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

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**Abstract**

We study the effect of increasing the statutory minimum wage on individual worker productivity. Within a workforce of base+commission salespeople from a large US retailer, and using a border-discontinuity research design, we document that a 65 cents (one standard deviation) increase in the minimum wage increases individual productivity (sales per hour) by 2%. With the help of a model, we seek evidence in favor of two distinct channels through which this productivity gain could arise: a demand increase, and an incentive effect due to the increase in compensation, part of which may be endogenous due the firm adjusting its compensation scheme. We find evidence only for the second, that is, the compensation scheme channel. Further, we find that the productivity gains are concentrated among low-productivity workers, and arise mostly during high-unemployment spells, which when read through the lens of our model suggests an efficiency-wage effect. We find some indication that the firm increases base pay in response to minimum wage increases, which is consistent with optimal contracting within our model, but the model suggests that the productivity gain is not fully mediated by this endogenous firm response.

Keywords: minimum wage, worker productivity, efficiency-wage.
JEL Classification: J24, J30, M52.

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# 1 Introduction

This paper studies the effect of increasing the minimum wage on individual worker productivity. The vast empirical literature on minimum wage is largely silent on the productivity effects of the minimum wage.[1]

We tackle this issue using unique data on the wages and individual productivity of salespeople from a large US retailer. Our firm operates across all 50 US States and employs between 5 and 10% of department store employees, or roughly 1-2% of employment in the entire US retail sector. The employees whose productivity is measured are salespeople who are paid an hourly base rate plus a commission tied to sales per hour. The law requires the firm to top up the worker's total wage (base+commission) in any week where that wage falls short of the statutory minimum wage level.

To estimate the effect of a minimum wage increase, we compare workers in stores which have experienced a minimum-wage increase with workers in nearby stores which haven't. Following the approach developed by Card and Krueger (1994, 2000), Dube et al. (2010, 2016), Allegretto et al. (2011), and Addison et al. (2012, 2014), we restrict our sample to stores located in near-border jurisdictions in order to achieve a sample of comparable treated and control stores. The final sample comprises more than 10,000 workers in more than 300 stores, with over half of the stores having experienced at least one increase in the minimum wage.

We find that a 65 cents increase in the minimum wage (one standard deviation) causes individual productivity (sales per hour) to increase by 2% after controlling for worker fixed effects.

Two channels exist through which the minimum wage could affect the productivity of salespeople. First, a demand channel: retail demand might change systematically in conjunction with minimum wage, and this may affect average sales per hour. Second, a compensation channel: a higher minimum wage increases the workers' income in low-productivity states, which may have complex effects. On the one hand, a higher minimum wage may decrease workers' incentives to exert effort; on the other hand, workers are made

[1] The one exception is Ku (2017), which we discuss below.

better off and so they may care more about being retained—especially when unemployment rate is high—and thus may exert more effort (this is an efficiency-wage channel). In addition, and separately, there may be an indirect effect if the firm strategically adjusts its base+commission in order to fine-tune the workers' incentives to the new minimum wage.

To help discriminate between these channels, we present a simple model of a monopolistic firm setting a base+commission compensation scheme for workers with different productivity. The analysis shows that, if a positive demand shock is responsible for increased productivity, then all workers, including the most productive, should benefit. If instead changes in the compensation scheme are responsible for the increase in productivity then the effect should work through increased effort, and the model indicates that: (i) it is the marginal (least productive) workers whose effort is most responsive; (ii) the effect should be sharper during worse unemployment spells. In addition, the model suggests that the firm should endogenously increase the base rate, but not the commission rate, in response to a minimum wage increase.

When we take these channels to the data, we find scant evidence for the demand channel: not only are the most productive workers not experiencing a productivity gain, but in addition, minimum wage levels do not appear to be correlated with accepted proxies for retail demand such as unemployment levels and residential housing prices. We find evidence for the compensation channel: first, average productivity gains are sharper during high-unemployment spells; second, the productivity gains are larger for the least-productive workers. We also find some indication that the firm raises base pay, but not the commission rate; however, this endogenous response by the firm is weak and cannot, we argue, fully account for the observed productivity gains.

We examine, and ultimately rule out the possibility that, despite the presence of worker fixed effects, our productivity estimates might be inflated by the selective termination of less-productive workers: when we restrict the sample to a balanced panel containing only workers who are employed throughout the sample period, the estimated productivity gain associated with a minimum wage increase remains stable. We also rule out the possibility that workers migrate from "control" to "treated" jurisdictions, which might confound our estimates if the best workers are migrating. By analyzing the distance between each worker's home zip code and workplace, we find no evidence of migration. Finally, we explore the robustness of our results to the definition of "bordering jurisdictions" by varying the definition of "bordering."

While we rule out worker selection as a confounder, worker composition has independent economic interest beyond its confounding effects on our estimates. So we explore the change in workforce composition and find that, after a minimum wage increase: employment increases slightly in a store, and this effect is driven by lower termination among low-productivity types. Both effects are consistent with the model's predictions.

Finally, we perform a back-of-the envelope calculation which suggests that an increase in minimum wage transfers money from firm to worker while generating higher worker productivity. The net effect is lower firm profits, and presumably higher worker welfare.

The paper proceeds as follows. Section 2 presents an overview of the literature on minimum wage and sheds light on our contribution. Section 3 presents the model. Sections 4 and 5 explain the data, the institutional context, and the identification strategy. Section 6 discusses the effect of minimum wage on worker productivity, explores the underlying channels and rules out a number of confounders. Sections 7 explores workforce composition. Section 8 calculates the effect of minimum wage on worker pay and firm profits. Section 9 concludes.

# 2 Related Literature

- **Minimum wage and worker productivity.** Ku (2017) measures the change in productivity for tomato pickers in a large Florida farm, before and after the January 2009 minimum wage increase. Like us, Ku (2017) finds that less-productive workers gained more productivity than more-productive workers. However, Ku's (2017) before-after research design does not allow her to obtain estimates of the average (as opposed to only relative) productivity gain. We are able to provide estimates of the average productivity gains because we implement a difference-in-difference strategy, with some nearby jurisdictions experiencing no minimum wage increase. Unlike Ku

(2017), we also document whether the firm endogenously adapts the contract offered to workers when minimum wage increases. Finally, our richer data comprising more than 50 minimum-wage events allows for a richer set of covariates, e.g., unemployment level. With that being said, our analysis is complementary and not substitute with Ku (2017) because the two workforces operate in different sectors (retail v. agriculture), and because Ku's (2017) dependent variable, weight of fruit picked, is a more direct measure of productivity than sales per hour.

