

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

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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 interpret these findings through an efficiency wage model. After a minimum wage increase, profits decrease, and a calibration exercise suggests that worker welfare increases.

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I. Introduction

Since the US 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 50 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 versus 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, and they are not 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

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¹ Employers of comparable size employ 23% of the US workforce and roughly 20% of minimum wage workers. See app. C.1 (apps. A–F are available online) for these computations.

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

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 by both the threat of termination, which is based on the direct monitoring of effort, and the variable component of pay, which reflects individual performance and which is in turn 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 demotivates 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 demotivate 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. In theory, welfare could be decreasing if unemployment duration sharply increases in the minimum wage. Nevertheless, our calibration suggests that the welfare of employed and unemployed workers increases with the minimum wage.

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

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 (2022) 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 (2022) 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 allow only 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 (2022) 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 nonpositive 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 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 paper closest to ours is Jayaraman, Ray, and de Vericourt (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)

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

⁵ For the literature on profits, see Draca, Machin, and Reenen (2011), Riley and Bondibene (2017), Mayneris, Poncet, and Zhang (2018), Harasztosi and Lindner (2019), Hau, Huang, and Wang (2020), and Clemens (2021) for a review.

⁶ See, e.g., Gneezy and List (2006) and Della Vigna et al. (2016).

or Rebitzer and Taylor (1995) cannot be invoked. In contrast, our paper 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 II presents the model, while section III describes the data, the institutional context, and the identification strategy. Section IV discusses our core results: the effect of the minimum wage on worker productivity. Section V examines the heterogeneous effects of the minimum wage on worker productivity by monitoring intensity. Section VI presents the store-level results on turnover, employment, output, and profits. Section VII discusses two alternative channels: demand and organizational adjustments. Section VIII calibrates the effect of a minimum wage increase on worker welfare. Section IX discusses the external validity of our findings and concludes.

II. 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 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).⁷ 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 $x \geq 0$ 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

⁷ The model generalizes Rebitzer and Taylor (1995) 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.

zero and is infinite at one; 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 nonnegative 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 e .⁸ 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 $\bar{w}(\cdot)$ that transforms performance into pay. For example, $\bar{w}(Y) = b + cY$, where b represents the base salary and c represents the commission rate. The expected wage is denoted by

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

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

Type x 's effort choice problem is

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

The function $V^E(x)$ represents type x 's discounted value of being employed. The numbers $r > 0$ and V^A respectively represent 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 is referred to as the "no-monitoring" case.⁹

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

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

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

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

⁹ Equation (1) is a continuous-effort counterpart of Rebitzer and Taylor's (1995) eqq. (2)–(4). In keeping with Rebitzer and Taylor (1995), eq. (1) states that the worker is fired *after* receiving the period's pay and that firing decisions are made based on effort provision, not realized performance.

$$u(x, e) = w(x, e) - c(x, e) - u^A \quad (3)$$

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 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 nonempty 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

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

The next lemma states that the model behaves “nicely.”

LEMMA 1. Suppose that 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 .

Proof. See appendix B.1. QED

A. Linking the Model to Our Empirical Setting

We study a single firm with many store locations across the United States, 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 $\bar{w}(\cdot)$ is optimally adapted to the local parameters, including the minimum wage M . We instead assume that when a locality increases M , $\bar{w}$ does not change.¹⁰ Thus, in a store that is subject to a local minimum wage M , the expected wage is

$$w(x, e; M) = \mathbb{E}(\max[M, \bar{w}(Y(x, e))]). \quad (5)$$

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.

1. Low Types

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

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 Rebitzer and Taylor (1995) 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 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.

2. Three Cases Nested by the Model

The model nests two polar cases and a hybrid one.

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

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.

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

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.

3. 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 were to slow the movement out of unemployment. Conversely, if 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 sec. IV).

B. Core Theoretical Results: Effect of Minimum Wage on Individual Productivity

ASSUMPTION 3. $\bar{w}(\cdot)$ 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 $\bar{w}(\cdot)$ 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 that assumptions 1–3 hold and also that $\pi'(e) > 0$ 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. QED

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, pt. 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 section III.A.4. 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.

C. 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 $\tilde{\pi}(e)$ than under $\pi(e)$ if, for every e , the elasticity of $[1 + r - \tilde{\pi}(e)]$ 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., 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 that $\pi'(e) \equiv 0$. Then MMW types (low types) exert zero effort. Increasing M does not increase their effort, and it decreases the effort of any type that exerts positive effort.

¹² For example, in the parametric family $\pi(e; a) = a[e/(e + 1)]$, monitoring is more intense when a is larger; see app. B.2.

¹³ Refer to the proof of proposition 2, pt. 3, in app. 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. QED

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 nonmonitored workers, the low types do not change their effort as the minimum wage increases (because nonmonitored MMW types shirk regardless of the minimum wage level), whereas higher types decrease their effort owing 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, we 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 (pt. 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 nonmonitored 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. 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 sec. V). Empirically, we find that on average a store behaves as a high-monitoring store.

¹⁴ In 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) and Eeckhout, Persico, and Todd (2010).

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 nondecreasing 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 V. 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.

*D. 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 cumulative distribution function of the type distribution that our firm can expect after 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 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

$$g^M(x) = \frac{\lambda(M)}{1 - \pi(e^*(x; M))} h(x). \quad (6)$$

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

¹⁵ This is the "border sample" defined in sec. III.A; see table 8.

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

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

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

Turning to the nonmonitored division, recall that $\underline{\pi}$ is the constant probability of retention under no monitoring. In a nonmonitored 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 nonmonitored divisions, is

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

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 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 nonmonitored workers, effort decreases after a minimum wage increase (proposition 2, pt. 2), but their turnover remains unchanged, as their probability of termination is independent of effort.

E. Effect of Minimum Wage on Store Output, Profits, and Employment

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

We now turn to profits. In our empirical setting, the compensation scheme $\bar{w}$ 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,

¹⁷ Increasing the minimum wage may increase profits in a store if the compensation scheme $\bar{w}$ is not profit maximizing given local store conditions. Take the following example. Suppose that $\pi(e) \equiv \bar{\pi}$ so that there is no monitoring and $\bar{w}(Y) < M$ so that all workers are paid the minimum wage. Suppose that 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 .

the average effect across all stores could never be positive if $\bar{w}$ 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 $\bar{w}$ 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 VI.C explores this prediction.

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

$$\max_L L \cdot \Pi(F_M, M) - \kappa(L), \quad (7)$$

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. However, if 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 VI.B explores the empirical effect of the minimum wage on employment.

III. Data and Empirical Strategy

A. Data and Institutional Background

We match the firm's biweekly 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 (sec. III.B) leaves us with more than 200 stores with over 10,000 salespeople. Table 1 reports the summary statistics of this border sample.

