnel records from February 2012 to June 2015. Restricting our attention to salespeople who are paid based on their performance produces our "total sample" of more than 40,000 hourly salespeople. Further restricting the sample to border stores as per our research design (Section 3.2 below) leaves us with more than 200 stores with over 10,000 salespeople. Table 1 reports the summary statistics of this "border" sample.

Workers and Compensation Our workers are consultative sales associates. They answer walk-in customer questions, demonstrate product features. What we call "exerting effort" consists of meeting and greeting the customer, taking the time to explain and persuade, up-selling (to higher-margin products), and cross-selling (warranties, loans, credit cards, etc.).¹⁹ They record a customer purchase as their own sale, and their pay consists of a base salary plus commissions on individual sales.

¹⁸This is the level attained by expression (34) in Appendix B.3; empirically, it is proxied by Ebitda per hour, where Ebitda are earnings before interest, taxes, depreciation, and amortization.

¹⁹A job description posted on the company's website can be paraphrased as follows: "our salespeople are responsible for making customers happy, providing them with information, increasing sales, helping to maintain the sales floor appearance, facilitating customer transactions as needed, and generally cooperating with other employees."

For every salesperson, we aggregate the following at the monthly level: hours worked (avg. 107), sales (avg. 2 per hour, units shrouded for confidentiality),²⁰ and pay (avg. \$1,361 per month; base \$6.12 per hour, variable \$5.95 per hour). Variable pay is the sum of various commissions earned on the sale of different items. We compute the average commission rate (avg. 3.5%) by dividing "variable pay" by the value of sales. We compute "sales per hour" – corresponding to "performance" in our model – as the value of sales divided by the number of hours worked. Tenure averages 49 months, as measured from the hiring date indicated in the HR records.

Stores and Employment There are on average 16.64 consultative sales associates in a store. As is typical in retail, store-level turnover is high: 3.4% per month (being the average of a 4.8% termination rate and a 2.1% hiring rate).²¹ Within a store, there are several departments across which conditions vary somewhat.²² We control for this heterogeneity by adding department fixed effects in all our specifications. Store-level profits are measured by Ebitda (earnings before interest, taxes, depreciation, and amortization; units shrouded). Profits are positive on average.

Each store has a manager and, sometimes, one or more assistant managers. They are excluded from our "workers" sample because they fall into the category of "supervisors." These figures are responsible for personnel decisions (hiring and termination) in coordination with central HR, and they monitor workers.²³ We use the ratio μ of supervisors to workers in a store as a proxy for monitoring coverage, with the caveat that such a ratio captures the extensive margin of monitoring but not the intensive margin (supervisor effort). The ratio of supervisors to workers is decided by the store manager in coordination with central HR, and varies both across and within stores. Table A.3 (Panel A) shows

 $^{^{20}}$ The number is re-scaled by a factor between 1/50 and 1/150 relative to its value in dollars.

²¹The termination (hiring) rate is defined as the percent of sales associates in the store who are terminated (hired) in a given month. We do not distinguish between voluntary and involuntary terminations because this distinction, being coded by HR, is arguably subjective. The turnover rate is defined as the percent of sales associates in the store who are terminated or hired in a given month divided by two.

²²While pay is always base plus commission across all departments, base and commission rates vary depending on the department.

²³According to a job posting, the supervisor position requires "skills in selecting, assessing, coaching, and developing sales associates," "proven ability in managing and mentoring team members, leading and influencing cross-functional working groups, and achieving results," "effective oral and written communication skills necessary to communicate with all levels of internal and external team members."

that within a store, variation in the supervisor-to-worker ratio over time does not correlate with turnover, profits, or with the fraction of low types as defined below.

Minimum Wage Variation Our sample contains minimum wage increases enacted by states, counties, and cities; the relevant constraint is the highest requirement. From February 2012 to June 2015, stores in our sample were affected by 70 minimum wage increases: 49 at the state level and 21 at the county or city level.²⁴ The mean minimum wage is \$7.87 per hour. The mean minimum wage increase is \$0.54.

If a worker's average hourly pay in a week (base plus variable) falls below the minimum wage, the employer is required to make up the difference as prescribed by the Fair Labor Standards Act (FLSA).²⁵ We create a variable called "minimum wage adjustment," which equals the amount paid by the employer to comply with the minimum wage (this variable is often zero and averages \$0.23 per hour). In an average month, 5% of our workers are paid no more than the minimum wage and 42% receive an adjustment in at least one of the four weeks. A \$1 increase in the minimum wage raises the "minimum wage adjustment" by \$0.25 per hour (Table 2, column 3).²⁶ In addition, variable pay per hour increases by \$0.44 per hour (Table 2, column 4), reflecting the endogenous increase in performance that is the subject of this paper. Overall, a \$1 increase in the minimum wage raises average total pay per hour by \$0.65 per hour (column 5), which corresponds to a 5% increase and an elasticity of 0.38.

Definition of Worker Types We divide workers into three "types." A worker is classified as a high, medium, or low type at time t based on her performance at time t-1 relative to the minimum wage at t-1. In the spirit of Aaronson et al. (2012) and Clemens and Wither (2019), and following Definition 1 in the theory, low types are those paid the minimum wage in t-1 (about 4% of our observations). The remainder of the workers are either medium or high types, with the threshold between the two being the third quartile

²⁴Refer to Appendix C.2 for a map and a full list of the minimum wage changes.

²⁵Under this law, commissioned workers can occasionally be deemed "exempt" and thus not receive a top-up. Based on administrative records, however, all of the workers in our sample are non-exempt.

²⁶A 1\$ increase in the minimum wage raises the share of workers who are topped up every single week of the month by 4.5pp (144%), while the share of workers who are topped up at least one week per month rises by 16pp (38.5%).

of the pay distribution.²⁷

As expected, higher types sell more per hour, they benefit from the minimum wage adjustment less often, and they are terminated less frequently: see Table 3. A low types' monthly earnings at t equal the minimum wage with a frequency of 20.5% and, moreover, are boosted by a minimum wage adjustment roughly every other week, thus suggesting that low types' incentives are significantly affected by the minimum wage. In contrast, a high types' monthly earnings at t equal the minimum wage with a frequency of only 0.7%, and they benefit from a minimum wage adjustment only once every ten weeks, implying that they are negligibly affected by the minimum wage.

HQ vs. Store-Level Decisions Headquarters set the nationwide compensation scheme (base and commission rates, not adjusted for minimum wage) uniformly across stores and jurisdictions. Accordingly, when a local minimum wage changes, the base and commission rates earned by individual workers do not change systematically in that location. We show this in Table 2 (columns 1 and 2). Such wage stickiness makes sense in the presence of menu costs. Our theory reflects these institutional features in the assumption that the compensation scheme \overline{w} does not vary with M, and by avoiding the assumption that \overline{w} is optimized at the local level.²⁸

As mentioned, local managers have relative autonomy in deciding whether to terminate a worker or hire a new one, subject to maintaining the number of workers close to an agreed-upon level with HR. In the model, the total number of workers L in a store is chosen to maximize expression (7), store by store.

Pricing for our company is nationwide, as is the case for most national retail chains

 $^{^{27}}$ We define low types at time t as those whose total pay in month t-1 is below 1.02*minimum wage. The 0.02 accounts for rounding errors, as the "total pay" field is occasionally off by a few cents. The results are robust to defining workers "at minimum wage" as those who earn exactly the minimum wage. The threshold between medium and high types happens to coincide with $180\% \times \text{minimum}$ wage in t-1; our results are robust to using alternative thresholds (120%, 140%, 160%) or various alternative classifications (e.g., dividing workers based on estimated worker fixed effects, or on average performance over more than one period before the minimum wage) – refer to Section 4.3.

 $^{^{28}}$ We would expect \overline{w} to vary with the *federal*, as opposed to the state or local, minimum wage. We do not have federal wage increases in our sample. Recent literature on the minimum wage (Flinn and Mullins 2018) analyzes the effect of wage renegotiation between a firm and employees as the minimum wage changes.

(Della Vigna and Gentzkow 2019). In Section 7.2 we compute a store-level price index for our company and confirm that it does not vary with the local minimum wage.

3.2 Identification Strategy

Sample Selection and Border Discontinuity Design Our main empirical specification implements a border discontinuity design in the spirit of Card and Krueger (2000), and closely follows Dube et al. (2010) and Allegretto et al. (2011). Specifically, workers on the side of the border where the minimum wage increased (treatment group) are compared to workers on the other side, where the minimum wage did not increase (control group). This research design aims to ensure that, apart from the minimum wage change, treated and control groups are similarly situated in terms of local economic conditions and demand shocks. The pre-trend analysis in Section 4.3 supports this presumption.

Appendix C.3 describes how the "border sample" is constructed. After restricting to stores located in counties whose centroids are less than 75 km apart, we are left with more than 200 stores and over 10,000 salespeople, approximately half of whom experienced variations in the minimum wage during our study period.

An alternative research design consists of the traditional "state-panel" approach, as employed by Neumark and Wascher (1992, 2007) among others, and recently summarized by Neumark (2019). This strategy uses the entire sample of stores, regardless of their distance from the border. In Section 4.3, we show that our core estimates are similar when applying this alternative research design.

Deriving Testable Implications from the Model Letting $e^*(x; M)$ denote type x's optimal effort at minimum wage M, type x's equilibrium performance is given by:

$$Y^{*}(x, M) = Y(x, e^{*}(x; M)).$$

Linearizing around M yields the following estimating equation:

$$Y^{*}(x, M') = Y^{*}(x, M) + (M' - M) \cdot \beta.$$
(8)

When β is estimated across all worker types, $\hat{\beta} = \mathbb{E}\left[\Delta Y^*(x, M)/\Delta M\right]$ represents the effect of the minimum wage on average worker's performance across all worker types. The analog of equation (8) by worker type x is:

$$Y^{*}(x, M') = Y^{*}(x, M) + (M' - M) \cdot [\beta_{L} \mathbf{1}_{L}(x) + \beta_{M} \mathbf{1}_{M}(x) + \beta_{H} \mathbf{1}_{H}(x)], \qquad (9)$$

where each β_i represents the within-category performance effect of the minimum wage.

Our testable predictions are as follows. In the pure pay for performance case, Proposition 2 part 2 predicts $\beta_L = 0$ and $\beta_M, \beta_H \leq 0$. We will reject these predictions. In the hybrid case, Proposition 1 part 1 predicts $\beta_L > 0$; furthermore, in the high-monitoring subcase of the hybrid case, Proposition 2 part 3 predicts $\beta_M, \beta_H \geq 0$. We will not reject these predictions.

Empirical Specification We translate equation (8) into the following regression specification:

$$Y_{ijpt} = \alpha + \beta MinW_{jt} + X_{it} \cdot \zeta + \eta Z_{jt} + \delta_i + \phi_{pt} + \varepsilon_{ijpt}. \tag{10}$$

 Y_{ijpt} is the performance (sales per hour) of worker i in store j of county-pair p in month t. $MinW_{jt}$ is the prevailing minimum wage in store j's jurisdiction in month t. X_{it} is a vector of time-varying worker characteristics that are likely to predict employee performance, specifically, the worker's tenure and the department in which she works. Z_{jt} includes the monthly county-level unemployment rate to account for time-varying local economic conditions and local demand shocks (see Lemieux et al. 2012). Adding worker fixed effects δ_i means that we leverage within-worker variation in the minimum wage.²⁹

Equation (10) includes county-pair \times month fixed effects ϕ_{pt} that restrict the comparison to "treated" and "control" stores/workers on either side of the *same* border. We estimate this equation by "stacking" our data as in Dube et al. (2010, 2016), meaning that stores/workers located in a county sharing a border with n other counties appear n times in the final sample. The standard errors are two-way clustered at the state level and at the border-segment level. Refer to Appendix C.3 for more details on the specification.

 $^{^{29}}$ Store fixed effects are redundant because less than 1% of the workers moved across stores.

To study the heterogeneous effects of the minimum wage on worker performance by worker type, we translate equation (9) into the following regression specification:

$$Y_{ijpt} = \beta_0 + \beta_1 MinW_{jt} + \beta_2 MediumType_{ijt} + \beta_3 HighType_{ijt} +$$

$$\beta_4 MinW_{jt} \cdot MediumType_{ijt} + \beta_5 MinW_{jt} \cdot HighType_{ijt} +$$

$$X_{it} \cdot \zeta + \eta Z_{jt} + \delta_i + \phi_{pt} + \varepsilon_{ijpt},$$

$$(11)$$

where $MediumType_{ijt}$ and $HighType_{ijt}$ are indicators for whether worker i is a medium or a high type. The effect of minimum wage on low, medium, and high types – i.e., the coefficients β_L , β_M , β_H in equation (9) – corresponds here to β_1 , $\beta_1 + \beta_4$, and $\beta_1 + \beta_5$, respectively.³⁰ The indicators for low, medium, and high types are pre-determined because they are defined based on a worker's pay in t-1 relative to the minimum wage in t-1: refer to the definition of types at page 18.

4 Core Empirical Results: Effect of Minimum Wage on Worker Productivity

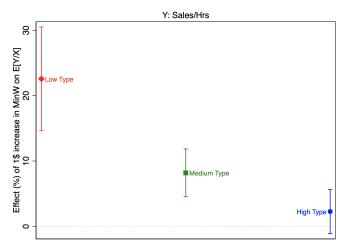
This section tests the predictions from Section 3.2 regarding the effect of the minimum wage on worker productivity.

4.1 Core Findings

Figure 1 displays the estimates of the β 's from equation (11), i.e., the effect of a \$1 minimum wage increase on the percent change in the performance of low, medium, and high types (see Table 4 column 2 for details). We find that a \$1 increase in the minimum wage increases performance – sales per hour – strongly among low types, i.e., by 0.244 (shrouded units) or 22.6%. In the notation from Section 3.2, this means that $\hat{\beta}_L > 0$, which rejects the pure pay-for-performance case and is consistent with the hybrid case.

 $^{^{30}}$ In equation (11), we use $MinW_{jt}$ in deviation from its sample mean so that the coefficients β_1 and β_2 can be interpreted as the difference in productivity across types when the minimum wage is equal to its sample mean.

Figure 1: The Minimum Wage Increases the Productivity for Low Types but not for High Types



Notes: Effect of a \$1 increase in the minimum wage on the percent change in Y (Sales/Hrs) for low, medium, and high types. Vertical bars represent 95% confidence intervals computed using the estimated coefficients $(\hat{\beta}_1, \hat{\beta}_1 + \hat{\beta}_4 \text{ and } \hat{\beta}_1 + \hat{\beta}_5)$ from equation (11) and the associated standard errors.

The effect is weaker, but still positive, for medium types ($\hat{\beta}_M = 0.156$, or 8.2%). Again, the pure pay-for-performance case is rejected and the hybrid case is not. According to the theory, this effect obtains because our medium types occasionally earn minimum wage,³¹ thus their response somewhat aligns with that of the low types. The effect vanishes, however, for high types ($\hat{\beta}_H = 0.062$, or 2.3%, statistically indistinguishable from zero). These workers' pay is least affected by the minimum wage, such that they barely respond to it.

Next, we study the effect of the minimum wage on average worker performance. Because the effect is nonnegative for every type, we expect average worker performance to increase. Table 4, column 1 shows that a \$1 increase in the minimum wage raises average individual performance by 0.094 (shrouded units), or 4.5%. This individual performance gain is economically sizable and statistically significant at the 5% level. The overall implied elasticity is 0.35.³²

 $^{^{31}}$ Our medium types receive the minimum wage adjustment 18% of the weeks, on average, compared to 47% for the low types (Table 3).

 $^{^{32}}$ A \$1 increase in the minimum wage is equivalent to a 12.7% increase relative to the mean, and 4.5/12.7 = 0.35.

We conclude with a sanity check: as expected, worker pay increases with the minimum wage (Table A.1). This increase is not explained by a change in the compensation scheme (recall that we do not find one), but rather by the mechanical effect of the minimum wage increase (more minimum wage adjustments) combined with the endogenous effort boost (more variable pay). Interestingly, the effect on pay is sizable for low and medium types, suggesting that both earn more due to larger and more frequent minimum wage adjustments and, also, from becoming more productive.

4.2 Dynamic Effects

We explore pre-trends and the time pattern of the minimum wage effect by estimating the following distributed lag specification:

$$Y_{ijpt} = \alpha + \sum_{m=-2}^{2} \beta_{1}^{3m} MinW_{j,t-3m} + \sum_{m=-2}^{2} \beta_{2}^{3m} MinW_{j,t-3m} \cdot MediumType_{ijt}$$

$$+ \sum_{m=-2}^{2} \beta_{3}^{3m} MinW_{j,t-3m} \cdot HighType_{ijt} + \gamma_{1} MediumType_{ijt}$$

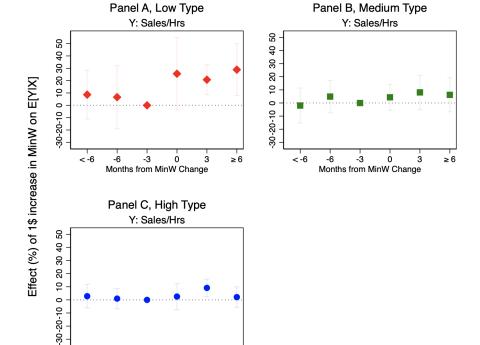
$$+ \gamma_{2} HighType_{ijt} + X_{it} \cdot \zeta + \eta Z_{jt} + \delta_{i} + \phi_{pt} + \varepsilon_{ijpt}, \qquad (12)$$

where β_1^{ℓ} captures the contemporaneous effect of the minimum wage on the productivity of low types if ℓ is zero, the ℓ -lagged (post-treatment) effect for low types if ℓ is positive, and the ℓ -lead (pre-treatment) effect for low types if ℓ is negative. β_x^{ℓ} captures the difference in these productivity effects for type x = 2, 3 (medium, or high) relative to low types.

Figure 2 and the corresponding Table A.2 present the cumulative response of the minimum wage on worker productivity, normalizing the estimates relative to the last pre-period (period -3).³³ They show that the cumulative leading coefficients are not statistically significant for any worker type, confirming that there is no pre-trend within worker type and

³³To assess the post-treatment effects, we calculate the cumulative response over event dates 0, 3 and 6 relative to event date -3 by summing the contemporaneous and lagged coefficients. To assess the pre-treatment effects, we calculate the cumulative response by summing the leading coefficients and multiplying that sum by -1. Refer to the figure and table notes for more details. Because of the normalization to period -3, the first lead represents the effect of the minimum wage before 6 months of the minimum wage change, while the last lag represents the effect at or after 6 months of the minimum wage change.

no differential pre-trend across types. They also show that low types display a 29% (statistically significant) cumulative increase in performance at or after the six-month mark, suggesting that the performance effect is persistent. The effect sets in immediately after the minimum wage increase. High types, in contrast, do not experience a statistically significant response to the minimum wage.



-6

-3

0 Months from MinW Change

Figure 2: Dynamic Effect of the Minimum Wage on Worker Productivity

Notes: Effect of a \$1 increase in the minimum wage on the percent change in Y (Sales/Hrs) for low, medium, and high types. The red, green and blue markers show the cumulative response to the minimum wage relative to event date -3 for low, medium, and high types respectively. The post-treatment effects for each type are computed by summing each type's contemporaneous and lagged coefficients from equation (12) (e.g., for low types, $\hat{\beta}_1^0$, $\hat{\beta}_1^0 + \hat{\beta}_1^3$, and $\hat{\beta}_1^0 + \hat{\beta}_1^3 + \hat{\beta}_1^6$) and dividing by that type's mean productivity. The pre-treatment effects are computed by summing each type's lead coefficients, multiplying the sum by -1 (e.g., for low types, $-\hat{\beta}_1^3 - \hat{\beta}_1^6$ and $-\hat{\beta}_1^3$) and dividing it by that type's mean productivity. Vertical bars represent 95% confidence intervals.

4.3 Threats to Identification and Robustness Checks

This section explores three potential threats to identification: violation of the common trends assumption, cross-border movements, and worker selection. We show that our core findings (productivity of low types increasing following a minimum wage hike) are robust across various alternative implementations of the research design. We briefly discuss each of these below; in-depth discussion and tables are provided in Appendix E.

Pre-Trends Figure 2 displays the dynamic effects of the minimum wage. It shows no pre-trends in performance by type for the sample of 102k workers-months who remain employed over a window with a 6-month pre-period and 6-month post-period around the minimum wage event. Figure A.1 confirms the lack of pre-trends in the smaller sample of 89k workers-months who are continuously employed over the wider window with a 9-months pre-period and 6-month post-period, with the caveat that some of these workers experience more than one minimum wage change in the window because changes often happen at a yearly cadence. We also observe no pre-trends for the larger sample of 144k workers-months who are continuously employed for 6 months before the minimum wage event and for the sample of 107k workers-months who are continuously employed for 12 months before the minimum wage event: see Table E.1, columns 1-3. That the pre-trends agree in these different samples is encouraging, as the difference in numerosity is nonnegligible and any difference in the estimates could indicate the presence of sample selection effects.

Cross-border Worker Movements Border-discontinuity research designs are vulnerable to the concern that workers may move across borders (Neumark et al. 2014). Our core results on individual productivity should not, however, be subject to this issue given that we include worker fixed effects, thus effectively comparing the "same worker" at two minimum wage levels. Further evidence against endogenous cross-border movements is provided by the absence of a correlation between the minimum wage increases and the home-to-work distance of new hires (Table E.2, column 1), which rules out changes in our workforce's commuting patterns after a minimum wage increase. One might worry that

cross-county migrants, rather than commuters, may confound store-level estimates. Zhang (2018), however, finds that after a minimum wage increase, migrants flow toward the same counties as commuters. The null effect in Table E.2, column 1 accordingly suggests that migration patterns, as well, do not change among our workforce after a minimum wage increase. Furthermore, migration is likely more costly across state lines than across county or city lines, yet our estimates are the same in the sample including only county-city minimum wage increases, as in the sample including only state-level increases (see page 29). Finally, Table E.2 shows that the minimum wage does not affect the home-to-work distance proportionally more for low, medium, or high types (Table E.2, column 3). In sum, we believe it is unlikely that the cross-border movement of workers plays a significant role in our estimates.³⁴

Worker Selection The estimated productivity gains could potentially suffer from a selection bias due to the change in the composition of retained workers following the minimum wage increase. We expect this "worker selection" confounder to have been largely controlled for by the inclusion of worker fixed effects in all our specifications. However, worker fixed effects may not necessarily eliminate the entirety of the selection bias.³⁵

To alleviate this concern, we present two sets of results. First, we replicate our findings restricting the sample to a balanced panel containing only workers who are employed throughout the sample period. When we do this, the sample size drops but its pre-trends are the same, and the results are similar to the main sample (Tables E.3 and E.4). Second, reverting to the full sample, we obtain bounds for the selection bias in the estimates of interest. We do this by modeling the portion of the productivity change that is due to the change in worker composition, and providing an upper bound for it (see Appendix E.3).³⁶ We find that the bounds are small relative to the size of the baseline estimates: selection bias accounts for at most 4.6% of the baseline estimate of the average worker's productivity change, and at most 8.1% of the estimate for the low types.

³⁴We thank an anonymous referee for helping us improve the analysis of cross-border movements.