- **Experimental literature on efficiency wages.** A large experimental literature has studied efficiency wages interpreted as gift exchange or reciprocity (e.g., Gneezy and List (2006), Della Vigna et al. (2016)). Our paper, in contrast, defines efficiency wages as in Shapiro and Stiglitz (1984), where the efficiency wage mechanism refers to the incentive effect provided by the outside option (being terminated). Only two experimental papers study this notion of efficiency wages: Macpherson et al. (2014), and Huck et al. (2011). Neither paper studies the effect of increasing the minimum wage.

- **Unemployment and worker productivity.** Lazear et al. (2016) study worker-level data from a large US service company before and after the great recession and find that worker productivity increases after the recession and that this effect cannot be attributed to selection into employment. In addition, this effect is stronger in higher-unemployment areas. This evidence is consistent with, but not necessarily indicative of, an efficiency-wage channel. To this extent, our paper is related with Lazear et al. (2016).

- **Minimum wage and worker turnover.** Dube et al. (2016) report evidence that in the U.S. a 10% increase in the minimum wage results in a reduction of 2.1% in turnover for restaurant workers and teenagers. With a similar research design, our estimates in Section 7 are fairly consistent with their finding.

- **Minimum wage and firm-level variables.** Myneris et al. (2016) look at firm-level TFP, before and after the 2004 increase in the Chinese minimum wage. They show that the productivity of more-exposed firms increased, conditional on survival, relative to less-exposed firms.

- **Minimum wage and demand.** There is a small literature on the pass-through from the minimum wage to the demand for retail goods: Aaronson et al. (2012), Leung (2017), and Ganapati and Weaver (2017). On balance, this literature is ambiguous as to whether such a pass-through exists. This literature is useful context for our analysis of the demand channel.

- **Minimum wage and employment.** There is a large literature on the effect of the minimum wage on employment summarized in Card and Kruger (2017). Within this literature, perhaps the closest paper is Giuliano (2013), who uses similarly-detailed HR data from a large US retailer (in the apparel industry). Whereas Giuliano (2013) focuses on employment as the outcome, we focus on worker productivity.

# 3 Model

Time is discrete and infinite. There is a monopolistic firm and many workers (to fix ideas: sales agents). Workers are indexed by $\sigma$, where $\sigma$ represents the hourly revenue that may be generated by that worker if the worker exerts effort. The index $\sigma$ captures a variety of factors contributing to labor productivity, including: the agent's skill as a salesperson; the schedule/shift to which the worker is assigned (for example, the 6pm-9pm shift might be less busy); and, finally, consumer demand (later we will model an increase in demand as a across-type increase from $\sigma$ to $\delta\sigma$, with $\delta > 1$). We assume that $\sigma$ is distributed according to the density $f(\sigma) = \frac{1}{\sigma}K$ with support $[\varepsilon, 1]$, with $K$ being the constant of integration.[2]

If a worker of type $\sigma$ exerts effort $e \in [0, 1]$ she produces sales of either 0 or $\sigma$, with:

$$\Pr(\sigma) = \frac{1}{2}e.$$

It costs a worker $c \cdot e$ to exert effort $e$.

In each period, a worker of type $\sigma$ is compensated with a base rate $B$, plus a commission $R\sigma$ in case the agent was productive, with $R \in [0, 1]$. If the compensation falls below the statutory minimum wage level $M$, compensation of low-$\sigma$ workers must be topped up to

[2]The density is decreasing, implying that more-productive workers are less represented. The constant $K = -1/\log\varepsilon$ ensures that $K\int_{\varepsilon}^{1}\frac{1}{\sigma}d\sigma = K[\log\sigma]_{\varepsilon}^{1} = K(-\log(\varepsilon)) = 1$.

$M$. The compensation scheme $(B, R)$ is committed to by the firm.[3] An agent is terminated in period $t+1$ unless the agent exerted effort in period $t$.[4]

Given a compensation scheme $(B, R)$ a worker of type $\sigma$ chooses her effort level $e^*(\sigma)$ by solving the following recursive problem:

$$V(\sigma) = \max_e \left[\max[M, B]\left(1 - \frac{1}{2}e\right) + (\max[M, B + R\sigma]) \cdot \frac{1}{2}e - c \cdot e\right] + \beta\left[eV(\sigma) + (1-e)\,\Omega(M, u)\right].$$

$\Omega(M, u)$ represents the value of the worker's outside option if terminated, i.e., her labor-market value. This value is assumed to be nondecreasing in the minimum wage $M$, and non-increasing in unemployment $u$.[5] We assume that $0 \leq \Omega_1 \leq 1$ and $\Omega_{12} < 0$, i.e.: as the minimum wage increases the worker's outside option does not grow faster than the value of the minimum wage itself, and this growth rate is decreasing in the unemployment level. For example, the worker's outside option might take the form:

$$\Omega(M, u) = \Pr(\text{finding another job}|u) \cdot W(M),$$

where $W(M)$ is the expected labor-market wage conditional on finding employment. Assuming that $\Pr(\text{finding another job}|u)$ is decreasing in $u$, all the assumptions in our model are satisfied. In this specification human capital $\sigma$ has no value on the outside labor market (it is purely firm-specific).[6]

The firm chooses the compensation scheme to solve:

$$\max_{B,R} \sum_{t=0}^{\infty} \beta^t \int_0^1 \left[-\max[M, B]\left(1 - \frac{1}{2}e^*(\sigma)\right) + [\sigma - (\max[M, B + R\sigma])] \cdot \frac{1}{2}e^*(\sigma)\right] f(\sigma)\, d\sigma. \tag{1}$$

[3]This commitment means that we are not in a relational contract setting, just in an efficiency wages setting.

[4]Note that the decision to terminate the worker is based on whether effort was exerted, whereas compensation is based on a noisy signal: whether the effort produced output. This modeling choice captures the idea that the decision to terminate is likely based on information that is less noisy than the factors that determine hourly compensation. In a more complex model one might build in a cost of terminating a worker, and a costly state-verification option (did the worker in fact shirk?) that the firm might trigger before deciding whether to terminate the worker.

[5]Note that allowing $\Omega$ to depend on $M$ or $u$ is not necessary: all the results hold if the outside option is independent of these quantities.

[6]At the cost of additional complexity it is possible to generalize the analysis to the case where $\Omega$ is an increasing and concave function of $\sigma$.