1. Workers and Compensation

Our workers are consultative sales associates. They answer walk-in customer questions and demonstrate product features. What we call "exerting effort" consists of meeting and greeting the customer, taking the time to explain and persuade, upselling (to higher-margin products), and

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

TABLE 1
DESCRIPTIVE STATISTICS

Variable	Mean (1)	Standard Deviation (2)	p10 (3)	p50 (4)	p90 (5)	N (6)
A. Worker-Level Variables						
Productivity:						
Sales/hour (shrouded units)	2.085	1.468	.781	1.872	3.522	217,822
Tenure and hours:						
Tenure (months)	48.92	65.01	4	24	126	217,822
Part-time (%)	60.25	48.94	0	100	100	217,822
Number of hours	106.5	44.12	46.47	107.6	162.3	217,822
Compensation:						
Base rate: regular pay/ hour (\$)	6.120	1.181	4.500	6	7	217,822
Commission rate: vari- able pay/sale (%)	3.462	3.188	1.057	2.343	7.531	213,726
Variable pay/hour (\$)	5.947	4.936	1.740	4.610	11.78	217,822
Minimum wage adjust- ments/hour (\$)	.225	1.736	0	0	.771	217,822
Total pay (\$)	1,361	831.2	494.6	1,218	2,343	217,822
Total pay/hour (\$)	12.51	4.620	8.734	11.15	17.94	217,822
B. Store-Level Variables						
Termination, hiring, and turnover:						
Terminated (%)	4.755	7.692	0	0	12.50	12,359
Hired (%)	2.060	4.285	0	0	7.692	12,359
Turnover (%)	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 (%)	6.990	4.886	3.448	5.882	11.11	12,359
EBITDA/hour (shrouded units)	5.946	11.97	-8.010	5.630	19.97	12,359

NOTE.—This table presents summary statistics of worker-level variables in panel A and store-level variables in panel B. “Sales/hour” is the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its dollar value. “Tenure” is the number of months of tenure. “Part-time” is the percentage probability that an employee is part-time in a given month (zero indicates full-time and 100 indicates part-time). “Number of hours” is the total number of hours for which an employee receives compensation in a given month. “Base rate: regular pay/hour” is monthly regular earnings per hour worked (in dollars per hour). “Commission rate: variable pay/sale” is earnings from commissions and incentives divided by sales (in percentage). “Variable pay/hour” is earnings from commissions and incentives per hour worked (in dollars per hour). “Minimum wage adjustments/hour” is the monthly earnings from minimum wage adjustments per hour worked (in dollars per hour). “Total pay” is the monthly total pay from total take-home pay. “Total pay/hour” is the monthly total pay from total take-home pay per hour worked (in dollars per hour). “Terminated” is the percentage of sales associates in the store who are terminated in a given month. “Hired” is the percentage of sales associates who are hired in the store in a given month. “Turnover” is the percentage 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 the store in a given month. “Supervisor-to-worker ratio” is measured as the number of supervisors per 100 sales associates. “EBITDA/hour” is equal to EBITDA per hour worked in the store. We do not disclose the units for confidentiality reasons.

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.

For every salesperson, we aggregate the following at the monthly level: hours worked (average: 107 hours), sales (average: two per hour; units shrouded for confidentiality),²⁰ and pay (average: \$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 (average: 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 human resources (HR) records.

2. 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 (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 (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

¹⁹ A 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 maintain the sales floor appearance, facilitating customer transactions as needed, and generally cooperating with other employees.”

²⁰ The number is rescaled by a factor between 1/50 and 1/150 relative to its value in dollars.

²¹ The termination (hiring) rate is defined as the percentage 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 percentage of sales associates in the store who are terminated or hired in a given month divided by two.

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

²³ According 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,” and “effective oral and written communication skills necessary to communicate with all levels of internal and external team members.”

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. Panel A in table A.3 (tables A.1–A.5, C.1, E.1–E.12, and F.1–F.7 are available online) shows that within a store, variation in the supervisor-to-worker ratio over time does not correlate with turnover, profits, or the fraction of low types as defined below.

3. 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.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 4 weeks. A \$1 increase in the minimum wage raises the minimum wage adjustment by \$0.25 per hour (table 2, col. 3).²⁶ In addition, variable pay per hour increases by \$0.44 per hour (table 2, col. 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 (col. 5), which corresponds to a 5% increase and an elasticity of 0.38.

4. 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, Agarwal, and French (2012) and Clemens and Wither (2019), and following

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

²⁵ Under this law, commissioned workers can occasionally be deemed exempt and thus not receive the adjustment. Based on administrative records, however, all of the workers in our sample are nonexempt.

²⁶ A \$1 increase in the minimum wage raises the share of workers who have their wage adjusted up every single week of the month by 4.5 percentage points (144%), while the share of workers who have their wage adjusted up at least 1 week per month rises by 16 percentage points (38.5%).

TABLE 2
EFFECT OF MINIMUM WAGE ON COMPENSATION SCHEME $\bar{w}$ AND OVERALL PAY INCLUSIVE OF MINIMUM WAGE ADJUSTMENT

	COMPENSATION SCHEME ($\bar{w}$)		OVERALL PAY INCLUSIVE OF MINIMUM WAGE ADJUSTMENT			
	Base Rate: Regular Pay/Hour (\$) (1)	Commission Rate: Variable Pay/Sale (%) (2)	Minimum Wage Adjust- ments/Hour (\$) (3)	Variable Pay/ Hour (\$) (4)	Total Pay/ Hour (\$) (5)	Total Pay (\$ in Hundreds) (6)
Minimum wage	-.059 (.042)	.126 (.077)	.250*** (.044)	.439* (.235)	.645*** (.172)	.856** (.336)
Observations	217,822	213,697	217,822	217,822	217,822	217,822
Units	Workers	Workers	Workers	Workers	Workers	Workers
Mean						
dependent variable	6.120	3.462	.225	5.947	12.51	13.61
Effect of minimum wage increase (%)	-.957	3.628	111.3	7.390	5.154	6.289

NOTE.—All the regressions include pair-month fixed effects, worker fixed effects, and control for worker tenure, worker department, and county-level unemployment. “Regular Pay/Hour” is the base rate: monthly regular earnings per hour worked (in dollars per hour). “Variable Pay/Sale” is the commission rate: earnings from commissions and incentives divided by sales (in percentage). “Minimum Wage Adjustments/Hour” is monthly earnings from minimum wage adjustments per hour worked (in dollars per hour). “Variable Pay/Hour” is earnings from commissions and incentives per hour worked (in dollars per hour). “Total Pay/Hour” is the monthly total pay from total take-home pay per hour worked (in dollars per hour). “Total Pay” is the monthly total pay from total take-home pay (in hundreds of dollars). “Minimum wage” is the predominant monthly minimum wage (in dollars). “Effect of minimum wage increase” is the percentage effect of a \$1 increase in minimum wage on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level.