³⁵Adding worker fixed effects does not fully account for selection if changes in the minimum wage affect the type of workers who exit/enter our panel. In this scenario, the effect of the minimum wage could be confounded by the fact that the panel of "retained" workers may have changed after a minimum wage increase and may consist of different types of individuals in treated vs. control locations.

³⁶We thank an anonymous referee for this suggestion.

Alternative Classifications of Low, Medium, and High Types Our baseline definition of type does not guarantee that types in the "control" county of a given county pair occupy the same quantiles in that county's wage distribution as the quantiles occupied by the types in the treated county. To ensure a perfect quantile-quantile match across counties within a pair, we can change the type definition in the control county only, and define these types using quantiles, so that the type distribution in the control county matches that in the treated county. When using this alternative approach, the results are nearly identical to our main findings (see Table E.5, column 1).³⁷

In Table E.5, columns 2-5, we explore alternative ways of defining types: classifying them based on average pay in the previous three months, as opposed to the previous month; and constructing time-invariant types based on pay in their first month of employment, or performance in their first quarter of employment. In Table E.6, we change the threshold that separates medium and high types to 120%, 140%, or 160% of the minimum wage. Reassuringly, the findings paint the same picture regardless of the classification method: when minimum wage increases, low types become significantly more productive, while high types do not.

Alternative Research Designs Our border-discontinuity research design discards a large portion of the sample. We now explore a state-level design à la Neumark and Wascher (1992), which uses the entire sample of stores regardless of their distance from a border. The state-level design raises the question of what controls to include. Adding more controls is generally thought to produce closer estimates to the border-discontinuity design. Accordingly, with the aim of demonstrating the robustness of our results, we examine three minimally-controlled specifications: with worker and month fixed effects; adding linear state-trends; or adding census-division × month fixed effects; see Table E.1 columns 2-4. The specification with division × month fixed effects is preferred because it is the only one that eliminates pre-trends in worker performance. In this specification, once again the minimum wage increases the performance of low types and does not affect

³⁷This new approach changes the status of less than 1,000 out of more than 10,000 workers. Further details are provided in Appendix E.4. We thank an anonymous referee for suggesting this alternative strategy.

the performance of high types (see Table E.7 and Figure 3, Panel A).³⁸

State vs. Local Variation in the Minimum Wage Restricting the analysis to state-level minimum wage changes only, or to county and city changes only (Figure 3, Panels B-C and Table E.8), does not change our findings. This is reassuring, as one could worry that the cross-state variation is contaminated by other state-level policy changes.

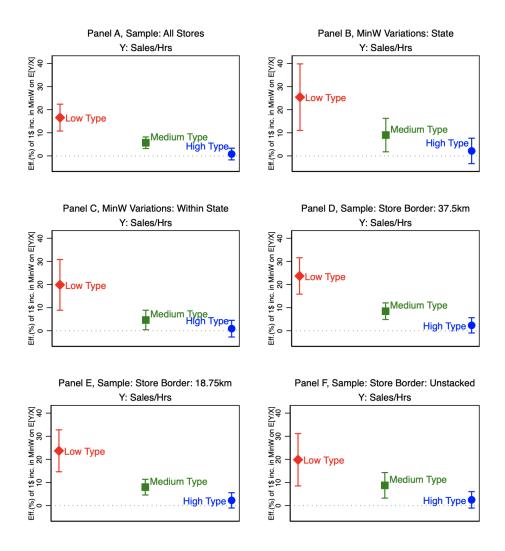
Alternative Definitions of "Bordering Stores" We explore alternative definitions of "bordering" that are based on the exact location of the store rather than its county's centroid. In addition, we set distance from the border to "less than 37.5 km," or "less than 18.75 km," both shorter than in the main definition. Reassuringly, our results are consistent across these samples. See Figure 3, Panels D-E and Table E.9.

Robustness to "Unstacking" The results are also robust to using the same county-level border discontinuity design as in our main estimates but without stacking the observations, with border-segment × month fixed effects and clustering standard errors at the border-segment level (Figure 3, Panel F and Table E.10). This specification is closer in spirit to an experimental-event design.

Alternative Controls The findings are similar if we control for $department \times store$ time trends and take into account potential differential trends across departments of a given store, or if we run our specifications by department. Likewise, we obtain nearly identical results if we remove potentially "bad controls," i.e., variables that might be endogenous to the minimum wage level (worker tenure and county-level unemployment). See Tables E.11 - E.12.

 $^{^{38}}$ We acknowledge that the inclusion of division \times month fixed effects is criticized by Neumark et al. (2014), who observe that "the identifying information about minimum wage effects comes from within-division variation in the minimum wages and removes a good deal of valid identifying information." The results are comparable if we use other state-level specifications.

Figure 3: The Minimum Wage Has a Robust Positive Effect on the Productivity of Low Types and no Effect on High Types



Notes: Effects of a \$1 increase in the minimum wage on the percent change in Y (Sales/Hrs) for low, medium, and high types. Panel A includes all stores, regardless of their distance from the border, in a specification with division × month fixed effects and standard errors clustered at the state level. Panel B (resp., C) considers our main sample but only for state (resp., within-state) variations in the minimum wage. Panel D (resp., E) considers the sample of stores that are located less than 37.5 km (resp., 18.75 km) from the border. Panel F considers our main sample but with non-stacked data and with border-segment-month fixed effects. Vertical bars represent 95% confidence intervals computed using the estimated coefficients $(\hat{\beta}_1, \hat{\beta}_1 + \hat{\beta}_4 \text{ and } \hat{\beta}_1 + \hat{\beta}_5)$ from equation (11) and the associated standard errors.

5 Heterogeneous Effect by Monitoring Illuminates Dual Nature of Model

The theory makes two kinds of predictions. First, monitoring a worker more intensely weakly increases her individual performance (Proposition 2 part 1). Second, and more interestingly, the effect of the minimum wage is heterogeneous by monitoring. Among the "non-monitored workers," the low types should not change their effort, while higher types should decrease their effort (Proposition 2 part 2). Among "highly monitored" workers, all types should increase their effort (Proposition 2 part 3), at least to some extent (Proposition 1 part 4). This bifurcated response to the minimum wage reflects the dual nature of worker incentives. If highly monitored, the efficiency wage logic dominates, meaning that the increase in the wage level due to a rise in M motivates the worker. If not monitored, the pay-for-performance logic dominates, meaning that the worker is demotivated by a rise in M due to the decrease in the sensitivity of the wage to effort. This bifurcated prediction is a strong test of the dual nature of the theoretical model.

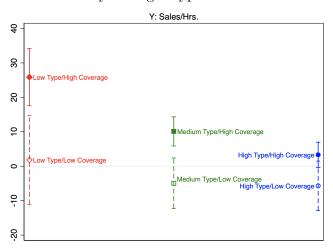
We test these predictions using within-store variation in μ . In the model, μ represents the fraction of workers (independent of type) who are "highly monitored." We proxy for μ using the supervisor-to-worker ratio in a store-month. A store is classified as either "low coverage" if it falls within the bottom quartile of the supervisor-to-worker ratio distribution, and "high coverage" otherwise.

Consistent with Proposition 2 part 1, we find that high coverage does positively correlate with average worker performance (Table 5, column 1). While reassuring, this is not a very strong test of the dual nature of our model as the presence of supervisors could also improve performance through channels other than monitoring. Next, we test the predictions that are most revealing of our model's dual nature.

Table 5 tests the effect of the minimum wage on worker performance when monitoring coverage is low or high. Column 2 shows that a higher minimum wage significantly boosts the performance of the average worker when monitoring is high (+6.6%). When monitoring is low, a higher minimum wage instead significantly decreases the performance of the average worker (-9.4%, column 4). Figure 4 and the corresponding Table 5 columns 3

and 5, provide similar results by worker type. Consistent with the distinctive predictions in Proposition 2 parts 2 and 3, we find that when coverage is high, low types become more productive as the minimum wage increases, while high types do not become less productive. When coverage is low, the low types do not change their effort while high types decrease their effort (though the p-value of the latter effect is only 0.11). This bifurcated pattern provides strong evidence in support of the dual nature of our model.

Figure 4: The Minimum Wage Increases the Productivity of Low Types with High Monitoring and Reduces the Productivity of High Types with Low Monitoring



Notes: Effects of a \$1 increase in the minimum wage on the percent change in Y (Sales/Hrs) for low, medium, or high types for high/low monitoring coverage. Monitoring coverage is measured as the ratio of supervisors to workers. "Low coverage" is an indicator for whether the store is in the bottom quartile of the monitoring coverage distribution. Vertical bars (solid for "Low coverage," dashed otherwise) represent 95% confidence intervals.

Our assumption thus far has been that coverage μ is not endogenous to the minimum wage M. If μ were endogenous to it, the theory in Appendix B.3 predicts that it should increase with M. Table A.4 (column 1) estimates the following store-level equation:

$$Y_{jpt} = \alpha + \beta MinW_{jt} + \eta Z_{jt} + \delta_j + \phi_{pt} + \varepsilon_{jpt}, \tag{13}$$

where Y_{jt} is the outcome of interest (supervisor-to-worker ratio) in store j of countypair p in month t, δ_j are store fixed effects, and all the other variables are defined as in equation (10). Our estimate of β is positive, consistent with our theory of endogenous monitoring, though the effect is small and not statistically significant.³⁹ This suggests that, if monitoring is endogenous to the minimum wage, this endogeneity is below detectable levels.

To address the concern that undetected endogeneity to the minimum wage might bias the estimates in Figure 4, we produce an analogue of this figure (Figure A.2) where the monitoring coverage is measured in the pre-minimum wage period t-1 (Panel A) or in our dataset's starting year (2012; Panel B). The coefficients are qualitatively similar, which is reassuring because both measures of monitoring coverage are pre-determined and likely exogenous to subsequent minimum wage changes.

6 Effect of Minimum Wage on Store-level Outcomes

6.1 Effect of Minimum Wage on Turnover

The theory (Proposition 3) predicts that termination rates should decrease after a minimum wage increase, because the subset of workers who are highly monitored exert more effort and thus are terminated less frequently. In steady state, fewer separations imply less hiring, and thus less turnover and longer worker tenure.⁴⁰ Because, empirically, the effect is driven by the low types, we expect these effects to be stronger in stores where low types are relatively numerous. Moreover, because low types form a relatively small part of our stores' workforce, we expect the impact of the minimum wage on store-level averages to be muted.

We estimate the following store-level model:

$$Y_{jpt} = \alpha + \beta MinW_{jt} + \gamma\% LowTypes_{j,t} + \delta MinW_{jt} \cdot \% LowTypes_{j,t} + \eta Z_{jt} + \delta_j + \phi_{pt} + \varepsilon_{jpt} \quad (14)$$

where Y_{jpt} is the outcome of interest in store j of county-pair p in month t, δ_j are store

³⁹Note that the positive sign for β , albeit small, does not support the RT theory of endogenous monitoring, which predicts that an increase in the minimum wage decreases the need for monitoring, and hence the equilibrium monitoring level.

 $^{^{40}}$ Table A.4 column 2 supports the assumption that store-level employment is in steady state conditional on store fixed effects and county-level unemployment.

fixed effects, and all the other variables are defined as in equation (10). As in equation (11), the fraction of low types in a store ($\%LowTypes_{j,t}$) is pre-determined because types are defined based on worker pay in t-1 relative to the minimum wage in t-1.

Panels A-D of Figure 5 plot the effect of minimum wage for the range of %LowTypes we observe in our stores (0 to 40%). As predicted, an increase in the minimum wage reduces store-level termination, hiring, and turnover, and raises tenure in stores with a high enough fraction of low types. The slope $\hat{\delta}$ is negative for termination, hiring, and turnover, and positive for tenure; it is statistically significant at the 5% level for hiring and at the 10% level for turnover and tenure (see Table 6).^{41,42}

To conclude our analysis on employment flows, we look at terminations in greater depth. A worker-level, as opposed to store-level, specification allows us to measure individual outcomes by type. We return to equation (11), with a dummy as dependent variable that is zero in every month that the worker is employed and is nonzero only in the termination month; after termination, the worker is dropped. We control for worker tenure, as well as remove worker fixed effects to capture store-level, rather than within-worker, variation. Because a terminated worker is dropped from the sample, this specification acts like a discrete time hazard model.⁴³ Figure 6 and Table 7 (column 2) confirm that low types are significantly less likely to be terminated after a minimum wage increase (-19%, statistically significant at the 10% level). These results reinforce those in Figure 5. While medium types are also less likely to be terminated (-7%) the effect is not statistically significant. Finally, no effect is found among high types.

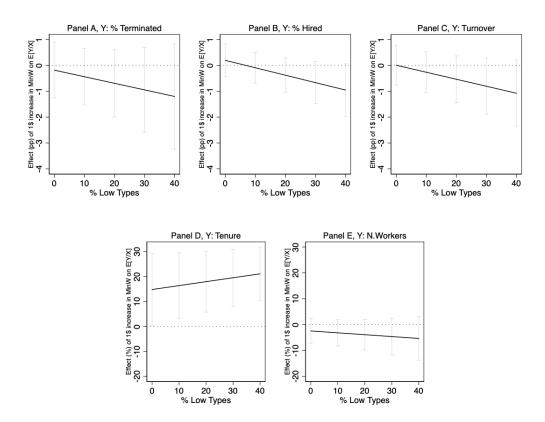
In sum, the heterogeneous effects are in the predicted direction (larger for low types), thus supporting the theoretical proposition that turnover should decrease as the minimum wage increases, especially among those types whose productivity response is stronger (em-

⁴¹Because low types form a relatively small part of our stores' workforce (the variable %LowTypes has a mean of 3.9% and a standard deviation of 7.5%), the impact of the minimum wage on store-level averages is muted: a \$1 increase in the minimum wages raises the average workers' monthly earnings by only \$35.3 (2.6%, not statistically significant) and store turnover by only 0.8% (Table 6, column 6).

⁴²Figure A.3 reports the dynamic effects of the minimum wage on termination, hiring and turnover. The effects are negative after the change in the minimum wage, albeit not always significantly.

⁴³This approach to analyzing duration data is used by Frederiksen et al. (2007) and Arellano (2008). Variants have also been employed by, among others, Hoffman and Tadelis (2021) and Sandvik et al. (2021).

Figure 5: The Minimum Wage Reduces Turnover and Increases Tenure in Stores with a High Fraction of Low Types



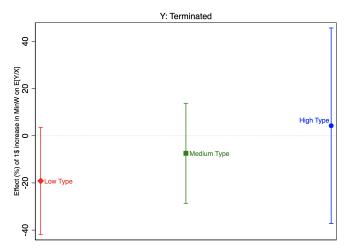
Notes: This figure plots $\hat{\beta} + \hat{\delta} \cdot \%LowTypes$ from equation (14). Y is the termination rate (Panel A), hiring (Panel B), turnover rate (Panel C), average worker tenure (Panel D), and number of sales associates (Panel E). Vertical bars represent 95% confidence intervals for the estimator of $\beta + \delta \cdot (\%LowTypes)$. We report the effects in percentage points in Panels A-C and in percent in Panels D-E.

pirically, the low types).

6.2 Effect of Minimum Wage on Employment

Table 6 (column 9) shows that, in the average store in the border sample, the minimum wage has no significant effect on employment. In terms of the theory of store size described by equation (7), this finding is consistent either with profits per worker not responding to the minimum wage increase, or with the function $\kappa(\cdot)$ being very convex around some \hat{L} , as discussed on page 16. We study the effects on profits in the next section.

Figure 6: The Minimum Wage Reduces the Termination of Low Types but not of High Types



Notes: Effects of a \$1 increase in the minimum wage on the percent change in termination (Y: Terminated) for low, medium, and high types. Vertical bars represent 95% confidence intervals computed using the estimated coefficients $(\hat{\beta}_1, \hat{\beta}_1 + \hat{\beta}_4, \text{ and } \hat{\beta}_1 + \hat{\beta}_5)$ from equation (11), but with store rather than worker fixed effects.

We also do not find any significant heterogeneous effect by the fraction of low types in the store ($\hat{\delta} = -0.012$, not statistically significant: see column 10 of Table 6 and Figure 5, Panel E). In the spirit of Draca et al. (2011) and Harasztosi and Lindner (2019), we use this estimate to compute the store-level employment elasticity with respect to the minimum wage by comparing a counterfactual store that is "fully treated," i.e., where all employees are low types, to a "fully untreated" store with no low types. The point estimate for this elasticity is -0.0057.⁴⁴ Furthermore, we compute that the employment elasticity with respect to a worker's own earnings is -0.219, in line with the -0.2 magnitude identified in the literature (Manning 2021).⁴⁵

⁴⁴This elasticity is computed by dividing -0.012 by 16.63*0.127, where 16.63 is the average number of workers in a store and 0.127 is the percent change of a 1\$ increase in the minimum wage relative to the mean (\$1/\$7.87). An implicit assumption in this elasticity calculation is the absence of "spillover effects" of the minimum wage on "untreated" stores.

⁴⁵This elasticity is computed by dividing -0.0057 by the percent change in average earnings in response to the minimum wage. A caveat to this elasticity calculation is that the effect of the minimum wage on a worker's average earnings is endogenous to the productivity boost.

6.3 Effect of Minimum Wage on Output and Profits

Output Increasing the minimum wage has two opposite effects on store-level output: low types work harder, but stores disproportionately increase the retention of the low types, as shown in Sections 4.1 and 6.1. The overall effect is theoretically ambiguous. Using equation (6) from the theory, we calibrate the size of these two effects using as inputs the point estimates from the worker-level analysis (Section 4). We find that, after a \$1 minimum wage increase, store-level output for a fixed type distribution increases by 13.9%; and the worsening of the type distribution decreases store-level output by 2.3% (see Appendix D.1). The estimated net effect is an increase of 11.6%. Reassuringly, this calibrated effect is comparable to the estimate obtained from an entirely different procedure: that which regresses the store-level sum of individual worker output on the minimum wage in equation (13) ($\hat{\beta} = 8\%$, see Table 8 column 1). In sum, regardless of the procedure, we find that increasing the minimum wage increases store-level productivity.

Profits There is no theoretical presumption that a minimum wage increase should reduce profits in a border store. This is because the nationwide compensation scheme \overline{w} is not adapted to local conditions, and border stores may not be representative of all stores. However, assuming that headquarters choose the compensation scheme \overline{w} to maximize nationwide profits, we would expect profits to decrease in the nationally representative store. Accordingly, we check whether profits decline in the nationwide sample.

What controls should be included in the nationwide specification is an open question. We run the three most common state-level specifications in the literature (store and month fixed effects; or with added linear state trends; or with added census-division × month fixed effects). As the only specification that eliminates pre-trends in profits, employment, and individual sales per hour is the census-division × month fixed effects (Tables A.5 and E.1), we report the results for this specification alone.

⁴⁶See page 19 for a discussion of this institutional feature. Footnote 17 provides a counterexample where profits *increase* with the minimum wage because \overline{w} is not well-adapted to local conditions.

⁴⁷By contrast, the border sample is suitable for testing theoretical predictions about worker behavior and store-level turnover, as both are optimized store-by-store such that the theoretical predictions should hold for every worker and even in non-representative stores

As expected, the effect of minimum wage on profits in the nationwide sample is negative. A \$1 increase in the minimum wage reduces profits per hour by 16% relative to the sample mean (statistically significant at the 10% level: see Table 8 column 4).⁴⁸

7 Alternative Explanations For the Core Results

Our core results concern the effect of the minimum wage on individual productivity, by type. In this section, we examine two alternative channels that could explain some of our main findings. Details on the tests performed to rule out these alternative channels are provided in Appendix F, along with the associated tables.

7.1 Demand Channel

A demand increase that systematically coincides with a minimum wage increase might account for the *average* increase in individual productivity.⁴⁹ Yet, a demand increase is at odds with the productivity reduction observed among low-monitored workers (Section 5). In addition, a demand increase alone does not easily account for why high types fail to experience a productivity boost (Section 4). If the demand channel was operative, such a boost would be expected. Indeed, we show that in times of high store-level demand – as measured by satellite imagery of parking lot occupancy rates around each store – the high types' sales increase more (and not less) than those of low types (Table F.3 and Figure F.3).

Further evidence that high types are more sensitive to minimum wage-induced variation in demand comes from counties that have a larger share of the population who earn

⁴⁸For the sake of comparison, we also present the results on profits in the border sample. We document a zero profits effect (Table 8, column 2). At the risk of overinterpreting differences in estimates across non-nested regression specifications, one might conclude that border stores are somewhat different than average stores. In any case, individual performance estimates by type are quite similar in the border and nationwide samples: compare Tables 4 and E.7.

⁴⁹The literature is divided as to whether there is pass-through from the minimum wage to the demand for retail goods. On the one hand, Aaronson et al. (2012) show a certain degree of pass-through for miscellaneous household items, which are sold by retail stores. On the other, Leung (2020) demonstrates a decrease in real sales of "General Merchandise" in mass merchandise stores after a minimum wage increase.

minimum wage; that is, where the demand channel is expected to be most powerful. In these counties, the effect of the minimum wage on productivity is found to be stronger for high than for low types, compared to less exposed counties. This suggests that in counties where the demand channel is most powerful, it is manifested disproportionately among high relative to low types (Table F.4). Overall, the demand channel seemingly has different implications than an efficiency wage channel, such that variation in demand alone cannot explain all of our findings.

A conceptually related channel is a change in demand per worker. Fix employee i. Any decrease in the number of co-workers -i might change i's residual demand, and thus increase i's individual performance mechanically, quite apart from any incentive effect on i. Such spillovers across workers do not exist in our model, but they could exist in reality. We can rule out that our results on individual productivity are confounded by variation in store-level employment because in Section 6.2 the number of salespeople employed by a store does not correlate significantly with the minimum wage. Furthermore, controlling for store-level employment does not affect our core estimates, either on average or by type (Table F.5). A similar form of negative spillover would exist if increased effort by coworkers reduced worker i's individual performance through, e.g., "demand stealing." This effect is difficult to control for directly, but if such a spillover existed it would depress every worker's performance given effort, and so our estimated coefficients (which are based on performance) would under-represent the true effect of the minimum wage on effort.

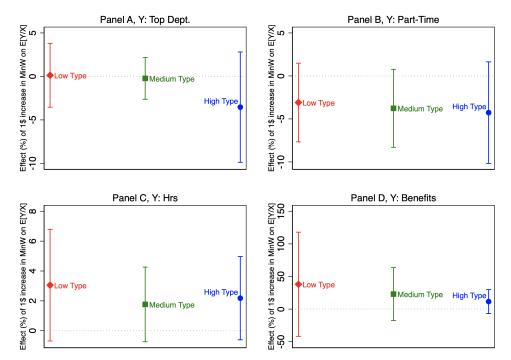
7.2 Organizational Adjustments Channel

Stores could respond to a higher minimum wage with organizational adjustments that, potentially, might disproportionately increase the low types' sales per hour. These could include, for example, reallocating them to "better-selling" departments,⁵⁰ moving them from part-time to full-time status (where they might then pick up higher-traffic work hours), reducing their number of hours (which could translate into higher productivity per hour if this attenuates the fatigue of working long hours), or increasing their vacation and

These are departments that, anecdotally, are viewed as more desirable for workers. We confirm that sales associates working in these departments earn higher variable pay.

illness benefits. Figure 7 (and the corresponding Table F.6) show that the company did not make these adjustments differentially across types.⁵¹

Figure 7: The Minimum Wage has no Differential Effect on Allocation to Best-Selling Departments, Part-Time Status, Hours Worked, or Benefits by Type



Notes: Effects of a \$1 increase in the minimum wage on the percent change in Y; where Y is an indicator for working in the best-selling departments (Panel A), an indicator for being a part-time worker (Panel B), the number of hours worked per month (Panel C), or benefits (in \$) earned (Panel D). Vertical bars represent 95% confidence intervals computed using the estimated coefficients $(\hat{\beta}_1, \hat{\beta}_1 + \hat{\beta}_4, \text{ and } \hat{\beta}_1 + \hat{\beta}_5)$ from equation (11) and the associated standard errors.