This formulation of the firm's objective function perfectly fits the case where $\sigma$ represents the worker's shift. In the case where $\sigma$ represents worker skill, this formulation implies the assumption that a terminated worker of skill $\sigma$ is replaced by a worker of the same skill; we accept this simplifying assumption as the price for tractability.

This formulation also maintains the assumption that it is optimal for the firm to employ a worker even if she does not exert effort. This makes sense if we reinterpret effort as "above-and-beyond effort," and assume that even a worker who does not put in such effort can still be productive. If we relaxed this assumption and allowed some worker types to be truly unproductive, the firm may well select the least productive workers and terminate them. The fired workers would likely be the low-$\sigma$ type. We stop short of making selective termination endogenous in this model, but we discuss it later as an empirical confounder of our estimates.

Denote the value of $V(\sigma)$ at $e = 0$ by:

$$V^S = \max[M, B] + \beta\Omega(M, u).$$

This is the value of shirking for worker of type $\sigma$. The value for worker $\sigma$ of exerting effort is given by the value of of $V(\sigma)$ at $e = 1$, which is denoted by:

$$V^W(\sigma) = \left[\frac{1}{2}\max[M, B] + \frac{1}{2}\max[M, B + R\sigma] - c\right] + \beta V^W(\sigma).$$

Solving for $V^W(\sigma)$ yields:

$$V^W(\sigma) = \frac{1}{2(1-\beta)}[\max[M, B] + \max[M, B + R\sigma] - 2c].$$

The function $V^W(\sigma)$ is nondecreasing in $\sigma$. The types who choose to exert effort are those $\sigma$'s for whom $V^W(\sigma) > V^S$ (typically, higher types).

## 3.1 Determinants of Worker Productivity for Given Compensation Scheme

In this section we fix the compensation scheme and study several channels that may cause productivity to increase as the minimum wage increases. To this end we make the following assumptions on the compensation scheme $(B, R)$.

**Assumption 1:** Base pay does not exceed the minimum wage: $B \leq M$.

**Assumption 2:** The compensation scheme $(B, R)$ is not so generous that every worker exerts effort, i.e., we assume that $V^W(\varepsilon) < V^S$.

The first assumption ensures that we focus on the empirically relevant case in our data, where the base pay is always below minimum wage. The second assumption ensures that, as the minimum wage increases, there is room for productivity to increase: this assumption ensures that our question is meaningful. These assumptions will be maintained throughout Section 3.1.

The next proposition characterizes worker productivity. All proofs are in Appendix A.

**Lemma 1.** ***(worker behavior for given compensation scheme)****. Fix any base+commission compensation scheme $(B, R)$ and let*

$$\overline{\sigma} \stackrel{\text{def}}{=} \frac{(1-2\beta)\max[M, B] + 2(1-\beta)\beta\Omega(M, u) - B + 2c}{R}. \tag{2}$$

*Then all types $\sigma$ below $\overline{\sigma}$ exert zero effort and produce zero, all others types exert maximum effort and produce $\sigma/2$ in expectation.*

Lemma 1 fully characterizes worker productivity. The expression for $\overline{\sigma}$ has intuitive properties: worker motivation to exert effort increases if the compensation scheme $(B, R)$ is more generous. In addition, if $\beta$ is sufficiently close to 1, increasing the minimum wage will motivates workers, provided that the minimum wage "bites," i.e., $M > B$.

We now explore what happens after a positive demand shock.

**Proposition 2.** ***(effect of demand increase, keeping the minimum wage constant)*** *Fix any base+commission compensation scheme $(B, R)$ such that $\overline{\sigma} \in (\varepsilon, 1)$. Suppose a positive demand shock increases every worker's type $\sigma$ to $(1+\delta)\sigma$. Then more workers exert effort, and workers at the upper tail of the productivity distribution become more productive after the demand increase.*

This proposition illustrates that the productivity of the most productive types increases. The productivity gains following a demand increase can be gleaned by comparing Panels (a) and (b) in Figure 1. Notice particularly that, as stated in proposition 2, the productivity of even the most productive types increases. This effect is not due to a change in effort since these types put in maximal effort even before the demand shock. This feature (increased productivity at the top) will provide a contrast with the effect of an increase in the minimum wage.

We now explore what happens after an increase in the minimum wage.

**Proposition 3.** ***(effect of increasing the minimum wage, keeping demand constant)*** *Fix any base+commission compensation scheme* $(B, R)$ *such that* $\overline{\sigma} \in [\varepsilon, 1)$*, and assume* $\beta > \sqrt{1/2}$*. Then average productivity increases as* $M$ *increases. This effect is generated by the behavior of the least-productive workers (the productivity of the most-productive workers does not change), and it is more pronounced in times of high unemployment. The workers who switch to exerting effort avoid termination.*

This proposition predicts that increasing the minimum wage should incentivize greater effort and thus increase productivity, at least if workers are sufficiently patient. This result may seem counter-intuitive because increasing the minimum wage increases the payoff from shirking. However, shirking is followed by termination and so, if workers are patient, the following efficiency-wage logic dominates: even a worker who plans to forever exert effort will produce zero sometime in the future, and in that case she will earn minimum wage. Thus increasing the minimum wage improves the future utility stream of forever exerting effort. If the worker is patient, the increase in this future utility outweighs the one-time increased payoff from shirking, which is followed by termination.

The previous propositions deal with the case in which the firm does not adjust the compensation scheme as the minimum wage increases; however, in our data we do find some evidence that increases in the minimum wage may be associated with an increase in the base rate. The following corollary covers this case.

**Corollary 4.** *Suppose that, as* $M$ *increases, the base pay increases. Then the results in Proposition 3 continue to hold. If base pay increases without any change in* $M$ *then the effects on productivity are independent of the unemployment level.*

Corollary 4 shows that if base pay happens to increase together with the minimum wage, productivity still increases. The productivity gains following a minimum wage increase can be gleaned by comparing Panels (a) and (c) in Figure 1. As stated in Proposition 3 and in contrast with Panel (b), the productivity of the most productive types does not change. This is because these types put in maximal effort even before the minimum wage increase. This contrast will provide a testable implication in the empirical section, which we will use to evaluate whether the productivity gains following an increase in the minimum wage can be partly attributed to a concurrent increase in demand.