* $p < .1$.
** $p < .05$.
*** $p < .01$.

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 of the pay distribution.²⁷

²⁷ We define low types at time t as those whose total pay in month $t - 1$ is below $1.02 \times$ 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 $180\% \times$ 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 1 period before the minimum wage)—refer to sec. IV.C.

TABLE 3
DESCRIPTIVE STATISTICS FOR LOW, MEDIUM, AND HIGH TYPES

	Low Types (1)	Medium Types (2)	High Types (3)
% workers	3.9	72.4	23.7
% terminated	6.8	5.2	3.0
Sales/hour	1.08	1.94	2.73
% weeks with minimum wage adjustment	48.9	18.5	12.2
% months with minimum wage adjustment, all weeks	20.5	3.1	.7

NOTE.—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 210,000, as in our main specifications. “% terminated” is the fraction of workers terminated. “Sales/hour” is the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its dollar value. “% weeks with minimum wage adjustment” is the fraction of weeks per month in which a worker’s pay is adjusted up by the firm. “% months with minimum wage adjustment, all weeks” is the fraction of months in which a worker’s pay is adjusted up by the firm each single week.

As expected, higher types sell more per hour, benefit from the minimum wage adjustment less often, and are terminated less frequently (see table 3). A low type’s monthly earnings at t equals the minimum wage with a frequency of 20.5% and, moreover, is 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 type’s monthly earnings at t equals the minimum wage with a frequency of only 0.7%, and they benefit from a minimum wage adjustment only once every 10 weeks, implying that they are negligibly affected by the minimum wage.

5. Headquarters versus 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 (cols. 1, 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 $\bar{w}$ does not vary with M and by avoiding the assumption that $\bar{w}$ is optimized at the local level.²⁸

²⁸ We would expect $\bar{w}$ 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.

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

B. Identification Strategy

1. 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, Lester, and Reich (2010) and Allegretto, Dube, and Reich (2011). Specifically, workers on the side of the border where the minimum wage increased (treatment group) are compared with 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 pretrend analysis in section IV.C 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 IV.C, we show that our core estimates are similar when applying this alternative research design.

2. 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:

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

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

$$Y^*(x, M') = Y^*(x, M) + (M' - M) \cdot [\beta_L \mathbf{1}_L(x) + \beta_M \mathbf{1}_M(x) + \beta_H \mathbf{1}_H(x)], \quad (9)$$

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 (pt. 2) predicts that $\beta_L = 0$ and $\beta_M, \beta_H \leq 0$. We will reject these predictions. In the hybrid case, proposition 1 (pt. 1) predicts that $\beta_L > 0$; furthermore, in the high-monitoring subcase of the hybrid case, proposition 2 (pt. 3) predicts that $\beta_M, \beta_H \geq 0$. We will not reject these predictions.

3. Empirical Specification

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

$$Y_{ijpt} = \alpha + \beta \text{MinW}_{jt} + X_{it} \cdot \zeta + \eta Z_{jt} + \delta_i + \phi_{pt} + \epsilon_{ijpt}, \quad (10)$$

where Y_{ijpt} represents the performance (sales per hour) of worker i in store j of county-pair p in month t , MinW_{jt} represents 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—and Z_{jt} includes the monthly county-level unemployment rate to account for time-varying local economic conditions and local demand shocks (see Lemieux, MacLeod, and Parent 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, Lester, and Reich (2010, 2016), meaning that stores/workers

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

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.

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

$$\begin{aligned} Y_{ijt} = & \beta_0 + \beta_1 \text{MinW}_{jt} + \beta_2 \text{MediumType}_{ijt} + \beta_3 \text{HighType}_{ijt} \\ & + \beta_4 \text{MinW}_{jt} \cdot \text{MediumType}_{ijt} + \beta_5 \text{MinW}_{jt} \cdot \text{HighType}_{ijt} \quad (11) \\ & + X_{it} \cdot \zeta + \eta Z_{jt} + \delta_i + \phi_{pt} + \epsilon_{ijpt}, \end{aligned}$$

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—that is, the coefficients β_L , β_M , and 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 predetermined 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 in section III.A.4.

IV. Core Empirical Results: Effect of Minimum Wage on Worker Productivity

This section tests the predictions from section III.B regarding the effect of the minimum wage on worker productivity.

A. Core Findings

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

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

³⁰ In eq. (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.

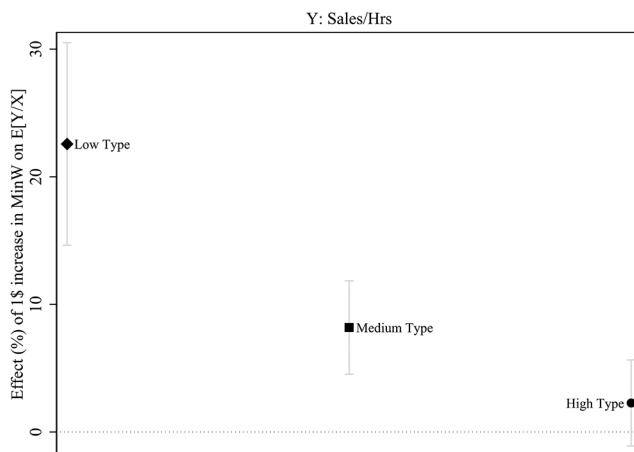


FIG. 1.—Minimum wage (MinW) has a robust positive effect on the productivity of low types and no effect on high types. Shown is the effect of a \$1 increase in the minimum wage on the percentage change in Y (sales per hour) for low-, medium-, and high-type workers. “Low type” refers to workers for whom the total pay per hour in month $t - 1$ is at minimum wage, “medium type” refers to workers for whom the total pay per hour in month $t - 1$ is between the minimum wage and 180% of the minimum wage, and “high type” refers to workers for whom the total pay per hour in month $t - 1$ is above 180% of the minimum wage. Vertical bars represent 95% confidence intervals computed using the estimated coefficients ($\hat{\beta}_1$, $\hat{\beta}_1 + \hat{\beta}_4$, and $\hat{\beta}_1 + \hat{\beta}_5$) from equation (11) and the associated standard errors.

medium types occasionally earn minimum wage;³¹ thus, their response somewhat aligns with that of the low types. However, the effect vanishes 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. Column 1 of table 4 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

We conclude with a sanity check: as expected, worker pay increases with the minimum wage (table A.1). This increase is explained not 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

³¹ Our medium types receive the minimum wage adjustment 18% of the weeks, on average, compared with 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 $4.5/12.7 = 0.35$.