Another firm adjustment that could account for the observed boost in the value of sales is an increase in *consumer prices*. Note, however, that a rise in prices should be a tide that lifts all boats, thus increasing sales for *all* workers, not just the low types. Moreover, in line with the findings of Della Vigna and Gentzkow (2019), our company has a national pricing strategy and applies uniform prices across all US stores. We confirm this by backing out a store-level aggregate retail price index from each store's monthly financials, and verifying that the index does not correlate with the local minimum wage

⁵¹The percentage change in benefits looks large for all types (though it is not statistically significant) but this is because it is calculated relative to a low mean; the absolute change is \$10 per month.

change (Table F.7).

Overall, the above findings indicate that the individual performance gains we see across types do not reflect organizational adjustments associated with minimum wage increases, to the extent we can measure.

8 Worker Welfare Calibration

In this section we study how the welfare of employed and unemployed workers changes with the minimum wage. To make this exercise meaningful, we relax the theoretical assumption that the value V^A of being in the unemployed state is unaffected by the minimum wage. We assume, instead, that (i) when unemployed, the worker has zero flow utility, and she exits unemployment with a constant probability s(M) which is a decreasing function of the minimum wage (consistent with our finding that increasing the minimum wage reduces turnover); (ii) when the worker finds a new job, she works at a firm with the same characteristics as the one we study and her type is drawn from the distribution h(x).

Given these assumptions, Appendix D.2 shows that the welfare in the unemployed state equals:

$$V^{A}(M) = \frac{s(M)}{r + s(M)} \mathbb{E}_{h} \left[V^{E}(x; M) \right], \tag{15}$$

where $V^E(x; M)$ is type x's welfare in the employed state. This expression indicates that $V^A(M)$ could, in theory, be decreasing in the minimum wage, because the function $s(\cdot)$ is decreasing in M. Intuitively, if unemployment duration, which is inversely related to s(M), increases sharply in the minimum wage, then the welfare of unemployed workers could decrease.

To assess empirically whether expression (15) is increasing or decreasing in M, it is helpful to know the sign and magnitude of ds(M)/dM. In Appendix D.2 we leverage existing estimates of the effect of the minimum wage on unemployment duration, and conclude that this quantity is negative (as expected) and small. Expression (15) also reveals that the negative impact of the function $s(\cdot)$ is magnified if $\mathbb{E}_h\left[V^E(x;M)\right]$ is large, which is the case if the cost of effort is small and workers are patient.

Appendix D.2 shows that, for any cost of effort, including zero, both the employed and the unemployed workers benefit from a higher minimum wage. This strong result, while intuitively plausible, is not obvious: it holds because the estimate of ds(M)/dM is relatively low, and because we assume that workers are relatively impatient (in line with field-experimental evidence on the personal discount factor).

9 Conclusion

We assess the effect of the minimum wage on worker productivity among more than 40,000 salespeople whose pay is partly based on performance, and who are employed by a large US retailer that operates more than 2,000 stores.

Using a border-discontinuity research design, we document that workers become more productive after a minimum wage increase, and this effect is stronger among workers whose pay is more often supported by the minimum wage. However, these effects reverse in sign when workers are monitored less intensely. We organize these findings using a theoretical model that features two sources of worker incentives: an efficiency wage channel and a pay-for-performance channel. When viewed through the lens of this model, our empirical results indicate that the efficiency wage channel is responsible for the productivity gain. It is interesting that efficiency wages play a major role despite the fact that pay is allowed to depend on performance (though not on effort).

At the store level, turnover decreases, employment does not change, output increases, and average profits across all stores decrease following a minimum wage increase. This last result indicates that the endogenous increase in output is not large enough to offset the increase in wage costs. Finally, a calibration exercise suggests that the welfare of employed and unemployed workers increases with the minimum wage.

This study is limited to a single large firm; therefore, it is appropriate to comment on the extent to which the analysis and results might generalize. First, in our nationwide firm, product prices and the wage schedule do not respond to local minimum wage changes. Small employers may more freely adjust their prices and/or wages, potentially making them somewhat more resilient to minimum wage increases. Second, the store-level response

to a minimum wage increase depends on its type composition – e.g., how many workers are at minimum wage. While the typical firm's type composition need not be the same as our stores', it is somewhat reassuring that our store-level estimates on labor flows, employment, and profits qualitatively align with aggregate estimates from the empirical labor literature, as detailed in the Introduction. Finally, the theory treats a worker's productivity as independent from her co-workers'. While this assumption has some empirical support in our case, as detailed in Section 7.1, productivity spillovers may exist in other firms.

This paper has shed light on the endogenous effort response of low-paid workers to the minimum wage. In addition, it has shown that the efficiency wage model is a helpful framework for interpreting the workers' response. Both contributions may be potentially important as the debate on the minimum wage continues to unfold.

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Table 1: Descriptive Statistics

Variables	Mean	S.D.	p10	p50	p90	N	
	(1)	(2)	(3)	(4)	(5)	(6)	
Panel A. Worker-level Variables							
Productivity							
${ m Sales/Hrs}$ (Shrouded Units)	2.085	1.468	0.781	1.872	3.522	217,822	
Tenure and Hours							
Tenure (in months)	48.92	65.01	4	24	126	217,822	
Part-Time (in %)	60.25	48.94	0	100	100	217,822	
Number of Hours (Hrs)	106.5	44.12	46.47	107.6	162.3	217,822	
Compensation							
Base Rate: Regular Pay/Hrs (in \$)	6.120	1.181	4.500	6	7	217,822	
Comm. Rate: Variable Pay/Sales (in %)	3.462	3.188	1.057	2.343	7.531	213,726	
Variable Pay/Hrs (in \$)	5.947	4.936	1.740	4.610	11.78	217,822	
MinW Adj/Hrs (in \$)	0.225	1.736	0	0	0.771	217,822	
Total Pay (in \$)	$1,\!361$	831.2	494.6	1,218	2,343	$217,\!822$	
Total Pay/Hrs (in \$)	12.51	4.620	8.734	11.15	17.94	$217,\!822$	
Panel B. Store-level Variables							
Termination, Hiring, and Turnover							
Terminated (in %)	4.755	7.692	0	0	12.50	12,359	
Hired (in %)	2.060	4.285	0	0	7.692	$12,\!359$	
Turnover (in %)	3.408	4.404	0	2.500	8.333	$12,\!359$	
Employment and Profits							
Number of Workers	16.64	6.855	8	16	26	12,359	
Supervisor-to-Worker Ratio (in %)	6.990	4.886	3.448	5.882	11.11	$12,\!359$	
Ebitda/Hrs (Shrouded Units)	5.946	11.97	-8.010	5.630	19.97	$12,\!359$	

Notes: This table presents summary statistics of worker-level variables in Panel A and store-level variables in Panel B. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. Tenure is the number of months of tenure. Part-Time (in %) is the percent probability that an employee is part-time in a given month (0 means full-time and 100 means part-time). Number of Hours is the total number of hours for which employee receives compensation in a given month. Base Rate: Regular Pay/Hrs are monthly regular earnings per hour worked (in \$ per hour). Comm.Rate: Variable Pay/Sales are earnings from commissions and incentives divided by sales (in %). Variable Pay/Hrs are earnings from commissions and incentives per hour worked (in \$ per hour). MinW Adj/Hrs are the monthly earnings from minimum wage adjustments per hour worked (in \$ per hour). Total Pay (in \$) is the monthly total pay from total take home pay. Total Pay/Hrs is the monthly total pay from total take home pay per hour worked (in \$ per hour). Terminated (in %) is the percent of sales associates in the store who are terminated in a given month. Hired (in \%) is the percent of sales associates who are hired in a store in a given month. Turnover (in %) is defined as the percent of sales associates in the store who are terminated or hired in a given month divided by two. Number of Workers is the number of sales associates employed by a store in a given month. Supervisor-to-Worker Ratio is measured as the number of supervisors per 100 sales associates. Ebitda/Hrs are equal to earnings before interest, tax, depreciation, and amortization, per hour worked in the store. We do not disclose the units for confidentiality reasons.

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Table 2: Effect of Minimum Wage on Compensation Scheme \overline{w} , and Overall Pay Inclusive of Minimum Wage Adjustment

	Compensation scheme (\overline{w})		Overall pay inclusive of minimum wage adjustment			$_{ m stment}$
Dep.Var.	$Base\ Rate:$ Reg.Pay/Hrs (in \$) (1)	Comm. Rate: Var.Pay/Sales (in %) (2)	MinW.Adj./Hrs (in \$) (3)	Var.Pay/Hrs (in \$) (4)	Tot.Pay/Hrs (in \$) (5)	Tot.Pay (in 100\$) (6)
MinW	-0.059 (0.042)	$0.126 \\ (0.077)$	0.250*** (0.044)	0.439* (0.235)	0.645*** (0.172)	0.856** (0.336)
Observations	217,822	213,697	217,822	217,822	217,822	217,822
Units	Workers	Workers	Workers	Workers	Workers	Workers
Mean Dep.Var.	6.120	3.462	0.225	5.947	12.51	13.61
Effect MinW (%)	-0.957	3.628	111.3	7.390	5.154	6.289

Notes: All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department and county-level unemployment. Reg.Pay/Hrs is the base rate: monthly regular earnings per hour worked (in \$ per hour). Var.Pay/Sales is the commission rate: earnings from commissions and incentives divided by sales (in %). MinW.Adj./Hrs are monthly earnings from minimum wage adjustments per hour worked (in \$ per hour). Var.Pay/Hrs are earnings from commissions and incentives per hour worked (in \$ per hour). Tot.Pay/Hrs is the monthly total pay from total take-home pay per hour worked (in \$ per hour). Tot.Pay is the monthly total pay from total take-home pay (in 100\$). MinW is the predominant monthly minimum wage (in \$). $Effect\ MinW\ (\%)$ is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Descriptive Statistics for Low, Medium, and High Types

Worker Types:	Low Types (1)	Medium Types (2)	High Types (3)
% Workers	3.9%	72.4%	23.7%
% Terminated	6.8%	5.2%	3.0%
$\mathrm{Sales}/\mathrm{Hrs}$	1.08	1.94	2.73
% Weeks with MinW Adjustment	48.9%	18.5%	12.2%
% Months with MinW Adjustment All Weeks	20.5%	3.1%	0.7%

Notes: This table presents summary statistics for low, medium, and high types. Low Types are workers paid at the minimum wage. Medium Types are workers paid between the minimum wage and 180% of the minimum wage. High Types are workers paid more than 180% of the minimum wage. The number of observations is 210k, as in our main specifications. % Terminated is the fraction of workers terminated. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. % Weeks with MinW Adjustment is the fraction of weeks per month in which a worker's pay is topped up by the firm. % Months with MinW Adjustment All Weeks is the fraction of months in which a worker's pay is topped up by the firm each single week.

Table 4: Effect of Minimum Wage on Worker Productivity

——————————————————————————————————————	m Sales/Hrs	$\overline{ m Sales/Hrs}$
	(1)	(2)
MinW	0.094**	0.244***
	(0.039)	(0.042)
Medium Type		0.354***
		(0.032)
High Type		1.169***
		(0.072)
$\operatorname{MinW} \cdot \operatorname{Medium} \operatorname{Type}$		-0.085***
		(0.025)
MinW · High Type		-0.182***
		(0.032)
Observations	217,822	209,513
Units	Workers	Workers
Mean Dep.Var.	2.085	2.085
Effect MinW (%)	4.485	
Effect MinW for Low Type (%)		22.56
p-value		0.009
Effect MinW for Med. Type (%)		8.186
p-value		0.009
Effect MinW for High Type (%)		2.273
p-value		0.179

Notes: All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department, and county-level unemployment. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. MinW is the predominant monthly minimum wage (in \$). MinW is in deviation from its sample mean in even columns. $Medium\ Type$ is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. $High\ Type$ is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group ($Low\ Types$) are workers for whom total pay in t-1 is "at minimum wage." $Effect\ MinW\ (\%)$ is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table 5: Effect of Minimum Wage on Worker Productivity with High or Low Monitoring

Dep.Var.	Sales/Hrs	Sales/Hrs	Sales/Hrs	Sales/Hrs	Sales/Hrs
Sample	All	High C	Coverage	Low C	overage
	(1)	(2)	(3)	(4)	(5)
Coverage	0.010***				
	(0.003)				
MinW		0.140***	0.281***	-0.192**	0.020
		(0.040)	(0.044)	(0.081)	(0.067)
Medium Type			0.368***		0.336***
			(0.033)		(0.044)
High Type			1.185***		1.121***
			(0.071)		(0.080)
$\operatorname{MinW} \cdot \operatorname{Medium} \operatorname{Type}$			-0.083***		-0.111*
			(0.027)		(0.054)
MinW · High Type			-0.188***		-0.168**
			(0.031)		(0.075)
Observations	217,822	132,384	126,852	84,549	81,800
Units	Workers	Workers	Workers	Workers	Workers
Mean Dep.Var.	2.085	2.118	2.130	2.030	2.032
Effect (%)	1.461	6.588		-9.444	
Effect MinW for Low Type (%)			25.87		1.824
p-value			0.009		0.773
Effect MinW for Med. Type (%)			10.11		-4.953
p-value			0.009		0.176
Effect MinW for High Type (%)			3.298		-5.714
p-value			0.077		0.114

Notes: All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department, and county-level unemployment. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. Coverage is measured as the supervisor-to-worker ratio (number of supervisors per 100 sales associates). Low (High) coverage is an indicator for whether the store is in the bottom quartile (not in the bottom quartile) of coverage. MinW is the predominant monthly minimum wage (in \$). MinW is in deviation from its sample mean in columns 3 and 5. $Medium\ Type$ is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. $High\ Type$ is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group ($Low\ Types$) are workers for whom total pay at t-1 is "at minimum wage." In Column 1, $Effect\ (\%)$ is the percent effect of one standard deviation increase in coverage on Sales/Hrs, and in Columns 2 and 4 it is the effect of a \$1 increase in MinW on the same outcome. $Effect\ MinW\ (\%)$ is the percent effect of a \$1 increase in MinW on Sales/Hrs for Low-, Med-, and High type workers. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

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Table 6: Effect of Minimum Wage on Store-level Turnover and Employment

Dep.Var.	% Tern	$ \overline{\text{ninated}} $	% I	Hired	% Tu	rnover	Ter	nure	N.Wo	orkers
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
MinW	-0.272	-0.282	0.213	0.084	-0.029	-0.099	7.205**	7.537**	-0.217	-0.451
	(0.503)	(0.538)	(0.308)	(0.310)	(0.368)	(0.393)	(3.513)	(3.479)	(0.423)	(0.405)
% Low Types		0.222		0.276**		0.249*		-0.740*		0.146
		(0.207)		(0.118)		(0.124)		(0.375)		(0.117)
MinW · % Low Types		-0.025		-0.029**		-0.027*		0.077^{*}		-0.012
		(0.025)		(0.013)		(0.014)		(0.044)		(0.014)
Observations	12,359	12,025	12,359	12,025	12,359	12,025	12,359	12,025	12,359	12,025
Units	Stores	Stores	Stores	Stores	Stores	Stores	Stores	Stores	Stores	Stores
Mean Dep.Var.	4.755	4.877	2.060	2.073	3.408	3.475	49.65	49.62	16.64	16.63

Notes: The variable % Low Types – which represents the percent of workers who are low types in the store pre-reform – is de-meaned so that the coefficient "MinW" in even columns captures the effect of the minimum wage for a store with the average fraction of low types. All the regressions include pair-month fixed effects, store fixed effects, and control for county-level unemployment. % Terminated is the percent of sales associates in the store who are terminated in a given month. % Hired is the percent of sales associates who are hired in a store in a given month. % Turnover is the percent of sales associates in the store who are terminated or hired in a given month divided by two. Tenure is the average number of months of tenure in the workforce. N. Workers is the number of sales associates in the store. Min W is the predominant monthly minimum wage in the store (in \$). Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Effect of Minimum Wage on Worker Termination

Dep.Var.	Terminated	Terminated
	(1)	(2)
MinW	-0.159	-1.297*
	(0.517)	(0.756)
Medium Type		-2.240***
		(0.755)
High Type		-3.753***
		(0.817)
MinW · Medium Type		0.912
		(0.620)
MinW · High Type		1.424**
		(0.573)
Observations	217,822	209,734
Units	Workers	Workers
Mean Dep.Var.	4.562	4.562
Effect MinW (%)	-3.482	
Effect MinW for Low Type (%)		-19.16
p-value		0.096
Effect MinW for Med. Type (%)		-7.434
p-value		0.480
Effect MinW for High Type (%)		4.247
p-value		0.836

Notes: All the regressions include pair-month fixed effects, store fixed effects (not worker fixed effects), and control for worker tenure, worker department and county-level unemployment. Terminated equals 100 if the worker is terminated in a given month, and 0 otherwise. MinW is the predominant monthly minimum wage (in \$). MinW is in deviation from its sample mean in even columns. Medium Type is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. High Type is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group (Low Types) are workers for whom total pay in t-1 is "at minimum wage." Effect MinW (%) is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table 8: Effect of Minimum Wage on Store-level Output and Profits in Border Stores and All Stores

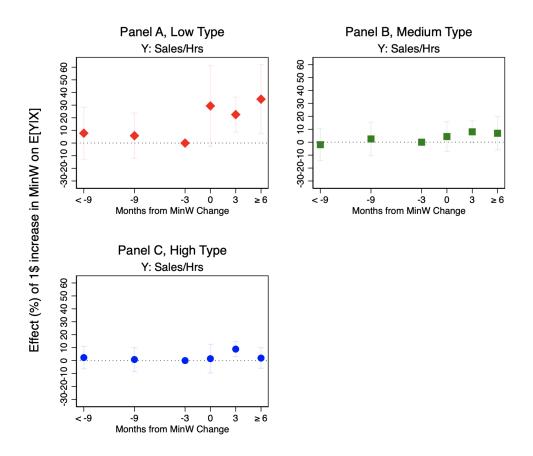
Dep.Var.	Output/Hrs	Ebitda/Hrs	Output/Hrs	Ebitda/Hrs
Sample	Border Stores	Border Stores	All Stores	All Stores
	(1)	(2)	(3)	(4)
MinW	0.062**	0.383	0.029*	-0.781*
	(0.026)	(1.317)	(0.017)	(0.436)
Observations	$12,\!359$	12,359	30,969	30,969
Units	Stores	Stores	Stores	Stores
Mean Dep.Var.	0.827	5.946	0.830	4.824
Effect MinW (%)	7.551	6.441	3.457	-16.18

Notes: In columns 1-2, the sample is restricted to bordering stores as in the other tables. The regressions include pair-month fixed effects, store fixed effects, county-level unemployment and standard errors are two-way clustered at the state level and at the border-segment level. In columns, 3-4, the sample comprises all stores (bordering + non-bordering). The regressions include census division-month fixed effects, month fixed effects, store fixed effects, county-level unemployment and standard errors are clustered at the state-level. Output/Hrs is equal to total store revenues per hour worked in the store. Ebitda/Hrs is equal to earnings before interest, tax, depreciation, and amortization, per hour worked in the store. We do not disclose the units for confidentiality reasons. MinW is the predominant monthly minimum wage (in \$). $Effect\ MinW\ (\%)$ is the percent effect of a \$1 increase in MinW on the store-level outcomes. *** p<0.01, *** p<0.05, * p<0.1.

Appendices

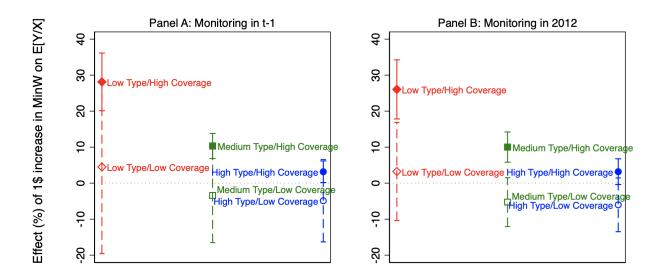
A Online Appendix: Tables and Figures

Figure A.1: Dynamic Effect of Minimum Wage on Worker Productivity – Longer Pre-Trends



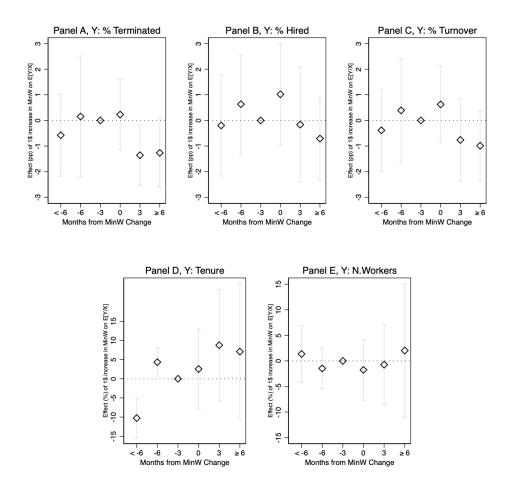
Notes: Effects of a \$1 increase in the minimum wage on the percent change in Y (Sales/Hrs) for low, medium, and high types. The red, green and blue markers show the cumulative response to the minimum wage relative to event date -3 for low, medium, and high types respectively. The post-treatment effects for each type are computed by summing each type's contemporaneous and lagged coefficients from equation (12) (e.g., for low types, $\hat{\beta}_1^0$, $\hat{\beta}_1^0 + \hat{\beta}_1^3$, and $\hat{\beta}_1^0 + \hat{\beta}_1^3 + \hat{\beta}_1^9$) and dividing by that type's mean productivity. The pre-treatment effects are computed by summing each type's lead coefficients, multiplying the sum by -1 (e.g., for low types, $-\hat{\beta}_1^3 - \hat{\beta}_1^9$ and $-\hat{\beta}_1^3$) and dividing it by that type's mean productivity. Vertical bars represent 95% confidence intervals.

Figure A.2: Effect of Minimum on Worker Productivity, by Monitoring Coverage



Notes: Effects of a \$1 increase in the minimum wage on the percent change in performance (Y: Sales/Hrs) for low, medium, or high types for high/low monitoring coverage. Monitoring coverage is measured as the ratio of supervisors to workers in time t-1 in Panel A, and in 2012 (the starting year in our dataset) in Panel B. "Low coverage" is an indicator for whether the store is in the bottom quartile of the monitoring coverage distribution. Vertical bars (solid for "Low coverage," dashed otherwise) represent 95% confidence intervals.