Panel (d) of Figure 1 represents the selection effect of terminating the least-productive workers. Average productivity increases because the lower tail of productivity is removed. If the firm does this following a minimum wage increase, this confounding effect could also be responsible, at least partly, for any observed *average* productivity gains following a minimum wage increase. Of course, Panel (d) also reveals that if we fix any type $\sigma$ (empirically, this is achieved by introducing fixed effects in our regression), then there is no *individual* productivity gain for that type during their employment period.[7]

Overall, in this section we have studied several channels that may cause productivity to increase as the minimum wage increases: a concurrent increased demand (Proposition 2); increased incentives due to the increase in minimum wage (Proposition 3); increased incentives due to a concurrent increase in compensation (Corollary 4). The theory provides ways to tease out these different channels. In addition we have pointed out a possible confounder: concurrent increased selection, and pointed to empirical specifications to deal with this confounder (see above discussion of Figure 1, Panel d).

A limitation of the analysis in this section is that the compensation scheme is not chosen optimally by the firm. Therefore the analysis in this section does not provide guidance on whether we should expect the firm to increase base pay following an increase in the minimum wage. To address this question, the next section studies the optimal compensation scheme.

[7]Fixed effects alone may not suffice to fully control for the selection effect in a population with high worker turnover. We carefully explore selection bias in Section 6.3.

## 3.2 Optimal Compensation Scheme

In this section we characterize the optimal compensation scheme in our setting. This is the pair $(B^*, R^*)$ that maximizes (1), noting that the choice of $(B, R)$ affects the types of workers that exert effort.

Proposition 5 below focuses on the case where it is optimal for some, but not all workers exert effort. This is the empirically relevant case, as opposed to the two extremes where either no worker exerts effort or all workers exert effort.[8] The extreme cases are treated in the Appendix B.

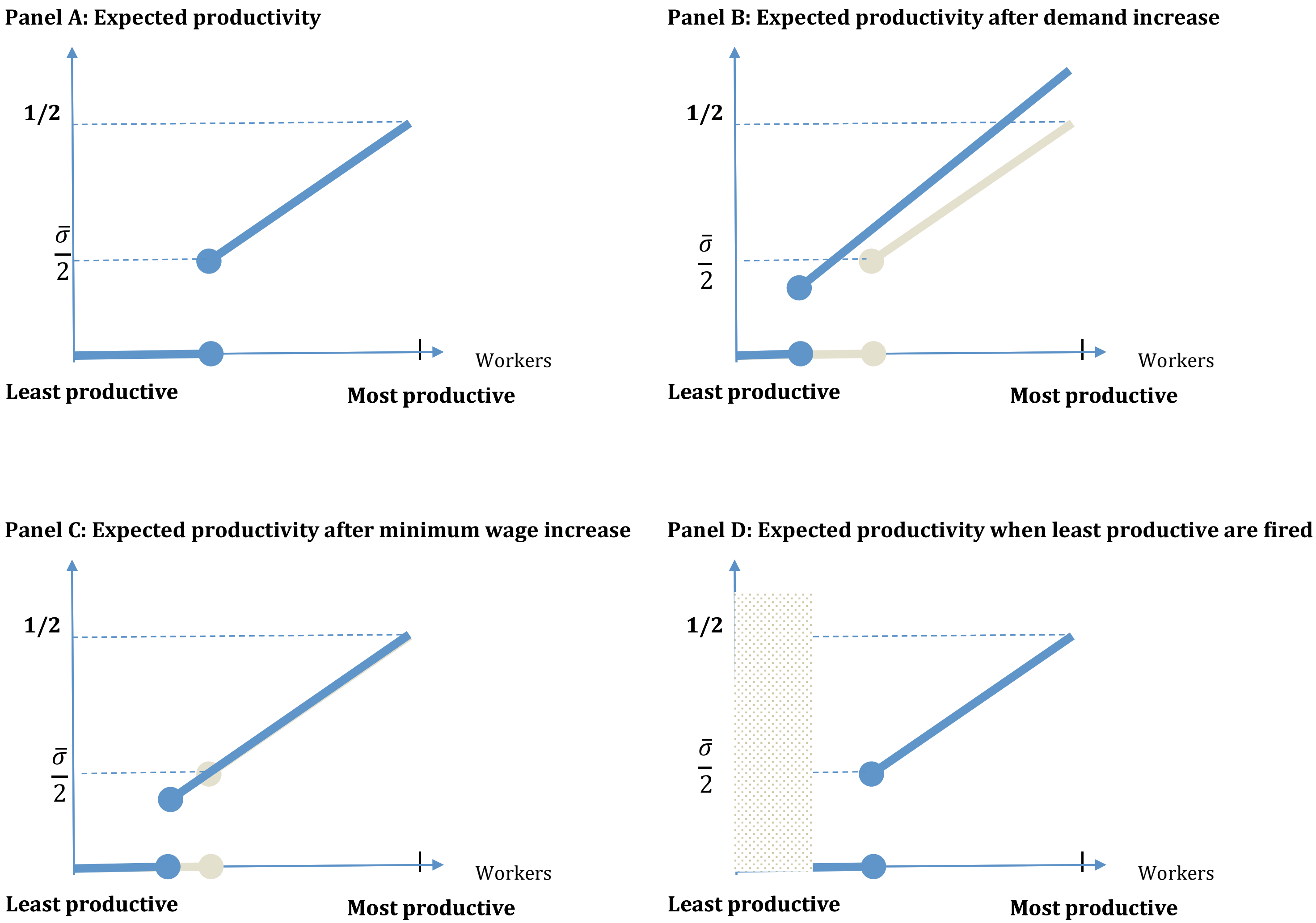
**Proposition 5.** ***(characterization of the optimal compensation scheme)*** *Suppose that it is optimal to have some, but not all workers exert effort in equilibrium. Then at the optimal compensation scheme we have:* $B^* = M$, $R^* = \overline{\sigma}^*$. *The optimal base pay* $B^*$ *is increasing in* $M$, *the optimal commission rate* $R^*$ *is decreasing in* $M$ *and productivity is increasing in* $M$.

The intuition for why it is optimal for the firm to increase base pay and lower the commission rate as the minimum wage increases is as follows. As the minimum wage increases, the efficiency-wage logic pushes workers to exert more effort. Thus the type $\overline{\sigma}^*$ who is indifferent between exerting effort and shirking is now lower. This is the marginal type that needs to be incentivized to exert effort, and the lower the type, the cheaper it is for the firm to provide incentives through base pay rather than through commissions.

Even though the optimal compensation scheme turns out to involve a higher base pay than is observed in our data, the optimal base pay is found to be increasing in the minimum wage level. Thus the theoretically-optimal compensation scheme matches the comparative statics of the observed compensation scheme. So it is reassuring to know that, at a theoretical level, it makes sense for every firm to systematically react as our firm did and raise compensation in response to an increase in the minimum wage.