TABLE 4
EFFECT OF MINIMUM WAGE ON WORKER PRODUCTIVITY

	DEPENDENT VARIABLE: SALES/HOUR	
	(1)	(2)
Minimum wage	.094** (.039)	.244*** (.042)
Medium type		.354*** (.032)
High type		1.169*** (.072)
Minimum wage · medium type		−.085*** (.025)
Minimum wage · high type		−.182*** (.032)
Observations	217,822	209,513
Units	Workers	Workers
Mean dependent variable	2.085	2.085
Effect of minimum wage increase (%)	4.485	
Effect of minimum wage increase for low type (%)		22.56
<i>p</i> -value		.009
Effect of minimum wage increase for medium type (%)		8.186
<i>p</i> -value		.009
Effect of minimum wage increase for high type (%)		2.273
<i>p</i> -value		.179

NOTE.—All the regressions include pair-month fixed effects, worker fixed effects, and controls for worker tenure, worker department, and county-level unemployment. “Sales/Hour” is the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its dollar value. “Minimum wage” is the predominant monthly minimum wage (in dollars) and is in deviation from its sample mean in col. 2. “Medium type” is an indicator for whether the worker’s total pay in month $t - 1$ is between the minimum wage and 180% of the minimum wage. “High type” is an indicator for whether the worker’s total pay in month $t - 1$ is above 180% of the minimum wage. The omitted group (“Low type”) is workers for whom total pay in $t - 1$ is at minimum wage. “Effect of minimum wage increase” is the percentage effect of a \$1 increase in minimum wage on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level. The *p*-value is approximated to .009 if $p < .01$.

** $p < .05$.
*** $p < .01$.

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 because of larger and more frequent minimum wage adjustments and also from becoming more productive.

B. Dynamic Effects

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

$$\begin{aligned}
Y_{ijt} = & \alpha + \sum_{m=-2}^2 \beta_1^{3m} \text{MinW}_{j,t-3m} + \sum_{m=-2}^2 \beta_2^{3m} \text{MinW}_{j,t-3m} \cdot \text{MediumType}_{ijt} \\
& + \sum_{m=-2}^2 \beta_3^{3m} \text{MinW}_{j,t-3m} \cdot \text{HighType}_{ijt} + \gamma_1 \text{MediumType}_{ijt} \\
& + \gamma_2 \text{HighType}_{ijt} + X_{it} \cdot \zeta + \eta Z_{jt} + \delta_i + \phi_{pt} + \epsilon_{ijpt},
\end{aligned} \tag{12}$$

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 (posttreatment) effect for low types if ℓ is positive, and the ℓ -lead (pretreatment) 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 preperiod (period -3).³³ They show that the cumulative leading coefficients are not statistically significant for any worker type, confirming that there is no pretrend within worker type and no differential pretrend across types. They also show that low types display a 29% (statistically significant) cumulative increase in performance at or after the 6-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.

C. 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.

1. Pretrends

Figure 2 displays the dynamic effects of the minimum wage. It shows no pretrends in performance by type for the sample of 102,000 observations

³³ To assess the posttreatment 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 pretreatment effects, we calculate the cumulative response by summing the leading coefficients and multiplying that sum by -1 . Refer to the figure legend and table note 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.

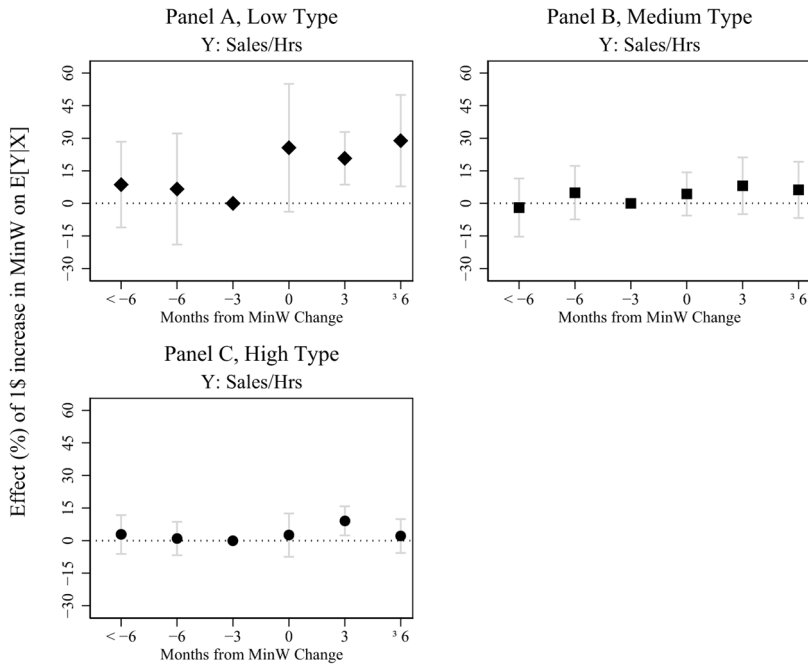


FIG. 2.—Dynamic effect of the minimum wage (MinW) on worker productivity. Shown is the effect of a \$1 increase in the minimum wage on the percentage change in Y (sales per hour) for low-, medium-, and high-type workers. “Low type” refers to workers for whom the total pay per hour in month $t - 1$ is at minimum wage, “medium type” refers to workers for whom the total pay per hour in month $t - 1$ is between the minimum wage and 180% of the minimum wage, and “high type” refers to workers for whom the total pay per hour in month $t - 1$ is above 180% of the minimum wage. Diamonds, squares, and circles show the cumulative response to the minimum wage relative to event date -3 for low, medium, and high types, respectively. The posttreatment 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 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 $-\hat{\beta}_1^3$) and dividing it by that type’s mean productivity. Vertical bars represent 95% confidence intervals.

generated by workers who remain employed over a window with a 6-month preperiod and 6-month postperiod around the minimum wage event. Figure A.1 (figs. A.1–A.3, C.1, C.2, and F.1–F.3 are available online) confirms the lack of pretrends in the smaller sample of 89,000 observations generated by workers who are continuously employed over the wider window with a 9-month preperiod and 6-month postperiod, 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 pretrends for the larger sample of 144,000 observations generated by workers who are continuously employed for 6 months before

the minimum wage event and for the sample of 107,000 observations generated by workers who are continuously employed for 12 months before the minimum wage event (see table E.1, cols. 1–3). The fact that the pretrends 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.

2. Cross-Border Worker Movements

Border-discontinuity research designs are vulnerable to the concern that workers may move across borders (Neumark, Salas, and Wascher 2014). However, our core results on individual productivity should not 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, col. 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 column 1 of table E.2 accordingly suggests that migration patterns also 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 sec. IV.C.6). 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, col. 3). In sum, we believe it is unlikely that the cross-border movement of workers plays a significant role in our estimates.

3. Worker Selection

The estimated productivity gains could potentially suffer from a selection bias owing 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.³⁴

³⁴ Adding 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.