Figure A.3: Dynamic Effect of Minimum Wage on Store-level Outcomes



Notes: Panels A-C present the dynamic effects of a \$1 increase in the minimum wage on the store-level percentage point change in Y; where Y is the percent of sales associates who are terminated (Panel A), the percent of sales associates who are hired (Panel B), or the turnover rate of a store in a given month (Panel C). Panel D-E present the dynamic effect of a \$1 increase in minimum wage on the percent change in average worker tenure (Panel D) and on the number of sales associates in a store (Panel E). The markers show cumulative response to the minimum wage relative to event date -3. The post-treatment effects are computed by summing the contemporaneous and lagged coefficients ($\hat{\beta}^0$, $\hat{\beta}^0 + \hat{\beta}^3$, and $\hat{\beta}^0 + \hat{\beta}^3 + \hat{\beta}^6$). The pre-treatment effects are computed by summing the lead coefficients, and multiplying the sum by -1 $(-\hat{\beta}^3 - \hat{\beta}^6)$ and $-\hat{\beta}^3$). Vertical bars represent 95% confidence intervals.

Table A.1: Effect of Minimum Wage on Worker Total Pay per Hour

——————————————————————————————————————	Tot.Pay/Hrs	Tot.Pay/Hrs
	(1)	(2)
351 337		
MinW	0.645***	0.807***
N. 11	(0.172)	(0.225)
Medium Type		0.469***
		(0.087)
High Type		1.037***
		(0.115)
MinW · Medium Type		-0.097
		(0.105)
MinW · High Type		-0.141*
		(0.083)
Observations	217,822	209,513
Units	Workers	Workers
Mean Dep.Var.	12.51	12.51
Effect MinW (%)	5.154	
Effect MinW for Low Type (%)		8.146
p-value		0.009
Effect MinW for Med. Type (%)		6.281
p-value		0.009
Effect MinW for High Type (%)		3.978
p-value		0.002

Notes: All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department and county-level unemployment. Tot.Pay/Hrs is the monthly total pay from total take-home pay per hour worked (in \$100 per hour). MinW is the predominant monthly minimum wage (in \$). MinW is in deviation from its sample mean in even columns. $Medium\ Type$ is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. $High\ Type$ is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group ($Low\ Types$) are workers for whom total pay in t-1 is "at minimum wage." $Effect\ MinW\ (\%)$ is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table A.2: Cumulative Dynamic Effect of Minimum Wage on Worker Productivity

Dep. Var	$ m Sales/Hrs \ (1)$
	· · · · · · · · · · · · · · · · · · ·
Effects for Low Types	
(Mean Dep. Var. for Low Types $= .936$)	
t < -6	0.081
	(0.091)
t = -6	0.062
	(0.117)
t = 0	0.240*
	(0.135)
t = 3	0.194***
	(0.056)
$t \ge 6$	0.270***
	(0.097)
Effects for Medium Types	
(Mean Dep. Var. for Med. Types $= 1.853$)	
t < -6	-0.036
	(0.122)
t = -6	0.091
	(0.112)
t = 0	0.080
	(0.091)
t = 3	0.150
	(0.119)
$t \ge 6$	0.115
	(0.118)
Effects for High Types	
(Mean Dep. Var. for High Types $= 2.596$)	
t < -6	0.073
	(0.114)
t = -6	0.025
	(0.098)
t = 0	0.066
	(0.127)
t = 3	0.237***
	(0.085)
$t \ge 6$	0.055
	(0.099)
Observations	$102,\!252$

Notes: The table presents the cumulative response to the minimum wage relative to event date -3 for low-, medium- and high-types. The post-treatment effects for each type are computed by summing each type's contemporaneous and lagged coefficients from equation (12) (e.g., for low types, $\hat{\beta}_1^0$, $\hat{\beta}_1^0 + \hat{\beta}_1^3$, and $\hat{\beta}_1^0 + \hat{\beta}_1^3 + \hat{\beta}_1^6$). The pretreatment effects are computed by summing each type's lead coefficients, multiplying the sum by -1 (e.g., for low types, $-\hat{\beta}_1^3 - \hat{\beta}_1^6$ and $-\hat{\beta}_1^3$). All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department, county-level unemployment. Sample restricted to workers who stayed on the job at least 12 consecutive months (six before the minimum wage change and six after). Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.3: Store-Level Correlations with Monitoring Coverage

Dep.Var.	N.Workers (1)	% Turnover (2)	$\frac{\mathrm{Ebitda/Hrs}}{(3)}$	% Low Types (4)	Exposure (5)
	(1)	(2)	(0)	(1)	(0)
Panel A: With Store Fixed Effects					
Monitoring Coverage	-0.319***	0.017	-0.054	-0.063	0.001
	(0.053)	(0.046)	(0.052)	(0.062)	(0.001)
Observations	12,359	12,359	12,359	12,025	12,359
Units	Stores	Stores	$\dot{\text{Stores}}$	Store	Stores
Mean Dep.Var.	16.64	3.408	5.946	3.911	9.291
Effect (%)	-9.384	2.406	-4.471	-7.854	0.043
Panel B: Without Store Fixed Effects					
Monitoring Coverage	-0.720***	0.132***	-0.274*	-0.076	-0.018
	(0.143)	(0.032)	(0.136)	(0.072)	(0.014)
Observations	12,359	12,359	12,359	12,027	12,359
Units	Stores	Stores	Stores	Stores	Stores
Mean Dep.Var.	16.64	3.408	5.946	3.911	9.291
Effect (%)	-21.15	18.96	-22.53	-9.540	-0.957

Notes: All the regressions include pair-month fixed effects and those in Panel A also control for store fixed effects. Monitoring Coverage is the supervisor-to-worker ratio (number of supervisors per 100 sales associates). N. Workers is the number of sales associates in the store. % Turnover is the percent of sales associates in the store who are terminated or hired in a given month divided by two. Ebitda/Hrs is equal to earnings before interest, tax, depreciation and amortization, per hour worked in the store. We do not disclose the units for confidentiality reasons. % Low Types is the percent of workers who are low types in the store. Exposure corresponds to the difference (in \$) between the average hourly wage in the county and the predominant monthly minimum wage. MinW is the predominant monthly minimum wage in the store (in \$). Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.4: Test of Endogenous Monitoring Coverage and Steady State

Dep.Var.	Monitoring Coverage	N.Workers
	(1)	(2)
MinW	0.202	
	(0.490)	
Time Trend		-0.026
		(0.017)
Observations	12,359	12,359
Units	Stores	Stores
Mean Dep.Var.	6.990	16.64
Effect (%)	2.883	-0.159

Notes: All the regressions include pair fixed effects, store fixed effects, and control for county-level unemployment. The regression in column 1 also controls for pair-month fixed effects. Monitoring Coverage is the supervisor-to-worker ratio (number of supervisors per 100 sales associates). N. Workers is the number of sales associates employed by a store in a given month. MinW is the predominant monthly minimum wage (in \$). Linear Trend is a monthly linear time trend. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1.

Table A.5: Test of Pre-Trends in Stores-Level Outcomes with Border-Discontinuity and State-Level Specifications

Dep.Var.	% Turnover	Ebitda/Hrs	N.Workers	% Turnover	Ebit da/Hrs	N.Workers	% Turnover	Ebitda/Hrs	N.Workers	% Turnover	Ebitda/Hrs	N.Workers
Sample	Store Border	Store Border	Store Border	All Stores	All Stores	All Stores	All Stores	All Stores	All Stores	All Stores	All Stores	All Stores
Model	County-Pair· Month FE				Month FE		${\rm Month}{\rm FE}+{\rm State\text{-}Trend}$			Division · Month FE		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Panel A: 6-Months Pre-Trend											
Pre-Trend	0.333	-2.252	-0.355	0.064	-0.853*	-0.034	0.097	-0.696	-0.209	-0.004	-0.343	-0.129
(6 Months)	(0.970)	(1.364)	(0.333)	(0.155)	(0.486)	(0.133)	(0.157)	(0.466)	(0.168)	(0.236)	(0.562)	(0.181)
Observations	12,073	12,073	$12,\!073$	30,156	30,156	$30,\!156$	30,156	30,156	$30,\!156$	$30,\!156$	$30,\!156$	$30,\!156$
	Panel B: 12-Months Pre-Trend											
Pre-Trend	-0.127	1.811	0.002	0.179	0.171	-0.099	0.182	0.337	-0.363*	0.161	0.268	-0.164
(12 Months)	(0.410)	(1.372)	(0.398)	(0.157)	(0.835)	(0.0962)	(0.166)	(0.895)	(0.214)	(0.169)	(0.879)	(0.176)
Observations	11,753	11,753	11,753	29,176	29,176	$29,\!176$	29,176	29,176	29,176	$29,\!176$	$29,\!176$	$29,\!176$
Units	Stores	Stores	Stores	Stores	Stores	Stores	Stores	Stores	Stores	Stores	Stores	Stores

Notes: In Panel A, Pre-Trend = $\eta_{3-0} - \eta_{6-3}$ estimated from: $Y_{jt} = \alpha + \eta_{6-3}(MinW_{j,t+6} - MinW_{j,t+3}) + \eta_{3-0}(MinW_{j,t+3} - MinW_{j,t}) + \rho MinW_{j,t} + \eta Z_{jt} + \delta_j + \varepsilon_{jt}$, where $MinW_{j,t+m}$ is the minimum wage m months after month t, η_{6-3} (η_{3-0}) is a leading coefficient that captures variations in the Y-variable 6 to 3 (3 to 0) months before each change in the minimum wage (see Dube et al. 2010). In Panel B, we report the estimates from a longer-trend model: Pre-Trend = $\eta_{12-6} - \eta_{6-0}$ estimated from: $Y_{jt} = \alpha + \eta_{12-6}(MinW_{j,t+12} - MinW_{j,t+6}) + \eta_{6-0}(MinW_{j,t+6} - MinW_{j,t}) + \rho MinW_{j,t} + \eta Z_{jt} + \delta_j + \varepsilon_{jt}$. In columns 1-3 (4-12) pre-trends are tested in the sample of bordering stores (bordering+non-bordering stores). All regressions include store fixed effects, and control for county unemployment rate. The regressions vary in the time controls: we include pair-month fixed effects in columns 1-3, month fixed effects in columns 4-6, month fixed effects and state-specific linear trends in columns 7-9, census division-month fixed effects in columns 9-12. % Turnover is the percent of sales associates in the store who are terminated or hired in a given month divided by two. Ebitda/Hrs is equal to earnings before interest, tax, depreciation and amortization, per hour worked in the store. We do not disclose the units for confidentiality reasons. N. Workers is the number of sales associates employed by a store in a given month. Standard errors are two-way clustered at the state level and at the border-segment level in columns 1-3 and at the state-level in columns 4-12. *** p<0.01, ** p<0.05, * p<0.1.

B Online Appendix: Model

B.1 Proofs

Lemma 3 (application of Blackwell's contraction theorem). The operator $B\left(f\right)$: $C\left(X,M\right)\to C\left(X,M\right)$ defined by:

$$(Bf)(x;M) = \max_{e} u(x,e;M) + \frac{1}{(1+r)}\pi(e)f(x;M)$$
 (16)

is a contraction with modulus $\frac{1}{1+r}$. Therefore:

- 1. The function V(x) defined by (2) is the unique fixed point of the operator B when u(x, e; M) is independent of M.
- 2. Let V(x; M) be the fixed point of the operator B. If u(x, e; M) < u(x', e; M') for all e then V(x; M) < V(x'; M')

Proof. The operator B satisfies monotonicity because f(x;M) < g(x;M) implies (Bf)(x;M) < (Bg)(x;M), and it satisfies discounting because for any positive constant a we have $[B(f+a)](x;M) \le (Bf)(x;M) + \frac{\pi(e)}{(1+r)}a$, and $\frac{\pi(e)}{(1+r)} \le \frac{1}{1+r} < 1$. Therefore B is a contraction with modulus $\frac{1}{1+r}$.

- 1. This is the definition of V(x), and uniqueness follows because a contraction mapping has at most one fixed point.
- 2. Take any quadruple (x, M, x', M') such that u(x, e; M) < u(x', e; M') for all e. If $f(x'; M') \ge f(x; M)$ then (Bf)(x'; M') > (Bf)(x; M). Therefore, the unique fixed point V of the operator B must have the property that V(x; M) < V(x'; M').

Proof of Lemma 1

Proof. Part 1. Because Assumptions 1 and 2 hold, problem (2) is strictly concave in e and so it has a unique maximizer $e^*(x)$.

Part 2. The statement holds if, for any e, the left-hand side of the first-order condition (4) is strictly increasing in x. The first addend in the left-hand side is strictly increasing in x because $u_{xe} > 0$ by Assumption 1. The second term is nondecreasing because $\pi'(e)$ is nonnegative by assumption, and V(x) is increasing in x in light of $u_x > 0$ (Assumption 1) together with Lemma 3 part 2.

Part 3. The first addend $u_e(x,0) = w_e(x,0) - c_e(x,0)$ in the left-hand side of the first-order condition (4) is nonnegative at e = 0 because $w_e(x,0)$ is nonnegative by the MLRP, and $c_e(x,0)$ vanishes because by assumption the marginal cost of effort vanishes at zero. The second addend is strictly positive at e = 0 because $\pi'(0) > 0$ by assumption, and V(x) > 0 (refer to the discussion following Assumption 1). Therefore e = 0 cannot be optimal. At e = 1 the first addend in the left-hand side of the first-order condition (4) equals negative infinity because $c_e(x,1) = \infty$ and $w_e(x,1)$ is finite (the latter follows from the smoothness of $f_Y(y;x,e)$ in e), and the second addend is finite (concavity of π guarantees that $\pi'(1) < \infty$). Therefore e = 1 cannot be optimal.

Proof of Proposition 1

Proof. Denote by u(x, e; M) the expression obtained by replacing w(x, e) with w(x, e; M) in the definition of u (expression 3). Denote by V(x; M) the lifetime payoff of an agent with type x when the minimum wage equals M. This is the fixed point of the functional equation (2) after replacing u(x, e) with u(x, e; M).

Part 1. Optimal effort is interior (Lemma 1 part 3), so it is strictly increasing in M if the first-order condition (4) is increasing in M for every x, e. For any MMW type x, $w_e(x, e; M) = 0$ for all e, therefore (4) reads:

$$-c_e(x, e) + \frac{1}{(1+r)}\pi'(e)V(x; M) = 0.$$

The left-hand side depends on M through V(x; M) only, and V(x; M) is strictly increasing in M by Lemma 3 part 2.

Part 2. Suppose, by contradiction, that there are some types whose response to the minimum wage switches sign and becomes negative between \widehat{M} and $\widehat{M} + \varepsilon$. Then by continuity there must be a "borderline" type \widehat{x} such that $\frac{de^*(\widehat{x};M)}{dM} = 0$ at \widehat{M} and $\frac{de^*(\widehat{x};M)}{dM} < 0$ at $\widehat{M} + \varepsilon$. We now show that such a type does not exist.

Because $\pi' > 0$, equilibrium effort is interior by Lemma 1. Then the first-order condition (4) identifies the optimal effort level $e^*(x; M)$. From the implicit function theorem we have:

$$sgn\left[\frac{de^{*}\left(x;M\right)}{dM}\right] = sgn\left[Q_{eM}\left(x,e;M\right)|_{e^{*}\left(x;M\right)}\right],\tag{17}$$

where

$$Q_{eM}(x,e) = u_{eM}(x,e;M) + \frac{1}{(1+r)}\pi'(e)\left[V_M(x;M)\right]. \tag{18}$$

is the derivative wrt M of the type x's first order condition (4).

From (2) and taking account of the envelope condition we have:

$$V_M(x; M) = u_M(x, e^*(x; M); M) + \frac{1}{(1+r)} \pi(e^*(x; M)) V_M(x; M).$$

Isolate V_M to get:

$$V_M(x;M) = \frac{1+r}{1+r-\pi(e^*(x;M))} u_M(x,e^*(x;M);M).$$
(19)

Plug this expression into (18) and evaluate at $e^*(x; M)$ to get:

$$Q_{eM}(x,e;M)|_{e^*(x;M)} = u_{eM}(x,e) + \frac{\pi'(e)}{1+r-\pi(e)} u_M(x,e;M) \Big|_{e^*(x;M)} .$$
 (20)

The definition of $(\widehat{x}, \widehat{M})$ implies that

$$Q_{eM}\left(\widehat{x}, e; \widehat{M}\right)\Big|_{e^*\left(\widehat{x}; \widehat{M}\right)} = 0$$
(21)

$$Q_{eM}\left(\widehat{x}, e; \widehat{M} + \varepsilon\right)\Big|_{e^*\left(\widehat{x}; \widehat{M} + \varepsilon\right)} < 0.$$
(22)

These two equations imply:

$$0 \geq \frac{d}{dM} Q_{eM}(\widehat{x}, e^*(\widehat{x}; M); M)|_{\widehat{M}}$$

$$= Q_{eeM}(\widehat{x}, e^*(\widehat{x}; \widehat{M}); \widehat{M}) \left[\frac{de^*(\widehat{x}; M)}{dM}\right]_{\widehat{M}} + Q_{eMM}(\widehat{x}, e^*(\widehat{x}; \widehat{M}); \widehat{M})$$

$$= Q_{eMM}(\widehat{x}, e^*(\widehat{x}; \widehat{M}); \widehat{M}),$$
(23)

where the last equality holds because $\frac{de^*(\widehat{x};M)}{dM} = 0$ at \widehat{M} , and Q_{eMM} represents the partial derivative of the function $Q_{eM}(x,e;M)$ with respect to M, keeping (x,e) fixed at $(\widehat{x},e^*(\widehat{x};\widehat{M}))$. Formally,

$$Q_{eMM}\left(\widehat{x}, e^*\left(\widehat{x}; \widehat{M}\right); \widehat{M}\right) = \left[\frac{\partial}{\partial M} Q_{eM}\left(\widehat{x}, e; M\right)\right]_{e^*\left(\widehat{x}; \widehat{M}\right), \widehat{M}}.$$

From (17) and (20) we know that for any triple (x, e, M):

$$sgn\left[Q_{eM}\left(x,e;M\right)\right] = sgn\left[\frac{\pi'\left(e\right)}{1 + r - \pi\left(e\right)} + \frac{w_{eM}\left(x,e;M\right)}{w_{M}\left(x,e;M\right)}\right],$$

and so in light of (21), equation (23) implies:

$$0 \geq sgn \left[\frac{\partial}{\partial M} Q_{eM}(\widehat{x}, e; M) \right]_{e^{*}(\widehat{x}; \widehat{M}), \widehat{M}}$$

$$= sgn \left[\frac{\partial}{\partial M} \left(\frac{\pi'(e)}{1 + r - \pi(e)} + \frac{w_{eM}(\widehat{x}, e; M)}{w_{M}(\widehat{x}, e; M)} \right) \right]_{e^{*}(\widehat{x}; \widehat{M}), \widehat{M}}$$

$$= sgn \left[\frac{\partial}{\partial M} \left(\frac{w_{eM}(\widehat{x}, e; M)}{w_{M}(\widehat{x}, e; M)} \right) \right]_{e^{*}(\widehat{x}; \widehat{M}), \widehat{M}}. \tag{24}$$

To finish the proof by contradiction, we will show that (24) is strictly positive. To this end, we provide expressions for $w_{eM}(\widehat{x}, e; M)$ and $w_{M}(\widehat{x}, e; M)$. Let $F_{W}(w; \widehat{x}, e)$ denote the c.d.f. of $W(\widehat{x}, e) = \overline{w}(Y(\widehat{x}, e))$ and $\overline{F}(z; \widehat{x}, e, M)$ the c.d.f. of $Z = \max[M, W(\widehat{x}, e)]$. Since

$$\overline{F}(z; \widehat{x}, e, M) = \begin{cases} 0 & \text{if } z < M \\ F_W(z; \widehat{x}, e) & \text{if } z \ge M, \end{cases}$$

we have:

$$w(\widehat{x}, e; M) = \mathbb{E} \left(\max \left[M, \overline{w} \left(Y \left(\widehat{x}, e \right) \right) \right] \right)$$

$$= \int_{0}^{\infty} \max \left[M, w \right] dF_{W} \left(w; \widehat{x}, e \right)$$

$$= \int_{0}^{\infty} z d\overline{F} \left(z; \widehat{x}, e, M \right)$$

$$= \int_{0}^{\infty} \left[1 - \overline{F} \left(z; \widehat{x}, e, M \right) \right] dz$$

$$= M + \int_{M}^{\infty} \left[1 - F_{W} \left(z; \widehat{x}, e \right) \right] dz. \tag{25}$$

From this we get:

$$w_M(\widehat{x}, e; M) = F_W(M; \widehat{x}, e) \tag{26}$$

$$w_{eM}(\widehat{x}, e; M) = \frac{d}{de} F_W(M; \widehat{x}, e).$$
 (27)

Plug back into (24) to get:

$$\begin{split} &\frac{\partial}{\partial M} \left(\frac{\frac{d}{de} F_W \left(M; \widehat{x}, e \right)}{F_W \left(M; \widehat{x}, e \right)} \right) \\ &= \frac{F_W \left(M; \widehat{x}, e \right) \frac{d}{de} f_W \left(M; \widehat{x}, e \right) - f_W \left(M; \widehat{x}, e \right) \frac{d}{de} F_W \left(M; \widehat{x}, e \right)}{\left[F_W \left(M; \widehat{x}, e \right) \right]^2} \\ &= \frac{f_W \left(M; \widehat{x}, e \right)}{\left[F_W \left(M; \widehat{x}, e \right) \right]} \left[\frac{\frac{d}{de} f_W \left(M; \widehat{x}, e \right)}{f_W \left(M; \widehat{x}, e \right)} - \frac{\frac{d}{de} F_W \left(M; \widehat{x}, e \right)}{F_W \left(M; \widehat{x}, e \right)} \right] \\ &= \frac{f_W \left(M; \widehat{x}, e \right)}{\left[F_W \left(M; \widehat{x}, e \right) \right]} \left[\frac{d}{de} \ln f_W \left(M; \widehat{x}, e \right) - \frac{d}{de} \ln F_W \left(M; \widehat{x}, e \right) \right] \\ &= \frac{f_W \left(M; \widehat{x}, e \right)}{\left[F_W \left(M; \widehat{x}, e \right) \right]} \left[\frac{d}{de} \ln \frac{f_W \left(M; \widehat{x}, e \right)}{F_W \left(M; \widehat{x}, e \right)} \right]. \end{split}$$

But this quantity is strictly positive because $f_W(M; \widehat{x}, e) > 0$ for every e (Assumption 3) and $\frac{f_W(M; \widehat{x}, e)}{F_W(M; \widehat{x}, e)}$ is increasing in e. The latter claim holds because by assumption $f_Y(y; \widehat{x}, e)$ has the strict MLRP w.r.t. e. Milgrom and Weber (1982) show that if $Y(\widehat{x}, e)$ has the MLRP wrt e then so does $\overline{w}(Y)$ for any monotone transformation $\overline{w}(\cdot)$. (This is because if $Y(\widehat{x}, e)$ has the MLRP wrt e then Y and e are affiliated, see their discussion at p. 1099, and then their Theorem 3 yields the result). Strictness follows because $\overline{w}(\cdot)$ is strictly

increasing by assumption.

Part 3. Because Y(x,e) is uniformly bounded from above over all (x,e) and $\overline{w}(\cdot)$ is continuous, $\overline{w}(Y(x,e))$ is bounded and so for M large enough it must be the case that $w(x,e;M) \equiv M$ for all x,e. For such high M levels, all types are MMW types, and then part 1 applies.