[8] The case where all workers exert effort is incompatible, we argue, with our empirical findings that individual productivity increases after a minimum wage increase.

Figure 1: Theory



# 4 Data and Institutional Background

We match bi-weekly worker-level payroll data with monthly personnel records of a nationwide American retail store chain. Our data also contains monthly store-level employment information. Confidentiality restrictions limit our ability to disclose the exact nature of the products being sold, and the exact number of stores/employees.

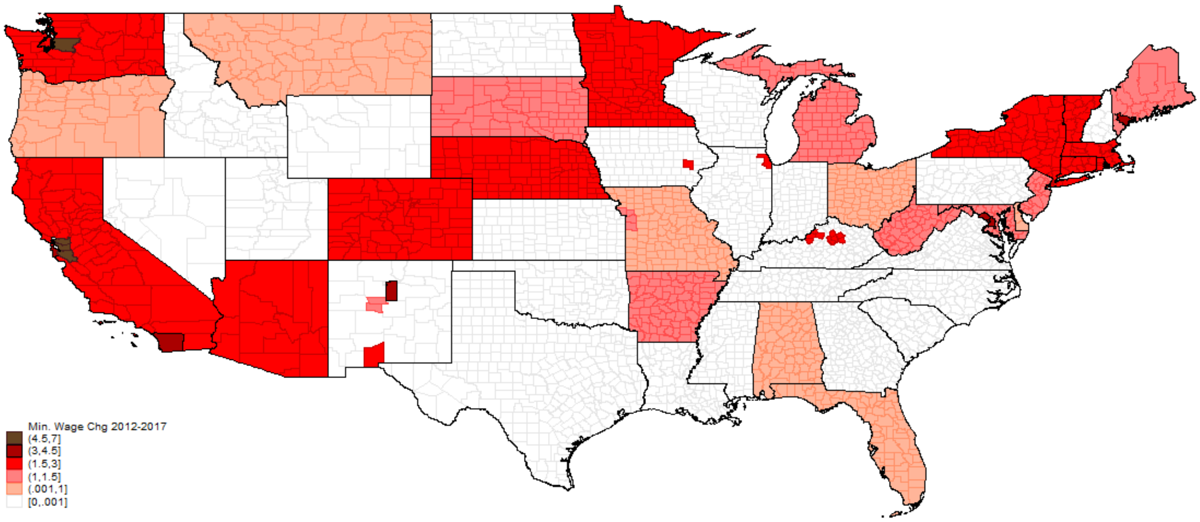
The sample consists of more than 40,000 hourly salespeople paid on base+commission, working in more than 500 stores across the United States. For each salesperson in our sample we observe monthly worker-level productivity (sales per hour) and earnings (hourly base and hourly commission) between February 2012 and June 2015. Our data also contains time-invariant information on the geographical location of stores (latitude and longitude), which are spread across all 50 US states.

We match store location with the monthly minimum wage level in that location.[9] Local jurisdictions differ in the minimum wage level. In Figure 2 we plot all variations in minimum wage since 2012. These variations take place at state, county and city levels; with city and county minimum wages always set to be higher than the state minimum wage. Since 2012, we count 44 variations in minimum wage at the county or city level and another 87 variations at the state level. The mean minimum wage is \$7.86 per hour and the average increase in minimum wage is \$0.56. Most of these variations occur in January, with a minority occurring in June, July, or other months. The exact timing of each minimum wage change is reported in Table C.2, and Table C.1 shows the states that had no change in their minimum wage since 2012.[10]

[9]the latter is extracted from the public dataset maintained by the Washington Center for Equitable Growth.

[10]Beyond the effect of changes in the statutory minimum wage, there is a notable event related to the minimum wage that is specific to our company. In November 2014 our company chose to increase the base pay in its California stores to the prevailing minimum wage levels, i.e., to a considerably higher level than base pay in other states. By increasing its base pay to the level of the minimum wage, the firm was able to use a safe-harbor provision which was endorsed by the California Labor and Workforce Development Agency as a legal means to avoid costly record-keeping requirement regarding the hour-by-hour nature of each worker's task. We regard this variation in base pay as not directly related to any minimum wage increases (there was none in November 2014), and so we account for this variation by including an interaction term for California post November 2014 in all specifications throughout the paper. The results are qualitatively and quantitatively robust to removing the post-November 2014 data from California.

Figure 2: Variations in Minimum Wage




Note: Store locations are withheld for confidentiality reasons.

Our identification strategy will require us to restrict to stores located close to each other, some of which have experienced a minimum wage increase. The sample selection procedure is described in the next section. Table 1 reports descriptive statistics for workers within this restricted sample. Average hourly productivity (sales per hour) is approximately 2 and total monthly pay 13.37. For confidentiality reasons, the units of both variables are hidden: the numbers are re-scaled by a factor between 1/50 and 1/150 relative to their $ value.

The average salesperson earns an average of $12.2 per hour. Total compensation includes base ($6.1/h) + commission pay ($5.65/h), and in addition small amounts ($0.22/h) in benefits and occasional retention bonuses. If a worker's average hourly pay (base + commission) falls below the minimum wage in a week, the worker is paid a "minimum wage adjustment" which brings total pay in line with the statutory minimum wage requirements. On average, workers receive a minimum wage adjustment 0.74 weeks per month, for a total of $0.23/h. 3.3% of workers receive the adjustment each week of the month, 37% of the workers receive it in some weeks only, 59% receive the adjustment zero weeks per month.

Table 1: Worker-Level Descriptive Statistics

| Variables | mean (1) | sd (2) | p10 (3) | p50 (4) | p90 (5) | N (6) |
|---|---|---|---|---|---|---|
| *Productivity* | | | | | | |
| Sales/Hrs. (hidden unit) | 2.061 | 1.540 | 0.669 | 1.875 | 3.562 | 179,049 |
| *Compensation* | | | | | | |
| Base Rate: Reg.Pay/Hrs. (in $) | 6.108 | 3.490 | 4.500 | 6 | 7 | 179,049 |
| Comm.Rate: Var.Pay/Sales (in %) | 3.295 | 3.013 | 1.069 | 2.276 | 6.926 | 171,139 |
| Var.Pay/Hrs. (in $) | 5.653 | 4.693 | 1.720 | 4.520 | 10.67 | 179,048 |
| MinW (in $) | 7.865 | 0.648 | 7.250 | 8 | 9 | 179,049 |
| Weekly MinW Adj. (=1 if yes) | 0.033 | 0.178 | 0 | 0 | 0 | 179,049 |
| # MinW Adj. (1 to 5) | 0.736 | 1.088 | 0 | 0 | 2 | 179,049 |
| MinW Pay/Hrs (in $) | 0.229 | 1.781 | 0 | 0 | 0.757 | 179,048 |
| Tot.Pay.Rate: Tot.Pay/T.Hrs. (in $) | 12.18 | 4.343 | 8.676 | 11.00 | 16.93 | 179,049 |
| Tot.Pay (hidden unit) | 13.37 | 7.971 | 4.968 | 12.13 | 22.67 | 179,049 |
| *Other* | | | | | | |
| Tenure (in months) | 46.82 | 66.71 | 3 | 21 | 124 | 179,049 |
| Terminated (in %) | 4.772 | 21.32 | 0 | 0 | 0 | 179,049 |