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 pretrends are the same, and the results are similar to the main sample (tables E.3, 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 app. E.3). 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.

4. 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, col. 1).³⁵

In columns 2–5 of table E.5, we explore alternative ways of defining types—classifying them based on average pay in the previous 3 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.

5. 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

³⁵ This new approach changes the status of fewer than 1,000 out of more than 10,000 workers. Further details are provided in app. E.4.

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 $\times$ month fixed effects (see table E.1, cols. 2–4). The specification with division $\times$ month fixed effects is preferred because it is the only one that eliminates pretrends in worker performance. In this specification, the minimum wage once again increases the performance of low types and does not affect the performance of high types (see table E.7; fig. 3A).³⁶

6. State versus Local Variation in the Minimum Wage

Restricting the analysis to state-level minimum wage changes only or to county and city changes only (fig. 3B, 3C; 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.

7. 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 3D, 3E and table E.9.

8. 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 $\times$ month fixed effects and clustering standard errors at the border-segment level (fig. 3F; table E.10). This specification is closer in spirit to an experimental-event design.

9. 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

³⁶ We acknowledge that the inclusion of division $\times$ month fixed effects is criticized by Neumark, Salas, and Wascher (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” (318). The results are comparable if we use other state-level specifications.

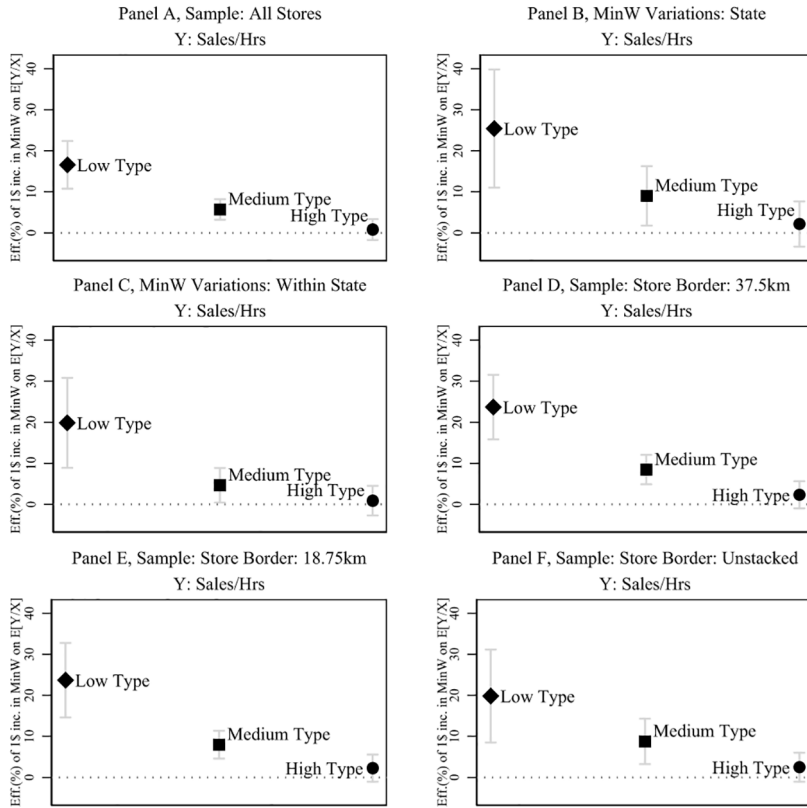


FIG. 3.—Minimum wage (MinW) has a robust positive effect on the productivity of low types and no effect on high types. Shown is the effect of a \$1 increase in the minimum wage on the percentage change in Y (sales per hour) for low-, medium-, and high-type workers. “Low type” refers to workers for whom the total pay per hour in month $t - 1$ is at minimum wage, “medium type” refers to workers for whom the total pay per hour in month $t - 1$ is between the minimum wage and 180% of the minimum wage, and “high type” refers to workers for whom the total pay per hour in month $t - 1$ is above 180% of the minimum wage. Panel A includes all stores, regardless of their distance from the border; in a specification with division $\times$ month fixed effects and standard errors clustered at the state level. Panel B (respectively, C) considers our main sample but only for state (respectively, within-state) variations in the minimum wage. Panel D (respectively, E) considers the sample of stores that are located less than 37.5 km (respectively, 18.75 km) from the border. Panel F considers our main sample but with nonstacked data and with border-segment-month fixed effects. Vertical bars represent 95% confidence intervals computed using the estimated coefficients ($\hat{\beta}_1$, $\hat{\beta}_1 + \hat{\beta}_4$, and $\hat{\beta}_1 + \hat{\beta}_5$) from equation (11) and the associated standard errors.

given store or if we run our specifications by department. Likewise, we obtain nearly identical results if we remove potentially “bad controls”—that is, variables that might be endogenous to the minimum wage level (worker tenure and county-level unemployment). See tables E.11 and E.12.

V. Heterogeneous Effect by Monitoring Illuminates Dual Nature of Model

The theory makes two kinds of predictions. First, monitoring a worker more intensely results in weakly increasing her individual performance (proposition 2, pt. 1). Second and more interestingly, the effect of the minimum wage is heterogeneous by monitoring. Among the nonmonitored workers, the low types should not change their effort, while higher types should decrease their effort (proposition 2, pt. 2). Among highly monitored workers, all types should increase their effort (proposition 2, pt. 3), at least to some extent (proposition 1, pt. 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 or high coverage otherwise.

Consistent with proposition 2 (pt. 1), we find that high coverage does positively correlate with average worker performance (table 5, col. 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%; col. 4). Figure 4 and the corresponding table 5 (cols. 3, 5) provide similar results by worker type. Consistent with the distinctive predictions in proposition 2 (pts. 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 .11). This bifurcated pattern provides strong evidence in support of the dual nature of our model.