Part 4. Fix M. The first order condition for optimal effort, expression (4), reads:

$$w_e(x, e; M) - c_e(x, e) + \frac{1}{(1+r)}\pi'(e)V(x; M) = 0.$$
(28)

We seek to show that for "types whose wage is negligibly affected by the minimum wage," i.e., those types x so large that $w_M(x, e; M) = F_W(M; x, e) \approx 0$, the left-hand side of (28) is negligibly affected by M. More precisely, we seek to show that if, for all $e \in [0, 1]$,

$$\lim_{x \to \infty} w_M(x, e; M) = 0, \tag{29}$$

then, for all $e \in [0,1]$,

$$\lim_{x \to \infty} w_{eM}(x, e; M) = 0 = \lim_{x \to \infty} V_M(x; M). \tag{30}$$

Equation (30), if it holds, guarantees that guarantees that by choosing x large enough, we can ensure that varying M has a negligible impact on the first-order condition (28) that determines $e^*(x; M)$. This will conclude the proof.

To check the first equality in (30), write:

$$\lim_{x \to \infty} w_{eM}(x, e; M)$$
= $\lim_{x \to \infty} \lim_{h \to 0} \frac{w_M(x, e + h; M) - w_M(x, e; M)}{h}$
= $\lim_{h \to 0} \lim_{x \to \infty} \frac{w_M(x, e + h; M) - w_M(x, e; M)}{h}$
= $\lim_{h \to 0} \frac{0 - 0}{h} = 0$.

To check the second equality in (30), observe that the function V(x; M) is the fixed

point of the operator B defined in (16). In the limit as $x = \infty$ the operator, and therefore the fixed point, is independent of M because u(x, e; M) is independent of M (this is our premise, by condition 29). Denote the fixed point of this limiting problem by \overline{V} . Since Blackwell's theorem guarantees that the value function V(x; M) is continuous in its arguments in the supporm, it follows that:

$$\lim_{x \to \infty} V(x; M) = \overline{V},$$

which implies (30).

Proof of Proposition 2

Proof. Part 1. The lifetime payoff of a type x who exerts stationary effort level e is:

$$V(x, e; M) = u(x, e; M) + \frac{1}{(1+r)}\pi(e)V(x, e; M).$$

Isolate V(x,e;M) to get:

$$V(x, e; M) = (1+r) \frac{u(x, e; M)}{(1+r-\pi(e))}.$$

By definition of V(x,e;M), the function

$$Q(x, e; M) = \log V(x, e; M)$$

must attain its global maximum at $e^*(x; M)$. We have:

$$Q_e(x, e; M) = \frac{d}{de} \log u(x, e; M) + \left[-\frac{d}{de} \log (1 + r - \pi(e)) \right].$$

The second term is the absolute value of the elasticity of $(1 + r - \pi(e))$. If this term gets larger pointwise, then the function $Q_e(x, \cdot; M)$ shifts up pointwise, which means that the maximizer of Q(x, e; M) must increase.

Part 2. Because $\pi'(e) \equiv 0$, MMW types maximize the function

$$u(x, e; M) = M - c(x, e),$$

which is strictly concave in e (Assumption 1) and whose derivative u_e equals zero at e = 0. Therefore, their optimal effort level is zero independent of M.

For types who exert positive effort in equilibrium, their optimal effort response to M has the same sign as expression (20). The second addend in (20) vanishes because $\pi'(e) \equiv 0$ by assumption. The first addend is negative because

$$w_{eM}(x, e; M)|_{e=e^*(x;M)} = \frac{d}{de} F_W(M; x, e)|_{e=e^*(x;M)} < 0,$$
 (31)

where the first equality is expression (27), and the inequality holds because the strict MLRP implies strict stochastic dominance. The inequality in (31) must be strict because $F_W(M;x,e)|_{e=e^*(x;M)} \in (0,1)$: indeed, for any e we have $F_W(M;x,e) \geq F_W(M;x,1) > 0$ where the first inequality reflects MLRP and the second one reflects Assumption 3 (refer to expression 26); and $F_W(M;x,e)|_{e=e^*(x;M)} < 1$ because if not then $w(x,e;M)|_{e=e^*(x;M)} = M$ (again, refer to expression 26) which, since the cost of effort is strictly increasing, implies that $e^*(x;M)$ must equal zero contradicting our premise that type x exerts positive effort. Equation (31) shows that increasing M decreases the effort of any type who exerts positive effort.

Part 3. If expression (20) is positive, the desired result is established. This expression reads:

$$Q_{eM}(x,e;M)|_{e^*(x;M)} = u_{eM}(x,e) + \frac{\pi'(e)}{1+r-\pi(e)} u_M(x,e;M) \Big|_{e^*(x;M)}$$
(32)

$$\geq \min_{\eta} w_{eM}(x,\eta) + \left. \frac{\pi'(e^*)}{1 + r - \pi(e^*)} \right|_{e^*(x;M)} w_M(x,1;M). \quad (33)$$

The inequality holds because, since $w_M(x, e; M)$ is nonincreasing in e in light of (26), $u_M(x, e^*; M) = w_M(x, e^*; M) \ge w_M(x, 1; M)$. If the term involving π is large enough, expression (33) is positive because the first addend in (33) is finite (from 27 we have $w_{eM}(x, e; M) = \frac{d}{de} F_W(M; x, e)$ which is a continuous function over $e \in [0, 1]$ because

f(y;x,e) is twice continuously differentiable in e) and $w_M(x,1;M) > 0$ by Assumption 3.

Let us now construct a concave probability function $\pi(\cdot)$ such that the ratio $\pi'(e) / [1 + r - \pi(e)]$ is arbitrarily large at any level e, for suitably low r. This will conclude the proof of part 3. Define:

$$\pi(e;r) = (1+r) - \frac{C}{K} \exp(-Ke)$$

$$K = \ln\left(\frac{1+r}{r}\right)$$

$$C = K(1+r).$$

For any r > 0 the constants K and C are positive, $\pi(e; r)$ is a continuous function of e on [0,1], and $\pi(0; r) = 0$, $\pi(1; r) = 1$. Moreover, $\pi(\cdot; r)$ is increasing because $\pi_e(e; r) = C \exp(-Ke) > 0$ and concave because $\pi_{ee}(e; r) = -K\pi_e(e; r) < 0$. Finally:

$$\frac{\pi_e(e;r)}{1+r-\pi(e;r)} = K = \ln\left(\frac{1+r}{r}\right).$$

Choosing r arbitrarily small makes the ratio $\pi_{e}\left(e;r\right)/\left[1+r-\pi\left(e;r\right)\right]$ arbitrarily large independent of e, as desired.

B.2 A Family of Ordered π 's

Suppose $\pi\left(e;a\right)=a\frac{e}{e+1}$ for $e\in\left[0,1\right]$, with $a\in\left(0,2\right)$. Then $\pi'\left(e;a\right)/\left[1+r-\pi\left(e;a\right)\right]$ is increasing in a. To see this, compute:

$$\pi(e) = a \frac{e}{e+1}$$

$$\pi'(e) = a \frac{(e+1)-e}{(e+1)^2} = a \frac{1}{(e+1)^2}$$

$$\pi''(e) = -2a \frac{1}{(e+1)^3}.$$

Then:

$$\frac{\pi'(e)}{[1+r-\pi(e)]}$$

$$= a\frac{1}{(e+1)^2} \left[1+r-a\frac{e}{e+1} \right]^{-1}$$

$$= a\frac{1}{(e+1)^2} \left[\frac{(1+r)(e+1)-ae}{e+1} \right]^{-1}$$

$$= a\frac{1}{(e+1)[(1+r)(e+1)-ae]},$$

which is increasing in a.

B.3 Endogenous Monitoring

For a given M, optimal monitoring coverage solves:

$$\max_{\mu} (1 - \mu) \cdot \pi^{NM} (M) + \mu \cdot \pi^{HM} (M) - K (\mu), \qquad (34)$$

where $\pi^{NM}(M)$ and $\pi^{HM}(M)$ denote steady-state profits from the non-monitored and highly monitored divisions, respectively, and $K(\cdot)$ is a convex cost function with K'(0) = 0, that captures the cost to the firm of increasing monitoring.

Next, we leverage Lemma 2 to rank-order steady-state profits.

Assumption 4. (profits increase with effort) Fix M. For every x, Y(x, e)-w(x, e; M) is increasing in e.

This is a mild assumption. It says that if type x exerts effort, profits are greater than with no effort. If $\overline{w}(Y) = b + cY$ (the "base plus commission" wage schedule), then the resulting schedule w satisfied the assumption if c < 1.

If this assumption holds then, with no monitoring, profits are decreasing in the minimum wage. This is because increasing M worsens the wage bill and, in addition, causes fewer workers to exert effort (Lemma 2). Thus the profit term $\pi^{NM}(M)$ in expression (34) is decreasing in M.

The second profit term in expression (34) could, according to theory, be either increasing or decreasing in M. Empirically, however, expression (34) in its entirety is shown not to decrease with M, at least within the border-store sample, which is the sample used in our empirical strategy. This means that the value of the firm's maximization problem has not decreased. This is only possible if $\pi^{HM}(M)$ is increasing in M. If that's the case, then the firm's optimal μ must increase with M, as indeed it does in the data. This discussion is summarized in the following lemma.

Lemma 4. (testable prediction of minimum wage on endogenous monitoring) Suppose that Assumption 4 holds, and that store-level profits in expression (34) do not decrease as the minimum wage increases. Then optimal monitoring in the store must increase with the minimum wage.

C Online Appendix: Data

C.1 Employment Shares Calculations

Employers with more than 20,000 employees employ roughly 23% of the US workforce. We compute this figure dividing "employment in firms with more than 20,000 employees" by employment in all firms.⁵²

Employers with more than 20,000 employees employ roughly 20% of minimum wage workers. We compute this rough estimate by restricting attention to the BLS low-wage sectors that employ at least 2% of the minimum wage workforce, namely: leisure and hospitality (59.9%), education and health services (11.6%), retail trade (8.3%), manufacturing (3.4%), professional and business services (2.4%).⁵³ Together, these sectors employ 85.6% of minimum wage workers. The 2018 Census allows one to calculate the fraction of total employment accounted for by firms with more than 20,000 employees, by Census sector. This fraction equals 17% in "accommodation and food services," 20% in "health care and social assistance," 12% in "education services," 48% in "retail trade", 16% in "manufacturing", 18% in "professional, scientific, and technical services." 54 We compute the probability that a generic minimum wage worker is employed by a firm with more than 20,000 employees as follows: (1/0.856) * (0.599 * 0.17 + 0.116 * (0.20 * 20.5/24.2 +0.12 * 3.7/24.2) + 0.083 * 0.48 + 0.034 * 0.16 + 0.024 * 0.18) = 0.20 where 24.2 = 20.5 + 3.7represents the total employments in the health care and education sectors, respectively. Therefore, the probability that a minimum wage worker is employed by a very large firm is 20%.

Our US retail chain employs more than 10% of department store employees nationwide. We get this fraction by dividing the number of workers in our retail chain by the total number of workers in retail.⁵⁵

 $^{^{52}} From$ the 2018 SUSB Annual Data Tables by Establishment Industry. See file "U.S., NAICS sectors, larger employment sizes up to 20,000+ in https://www.census.gov/data/tables/2018/econ/susb/2018-susb-annual.html

⁵³See https://www.bls.gov/opub/reports/minimum-wage/2020/home.htm.

 $^{^{54}}$ See file "U.S., NAICS sectors, larger employment sizes up to 20,000+" in https://www.census.gov/data/tables/2018/econ/susb/2018-susb-annual.html.

⁵⁵See https://www.bls.gov/ooh/sales/retail-sales-workers.htm

Among US workers with comparable hourly pay to our firm's, roughly 43% have some form of variable pay. This figure is the frequency of performance-based-pay among US workers in the second-lowest quartile of hourly wages.⁵⁶ We pick this quartile because our workers' median hourly wage is \$11.15, which is comparable to, but less than \$12.8, the median hourly wage among all US workers in 2012.⁵⁷

C.2 Minimum Wage Data

Our data contain information on the geographical location of stores (latitude and longitude), which we match with the monthly statutory minimum wage level in that store, extracted from the public dataset maintained by the Washington Center for Equitable Growth. Variations in minimum wage take place at state, county, and city levels; with city and county minimum wages always set to be higher than the state minimum wage.

From February 2012 to June 2015, our sample of stores is affected by 70 variations in minimum wage: 49 variations are at the state level, and 21 are at the county or city level. The exact timing of each minimum wage change is reported in Table C.1 and presented visually in Figure C.1.

There is a notable event related to the minimum wage that is specific to California. In November 2014 our company chose to increase the base pay in its California stores to the prevailing minimum wage levels, not in response to a minimum wage increase (there was none in November 2014) but, rather, to avoid costly record-keeping requirements regarding the hour-by-hour nature of each worker's task. We account for this variation by including an interaction term for California post-November 2014 in all specifications throughout the paper. The results are qualitatively and quantitatively robust to removing the post-November 2014 data from California.

 $^{^{56}}$ Table 1, Gittleman and Pierce (2013), using a comparable definition to Lemieux et al (2012) as stated in footnote 15 in Gittleman and Pierce (2013). Higher wage quartiles have a higher incidence of performance-based pay.

⁵⁷Source: Current Population Survey, Series title: (unadj)- Median hourly earnings, Wage and salary workers paid hourly rates.

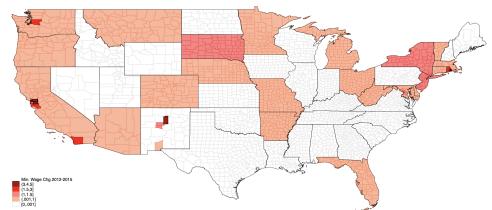


Figure C.1: Variations in Minimum Wage from February 2012 to June 2015

Notes: Store locations are withheld for confidentiality reasons.

C.3 Border Discontinuity Design

We use a border discontinuity design, as implemented in Card and Krueger (2000), Dube et al. (2010, 2016), Allegretto et al. (2013, 2017). This approach exploits minimum wage policy discontinuities at the state- or county-border by comparing workers on one side of the border where the minimum wage increased (treatment group) to workers on the other side where the minimum wage did not increase (control group). As shown in Dube et al. (2010), this research design has desirable properties for identifying minimum wage effects since workers on either side of the border are more likely to face similar economic conditions and are likely to experience similar shocks at the same time.

Following Card and Krueger (2000), Dube et al. (2010, 2016), and Allegretto et al. (2013, 2017), we restrict our sample to stores (and their respective workers) located in adjacent counties that share a border. For *state*-level minimum wage variations, we keep stores located in county pairs that: share a *state* border, and whose centroids are within 75 km of each other (see Figure C.2). For *county*-level minimum wage variations, we "seed" the sample with stores located in those counties that increased their minimum wage, and then add as controls all adjacent counties whose centroids are within 75 km of the seed county. Minimum wage changes at the *city* level are attributed only to stores within the city limits, but not to stores in the county containing that city. Such stores

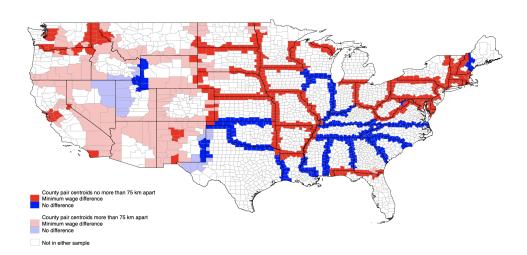


Figure C.2: Variations in the Minimum Wage in Bordering Counties

Notes: Store locations are withheld for confidentiality reasons.

are included as controls, as are stores in all neighboring counties. (In our sample there are no municipalities that lie in more than one county). For instance, for the city of San Francisco (which increased its minimum wage) we include all the counties that share a county-border with San Francisco County and whose centroids are within 75 km of its centroid (i.e., the counties of Marin, Alameda, and San Mateo).

As explained in the main text, our key specifications (10) and (11) include county-pair \times month fixed effects ϕ_{pt} . These interact 113 unique county-pair identifiers with 41 month dummies. We "stack" our data as in Dube et al. (2010, 2016), meaning that stores/workers located in a county sharing a border with n other counties appear n times in the final sample. The presence of a single county in multiple pairs along a border segment induces a mechanical correlation across county-pairs, and potentially along an entire border segment (Dube et al. 2010). This requires standard errors to be clustered both at the state level and at the border-segment level (32 states and 44 border segments).

Table C.1: Changes in Minimum Wages from February 2012 and June 2015

State	State	Date C.1	W_{t-1}	W_t	Date C.2	W_{t-1}	W_t	Date C.3	W_{t-1}	W_t	Date C.4	W_{t-1}	W_t
Alaska	AK	2015m2	$\frac{vv_{t-1}}{7.75}$	8.75	Date C.2	vv t-1	vv t	Date C.5	vv t-1	vv t	Date C.4	vv t-1	vv t
Arkansas	AR	2015 m2 2015 m1	7.75	7.5									
Arizona	AT. AZ	2013m1 2013m1	7.25	7.8	2014m1	7.8	7.9	2015m1	7.9	8.05			
Arizona California	CA	2013HI1 2014m7	7.05 8	9	20141111	1.0	1.9	20131111	1.9	6.00			
Camorma Colorado	CA				201.4m.1	770	0	2015 - 1	8	0.09			
		2013m1	7.64	7.78	2014m1	7.78	8	2015m1	8	8.23			
Connecticut	СТ	2014m1	8.25	8.7	2015m1	8.7	9.15						
DC	DC	2014m7	8.25	9.5	0015 0		0.05						
Delaware	DE	2014m6	7.25	7.75	2015m6	7.75	8.25	2015 1	7 00	0.05			
Florida	FL	2013m1	7.67	7.79	2014m1	7.79	7.93	2015m1	7.93	8.05			
Hawaii	HI	2015m1	7.25	7.75									
Massachusetts	MA	$2015\mathrm{m}1$	8	9									
Maryland	MD	$2015\mathrm{m}1$	7.25	8									
Michigan	MI	2014 m9	7.4	8.15									
Minnesota	MN	$2014 \mathrm{m}8$	7.25	8									
Missouri	MO	$2013\mathrm{m}1$	7.25	7.35	2014m1	7.35	7.5	2015m1	7.5	7.65			
Montana	MT	$2013\mathrm{m}1$	7.65	7.8	2014m1	7.8	7.9	2015m1	7.9	8.05			
Nebraska	NE	$2015\mathrm{m}1$	7.25	8									
New Jersey	NJ	2014m1	7.25	8.25	2015m1	8.25	8.38						
New York	NY	2013m12	7.25	8	2014m12	8	8.75						
Ohio	OH	$2013\mathrm{m}1$	7.7	7.85	2014m1	7.85	7.95	2015m1	7.95	8.1			
Oregon	OR	$2013{\rm m}1$	8.8	8.95	2014m1	8.95	9.1	2015m1	9.1	9.25			
Rhode Island	RI	$2013{\rm m}1$	7.4	7.75	2014m1	7.75	8	2015m1	8	9			
South Dakota	$^{\mathrm{SD}}$	$2015\mathrm{m}1$	7.25	8.5									
Vermont	VT	2014m1	8.6	8.73	2015m1	8.73	9.15						
Washington	WA	$2013{\rm m}1$	9.04	9.19	2014m1	9.19	9.32	2015m1	9.32	9.47			
West Virginia	WV	$2015\mathrm{m}1$	7.25	8									
County	State	Date C.1	W_{t-1}	W_t	Date C.2	W_{t-1}	W_t	Date C.3	W_{t-1}	W_t			
Bernalillo	NM	2013m7	7.5	8	2014m1	8	8.5	2015m1	8.5	8.65			
Johnson	IΑ	2015m11	7.25	8.2									
Montgomery	MD	2014m10	7.25	8.4									
Prince George's	MD	2014m10	7.25	8.4									
Santa Fe	NM	$2014 \mathrm{m}4$	7.5	10.66	$2015 \mathrm{m}3$	10.66	10.84						
City	State	Date C.1	W_{t-1}	W_t	Date C.2	W_{t-1}	W_t	Date C.3	W_{t-1}	W_t	Date C.4	W_{t-1}	W_t
Alburquerque	NM	2013m1	7.5	8.5	2014m1	8.5	8.6	2015m1	8.6	8.75			
Berkeley	CA	2014m10	9	10									
Las Cruces	NM	$2015\mathrm{m}1$	7.5	8.4									
Oakland	$_{\mathrm{CA}}$	$2015\mathrm{m}3$	9	12.25	2016m1	12.25	12.55						
Richmond	$_{\mathrm{CA}}$	$2015{\rm m}1$	9	9.6	2016m1	9.6	11.52						
San Diego	CA	$2015{\rm m}1$	9	9.75									
San Francisco	CA	2013 m1	10.24	10.55	2014m1	10.55	10.74	2015m1	10.74	11.05	2015 m5	11.05	12.25
San Jose	$^{\rm CA}$	2013 m3	8	10	2014m1	10	10.15	2015m1	10.15	10.3			
Santa Fe	NM	2012m3	9.5	10.29	2013m3	10.29	10.51	2014m3	10.51	10.66	2015 m3	10.66	10.84
SeaTac	WA	2012m3 2013m1	9.04	9.19	2013m3 2014m1	9.19	10.51	20171110	10.01	10.00	20 101110	10.00	10.01
Seattle	WA	2013m1 2013m1	9.04	9.19	2014m1	9.19	9.32	2015m1	9.32	9.47	2015m4	9.47	11
Sunnyvale	CA	2015m1 2015m1	9.04	10.3	20141111	J.13	∂.J∠	7019HH	∂.J∠	9.41	70 10HH4	9.41	11
		2013 m1 2013 m1		9.19	20141	9.19	0.20	20151	9.32	0.47			
Tacoma	WA		9.04		2014m1	9.19	9.32	2015m1	9.3∠	9.47			
Washington	DC	2014m7	8.25	9.5									

Notes: This table reports all state/county/city variations in statutory minimum wage from 2/1/2012 to 6/30/2015, irrespective of whether there is a store located in that state/county/city. The data are extracted from the public dataset maintained by the Washington Center for Equitable Growth. Our identification strategy effectively leverages only a sub-sample of these changes (70 out of 89), i.e., those that affect at least one store in our sample. We do not report which ones are the 70 variations we leveraged in the paper for confidentiality reasons. W_t (W_{t-1}) refers to the minimum wage level after (before) the change. The states with no change in minimum wage from February 2012 and June 2015 are: AL, GA, IA, ID, IL, IN, KS, KY, LA, ME, MS, NC, ND, NH, NM, NV, OK, PA, SC, TN, TX, UT, VA, WI, WY.

D Online Appendix: Calibration

D.1 Decomposing Store-Level Output

The effect of the minimum wage on store-level output for fixed types is

$$\sum_{x} \widetilde{g}^{M}(x) \left[Y(x, e^{*}(x; M')) - Y(x, e^{*}(x; M)) \right], \tag{35}$$

where x represents the type of a worker (low, medium or high).