Note: N=Workers*Months. *Sales/Hrs.* are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its $ value. *Base: Reg.Pay/Hrs.* are monthly regular earnings per hour worked (in $ per hour). *Comm.Rate: Var.Pay/Sales* are earnings from commissions and incentives divided by sales (in %). *Var.Pay/Hrs.* are earnings from commissions and incentives per hour worked (in $ per hour). *MinW* is the monthly minimum wage in the jurisdiction in which the worker is located (in $). *Weekly MinW Adj.* is a dummy for whether the worker received minimum wage adjustments each week of the month. *# MinW Adj.* is the number of weekly adjustments per month. *MinW Adj.Pay/Hrs* are monthly earnings from minimum wage adjustments divided by hours worked (in $ per hour). *Tot.Pay/T.Hrs.* is the monthly total pay from total take home pay divided by total hours (in $ per hour). *Tot.Pay* is the monthly total pay from total take home pay, and it is rescaled by a factor between $ 1/50 and 1/150 relative to its $ value. *Tenure* is the number of months of tenure. *Termination (in %)* is the percent probability that an employee is terminated in a given month (takes value 0 in a given month if a worker is not terminated and takes value 100 if the worker is terminated).

We define the compensation scheme as base and commission hourly rates. The base rate ($6.1/h) is computed by dividing "total monthly regular pay" by "hours worked." The commission rate (3.2%) is computed by dividing "total monthly variable pay" by ("sales per hour" x "hours worked").[11] Table 1 reveals considerable cross-worker variation in base and commission rates. This reflects both within- and cross-store variation. Within a store, the compensation scheme varies from one department to another. We will later control for this by adding department fixed-effects. Across stores, the compensation scheme varies because the firm adapts the base or the commission rate to local labor market conditions. We will later test whether the compensation scheme in a given store reacts to changes in the minimum wage in that same jurisdiction.

Tenure is based on the worker's hiring date. The data show a large dispersion in tenure; this dispersion partly reflects a large turnover, which is typical in retail sales position (see average monthly termination rate of 5%).[12]

Finally, we collect information on local labor market conditions around each store. We obtain data on unemployment level at the county-level from the Bureau of Labor Statistics website. We also obtain data on the median housing price at the zip-code level from the Zillow website.

# 5 Identification Strategy: County-Level Border Discontinuity Design

We estimate the causal effect of a $1 increase in the minimum wage using Allegretto et al. (2013), Card and Krueger (2000) and Dube et al.'s (2010, 2016) approach by estimating the following model:

$$Y_{wlm} = \alpha + \beta MinW_{lm} + \zeta Tenure_{wm} + \gamma U_{lm} + \phi State_l \cdot Month_m + \delta_w + \eta_m + \varepsilon_{wlm}, \quad (3)$$

where: $Y$ is the outcome of interest (e.g., individual worker productivity) for worker $w$, in location $l$ and in month $m$. $MinW_{lm}$ is the predominant minimum wage (the highest

[11] The field "total monthly variable pay" is an aggregate of a number of corporate incentive programs tied to productivity (sales per hour).

[12] Termination is defined as the sum of voluntary and involuntary terminations in order to sidestep the arguably subjective distinction between leaving one's job voluntarily and involuntarily.

among state-county-city minimum wages) in location $l$ and in month $m$. $Tenure_{wm}$ is the worker's tenure; $U_{lm}$ is the monthly unemployment rate at county level; $State_l \cdot Month_m$ are state-specific trends that control for possible differential state trends.[13] $\delta_w$ and $\eta_m$ are worker and month fixed effects. To account for differences across workers in different departments, the model also includes department fixed effects. Since most of the variation in the minimum wage is at the state level, we cluster standard errors at the state level.

This two-way fixed effects model approximates a difference-in-differences design, which compares changes in individual productivity for workers located in *treated* jurisdictions (i.e., states, counties, cities) where the minimum wage increased to *control* jurisdictions where it did not increase at all. Estimates of the overall impact of minimum wage are based on multiple variations in the minimum wage over time. If the variation is at the state- or county-level, all workers in these jurisdictions are simultaneously affected (they are all "treated"). If the variation is at the city-level, the workers in that specific city are "treated" while those in the rest of the city's county or state are not.

Following Card and Krueger (2000), Dube et al. (2010, 2016), Allegretto et al. (2013), we restrict our sample to stores located in counties that share a border and whose centroids are within 75km of each other. All counties sharing a border but whose centroid are more than 75km apart are removed from the sample (see Figure 3). Dube et al. (2010) argue that this procedure ensures that bordering counties face similar economic conditions except for minimum wage policies. Our final sample contains more than 300 stores (with over 10,000 salespeople), half of which experienced variations in minimum wage in our sample period.[14]

Following Dube et al. (2010) we formally test for the presence of pre-existing trends in the outcomes of interest by estimating this model:

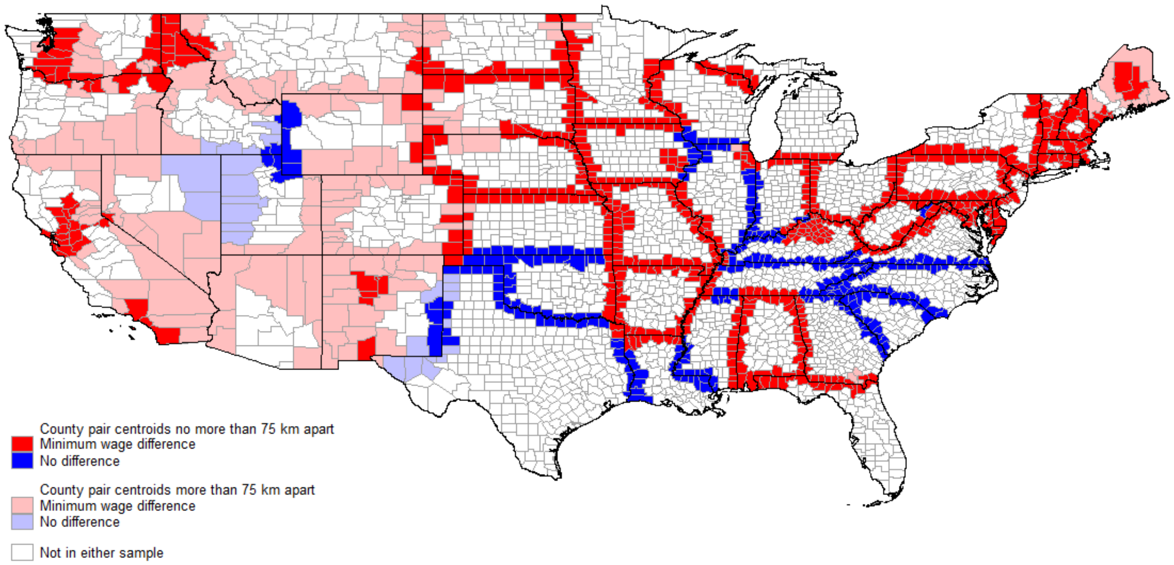
$$
\begin{aligned}
Y_{wlm} = \alpha &+ \eta_{m+3}(MinW_{l,m+3} - MinW_{l,m+1}) + \eta_{m+1}(MinW_{l,m+1} - MinW_{l,m}) \\
&+ \rho MinW_{lm} + \zeta Tenure_{wm} + \gamma U_{lm} + \phi State_l \cdot Month_m + \delta_w + \eta_m + \varepsilon_{wlm},
\end{aligned}
$$

where $MinW_{l,m+j}$ is the minimum wage $j$ months after month $m$ and all other variables

[13] See Card and Krueger (1994, 2000); Dube et al. (2010, 2016); Allegretto et al. (2011), and Addison et al. (2012, 2014).

[14] As a robustness check we refine the analysis by restricting our sample to stores (rather than counties) whose distance is 75km (or 37.5 km or 18 km) from the county-border (see Section 6.3).

Figure 3: Variations in Minimum Wage in Bordering Counties




Note: Store locations are withheld for confidentiality reasons.

are defined as in equation (3). In this specification $\eta_{m+3}$ and $\eta_{m+1}$ capture one quarter and one month variations in $Y$ before each change in the minimum wage. To test for pre-trends we estimate whether $\beta = \eta_{m+3} - \eta_{m+1}$ is statistically different from zero. Table 2 indicates that no $\beta$ is statistically different from zero and that there is no evidence of pre-trends in individual worker productivity or in worker compensation (details on these variables in the next section).

# 6 Results: Effects of Minimum Wage on Productivity and Underlying Channels

Table 3 explores the effect of minimum wage on individual productivity. A \$0.65 (one standard deviation) increase in the minimum wage raises individual productivity (sales per hour) by approximately 2%. This is reported at the bottom of the table – see *Eff.MinW%*. This effect is statistically significant at the 5 percent level.

Table 2: No Pre-Trends in Outcomes

| Var.Desc. | Productivity | Compensation scheme | | MinW Adjustments | | | Compensation | |
|---|---|---|---|---|---|---|---|---|
| Dep.Var. | Sales/Hrs. | Base Rate: Reg.Pay/Hrs. | Comm. Rate: Var.Pay/Sales | Weekly Adj. | # Adj. | Adj.Pay/Hrs. | Tot.Pay/T.Hrs. | Tot.Pay |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Test for pre-trend ($\beta$) | 0.0003 | 0.057 | -0.215 | -0.005 | -0.029 | -0.002 | 0.035 | -0.0194 |
| | (0.041) | (0.036) | (0.137) | (0.006) | (0.036) | (0.013) | (0.141) | (0.213) |
| Observations | 130,220 | 130,220 | 124,749 | 130,220 | 130,220 | 130,220 | 130,220 | 130,220 |
| Units | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers |
| R-squared | 0.431 | 0.091 | 0.539 | 0.311 | 0.516 | 0.460 | 0.643 | 0.744 |
| Mean Y | 2.076 | 6.059 | 3.407 | 0.0291 | 0.704 | 0.195 | 12.36 | 13.93 |

Note: *Sales/Hrs.* are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its $ value. *Base: Reg.Pay/Hrs.* are monthly regular earnings per hour worked (in $ per hour). *Comm.Rate: Var.Pay/Sales* are earnings from commissions and incentives divided by sales (in %). *MinW* is the monthly minimum wage in the jurisdiction in which worker is located (in $). *Weekly Adj.* is a dummy for whether the worker received minimum wage adjustments each week of the month. *# Adj.* is the number of weekly adjustments per month. *Adj.Pay/Hrs* are monthly earnings from minimum wage adjustments divided by hours worked (in $ per hour). *Tot.Pay/T.Hrs.* is the monthly total pay from total take home pay divided by total hours (in $ per hour). *Tot.Pay* is the monthly total pay from total take home pay, and it is rescaled by a factor between $ 1/50 and 1/150 relative to its $ value.. *Tenure* is the number of months of tenure. *Test for pre-trend ($\beta$)* is the difference in between $\eta_{m+3}$ and $\eta_{m+1}$ with standard errors reported in parenthesis. All the regressions include county-unemployment, worker tenure, month FE, worker FE, department FE and state-specific trends.*** p<0.01, ** p<0.05, * p<0.1.

This increase in worker productivity, which is consistent with the theory, can be explained by two channels. First, a higher minimum wage may increase demand and, through this, raise worker productivity (sales per hour).[15] The second is a "compensation" channel: the theory shows that a higher compensation due to a minimum wage hike will result in increased effort and increased productivity, whether or not the firm optimally adjusts its base and/or commission rate (refer to Propositions 3 and 5). We explore the relative contribution of the demand and compensation channels in turn.

## 6.1 Demand Channel

The productivity gains might result from a demand channel, if hikes in the minimum wage increase the demand for retail goods. The literature is mixed on whether there is a pass-through from the minimum wage to the demand for retail goods.[16] In this section we

[15]Demand affects worker productivity in all jobs in which productivity is directly related to the number of clients (e.g., in retail). This is not necessarily the case for all jobs outside retail.