TABLE 5
EFFECT OF MINIMUM WAGE ON WORKER PRODUCTIVITY WITH HIGH OR LOW MONITORING

	DEPENDENT VARIABLE: SALES/HOUR				
	All	High Coverage		Low Coverage	
	(1)	(2)	(3)	(4)	(5)
Coverage	.010*** (.003)				
Minimum wage		.140*** (.040)	.281*** (.044)	-.192** (.081)	.020 (.067)
Medium type			.368*** (.033)		.336*** (.044)
High type			1.185*** (.071)		1.121*** (.080)
Minimum wage · medium type			-.083*** (.027)		-.111* (.054)
Minimum wage · high type			-.188*** (.031)		-.168** (.075)
Observations	217,822	132,384	126,852	84,549	81,800
Units	Workers	Workers	Workers	Workers	Workers
Mean dependent variable	2.085	2.118	2.130	2.030	2.032
Effect (%)	1.461	6.588		-9.444	
Effect of minimum wage increase for low type (%)			25.87		1.824
<i>p</i> -value			.009		.773
Effect of minimum wage increase for medium type (%)			10.11		-4.953
<i>p</i> -value			.009		.176
Effect of minimum wage increase for high type (%)			3.298		-5.714
<i>p</i> -value			.077		.114

NOTE.—All the regressions include pair-month fixed effects, worker fixed effects, and controls for worker tenure, worker department, and county-level unemployment. “Sales/Hour” is the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its dollar value. “Coverage” is measured as the supervisor-to-worker ratio (number of supervisors per 100 sales associates). “Low Coverage” (“High Coverage”) is an indicator for whether the store is in the bottom quartile (not in the bottom quartile) of coverage. “Minimum wage” is the predominant monthly minimum wage (in dollars) and is in deviation from its sample mean in cols. 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 the minimum wage. “High type” is an indicator for whether the worker’s total pay in month $t - 1$ is above 180% of the minimum wage. The omitted group (“low type”) is workers for whom total pay at $t - 1$ is at minimum wage. In col. 1, “Effect” is the percentage effect of a 1 standard deviation increase in coverage on sales per hour; and in cols. 2 and 4 it is the effect of a \$1 increase in minimum wage on the same outcome. “Effect of minimum wage increase” is the percentage effect of a \$1 increase in minimum wage on sales per hour for low-, medium-, and high-type workers. Standard errors are two-way clustered at the state level and at the border-segment level. The *p*-value is approximated to .009 if $p < .01$.

* $p < .1$.
 ** $p < .05$.
 *** $p < .01$.

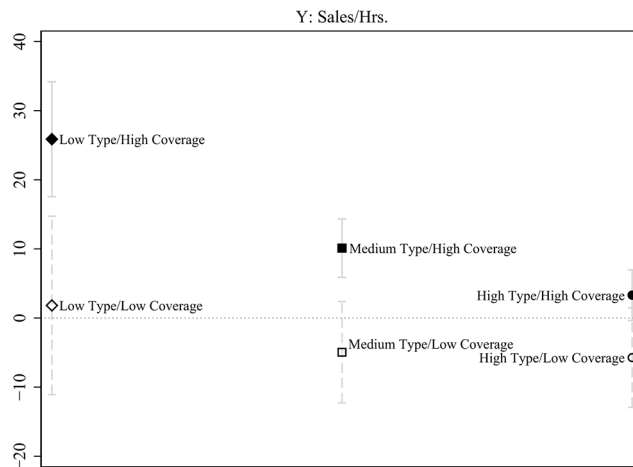


FIG. 4.—Minimum wage increases the productivity of low types with high monitoring and reduces the productivity of high types with low monitoring. Shown is the effect of a \$1 increase in the minimum wage on the percentage change in Y (sales per hour) for low-, medium-, or high-type workers for high/low monitoring coverage. “Low type” refers to workers for whom the total pay per hour in month $t - 1$ is at minimum wage, “medium type” refers to workers for whom the total pay per hour in month $t - 1$ is between the minimum wage and 180% of the minimum wage, and “high type” refers to workers for whom the total pay per hour in month $t - 1$ is above 180% of the minimum wage. 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 (col. 1) estimates the following store-level equation:

$$Y_{jpt} = \alpha + \beta \text{Min}W_{jt} + \eta Z_{jt} + \delta_j + \phi_{pt} + \epsilon_{jpt}, \quad (13)$$

where Y_{jt} represents the outcome of interest (supervisor-to-worker ratio) in store j of county-pair p in month t , δ_j represents 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.³⁷ 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

³⁷ Note that the positive sign for β , albeit small, does not support the Rebitzer and Taylor (1995) theory of endogenous monitoring, which predicts that an increase in the minimum wage decreases the need for monitoring and hence the equilibrium monitoring level.

figure (fig. A.2) where the monitoring coverage is measured in the pre–minimum wage period $t - 1$ (fig. 4A) or in our data set’s starting year (2012; fig. 4B). The coefficients are qualitatively similar, which is reassuring because both measures of monitoring coverage are predetermined and likely exogenous to subsequent minimum wage changes.

VI. Effect of Minimum Wage on Store-Level Outcomes

A. 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.³⁸ Empirically, the effect is driven by the low types, so 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:

$$Y_{jpt} = \alpha + \beta \text{MinW}_{jt} + \gamma \% \text{LowTypes}_{j,t} + \delta \text{MinW}_{jt} \cdot \% \text{LowTypes}_{j,t} + \eta Z_{jt} + \delta_j + \phi_{pt} + \epsilon_{jpt}, \quad (14)$$

where Y_{jpt} represents the outcome of interest in store j of county-pair p in month t , δ_j represents store 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 ($\% \text{LowTypes}_{j,t}$) is predetermined because types are defined based on worker pay in $t - 1$ relative to the minimum wage in $t - 1$.

Figure 5A–5D plots the effect of minimum wage for the range of $\% \text{LowTypes}$ we observe in our stores (0%–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.³⁹ 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).⁴⁰

³⁸ Table A.4 (col. 2) supports the assumption that store-level employment is in steady state conditional on store fixed effects and county-level unemployment.

³⁹ Because low types form a relatively small part of our stores’ workforce (the variable $\% \text{LowTypes}$ 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 wage raises the average workers’ monthly earnings by only \$35.30 (2.6%, not statistically significant) and store turnover by only 0.8% (table 6, col. 6).

⁴⁰ Figure 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.

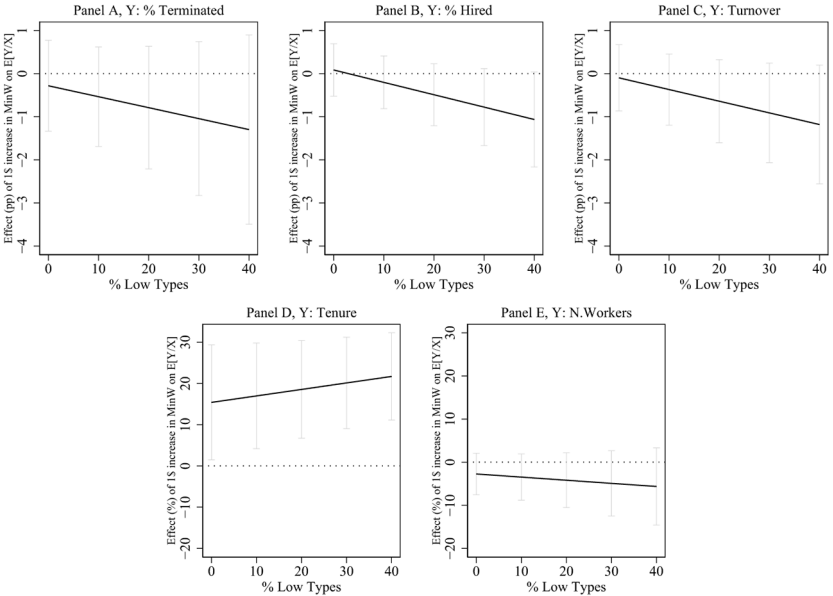


FIG. 5.—Minimum wage (MinW) reduces turnover and increases tenure in stores with a high fraction of low types. This figure plots $\beta + \delta \cdot \% \text{ LowTypes}$ from equation (14). The parameter Y represents the termination rate (A), hiring (B), turnover rate (C), average worker tenure (D), and number of sales associates (E). Vertical bars represent 95% confidence intervals for the estimator of $\beta + \delta \cdot (\% \text{ LowTypes})$. We report the effects in percent points in A–C and in percentages in D and E.