From Table 3, row 1, we have the following average store-level distribution of types:

$$\widetilde{g}^{M}(x) = \begin{cases} 0.039 \text{ if } x = \text{low} \\ 0.724 \text{ if } x = \text{medium} \\ 0.237 \text{ if } x = \text{high.} \end{cases}$$

From Table 4 (column 2), we have the following increase in sales per hour for a \$1 increase in the minimum wage:

$$Y(x, e^{*}(x; M')) - Y(x, e^{*}(x; M)) = \begin{cases} 0.244 \text{ if } x = \text{low} \\ 0.159 \text{ if } x = \text{medium} \\ 0.062 \text{ if } x = \text{high.} \end{cases}$$

Plugging into formula (35) yields:

$$= 3.9\% \cdot (0.244) + 72.4\% \cdot (0.159) + 23.7\% \cdot (0.062)$$
$$= 13.933\%.$$

Next, we seek to compute how the type distribution g^M changes when M increases to M'. However, $g^{M'}$ is unobservable and our proxy, call it $\tilde{g}^{M'}(x)$ depends on the minimum wage level mechanically (see page 18 for the definition) so that, for example, even if the distribution of true types x within the store did not change, i.e., $g^M(x) = g^{M'}(x)$, our proxy type distribution would still change (i.e., $\tilde{g}^{M'}(x) \neq \tilde{g}^M(x)$ because, mechanically, there would be more types "at minimum wage"). To get around this problem, we compute

 $g^{M'}(x)$ starting from $\widetilde{g}^{M}(x)$ and using our knowledge about how the probability of termination π is affected by the minimum wage. Let's start by backing out the unobservable type distribution h(x). From Table 3, row 2, the monthly probability of termination is:

$$1 - \pi \left(e^*(x; M)\right) = \begin{cases} 0.068 \text{ if } x = \text{low} \\ 0.052 \text{ if } x = \text{medium} \\ 0.030 \text{ if } x = \text{high.} \end{cases}$$
 (36)

From equation (6) we get:

$$\lambda(M) h(x) = \tilde{g}^{M}(x) [1 - \pi(e^{*}(x; M))] = \begin{cases} 0.0027 \text{ if } x = \text{low} \\ 0.0376 \text{ if } x = \text{medium} \\ 0.0071 \text{ if } x = \text{high.} \end{cases}$$
(37)

Integrate both sides of (37) with respect to x and use the fact that $\int h(x) dx = 1$ to get:

$$\lambda\left(M\right) = \int \widetilde{g}^{M}\left(x\right) \left[1 - \pi\left(e^{*}\left(x;M\right)\right)\right] dx = 0.000474.$$

Divide (37) by $\lambda(M)$ to get:

$$h(x) = \begin{cases} 0.0569 \text{ if } x = \text{low} \\ 0.7932 \text{ if } x = \text{medium} \\ 0.1498 \text{ if } x = \text{high} \end{cases}$$
 (38)

Now, with M' = M + \$1 we get a new probability of termination for our proxy types (adding the point estimates of the effect of a \$1 minimum wage increase in Table 7 column (2) to the baseline in (36), with the caveat that the point estimates for medium and high types are not statistically significant):

$$1 - \pi (e^*(x; M')) = \begin{cases} 0.068 - 0.013 & \text{if } x = \text{low} \\ 0.052 - 0.004 & \text{if } x = \text{medium} \\ 0.030 + 0.001 & \text{if } x = \text{high} \end{cases}$$
$$= \begin{cases} 0.055 & \text{if } x = \text{low} \\ 0.048 & \text{if } x = \text{medium} \\ 0.031 & \text{if } x = \text{high} \end{cases}$$

Using (37) we get:

$$\frac{g^{M'}(x)}{\lambda(M)} = \frac{h(x)}{[1 - \pi(e^*(x; M'))]} = \begin{cases} \frac{0.0569}{0.055} & \text{if } x = \text{low} \\ \frac{0.7932}{0.048} & \text{if } x = \text{medium} \\ \frac{0.1498}{0.031} & \text{if } x = \text{high} \end{cases}$$
$$= \begin{cases} 1.03 & \text{if } x = \text{low} \\ 16.53 & \text{if } x = \text{medium} \\ 4.83 & \text{if } x = \text{high}. \end{cases}$$

Multiplying by the constant $\lambda(M)$ must yield a probability distribution. Since that probability sums to 1, it must be that $\lambda(M) = 1/(1.03 + 16.53 + 4.83) = 1/(22.39)$. Therefore,

$$g^{M'}(x) = \begin{cases} 0.0462 \text{ if } x = \text{low} \\ 0.738 \text{ if } x = \text{medium} \\ 0.2158 \text{ if } x = \text{high.} \end{cases}$$

Average productivity $Y(x, e^*(x; M))$ for low, medium and high types is, respectively, 1.08, 1.94, 2.73 (see Table 3, raw 3). Therefore, the output gain of going from $\tilde{g}^M(x)$ to $\tilde{g}^{M'}(x)$ is:

$$\sum_{x} \left[g^{M'}(x) - \widetilde{g}^{M}(x) \right] Y(x, e^{*}(x; M))$$

$$= [4.62 - 3.9] \% \cdot 1.08 + [73.8 - 72.4] \% \cdot 1.94 + [21.58 - 23.7] \% \cdot 2.73$$

$$= -2.294\%$$

D.2 Worker Welfare

We assume that the monthly discount rate is r = 0.025. This level of discounting is larger than is normally assumed in welfare analyses, but is in line with field-experimental evidence on the personal discount factor. Indeed, yearly personal discount rates are estimated at 28% in a representative sample of the Danish population (Harrison et al. 2002 p. 1612) and as large as 35% for enlisted military personnel (Warner and Pleeter 2001, p. 49).

We use Census and BLS data to compute the monthly probability of exiting unemployment, s = 0.26. This is the ratio of "hires from non-employment in a month" (2.77M)

over "total average annual unemployed between 2012-2015" (10.46M), a rough proxy of the probability of transitioning from unemployment into employment.⁵⁸

By assumption,

$$V^{A}(M) = \frac{s(M) \mathbb{E}_{h} V^{E}(x; M) + [1 - s(M)] V^{A}(M)}{(1 + r)}.$$
 (39)

Isolating $V^{A}(M)$ yields:

$$V^{A}(M) = \frac{s(M)}{r + s(M)} \mathbb{E}_{h} \left[V^{E}(x; M) \right]. \tag{40}$$

Differentiation with respect to M yields:

$$\frac{dV^{A}\left(M\right)}{dM} = \mathbb{E}_{h}\left[V^{E}\left(x;M\right)\right] \cdot \frac{d}{dM}\left[\frac{s\left(M\right)}{r+s\left(M\right)}\right] + \frac{s\left(M\right)}{r+s\left(M\right)}\mathbb{E}_{h}\left[\frac{dV^{E}\left(x;M\right)}{dM}\right]. \tag{41}$$

Expression (19) rewrites as:

$$\frac{dV^{E}(x;M)}{dM} - \frac{dV^{A}(M)}{dM} = \frac{1+r}{1+r-\pi(e)} \left[w_{M}(x,e;M) - \frac{r}{1+r} \frac{dV^{A}(M)}{dM} \right] \Big|_{e=e^{*}(x;M)},$$

where the equality follows after noting that, by definition, $V^{E}(x; M) - V^{A}(M) = V(x; M)$ and $u^{A} = [r/(1+r)] V^{A}(M)$. Isolate $dV^{E}(x; M)/dM$ to get:

$$\frac{dV^{E}(x;M)}{dM} = \frac{1+r}{1+r-\pi(e)} w_{M}(x,e;M) + \left[\frac{1-\pi(e)}{1+r-\pi(e)} \right] \frac{dV^{A}(M)}{dM} \Big|_{e=e^{*}(x;M)}.$$
 (42)

Substitute (42) into (41) and isolate $dV^A(M)/dM$ to get:

$$\frac{dV^{A}(M)}{dM} \left\{ 1 - \frac{s(M)}{r+s(M)} \mathbb{E}_{h} \left[\frac{1-\pi(e)}{1+r-\pi(e)} \right] \right\} \Big|_{e=e^{*}(x;M)}$$

$$= \mathbb{E}_{h} \left[V^{E}(x;M) \right] \cdot \frac{d}{dM} \left[\frac{s(M)}{r+s(M)} \right] + \frac{s(M)}{r+s(M)} \mathbb{E}_{h} \left[\frac{1+r}{1+r-\pi(e)} w_{M}(x,e;M) \right] \Big|_{e=e^{*}(x;M)}$$
(43)

The term in curly brackets on the LHS is positive, therefore $\frac{d}{dM}V^{A}(M)$ has the same sign as the RHS, expression (43).

⁵⁸The data for the numerator are obtained from Census, https://j2jexplorer.ces.census.gov/, and the data for the denominator from the BLS, https://data.bls.gov/cgi-bin/surveymost?bls.

We seek an upper bound for the term $\mathbb{E}_h\left[V^E\left(x;M\right)\right]$. To this end, substitute (40) into (1). We get:

$$V^{E}\left(x;M\right) = w(x,e;M) - c(x,e) + \frac{1}{(1+r)} \left[\pi\left(e\right)V^{E}\left(x;M\right) + (1-\pi\left(e\right))\frac{s\left(M\right)}{r+s\left(M\right)} \mathbb{E}_{h}\left[V^{E}\left(x;M\right)\right]\right]\Big|_{e=e^{*}\left(x;M\right)}.$$

Rearranging, we get:

$$V^{E}(x; M) [1 + r - \pi(e)] - (1 - \pi(e)) \frac{s(M)}{r + s(M)} \mathbb{E}_{h} \left[V^{E}(x; M) \right] \Big|_{e = e^{*}(x; M)}$$

$$= (1 + r) \left[w(x, e; M) - c(x, e) \right] \Big|_{e = e^{*}(x; M)}.$$

This implies that, for all x,

$$V^{E}(x; M) \min_{x} \left[1 + r - \pi(e) \right] - (1 - \pi(e)) \frac{s(M)}{r + s(M)} \mathbb{E}_{h} \left[V^{E}(x; M) \right] \Big|_{e = e^{*}(x; M)}$$

$$\leq (1 + r) \cdot w(x, e; M) \Big|_{e = e^{*}(x; M)}.$$

Taking expectations over x on both sides and then collecting terms yields:

$$\mathbb{E}_{h}\left[V^{E}(x;M)\right] \left\{ \frac{[r+s(M)]\min_{x}\left[1+r-\pi\left(e^{*}(x;M)\right)\right]-s(M)\mathbb{E}_{h}([1-\pi\left(e^{*}(x;M)\right)]\right]}{r+s(M)} \right\}$$

$$\leq (1+r)\mathbb{E}_{h}\left[w(x,e^{*}(x;M);M)\right]. \tag{44}$$

The fraction in curly brackets in (44) equals (see equation 49 below for the computations):

$$\left\{ \frac{2.779 \times 10^{-3}}{0.025 + 0.26} \right\} = 9.7509 \times 10^{-3}.$$
(45)

Because this term is positive, inequality (44) rewrites as:

$$\mathbb{E}_{h}\left[V^{E}(x;M)\right] \leq \frac{(1+r)}{9.7509 \times 10^{-3}} \mathbb{E}_{h}\left[w(x,e^{*}(x;M);M)\right]$$

$$= 105.12 \cdot \mathbb{E}_{h}\left[w(x,e^{*}(x;M);M)\right], \tag{46}$$

which is the desired upper bound.

Next, we note that

$$\frac{d}{dM}\left[\frac{s(M)}{r+s(M)}\right] = \frac{r}{\left[r+s(M)\right]^2} \frac{ds(M)}{dM}.$$
(47)

To compute $\frac{ds}{dM}$ we must proceed indirectly, because, to the best of our knowledge, direct estimates are not available in the literature. Observe that in a duration model with constant hazard of exiting unemployment s(M), average unemployment duration is 1/s(M). According to Gittings and Schmutte (2016) a \$1 increase in the minimum wage (about 15% of the minimum wage level) results in a percent increase in unemployment duration of 1.077%.⁵⁹ Therefore, after setting s(M) = 0.26 (see below for details), we get:

$$\frac{1}{s(M+1)} = (1+0.01077) \frac{1}{s(M)} = (1+0.01077) \frac{1}{0.26}.$$

Solving yields s(M+1) = 0.25723, so the effect of a \$1 minimum wage increase on the hazard of exiting unemployment is:

$$\frac{ds(M)}{dM} = \frac{s(M+1) - s(M)}{1} = 0.25723 - 0.26 = -0.00277. \tag{48}$$

Plugging (46), (47), and (48) into (43) we get:

$$\mathbb{E}_{h} \left[V^{E}(x; M) \right] \cdot \frac{r}{[r + s(M)]^{2}} \frac{ds(M)}{dM} + \frac{s(M)}{r + s(M)} \mathbb{E}_{h} \left[\frac{1 + r}{1 + r - \pi(e)} w_{M}(x, e; M) \right] \Big|_{e = e^{*}(x; M)}$$

$$\geq (105.12) \mathbb{E}_{h} \left(w(x, e; M) \right) \cdot \frac{0.025}{(0.025 + 0.26)^{2}} \left(-0.00277 \right) \Big|_{e = e^{*}(x; M)}$$

$$+ \frac{0.26}{0.025 + 0.26} \mathbb{E}_{h} \left[\frac{1 + 0.025}{1 + 0.025 - \pi(e)} w_{M}(x, e; M) \right] \Big|_{e = e^{*}(x; M)}$$

$$= (105.12) (12.023) \cdot \frac{0.025}{(0.025 + 0.26)^{2}} \left(-0.00277 \right) + \frac{0.26}{0.025 + 0.26} 9.6343$$

$$= 7.711 > 0.$$

From Gittings and Schmutte (2016), the elasticity of unemployment duration is: $\frac{\widehat{\beta}/100}{E(NS)} = \frac{0.13/100}{1.81}$, where $\widehat{\beta}$ can be found in Table 4, Panel B, column 4 and E(NS) in Table 1. The effect of a 1\$ increase in the minimum wage on unemployment duration is $15 \cdot \frac{0.13/100}{1.81} = 1.077\%$ We use Gittings and Schmutte's (2016) estimate because it is the largest statistically significant estimate in the literature, which gives the best fighting chance of the minimum wage decreasing welfare. Dube et al. (2016, Table D1) find a non-significant estimate of the elasticity.

The direction of the above inequality reflects the majorization (46) because ds(M)/dM < 0, and the expectations are computed in (50) and (51). Therefore $\frac{d}{dM}V^A(M) > 0$, as desired. Then, (42) yields $\frac{d}{dM}V^E(x;M) > 0$ for all x.

Computation of Terms From (36) and (38) we get calibrated values for $1 - \pi^*$ and h that allows us to compute:

$$\mathbb{E}_h(1-\pi^*) = 0.068 \cdot 0.0569 + 0.052 \cdot 0.7932 + 0.03 \cdot 0.1498$$
$$= 4.9610 \times 10^{-2},$$

and then using $\min_x [(1 - \pi^*)] = 0.03$, we can compute the numerator of expression (45):

$$[r + s(M)] \min_{x} [(1 + r - \pi^*)] - s(M) \mathbb{E}_h (1 - \pi^*)$$

$$= (0.025 + 0.26) (0.03 + 0.025) - 0.26 \cdot 0.0496$$

$$= 2.779 \times 10^{-3}.$$
(49)

Hence,

$$\mathbb{E}_h\left(w(x,e;M)\right) = 9.9 \cdot 0.0569 + 11.29 \cdot 0.7932 + 16.72 \cdot 0.1498$$

$$= 12.023,$$
(50)

where 9.9, 11.29 and 16.72 is the average total pay per hour of low, medium and high types, respectively.

$$\mathbb{E}_{h} \left[\frac{1}{1 - \pi(e^{*}(x; M)) + 0.025} w_{M}(x, e^{*}(x; M); M) \right]$$

$$= \frac{w_{M}(low, e^{*}(low; M); M)}{1 - \pi(e^{*}(low; M)) + 0.025} \cdot 0.0569 + \frac{w_{M}(med, e^{*}(med; M); M)}{1 - \pi(e^{*}(med; M)) + 0.025} \cdot 0.7932 + \frac{w_{M}(h, e^{*}(high; M); M)}{1 - \pi(e^{*}(high; M)) + 0.025} \cdot 0.1498$$

$$= \frac{w_{M}(low, e^{*}(low; M); M)}{0.068 + 0.025} \cdot 0.0569 + \frac{w_{M}(med, e^{*}(med; M); M)}{0.052 + 0.025} \cdot 0.7932 + \frac{w_{M}(high, e^{*}(high; M); M)}{0.03 + 0.025} \cdot 0.1498$$

$$= \frac{0.81}{0.068 + 0.025} \cdot 0.0569 + \frac{0.71}{0.052 + 0.025} \cdot 0.7932 + \frac{0.67}{0.03 + 0.025} \cdot 0.1498$$

$$= 9.6343. \tag{51}$$

where 0.81, 0.71 and 0.67 are the effects of an extra dollar of minimum wage on the total pay per hour of low, medium and high types, respectively (see Table A.1 column 2).

E Online Appendix: Threats to Identification and Robustness

E.1 Pre-Trends

Table E.1, Panel A tests for pre-trends in the 6 months preceding the minimum wage change by estimating $\eta_{3-0} - \eta_{6-3}$ from the following specification:

$$Y_{ijpt} = \alpha + \eta_{6-3}(MinW_{j,t+6} - MinW_{j,t+3}) + \eta_{3-0}(MinW_{j,t+3} - MinW_{j,t}) + \rho MinW_{j,t} + X_{it} \cdot \zeta + \eta Z_{jt} + \delta_i + \phi_{pt} + \varepsilon_{ijpt},$$
(52)

where $MinW_{j,t+m}$ is the minimum wage m months after month t and all other variables are defined as in equation (10). η_{6-3} (η_{3-0}) is a leading coefficient that captures variations in the Y-variable 6 to 3 (3 to 0) months before each change in the minimum wage. We test for the presence of pre-trends by estimating whether $\eta_{3-0} - \eta_{6-3}$ is statistically different from zero.

Table E.1, Panel B tests for pre-trends in the 12 months preceding the minimum wage change by estimating $\eta_{12-6} - \eta_{6-0}$ from the following specification:

$$Y_{ijpt} = \alpha + \eta_{12-6}(MinW_{j,t+12} - MinW_{j,t+6}) + \eta_{6-0}(MinW_{j,t+6} - MinW_{j,t}) + \rho MinW_{j,t} + X_{it} \cdot \zeta + \eta Z_{jt} + \delta_i + \phi_{pt} + \varepsilon_{ijpt},$$
(53)

(10). η_{12-6} (η_{6-0}) is a leading coefficient that captures variations in the Y-variable 12 to 6 (6 to 0) months before each change in the minimum wage.

We also present the type-interacted version of equation (52) and (53) in the bottom of Panels A and B.

E.2 Cross-border Worker Movements

See Table E.2.

E.3 Worker Selection

For the balanced-sample estimates, see Tables E.3 and E.4.

Next, we turn to estimating bounds for the selection bias. The average productivity in a

worker population is:

$$Avg\ prod = \int Y\left(e^{*}(x; M), x\right)g^{M}(x) dx,$$

where g^M represents the type distribution for a given level of the minimum wage. Our empirical estimates capture the *total* change in the average worker's productivity, that is:

$$\frac{dAvg\ prod}{dM} = \int \left[\frac{dY\left(e^{*}(x;M),x\right)}{dM} g^{M}\left(x\right) + Y\left(e^{*}(x;M),x\right) \frac{dg^{M}\left(x\right)}{dM} \right] dx$$

$$= \int \frac{dY\left(e^{*}(x;M),x\right)}{dM} g^{M}\left(x\right) dx + \int Y\left(e^{*}(x;M),x\right) \frac{dg^{M}\left(x\right)}{dM} dx.$$

The total change in the average worker's productivity (left hand side) is the sum of two changes. The first term in the right hand side represents the portion of the productivity change that is due only to the individual worker's productivity reponse. The second term captures the portion of the productivity change due to the change in the composition of the worker population. The latter term represents a potential selection bias, which equals:

$$\int Y(e^{*}(x;M),x) \frac{dg^{M}(x)}{dM} dx
= \int Y(e^{*}(x;M),x) \left[\frac{dg^{M}(x)}{dM} \right]^{+} + Y(e^{*}(x;M),x) \left[\frac{dg^{M}(x)}{dM} \right]^{-} dx
\leq \int \max_{x} Y(e^{*}(x;M),x) \left[\frac{dg^{M}(x)}{dM} \right]^{+} + \min_{x} Y(e^{*}(x;M),x) \left[\frac{dg^{M}(x)}{dM} \right]^{-} dx
= \int \max_{x} Y(e^{*}(x;M),x) \left[\frac{dg^{M}(x)}{dM} \right]^{+} dx - \min_{x} Y(e^{*}(x;M),x) (-1) \left[\frac{dg^{M}(x)}{dM} \right]^{-} dx
= \max_{x} Y(e^{*}(x;M),x) \int \left[\frac{dg^{M}(x)}{dM} \right]^{+} dx - \min_{x} Y(e^{*}(x;M),x) \int (-1) \left[\frac{dg^{M}(x)}{dM} \right]^{-} dx
= \max_{x} Y(e^{*}(x;M),x) \int \left[\frac{dg^{M}(x)}{dM} \right]^{+} dx - \min_{x} Y(e^{*}(x;M),x) \int \left[\frac{dg^{M}(x)}{dM} \right]^{+} dx \quad (54)
= \left[\max_{x} Y(e^{*}(x;M),x) - \min_{x} Y(e^{*}(x;M),x) \right] \cdot \int \left[\frac{dg^{M}(x)}{dM} \right]^{+} dx, \quad (55)$$

where

$$\left[\frac{dg^{M}(x)}{dM}\right]^{+} = \max\left[\frac{dg^{M}(x)}{dM}, 0\right]$$

$$\left[\frac{dg^{M}(x)}{dM}\right]^{-} = \min\left[\frac{dg^{M}(x)}{dM}, 0\right]$$

represent the positive and negative parts of $\frac{dg^M(x)}{dM}$, respectively, and the equal sign in (54) makes

use of the identity:

$$\int \left[\frac{dg^{M}\left(x\right) }{dM}\right] ^{+}dx=-\int \left[\frac{dg^{M}\left(x\right) }{dM}\right] ^{-}dx,$$

which holds because, since $\int g^{M}(x) dx = 1$ irrespective of M,

$$0 = \int \frac{dg^{M}(x)}{dM} dx = \int \left(\left[\frac{dg^{M}(x)}{dM} \right]^{+} + \left[\frac{dg^{M}(x)}{dM} \right]^{-} \right) dx.$$

The term $\int \left[\frac{dg^M(x)}{dM}\right]^+ dx$ represents the fraction of employees whose type is more numerous because of the increase in the minimum wage. This fraction can be no greater than the absolute value of the change in the fraction of workers hired (or, in steady state, terminated) because of the increase in the minimum wage. The latter is the change in the retention rate due to the minimum wage increase.

Therefore, the selection bias can be bounded above by the following term (corresponding to expression 55):

$$(Y_{\text{max}} - Y_{\text{min}}) \cdot \frac{dR}{dM}$$
= $(3.522 - 0.781) \cdot 0.00159 = 4.3582 \times 10^{-3}$

where we have used the highest (resp., lowest) productivity decile to proxy for Y_{max} and Y_{min} (refer to Table 1) and the change in retention rate (dR/dM) is proxied for by the coefficient for "MinW" in Table 7 column 1 divided by 100. We conclude that the selection bias on our headline estimate of 0.094 (effect of minimum wage on average worker productivity) cannot exceed 0.004358.