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 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.⁴¹ Figure 6 and table 7 (col. 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.

⁴¹ This approach to analyzing duration data is used by Frederiksen, Honoré, and Hud (2007) and Arellano (2008). Variants have also been employed by, among others, Hoffman and Tadelis (2021) and Sandvik et al. (2021).

TABLE 6
EFFECT OF MINIMUM WAGE ON STORE-LEVEL TURNOVER AND EMPLOYMENT

	DEPENDENT VARIABLE									
	% Terminated		% Hired		% Turnover		Tenure		Number of Workers	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Minimum wage	-.272 (.503)	-.282 (.538)	.213 (.308)	.084 (.310)	-.029 (.368)	-.099 (.393)	7.205** (3.513)	7.537** (3.479)	-.217 (.423)	-.451 (.405)
% low types		.222 (.207)		.276** (.118)		.249* (.124)		-.740* (.375)		.146 (.117)
Minimum wage · % low types		-.025 (.025)		-.029** (.013)		-.027* (.014)		.077* (.044)		-.012 (.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 dependent variable	4.755	4.877	2.060	2.073	3.408	3.475	49.65	49.62	16.64	16.63

NOTE.—The variable “% low types”—which represents the percentage of workers who are low types in the store before reform—is de-measured so that “Minimum wage” 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 a control for county-level unemployment. “% Terminated” is the percentage of sales associates in the store who are terminated in a given month. “% Hired” is the percentage of sales associates who are hired in the store in a given month. “% Turnover” is the percentage 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. “Number of Workers” is the number of sales associates in the store. “Minimum wage” is the predominant monthly minimum wage in the store (in dollars). Standard errors are two-way clustered at the state level and at the border-segment level.

* $p < .1$.

** $p < .05$.

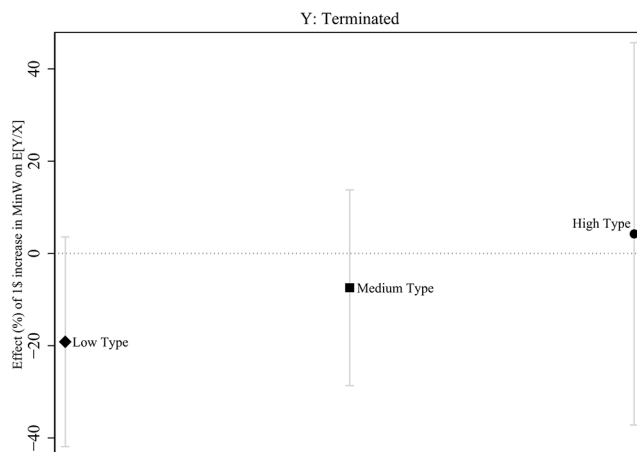


FIG. 6.—Minimum wage (MinW) reduces the termination of low types but not of high types. Shown is the effect of a \$1 increase in the minimum wage on the percentage change in termination ($Y = \text{terminated}$) for low-, medium-, and high-type workers. “Low type” refers to workers for whom the total pay per hour in month $t - 1$ is at minimum wage, “medium type” refers to workers for whom the total pay per hour in month $t - 1$ is between the minimum wage and 180% of the minimum wage, and “high type” refers to workers for whom the total pay per hour in month $t - 1$ is above 180% of the minimum wage. Vertical bars represent 95% confidence intervals computed using the estimated coefficients ($\hat{\beta}_1$, $\hat{\beta}_1 + \hat{\beta}_4$, and $\hat{\beta}_1 + \hat{\beta}_5$) from equation (11) but with store rather than worker fixed effects.

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 (empirically, the low types).

B. Effect of Minimum Wage on Employment

Table 6 (col. 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 with either profits per worker not responding to the minimum wage increase or the function $\kappa(\cdot)$ being very convex around some $\hat{L}$, as discussed in section II.E. We study the effects on profits in the next section.

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 table 6, col. 10; fig. 5E). In the spirit of Draca, Machin, and Reenen (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—that is, where all employees are low types—to a fully untreated store with no

TABLE 7
EFFECT OF MINIMUM WAGE ON WORKER TERMINATION

	DEPENDENT VARIABLE	
	Terminated (1)	Terminated (2)
Minimum wage	-.159 (.517)	-1.297* (.756)
Medium type		-2.240*** (.755)
High type		-3.753*** (.817)
Minimum wage · medium type		.912 (.620)
Minimum wage · high type		1.424** (.573)
Observations	217,822	209,734
Units	Workers	Workers
Mean dependent variable	4.562	4.562
Effect of minimum wage increase (%)	-3.482	
Effect of minimum wage increase for low type (%)		-19.16
<i>p</i> -value		.096
Effect of minimum wage increase for medium type (%)		-7.434
<i>p</i> -value		.480
Effect of minimum wage increase for high type (%)		4.247
<i>p</i> -value		.836

NOTE.—All the regressions include pair-month fixed effects, store fixed effects (not worker fixed effects), and controls for worker tenure, worker department, and county-level unemployment. “Terminated” equals 100 if the worker is terminated in a given month and equals zero otherwise. “Minimum wage” is the predominant monthly minimum wage (in dollars) and is in deviation from its sample mean in col. 2. “Medium type” is an indicator for whether the worker’s total pay in month $t - 1$ is between the minimum wage and 180% of the minimum wage. “High type” is an indicator for whether the worker’s total pay in month $t - 1$ is above 180% of the minimum wage. The omitted group (“low type”) is workers for whom total pay in $t - 1$ is at minimum wage. “Effect of minimum wage increase” is the percentage effect of a \$1 increase in minimum wage on the outcomes. Standard errors are two-way clustered at the state level and at the border-segment level.

* $p < .1$.
 ** $p < .05$.
 *** $p < .01$.

low types. The point estimate for this elasticity is -0.0057 .⁴² 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).⁴³

⁴² This 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 percentage 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.

⁴³ This elasticity is computed by dividing -0.0057 by the percentage 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.