We repeat this computation for the subpopulation of low types. Within this subpopulation, we compute that the highest (resp., lowest) productivity decile equal 1.832 and 0.301. We set (dR/dM) = 0.01297 (from Table 7 column 2). The upper bound for the selection bias equals

$$(1.832 - 0.301) \cdot 0.01297 = 1.9857 \times 10^{-2},$$

which is relative to a headline estimate (effect of minimum wage on the low types' productivity) of 0.244.

E.4 Alternative Classifications of Low, Medium and High Types

In Section 4, we defined low, medium, or high types as those whose total pay in month t-1 is "at minimum wage," between the minimum wage and 180% of the minimum wage, and above

180% of the minimum wage (about equal to the top quartile), respectively. We now assess the robustness of our results to alternative classifications.

Using the 180% threshold, Table E.5 column 1 defines low, medium and high types in the control county using the same percentile as in the treated county of the same county-pair. To illustrate the approach, imagine a treated county with a higher minimum wage than in the control county of the same county-pair. Moreover, imagine that in the treated county 5% of the workers are categorized as low-types (paid minimum wage) and 70% as medium-types. The approach consists in defining control workers as low types if their total pay is in the bottom 5% of the pay distribution in that county, medium types if their pay is in the 5% to 75% percentile, and high types if the pay is above the 75% percentile. The results are very robust.

Using the 180% threshold, Table E.5 column 2 divides workers into low, medium, or high types based on their average pay in the *three months* before a minimum wage change (t-1, t-2 and t-3) rather than on the past month only. Table E.5 column 3 follows a similar approach but divides workers based on their maximum pay in the *three months* before a minimum wage change. This reduces the likelihood of mis-categorizing a high type as a low one due to surprisingly low demand in t-1, but also shrinks the sample size. Similarly, Table E.5 column 4 divides workers into low-medium-high types based on their pay in the *first* month on the job.

Table E.5 column 5 divides workers in low-medium-high types using their performance (sales per hour) during the first quarter on the job. To do so, we estimate workers' fixed effects based on their sales per hour in the first quarter and we use that to then divide workers into terciles. This latter classification has the advantage of better isolating permanent unobserved heterogeneity from state dependence or mean-reverting shocks, but it has the disadvantage of being time-invariant and does not allow us to quantify level effects in our specification with worker fixed effects. Reassuringly, the findings paint the same picture regardless of the classification method: the low types become significantly more productive, while the high types do not become more productive when minimum wage increases.

Table E.6 presents the results with alternative thresholds: 120%, 140%, or 160% (rather than 180%). Notice that as the threshold increases (i.e., from 120% to 180%), the mass of low types remains unchanged but the top category of high types becomes thinner and more outstanding. In this sense, the highest the threshold, the most "productive" is the top category and the least affected this category should be by the minimum wage increase. Consistent with this, we find that the performance effect on the top category of workers vanishes as the threshold increases, achieving

⁶⁰We define low types as those whose average (or maximum) pay per hour in the past three months equal to the minimum wage, while medium (high) types are defined as those whose average (or maximum) pay per hour in the past three months is below (above) 180% of the minimum wage.

a precisely estimated zero at the highest (180%) threshold.⁶¹ In contrast, the performance of low types is found to increase by 19% - 23% regardless of the threshold; while the performance of medium types increases by 7% - 9%.

E.5 Alternative Research Designs

See Table E.7.

E.6 State vs. Local Variation in the Minimum Wage

See Table E.8.

E.7 Alternative Definitions of "Bordering Stores"

We show that our results are robust to changing the definition of a "bordering" store. In our main estimates, we follow the existing literature by restricting the sample to all stores located in counties that: (a) share a border and (b) whose centroids are less than 75 km apart (Card and Krueger 1994, Dube et al. 2010, Allegretto et al. 2013). In Table E.9, we check the robustness of our results to restricting our sample to a subset of stores: those stores whose distance from the border is less than 75 km, less than 37.5 km, and less than 18.75 km. The rationale behind this test is that by narrowing down the definition of "bordering" store in our main sample, we lose a few observations but we increase the comparability of treated and control stores around the borders. Reassuringly, our results are broadly consistent across these samples.

E.8 Robustness to "Unstacking"

In Table E.10 we show that our results are robust to an experimental approach that considers each of the 44 unique border-segments as an "experimental event" with a treated and a control county each. The effect of minimum wage is estimated in a regression model similar to equation (11) but without stacking the data – and the in a smaller sample – with experimental event × month (border-segment × month) fixed effects and standard errors clustered at the experimental event (border-segment) level.

 $^{^{61}}$ Mean reversion is an unlikely explanation for this phenomenon because the estimated coefficient for "high type" is consistently positive, not negative.

E.9 Alternative Controls

Table E.11 columns 1-2 show that the results are robust to extending our main equation (11) to also include $department \cdot store$ time-trends (i.e., unique department ID \cdot time), in order to account for potential differential trends across departments of a given store. We do so because one may be concerned that a higher minimum wage induces demand/price changes that are confined into departments that exclude the most performing salespeople, thus potentially confounding the heterogeneous performance effects identified in the paper. We attenuate this concern by showing that our findings are unaffected by the inclusion of department-specific trends.

The results are also robust to running our main specification department-by-department (Table E.12).

Finally, the results are also robust to removing worker tenure and unemployment. This is reassuring as one might worry that these are "bad controls" directly affected by the minimum wage increase. Refer to Table E.11 columns 3-4.

Table E.1: Test of Pre-Trends in Worker Productivity with Border-Discontinuity and State-Level Specifications

Dep.Var. Sample	Sales/Hrs Border Stores	Sales/Hrs All Stores	Sales/Hrs All Stores	Sales/Hrs All Stores			
Model	Pair·Month FE (1)	Month FE (2)	Month FE+State-Tr. (3)	Division·Month FE (4)			
		Panel A	A: 6-Months Pre-Trend				
Uninteracted Model							
Pre-Trend (6 Months)	-0.126	-0.089**	-0.081**	-0.021			
	(0.095)	(0.037)	(0.036)	(0.040)			
Observations	149,642	276,825	276,825	276,825			
Interacted Model							
Pre-Trend (6 Months)	-0.035	0.127	0.132	0.190			
	(0.108)	(0.119)	(0.119)	(0.123)			
Pre-Trend · Medium Type	-0.064	-0.228	-0.226	-0.230*			
	(0.087)	(0.141)	(0.141)	(0.131)			
$\operatorname{Pre-Trend} \cdot \operatorname{High} \operatorname{Type}$	-0.003	-0.151	-0.151	-0.150			
	(0.112)	(0.174)	(0.173)	(0.162)			
Observations	$144,\!298$	266,702	266,702	266,702			
	Panel B: 12-Months Pre-Trend						
Uninteracted Model							
Pre-Trend (12 Months)	0.029	-0.038	-0.027	0.036			
,	(0.069)	(0.046)	(0.041)	(0.030)			
Observations	111,057	201,106	201,106	201,106			
Interacted Model							
Pre-Trend (12 Months)	-0.013	0.132	0.139	0.164*			
	(0.126)	(0.115)	(0.105)	(0.086)			
$\operatorname{Pre-Trend} \cdot \operatorname{Medium} \operatorname{Type}$	0.083	-0.120	-0.125	-0.101			
	(0.116)	(0.090)	(0.090)	(0.085)			
$\operatorname{Pre-Trend} \cdot \operatorname{High} \operatorname{Type}$	0.028	-0.232***	-0.238***	-0.200***			
	(0.068)	(0.065)	(0.064)	(0.061)			
Observations	106,981	193,434	193,434	193,434			
Units	Workers	$\mathbf{Workers}$	Workers	Workers			

Notes: In Panel A, $Pre-Trend = \eta_{3-0} - \eta_{6-3}$ estimated from equation (52). In Panel B, $Pre-Trend = \eta_{6-0} - \eta_{12-6}$ estimated from equation (53). We also present the type-interacted version of equation (52) and (53) in the bottom of Panels A and B. In columns 1 (3-4) pre-trends are tested in the sample of bordering stores (bordering+non-bordering stores). All regressions include worker fixed effects, and control for worker tenure, worker department and for county unemployment rate. The regressions vary in the time controls: we include pair-month fixed effects in column 1, month fixed effects in column 2, month fixed effects and state-specific linear trends in column 3, census division month fixed effects in column 4. Standard errors are two-way clustered at the state level and at the border-segment level in column 1 and at the state-level in columns 3-4. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table E.2: Effect of Minimum Wage on Work-to-Home Distance

Dep.Var.	Distance	Distance	Distance
Sample of Workers	New hires	All	All
	(1)	(2)	(3)
MinW	-0.309	0.409	0.052
	(0.909)	(0.573)	(0.653)
Medium Type			-0.012
			(0.416)
High Type			0.482
			(0.510)
MinW · Medium Type			0.442
			(0.441)
MinW · High Type			0.138
			(0.432)
Observations	10,783	$212,\!509$	204,761
Units	Stores	Workers	Workers
Mean Dep.Var.	9.666	9.779	9.779
Effect MinW (%)	-3.201	4.186	
Effect MinW for Low Type (%)			0.557
p-value			0.937
Effect MinW for Med. Type (%)			5.126
p-value			0.392
Effect MinW for High Type (%)			1.837
p-value			0.764

Notes: All the regressions include pair-month fixed effects, store fixed effects, and control for county-level unemployment. Columns 2 and 3 also include worker fixed effects, tenure and worker departments. Column 1 restricts the sample to the newly hired workers in the month in which they are hired in a given store. Distance is the distance between the worker's home and the store in which he/she works in a given month. MinW is the predominant monthly minimum wage (in \$). MinW is in deviation from its sample mean in column 3. Medium Type is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. High Type is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group (Low Types) are workers for whom total pay in t-1 is "at minimum wage." Effect MinW (%) is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table E.3: Test of Pre-Trends in Worker Productivity for Balanced vs. Not Balanced Sample

Dep.Var.	Sales/Hrs	Sales/Hrs
	(1)	(2)
	0.100	
Pre-Trend (6 Months)	-0.128	
	(0.091)	
Pre-Trend (6 Months) \cdot Balanced Sample	-0.016	
	(0.052)	
Pre-Trend (12 Months)		0.043
		(0.077)
Pre-Trend (12 Months) · Balanced Sample		-0.055
, <u> </u>		(0.046)
Observations	149,615	111,035
Units	Workers	Workers

Notes: See equation (52) and (53) for details on the underlying empirical specification, which we further interact with "Balanced Sample." All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department and county-level employment. Balanced Sample is a time-invariant indicator for whether the worker is observed throughout the entire sample period. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1.

Table E.4: Effect of Minimum Wage on Worker Productivity with Balanced Sample

Dep.Var.	m Sales/Hrs	$\overline{ m Sales/Hrs}$
\mathbf{Sample}	$\operatorname{Balanced}$	$\operatorname{Balanced}$
	(1)	(2)
MinW	0.137*	0.264*
	(0.0675)	(0.135)
Medium Type		0.413***
		(0.086)
High Type		1.317***
		(0.114)
$\operatorname{MinW} \cdot \operatorname{Medium} \operatorname{Type}$		-0.060
		(0.083)
$\operatorname{MinW} \cdot \operatorname{High} \operatorname{Type}$		-0.168**
		(0.080)
Observations	$32,\!224$	$31,\!439$
Units	Workers	$\operatorname{Workers}$
Mean Dep.Var.	2.093	2.096
Effect MinW (%)	6.524	
Effect MinW for Low Type (%)		32.46
p-value		0.063
Effect MinW for Med. Type (%)		10.54
p-value		0.009
Effect MinW for High Type (%)		3.734
p-value		0.305

Notes: The sample is restricted to workers who we observe throughout the entire sample period (i.e., balanced sample). All the regressions include pairmonth fixed effects, worker fixed effects, and control for worker tenure, worker department and county-level employment. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. MinW is the predominant monthly minimum wage (in \$). MinW is in deviation from its sample mean in even columns. $Medium\ Type$ is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. $High\ Type$ is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group ($Low\ Types$) are workers for whom total pay in t-1 is "at minimum wage." $Effect\ MinW\ (\%)$ is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table E.5: Effect of Minimum Wage on Worker Productivity with Alternative Classifications of Low, Medium and High Types

Dep.Var.	Sales/Hrs	Sales/Hrs	Sales/Hrs	m Sales/Hrs	$\overline{ m Sales/Hrs}$
"Type" Definition	Tot Pay in	Avg pay	Max pay	Pay in	Sales/Hrs in
	t-1	from $t=-1,-3$	from $t=-1,-3$	1st month	1st Q. (FE)
	(1)	(2)	(3)	(4)	(5)
MinW	0.210***	0.131**	0.174***	0.168***	0.178***
	(0.040)	(0.048)	(0.048)	(0.033)	(0.045)
Medium Type	0.316***	0.247***	0.309***		
	(0.031)	(0.028)	(0.058)		
High Type	0.974***	0.745***	0.759***		
	(0.074)	(0.029)	(0.055)		
$\operatorname{Min} \cdot \operatorname{Medium} \operatorname{Type}$	-0.076***	-0.077*	-0.071*	-0.104***	-0.113**
	(0.020)	(0.040)	(0.041)	(0.023)	(0.044)
Min · High Type	-0.109***	-0.133***	-0.181***	-0.028	-0.121***
	(0.037)	(0.043)	(0.043)	(0.070)	(0.026)
Obganyations	200 550	104 107	107 107	200 512	216 444
Observations	209,559	184,107	184,107	209,513	216,444
Units	Workers	Workers	Workers	Workers	Workers
Mean Dep.Var.	2.085	2.085	2.085	2.092	2.085
Effect MinW for Low Type (%)	19.42	11.85	16.45	9.709	16.50
p-value	0.009	0.011	0.009	0.009	0.009
Effect MinW for Med. Type (%)	6.625	2.827	5.552	3.030	4.395
p-value	0.009	0.068	0.009	0.057	0.152
Effect MinW for High Type (%)	3.662	-0.061	-0.280	6.483	2.449
p-value	0.034	0.967	0.884	0.043	0.220

Notes: All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department and county-level employment. In column 1, we constrain the fraction of low, medium and high types to be comparable in the treatment and control county-pairs. In column 2, Medium Type (High Type) is an indicator for whether the worker's average pay in the three months before the minimum wage change is between the minimum wage and 180% of minimum wage (above 180% of minimum wage). In column 3, Medium Type (High Type) is an indicator for whether the worker's maximum pay in the three months before the minimum wage change is between the minimum wage and 180% of minimum wage (above 180% of minimum wage). In column 4, Medium Type (High Type) is an indicator for whether the worker's total pay in the first month in which she appears in our dataset is between the minimum wage and 180% of minimum wage (above 180% of minimum wage). In column 5, Medium Type (High Type) is an indicator for whether the worker's performance in the first quarter in which he/she appears in the dataset is in the second (third) tercile of the performance distribution based on the estimated worker fixed effects. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. MinWis the monthly predominant minimum wage (in \$). Min W is the predominant monthly minimum wage (in \$) and it is in deviation from its sample mean. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value < 0.01.

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Table E.6: Effect of Minimum Wage on Worker Productivity with Alternative Classifications of Low, Medium and High Types (Continued)

Dep.Var.	Sales/Hrs	m Sales/Hrs	Sales/Hrs	Sales/Hrs
Threshold	120%	140%	160%	180%
				$main\ spec.$
	(1)	(2)	(3)	(4)
MinW	0.209***	0.228***	0.234***	0.244***
	(0.035)	(0.035)	(0.035)	(0.042)
Medium Type	0.230***	0.283***	0.326***	0.354***
	(0.028)	(0.030)	(0.032)	(0.032)
High Type	0.625***	0.870***	1.051***	1.169***
	(0.043)	(0.055)	(0.068)	(0.072)
$\operatorname{MinW} \cdot \operatorname{Medium} \operatorname{Type}$	-0.099***	-0.076***	-0.075***	-0.085***
	(0.026)	(0.026)	(0.025)	(0.025)
MinW · High Type	-0.056***	-0.079***	-0.130***	-0.182***
	(0.016)	(0.021)	(0.029)	(0.032)
Observations	209,513	209,513	209,513	209,513
Units	Workers	Workers	Workers	Workers
Mean Dep.Var.	2.085	2.085	2.085	2.085
Effect MinW for Low Type (%)	19.33	21.13	21.67	22.56
p-value	0.009	0.009	0.009	0.009
Effect MinW for Med. Type (%)	7.424	9.021	8.673	8.186
p-value	0.009	0.009	0.009	0.009
Effect MinW for High Type (%)	6.622	5.963	3.944	2.273
p-value	0.009	0.009	0.009	0.179

Notes: All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department and county-level employment. Medium Types is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and X% of minimum wage, where X is 120 in column 1, 140 in column 2, 160 in column 3 and 180 in column 4. (column 4 is equivalent to our main specification). High Types is an indicator for whether the worker's total pay in month t-1 is above X% of minimum wage. As the threshold increases (i.e., from 120% to 180%), the mass of low types remains unchanged but the top category of high types becomes thinner and more outstanding. High types represent 75% of the workforce with the 120% threshold, 52% with the 140% threshold, 35% with the 160% threshold and 25% with the 180% threshold. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. MinW is the predominant monthly minimum wage (in \$), and it is in deviations from its sample mean. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table E.7: Effect of Minimum Wage on Worker Productivity with State-Level Specification

D. V	C 1 /TT	C 1 /II
${ m Dep.Var.}$	$\mathrm{Sales}/\mathrm{Hrs}$	$\mathrm{Sales}/\mathrm{Hrs}$
Sample	All stores	All stores
	(1)	(2)
MinW	0.038	0.175***
	(0.031)	(0.030)
Medium Type		0.293***
		(0.032)
High Type		1.140***
		(0.055)
$MinW \cdot Medium Type$		-0.059***
		(0.021)
MinW · High Type		-0.151***
		(0.029)
Observations	416,439	399,100
Units	Workers	Workers
Mean Dep.Var.	2.196	2.196
Effect MinW (%)	1.753	
Effect for Low (%		16.57
p-value		0.009
Effect for Med. (%)		5.703
p-value		0.009
Effect for High $(\%)$		0.804
p-value		0.526

Notes: The sample comprises of all stores (bordering + non-bordering). All the regressions include census division \cdot month fixed effects, worker fixed effects, month fixed effects, and control for worker tenure, worker department and county-level unemployment. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. MinW is the predominant monthly minimum wage (in \$). MinW is in deviation from its sample mean in even columns. $Medium\ Type$ is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. $High\ Type$ is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group ($Low\ Types$) are workers for whom total pay in t-1 is "at minimum wage." $Effect\ MinW\ (\%)$ is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are clustered at the state level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table E.8: Effect of Minimum Wage on Worker Productivity with State and Local Variations in the Minimum Wage

Dep.Var.	Sales/Hrs	Sales/Hrs	Sales/Hrs	$\overline{ m Sales/Hrs}$
MinW Variations	State	State	Local	Local
	(1)	(2)	(3)	(4)
MinW	0.100	0.271***	0.102	0.195***
	(0.066)	(0.076)	(0.071)	(0.052)
Medium Type		0.350***		0.339***
		(0.024)		(0.029)
High Type		1.163***		1.192***
		(0.051)		(0.047)
MinW · Medium Type		-0.096***		-0.099***
		(0.028)		(0.025)
MinW · High Type		-0.212***		-0.168***
		(0.028)		(0.050)
Observations	212,916	204,641	192,663	184,638
Units	$\widetilde{\mathrm{Workers}}$	$\widetilde{\mathrm{Workers}}$	$\widetilde{\mathrm{Workers}}$	Workers
Mean Dep.Var.	2.088	2.088	2.253	2.253
Effect MinW (%)	4.810		4.533	
Effect MinW for Low Type (%)		25.39		19.85
p-value		0.009		0.009
Effect MinW for Med. Type (%)		9.003		4.657
p-value		0.016		0.032
Effect MinW for High Type (%)		2.150		0.905
p-value		0.435		0.610

Notes: All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department and county-level employment. Columns 1-2 leverage state-level minimum wage variations only. Columns 3-4 leverage within-state (county or city) minimum wage level variations. Refer to Table C.1 for the list of minimum wage variations in our sample. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. MinW is the monthly predominant minimum wage (in \$). MinW is in deviation from its sample mean in even columns. $Medium\ Type$ is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. $High\ Type$ is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group ($Low\ Types$) are workers for whom total pay in t-1 is "at minimum wage." $Effect\ MinW\ (\%)$ is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. **** p<0.01, *** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table E.9: Effect of Minimum Wage on Worker Productivity with Alternative Definitions of "Bordering Stores"

Dep. Var.	Sales/Hrs	Sales/Hrs	Sales/Hrs	Sales/Hrs	Sales/Hrs	m Sales/Hrs
Distance Store Border	$75\mathrm{km}$	$75 \mathrm{km}$	$37.5\mathrm{km}$	$37.5\mathrm{km}$	$18.75 \mathrm{km}$	$18.75\mathrm{km}$
	(1)	(2)	(3)	(4)	(5)	(6)
MinW	0.094**	0.244***	0.098**	0.255***	0.088**	0.261***
	(0.039)	(0.042)	(0.038)	(0.042)	(0.042)	(0.049)
Medium Type		0.354***		0.359***		0.370***
		(0.032)		(0.033)		(0.041)
High Type		1.169***		1.171***		1.173***
		(0.072)		(0.073)		(0.082)
$\operatorname{MinW} \cdot \operatorname{Medium} \operatorname{Type}$		-0.085***		-0.091***		-0.108***
		(0.025)		(0.027)		(0.039)
MinW · High Type		-0.182***		-0.192***		-0.199***
		(0.032)		(0.034)		(0.042)
Observations	217,822	209,513	208,451	200,506	159,352	153,329
Units	Wrk	Wrk	Wrk	Wrk	Wrk	Wrk
Mean Dep.Var.	2.085	2.085	2.089	2.089	2.077	2.077
Effect MinW (%)	4.485		4.701		4.234	
Effect for Low Type (%)		22.56		23.69		23.68
p-value		0.009		0.009		0.009
Effect for Med. Type (%)		8.186		8.476		7.981
p-value		0.009		0.009		0.009
Effect for High Type (%)		2.273		2.339		2.269
p-value		0.179		0.158		0.171

Notes: All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department and county-level employment. Columns 1-2 (3-4) [5-6] restrict the sample to stores within 75 km (37.5 km) [18.75 km] from the border. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. MinW is the predominant monthly minimum wage (in \$). MinW is in deviation from its sample mean in even columns. $Medium\ Type$ is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. $High\ Type$ is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group ($Low\ Types$) are workers for whom total pay in t-1 is "at minimum wage." $Effect\ MinW\ (\%)$ is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table E.10: Effect of Minimum Wage on Worker Productivity without "Stacking" the Data (Experimental Event Approach)

Dep.Var.	Sales/Hrs	Sales/Hrs
1	(1)	(2)
MinW	0.112**	0.221***
	(0.051)	(0.063)
Medium Type		0.314***
		(0.029)
High Type		1.159***
		(0.051)
$MinW \cdot Medium Type$		-0.049
		(0.031)
$\operatorname{MinW} \cdot \operatorname{High} \operatorname{Type}$		-0.152***
		(0.032)
Observations	128,958	123,745
Units	Workers	Workers
Mean Dep.Var.	2.094	2.094
Effect MinW (%)	5.365	
Effect MinW for Low Type (%)		19.83
p-value		0.009
Effect MinW for Med. Type (%)		8.773
p-value		0.009
Effect MinW for High Type (%)		2.485
p-value		0.165

Notes: The sample comprises of bordering stores without stacking the data. All the regressions include worker fixed effects, border-segment-month fixed effects, and control for worker tenure, worker department and county-level unemployment. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. MinW is the predominant monthly minimum wage (in \$). MinW is in deviation from its sample mean in even columns. $Medium\ Type$ is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. $High\ Type$ is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group ($Low\ Types$) are workers for whom total pay in t-1 is "at minimum wage." $Effect\ MinW\ (\%)$ is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are clustered at the border-segment level. **** p<0.01, *** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table E.11: Effect of Minimum Wage on Worker Productivity with Alternative Controls

Dep.Var.	m Sales/Hrs	$\mathrm{Sales}/\mathrm{Hrs}$	$\mathrm{Sales}/\mathrm{Hrs}$	$\mathrm{Sales}/\mathrm{Hrs}$
Controls	${ m DeptTrends}$	${ m DeptTrends}$	No Tenure&UR	No Tenure&UR
	(1)	(2)	(3)	(4)
MinW	0.121*	0.271***	0.094**	0.244***
	(0.063)	(0.064)	(0.038)	(0.042)
Medium Type	,	0.349***	,	0.354***
<i>J</i> 1		(0.033)		(0.032)
High Type		1.159***		1.169***
3 71		(0.071)		(0.072)
MinW · Medium Type		-0.085**		-0.085***
0.1		(0.032)		(0.025)
MinW · High Type		-0.187***		-0.182***
0 71		(0.033)		(0.032)
Observations	217,822	209,513	217,822	209,513
Units	$\overline{\text{Workers}}$	Workers	Workers	Workers
Mean Dep.Var.	2.085	2.085	2.085	2.085
Effect MinW (%)	5.788		4.526	
Effect for Low Type (%)		25.06		22.56
p-value		0.009		0.009
Effect for Med. Type (%)		9.566		8.186
p-value		0.009		0.009
Effect for High Type (%)		3.074		2.273
p-value		0.236		0.179

Notes: All the regressions control for pair-month fixed effects, worker fixed effects, worker department. Columns 1 and 2 also controls for worker tenure, unemployment rate, and department-store specific time-trends (unique department ID · time-trend). Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. MinW is the predominant monthly minimum wage (in \$). MinW is in deviation from its sample mean in even columns. Medium Type is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. High Type is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group (Low Types) are workers for whom total pay in t-1 is "at minimum wage." Effect MinW (%) is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table E.12: Effect of Minimum Wage on Worker Productivity by Department

Dep.Var.	Sales/Hrs	Sales/Hrs	m Sales/Hrs	Sales/Hrs
Department	$\operatorname{Dpt} 1$	Dpt 2	Dpt 3	Dpt 4
-	(1)	(2)	(3)	(4)
MinW	0.395***	0.259*	0.139	0.726
	(0.104)	(0.139)	(0.092)	(0.586)
Medium Type	0.513***	0.388***	0.306***	0.365***
	(0.109)	(0.047)	(0.062)	(0.128)
High Types	1.354***	1.015***	0.743***	1.321***
	(0.160)	(0.062)	(0.077)	(0.197)
MinW · Medium Type	-0.238***	-0.161***	-0.145*	-0.073
	(0.080)	(0.041)	(0.084)	(0.134)
MinW · High Type	-0.208***	-0.259***	-0.087	0.298
	(0.063)	(0.072)	(0.110)	(0.234)
Observations	72,616	48,062	36,107	19,793
Units	Workers	Workers	Workers	Workers
Mean Dep.Var.	2.587	2.123	1.595	2.639
Effect MinW for Low Type (%)	27.19	24.90	15.32	44.75
p-value	0.009	0.0719	0.146	0.226
Effect MinW for Med. Type (%)	6.462	5.559	-0.499	25.85
p-value	0.009	0.474	0.924	0.248
Effect MinW for High Type (%)	4.768	-0.007	2.748	22.78
p-value	0.027	0.999	0.449	0.112

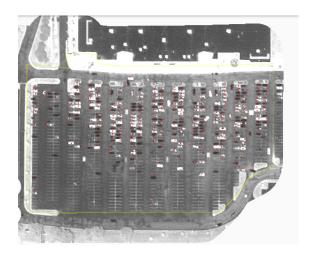
Notes: This specification isolates the four largest departments, making up approximately 90% of the observations. The remaining observations are split among eight small departments, not reported here. All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, and county-level unemployment. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. MinW is the predominant monthly minimum wage (in \$), and it is in deviation from its sample mean. $Medium\ Type$ is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. $High\ Type$ is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group ($Low\ Types$) are workers for whom total pay in t-1 is "at minimum wage." $Effect\ MinW\ (\%)$ is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

F Online Appendix: Alternative Explanations

F.1 Demand Channel

We start by checking directly for demand shifts caused by changes in the minimum wage. To do so, we introduce parking lot occupancy as a proxy for demand (see Figure F.1 for an example of the satellite pictures from which the data are coded). These data have been used by financial traders to forecast revenues for nationwide retailers, ⁶² and they are suitable for our purposes because they capture *customer volume*, which is exogenous to worker effort, as opposed to *quantity purchased* which is not. ⁶³

Figure F.1: Satellite Image of One Store with Parking Lot Area and Car Counts Highlighted



Notes: Data © 2018 RS Metrics; Imagery © (CNES) 2018; Distribution Airbus DS Imagery © 2018 DigitalGlobe

Each satellite image is digitized using a machine learning and computer vision algorithm which (1) identifies parking lot areas around each store, (2) counts the number of parking spaces in the parking lot, and (3) counts the number of cars parked. We aggregate these high-frequency satellite data at the store-month level and create a store-specific monthly measure of parking occupancy, i.e., the average proportion of parking spaces that are filled in a given store and a

 $^{^{62}}page~49,~J.page~Morgan's~Guide~to~Big~Data~and~AI~Strategies. Published on May 29, 2017$ https://www.cfasociety.org/cleveland/Lists/Events%20Calendar/Attachments/1045/BIG-Data~AI-JPMmay2017.pdf

⁶³However, a limitation is that we have no specific visibility on spending per shopper. This might be problematic if there are distributional effects of the minimum wage such that the number of shoppers does not change but spending per shopper increases.

given month.⁶⁴ In our sample, the average parking lot holds 125 cars and the average occupancy rate is 23%.⁶⁵

To validate our proxy for store-level demand, we start by showing that it is highly co-moves with store output. Table F.1 column 1 shows that a one-unit increase in occupancy rate is associated with a statistically significant 12% increase in store output. Figure F.2 moreover shows that the two variables co-move over time with peaks around holiday seasons.

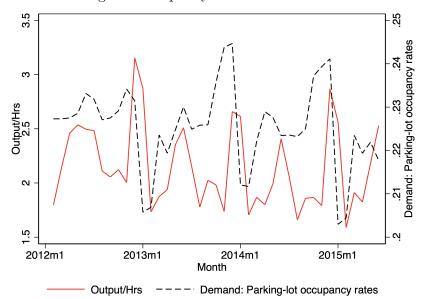


Figure F.2: Parking-lot Occupancy Rates Co-move With Store Output

Notes: This figure plots the evolution over time of "store output" and "parking lot occupancy rates", averaged at the store-month level. Output/Hrs is the (average) total monthly store sales generated by all sales associates in our sample divided by the total number of hours worked by these sales associates. We do not disclose the units for confidentiality reasons. $Parking\ lot\ occupancy\ rates$ is the (average) occupancy rate of the store's parking lot.

Next, we use the data on parking occupancy to show that variations in the minimum wage do not cause variations in our proxy of store-level demand. First, an increase in the minimum wage does not affect parking lot occupancy rate (Table F.1, column 2). Second, the effect of minimum wage on individual worker performance does not shrink when we control for parking lot occupancy rate, indicating that the observed performance gains are not explained by a demand surge (Table

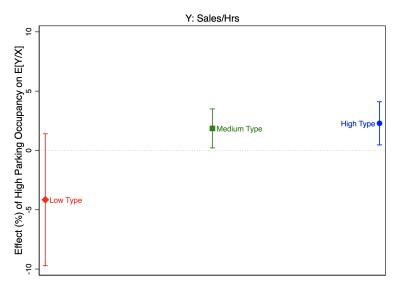
⁶⁴During our sample period, the data contain about 51,000 satellite images of the parking lots of the stores in our data. Images cover 93% of the stores in our dataset and, conditional on having at least one picture in a given month, the average store has 2.6 images per month. Missing images are attributable to indoor parking lots that could not be caught by satellites, and to the lower frequency of satellite images in less populated areas.

⁶⁵Because we control for store fixed effects, using the occupancy rate as a proxy of demand is equivalent to using the number of cars in the parking lot.

F.2, columns 2-3).66

Table F.3 (and the corresponding Figure F.3) show that – even if there was a positive demand shock as a result of a higher minimum wage – this shock would unlikely be concentrated among low types only. We use a regression model similar to equation (11) with the only difference that indicators for worker types are interacted with a dummy for high demand (top quartile of occupancy rate) rather than with the minimum wage. Figure F.3 plots the estimated coefficients $\hat{\beta}_1$, $\hat{\beta}_1 + \hat{\beta}_4$ and $\hat{\beta}_1 + \hat{\beta}_5$ and the associated confidence intervals. We find that sales per hour are higher in high-occupancy than low-occupancy periods only for medium and high types, while higher occupancy does not increase sales per hour of low types. The fact that minimum wage raises the performance of low types only is thus inconsistent with a demand shock.

Figure F.3: A Positive Demand Shock Increases the Productivity of High Types but not of Low Types



Notes: Effects of being in the top quartile of demand on the percent change in Y (Sales/Hrs) for low, medium, and high types. Top quartile of demand is defined as being in the top quartile of the parking-lot occupancy rates in a given month t. Vertical bars represent 95% confidence intervals.

One may wonder whether the performance boost we observe among low types is explained by these workers being disproportionately located in high-exposure counties (where the demand response might be stronger) relative to high types. This is unlikely the case. First, all our estimates are based on comparisons across types within the same store. Second, Table F.1 shows that low types are not disproportionately located in high-exposure counties (column 4) and,

⁶⁶The results hold if we further control for parking lot occupancy rate interacted with a county measure of how binding the minimum wage is ("county-level exposure", see below for more information).

moreover, that the effect of the minimum wage on parking occupancy rates is not stronger in high-exposure counties (column 3).

Finally, we show that the minimum wage affects our workers' performance independently of the share of the population who earn minimum wage (Table F.4). We compute two measures of "exposure to the minimum wage:" one at the county level and the other at the state level. The former uses the QWI data to calculate the quarterly, county-level difference between the average hourly wage and the prevailing minimum wage (as in Renkin et al. 2021). The latter uses the individual-level NBER Merged Outgoing Rotation Group of the Current Population Survey for 2012-2015 (CPS) to calculate the quarterly, state-level fraction of workers whose earnings per hour is equal to the prevailing minimum wage (as in Cengiz et al. 2019).

F.2 Organizational Adjustments Channel

Table F.6 (and the corresponding Figure 7) show that the minimum wage has no statistically significant effect on the proportion of low vs. high types who are moved to a best-selling department (columns 1-2) or moved to part-time status (with worse shifts, columns 3-4). The effect of minimum wage on hours worked (columns 5-6) and formal benefits (vacation and illness benefits, columns 7-8) also does not differ for low vs. high types.

Concerning the results on hours, note that the effect of minimum wage on hours is positive for all worker types but is never statistically significant, even when we aggregate data across all worker types. While Doppelt (2019) finds a disproportionate adjustment in hours worked among part-time workers, we do not observe any difference between part-time and full-time workers.

An increase in prices as a result of a higher minimum wage is also unlikely to explain our core results. First, any price change should affect sales for *all* types, not specifically for the low types. Second, as with many national nationwide retailers, our company has a national pricing strategy and has uniform prices across all US stores (Della Vigna and Gentzkow 2019). In line with this, Table F.7 shows that the minimum wage does not affect our company's price-to-cost index. We compute the price-to-cost index as the ratio between: (a) store output (price × quantity) and (b) monthly store output minus gross margin (cost × quantity).

⁶⁷The assumption is that counties with a low average wage relative to the minimum wage are states in which the minimum wage is binding for a larger share of the population.

⁶⁸Renkin et al. (2021) show evidence of an increase in consumer prices before the minimum wage implementation date. Our retail price index does not, however, display such an effect.

Table F.1: Minimum Wage, Parking Occupancy and Store Output

Dep.Var.	Output/Hrs	Parking	Parking	% Low Types
		Occupancy	Occupancy	
	(1)	(2)	(3)	(4)
MinW		-0.005	0.001	
		(0.017)	(0.019)	
Parking Occupancy	0.252**			
_	(0.096)			
Exposure	,		0.020	-0.117
			(0.021)	(0.250)
MinW * Exposure			-0.002	,
-			(0.002)	
Observations	12,359	12,359	12,359	12,275
Units	Stores	Stores	Stores	Stores
Mean Dep.Var.	2.135	0.230	0.230	5.964
Effect (%)	11.81	-2.028	0.343	-

Notes: All the regression includes pair-month fixed effects, store fixed effects, and controls for county-level unemployment. Output/Hrs are computed by aggregating the sales produced by all sales associates in our sample in a given month divided by the total number of hours these sales associates worked in that month (the units are hidden for confidentiality reason). MinW is the predominant monthly minimum wage (in \$). $Parking\ Occupancy$ is the average occupancy rate of the store's parking lot (0 means no-occupancy, 1 means full-occupancy). Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1.

Table F.2: Effect of Minimum Wage on Worker Productivity Controlling for Demand

Dep.Var.	m Sales/Hrs	Sales/Hrs	Sales/Hrs
	(1)	(2)	(3)
MinW	0.092**	0.230***	0.085**
1V1111 V V	(0.032)	(0.042)	(0.038)
Medium Type	(0.033)	0.383***	(0.030)
Wediani Type		(0.030)	
High Type		1.174***	
ingh Type		(0.046)	
MinW · Medium Type		-0.041	
William Type		(0.025)	
MinW · High Type		-0.165***	
William Type		(0.031)	
		(0.001)	
Controls included in the regression:			
Parking Occupancy	Yes	Yes	Yes
Parking Occupancy · Med. Type	No	Yes	No
Parking Occupancy · High Type	No	Yes	No
Exposure	No	No	Yes
Parking Occupancy*Exposure	No	No	Yes
Observations	217,822	209,513	217,822
Units	Workers	Workers	Workers
Mean Dep.Var.	2.085	2.085	2.085
Effect MinW (%)	4.424		4.055
Effect MinW for Low Type (%)		21.30	
p-value		0.009	
Effect MinW for Med. Type (%)		9.766	
p-value		0.009	
Effect MinW for High Type (%)		2.400	
p-value		0.153	

Notes: All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department and county-level unemployment. Parking Occupancy is the average occupancy rate of the store's parking lot (0 means no-occupancy and 100 means full occupancy). Exposure corresponds to the difference (in \$) between the average hourly wage in the state and the predominant monthly minimum wage. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. MinW is the predominant monthly minimum wage (in \$). MinW is in deviation from its sample mean in even columns. Medium Type is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. High Type is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group (Low Types) are workers for whom total pay in t-1 is "at minimum wage". Effect MinW (%) is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table F.3: Effect of Positive Demand Shock on Worker Productivity

Dep.Var.	m Sales/Hrs	$\mathrm{Sales}/\mathrm{Hrs}$	
	(1)	(2)	
High Parking Occupancy	0.045**	-0.045	
	(0.020)	(0.029)	
Medium Type		0.291***	
		(0.039)	
High Type		1.102***	
		(0.093)	
High Parking Occupancy · Medium Type		0.081***	
		(0.021)	
High Parking Occupancy · High Type		0.107***	
		(0.030)	
Observations	217,822	209,513	
Units	Workers	Workers	
Mean Dep.Var.	2.085	2.085	
Effect High Occupancy (%)	2.156		
Effect High Occupancy for Low Type (%)		-4.155	
p-value		0.138	
Effect High Occupancy for Med. Type (%)		1.859	
p-value		0.028	
Effect High Occupancy for High Type (%)		2.287	
p-value		0.016	

Notes: All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department and county-level unemployment. High Parking Occupancy is an indicator for whether the average occupancy rate is in the top quartile of the store distribution. MinW is the predominant monthly minimum wage (in \$). MinW is in deviation from its sample mean in even columns. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. MinW is the predominant monthly minimum wage (in \$). MinW is the predominant monthly minimum wage (in \$). Medium Type is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. High Type is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group (Low Types) are workers for whom total pay in t-1 is "at minimum wage". Effect MinW (%) is the percent effect of a \$1 increase in MinW on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. s*** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value < 0.01.

Table F.4: Effect of Minimum Wage on Worker Productivity by Exposure

Dep.Var.	Sales/Hrs	Sales/Hrs	Sales/Hrs	m Sales/Hrs
	(1)	(2)	(3)	(4)
MinW	0.082*	0.231***	0.115**	0.278***
	(0.042)	(0.040)	(0.045)	(0.050)
Exposure	-0.033	-0.038*	-1.028	-0.768
	(0.022)	(0.021)	(0.816)	(1.171)
$MinW \cdot Exposure$	0.002	0.002	-0.685	-1.469
	(0.006)	(0.009)	(0.950)	(0.977)
MinW · Medium Type		-0.089***		-0.099***
		(0.020)		(0.021)
MinW · High Type		-0.201***		-0.180***
		(0.023)		(0.065)
$MinW \cdot Exposure \cdot Medium Type$		-0.002		$0.316^{'}$
		(0.007)		(0.335)
$MinW \cdot Exposure \cdot High Type$		0.021**		2.831**
		(0.010)		(1.306)
Other regressors:		, ,		,
Medium Type	No	Yes	No	Yes
High Type	No	Yes	No	Yes
Exposure · Medium Type	No	Yes	No	Yes
Exposure · High Type	No	Yes	No	Yes
Observations	217,822	209,513	217,822	209,513
Units	$\overline{\mathrm{Workers}}$	Workers	Workers	Workers
Mean Dep.Var.	2.085	2.085	2.085	2.085

Notes: All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department and county-level unemployment. In columns 1-2, Exposure corresponds to the difference (in \$) between the average hourly wage in the county and the predominant monthly minimum wage. In columns 3-4, Exposure corresponds to the fraction of workers in the state (in %) whose earnings are at minimum wage. Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. MinW is the predominant monthly minimum wage (in \$), and it is in deviation from its sample mean. Medium Type is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. High Type is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group (Low Types) are workers for whom total pay in t-1 is "at minimum wage". Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1.

Table F.5: Effect of Minimum Wage on Worker Productivity Controlling for Employment

Dep.Var.	Sales/Hrs	$\overline{ m Sales/Hrs}$
	(1)	(2)
	o o o o dudi	o oo waladada
MinW	0.090**	0.237***
37 777 J	(0.038)	(0.043)
N.Workers	-0.019**	-0.048**
	(0.007)	(0.018)
Parking Occupancy	0.212**	0.178**
	(0.104)	(0.083)
Medium Type		0.220***
		(0.035)
High Type		0.901***
		(0.049)
$MinW \cdot Medium Type$		-0.081***
		(0.026)
MinW · High Type		-0.173***
		(0.035)
$N.Workers \cdot Medium Type$		0.025*
		(0.012)
N.Workers · High Type		0.048***
		(0.014)
Observations	217,822	209,513
Mean Dep.Var.	2.085	2.092
Effect N.Workers (%)	-0.932	
Effect N. Workers for Low Type (%)		-2.305
p-value		0.0101
Effect N. Workers for Med. Type (%)		-1.126
p-value		0.002
Effect N. Workers for High Type (%)		-0.028
p-value		0.949
p-varue		U.949

Notes: All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department and county-level unemployment. N. Workers is the number of sales associates in the store. Parking Occupancy is the average occupancy rate of the store's parking lot (0 means no-occupancy and 100 means full occupancy). Sales/Hrs are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its \$ value. Min W is the predominant monthly minimum wage (in \$). Min W is in deviation from its sample mean in even columns. Medium Type is an indicator for whether the worker's total pay in month t-1 is between the minimum wage and 180% of minimum wage. High Type is an indicator for whether the worker's total pay in month t-1 is above 180% of minimum wage. The omitted group (Low Types) are workers for whom total pay in t-1 is "at minimum wage". Effect (%) is the percent effect of a 1 unit increase in the independent variable on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1. The p-value is approximated to 0.009 if p-value <0.01.

Table F.6: Effect of Minimum Wage on Allocation to Best-Selling Departments, Part-Time Status, Hours Worked and Benefits

Dep.Var.	Top	Dept.	Part-	Time	Н	[rs	Ben	efits
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MinW	-0.454	0.044	-2.395	-2.291	1.942	2.720	8.006	7.402
	(0.655)	(0.623)	(1.434)	(1.665)	(1.265)	(1.637)	(7.281)	(7.622)
Medium Type		-0.092		-2.220		4.762***		0.213
		(0.283)		(1.392)		(1.181)		(2.144)
High Type		-1.218***		-2.381		5.439***		4.904*
		(0.265)		(1.768)		(1.549)		(2.609)
$\operatorname{MinW} \cdot \operatorname{Medium} \operatorname{Type}$		-0.160		-0.028		-0.856		1.406
		(0.218)		(0.826)		(0.851)		(1.161)
MinW · High Type		-0.878*		0.036		-0.240		2.424
		(0.466)		(0.917)		(1.236)		(1.961)
Observations	$217,\!822$	$209,\!514$	$217,\!822$	$209,\!513$	$217,\!822$	$209,\!513$	$217,\!822$	$209,\!513$
Units	Workers	Workers	Workers	Workers	Workers		Workers	Workers
Mean Dep.Var.	44.29	44.29	60.25	60.25	106.5	106.5	48.23	48.23
Effect MinW (%)	-1.024		-3.975		1.824		16.60	
Effect MinW for Low (%)		0.128		-3.090		3.052		38.08
p-value		0.944		0.178		0.106		0.339
Effect MinW for Med. (%)		-0.225		-3.790		1.754		22.68
p-value		0.849		0.100		0.161		0.255
Effect MinW for High (%)		-3.535		-4.268		2.179		11.56
p-value		0.265		0.150		0.121		0.209

Table F.7: Effect of Minimum Wage on Price-to-Cost Index

	D: /C / D /:
Dep.Var.	Prices/Costs Ratio
	(1)
MinW	0.009
	(0.008)
Observations	12,359
	· · · · · · · · · · · · · · · · · · ·
Units	Stores
Mean Dep.Var.	1.451
Effect MinW (%)	0.645

Notes: The regression includes pair-month fixed effects, store fixed effects, and controls for county-level unemployment. Prices/Costs Ratio is computed as the ratio between: (a) store output and (b) store output minus gross margin. MinW is the predominant monthly minimum wage (in \$). Effect MinW (%) is the percent effect of a \$1 increase in MinW on the outcome. Standard errors are two-way clustered at the state level and at the border-segment level. *** p<0.01, ** p<0.05, * p<0.1.