C. *Effect of Minimum Wage on Output and Profits*

1. 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 IV.A and VI.A. The overall effect is theoretically ambiguous. Using equation (6) from the theory, we calibrate the size of these two effects using the point estimates from the worker-level analysis as inputs (sec. IV). 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 app. 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, col. 1). In sum, regardless of the procedure, we find that increasing the minimum wage increases store-level productivity.

TABLE 8
EFFECT OF MINIMUM WAGE ON STORE-LEVEL OUTPUT AND PROFITS
IN BORDER STORES AND ALL STORES

	DEPENDENT VARIABLE			
	Border Stores		All Stores	
	Output/ Hour	EBITDA/ Hour	Output/ Hour	EBITDA/ Hour
	(1)	(2)	(3)	(4)
Minimum wage	.062** (.026)	.383 (1.317)	.029* (.017)	−.781* (.436)
Observations	12,359	12,359	30,969	30,969
Units	Stores	Stores	Stores	Stores
Mean dependent variable	.827	5.946	.830	4.824
Effect of minimum wage increase (%)	7.551	6.441	3.457	−16.18

NOTE.—In cols. 1 and 2, the sample is restricted to bordering stores as in the other tables. The regressions include pair-month fixed effects, store fixed effects, and county-level unemployment, and standard errors are two-way clustered at the state level and at the border-segment level. In cols. 3 and 4, the sample comprises all stores (bordering and nonbordering). The regressions include census division-month fixed effects, month fixed effects, store fixed effects, and county-level unemployment, and standard errors are clustered at the state level. “Output/Hour” is equal to total store revenues per hour worked in the store. “EBITDA/Hour” is equal to EBITDA per hour worked in the store. We do not disclose the units for confidentiality reasons. “Minimum wage” is the predominant monthly minimum wage (in dollars). “Effect of minimum wage increase” is the percentage effect of a \$1 increase in minimum wage on the store-level outcomes.

* $p < .1$.
** $p < .05$.

2. 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 $\bar{w}$ is not adapted to local conditions, and border stores may not be representative of all stores.⁴⁴ However, assuming that headquarters choose the compensation scheme $\bar{w}$ 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, with added linear state trends, or with added census division $\times$ month fixed effects). As the only specification that eliminates pretrends in profits, employment, and individual sales per hour is the census division $\times$ month fixed effects (tables A.5, E.1), we report the results for this specification alone.

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, col. 4).⁴⁵

VII. 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.

A. Demand Channel

A demand increase that systematically coincides with a minimum wage increase might account for the average increase in individual productivity.⁴⁶

⁴⁴ See sec. III.A.5 for a discussion of this institutional feature. Footnote 17 provides a counterexample where profits increase with the minimum wage because $\bar{w}$ is not well adapted to local conditions. By 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 nonrepresentative stores.

⁴⁵ For the sake of comparison, we also present the results on profits in the border sample. We document a zero-profits effect (table 8, col. 2). At the risk of overinterpreting differences in estimates across nonnested 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; cf. tables 4, E.7.

⁴⁶ The 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, Agarwal, and French (2012)

Yet a demand increase is at odds with the productivity reduction observed among low-monitored workers (sec. V). In addition, a demand increase alone does not easily account for why high types fail to experience a productivity boost (sec. IV). 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; fig. 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 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 with 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 coworkers — 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 VI.B the number of salespeople employed by a store does not significantly correlate 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, for example, “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 underrepresent the true effect of the minimum wage on effort.

B. Organizational Adjustments Channel

Stores could respond to a higher minimum wage with organizational adjustments that (potentially) might disproportionately increase the low

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.

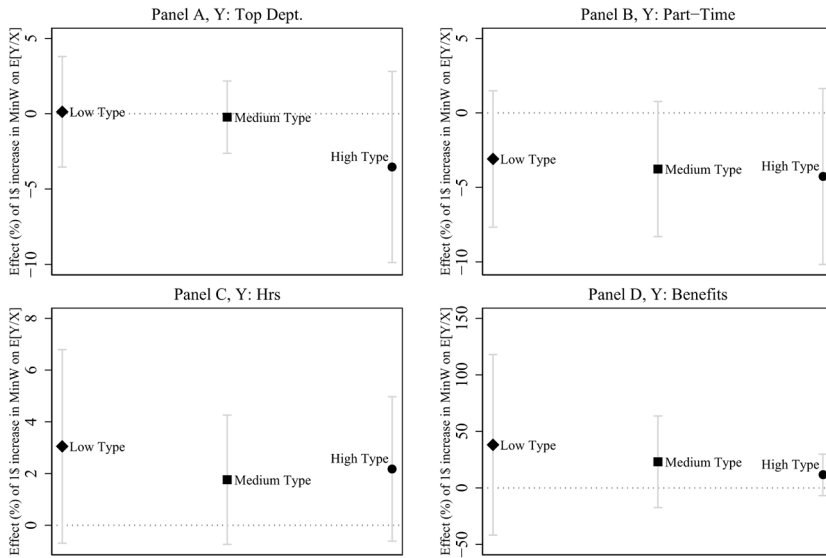


FIG. 7.—Minimum wage (MinW) has no differential effect on allocation to best-selling departments, part-time status, hours worked, or benefits by type. Shown is the effect of a \$1 increase in the minimum wage on the percentage change in Y for low-, medium-, and high-type workers. “Low type” refers to workers for whom the total pay per hour in month $t - 1$ is at minimum wage, “medium type” refers to workers for whom the total pay per hour in month $t - 1$ is between the minimum wage and 180% of the minimum wage, and “high type” refers to workers for whom the total pay per hour in month $t - 1$ is above 180% of the minimum wage. The parameter Y is an indicator for working in the best-selling departments (A), being a part-time worker (B), the number of hours worked per month (C), or benefits (in dollars) earned (D). Vertical bars represent 95% confidence intervals computed using the estimated coefficients (β_1 , $\beta_1 + \beta_4$, and $\beta_1 + \beta_5$) from equation (11) and the associated standard errors.

types’ sales per hour. These could include, for example, reallocating them to “better-selling” departments,⁴⁷ 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 illness benefits. Figure 7 (and the corresponding table F.6) shows that the company did not make these adjustments differentially across types.⁴⁸

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

⁴⁷ 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.

⁴⁸ The 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.

rise in prices should be a tide that lifts all boats, thus increasing sales for all workers, not only 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 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.

VIII. 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), and (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

$$V^A(M) = \frac{s(M)}{r + s(M)} \mathbb{E}_h[V^E(x; M)], \quad (15)$$

where $V^E(x; M)$ represents 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 empirically assess 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 $\mathbb{E}_h[V^E(x; M)]$ 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).

IX. 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—for example, 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 coworkers'. While this assumption has some empirical support in our case, as detailed in section VII.A, 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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