[16]Aaronson et al. (2012, Table 3) show that while most pass-through is channeled by automobile purchases, some pass-through is channeled by miscellaneous household items, which are sold by retail stores. On the other hand, Leung (2017, Table G8) shows that real sales of "General Merchandise" in

Table 3: Minimum Wage Increases Individual Worker Productivity

| Dep.Var. | Sales/Hrs. |
|---|---|
| MinW | 0.061** |
| | (0.025) |
| Observations | 179,046 |
| Units | Workers |
| R-squared | 0.415 |
| Mean Y | 2.061 |
| Eff.MinW % | 1.923 |

Note: *Sales/Hrs.* are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its $ value. *MinW* is the monthly minimum wage in the jurisdiction in which the worker is located (in $). *Eff.MinW%* is the percent effect of one standard deviation increase in MinW ($0.65) on the outcomes. The regression includes county-unemployment, worker tenure, month FE, worker FE, department FE and state-specific trends.*** p<0.01, ** p<0.05, * p<0.1.

look for evidence of a demand shock within our sample.

**Are productivity gains shared by workers of all productivity levels?**

A positive demand shock should be a tide that lifts all boats, that is, workers of all productivity types should become more productive if more customers walk through the doors. (This assumption is embedded in our theory: see Figure 1, Panel (b).) To explore whether a minimum wage increase is in fact a tide that lifts all boats, following Aaronson et al. (2012), we create three categories: workers who at month $m$-1 are paid the minimum wage (the least productive types); intermediate types who are paid more than the minimum wage but less than a threshold (120% of the minimum wage as in Aaronson 2012, or alternatively 140%, 160%, 180%); and the most productive types who are paid more than

mass merchandise stores decrease after a minimum wage hike. Focusing on price alone, using Nielsen retail scanner data and a variety of identification strategies, Ganapati and Weaver (2017) find no increase in prices following a minimum wage increase.

the threshold. We use total pay as opposed to "sales per hour" to proxy for productivity because our theoretical definition of an unproductive worker is a worker whose total pay is propped up by the minimum wage.[17]

To stay as close as possible to our main specification (3) and to the spirit of Allegretto et al. (2013), Card and Krueger (2000) and Dube et al. (2010, 2016), we estimate the following model:

$$\begin{aligned} Y_{wlm} \quad = \quad & \beta_0 + \beta_1 MinW_{lm} + \beta_2 \mathbb{1}(W_{wm-1} > MinW_{lm-1})_{wm} + \beta_3 \mathbb{1}(W_{wm-1} >> MinW_{lm-1})_{wm} + \\ & \beta_4 MinW_{lm} \cdot \mathbb{1}(W_{wm-1} > MinW_{lm-1})_{wm} + \beta_5 MinW_{lm} \cdot \mathbb{1}(W_{wm-1} >> MinW_{lm-1})_{wm} + \\ & \gamma U_{lm} + \zeta Tenure_{wm} + \phi State_l \cdot Month_m + \delta_w + \eta_m + \varepsilon_{wlm}, \end{aligned}$$

where $Y$ is individual worker productivity. $\mathbb{1}(W_{wm-1} > MinW_{m-1})$ is a lagged indicator for workers paid between the minimum wage and 120% (140%, 160%, 180%) of the minimum wage. $\mathbb{1}(W_{wm-1} >> MinW_{m-1})$ is a lagged indicator for workers paid more than 120% (140%, 160%, 180%) of the minimum wage. Workers paid at the minimum wage are the omitted group. In this specification, $MinW_{lm}$ is centered around the sample mean; the other variables are as in equation (3). The effect of a $1 increase in the minimum wage is given by $\beta_1$ for the low-productive group, $\beta_1 + \beta_4$ for the intermediate group and $\beta_1 + \beta_5$ for the most productive group. The interaction terms, $\beta_4$ and $\beta_5$, measure whether the effect of minimum wage is statistically different for intermediate and high-productive workers, relative to the low-productive ones.

The distribution of workers across the three categories is presented in Table D.1 for each threshold. 4% of workers have their monthly pay "at minimum wage." These low-productive workers, who are often topped-up on a weekly basis by the company, are likely those most affected by an increase in the minimum wage.[18] 21% of the workers earn between the minimum wage and 120% * minimum wage ("just above"), while 75% earn more than 120% * minimum wage ("well above"). Using the 180% threshold, these proportions swap: 75% of the workers earn between the minimum wage and 180% * minimum wage, and 21% earning more than 180% * minimum wage. As the cutoff increases, our pool of

[17] Ranking workers in terms of their "sales per hour" is equivalent to ranking them in terms of their total pay, because the relationship between sales per hour and total pay is monotonically increasing.

[18] We define a worker as being "at minimum wage" if her total compensation is below 1.02*minimum wage. We do so because the "total compensation" field is sometimes off by a few cents. The results are robust to defining workers "at minimum wage" as those who earn exactly the minimum wage.

high-productive types thus becomes thinner and more outstanding.[19]

Table 4 reports the estimated effects of minimum wage on the productivity of the three worker "types," as a function of different thresholds (120% to 180%). The productivity of low-productive workers increases by 18% - 20%, and it is statistically significant. The effect on medium-productivity workers is between 6.5% and 8.6%, and it is statistically significant too. By comparing across specifications (120% to 180%), we see that the productivity effect of the minimum wage hike is consistently weaker for more-productive types.[20] The effect of a minimum wage increase on the productivity of the most productive types vanishes as the threshold increases, achieving a negative point estimate at the highest (180%) threshold for the best 20% workers. Mean reversion is an unlikely explanation for this phenomenon because the estimated coefficient for $\mathbb{1}(W_{wm-1} >> MinW_{m-1})$, $\beta_3$, is consistently positive, not negative. This vanishing effect of the minimum wage on the most productive types is difficult to reconcile with a positive demand shock that lifts all boats.

In Table D.3, we assess the robustness of these results using an alternative worker classification. We divide workers in three categories (low-medium-high productive) based on their total pay in the *first* month on the job, rather than on their lagged monthly pay. This definition has pros and cons. It better isolates permanent unobserved heterogeneity from state dependence or mean-reverting shocks. However, it has the disadvantage of being time-invariant. The results remain consistent.

**Do correlates of retail demand increase after a minimum wage hike?**

We test whether house prices, which have been shown to be good proxies for demand,[21] are predicted by minimum wage levels. To do so, we estimate the following store-level

[19]This is reflected in Table D.2 which reports the average productivity of these three categories. Low-productivity type ("at minimum wage") produce 106$/hr; medium-productivity types ("just-above") between 147 and 197$/hr; and high-productivity types ("well-above") between 237 and 285$/hr, depending on the definition of most-productive types (120% to 180%).

[20]This finding is consistent with Ku's (2017) results.

[21]Mian and Sufi (2014), and Stroebel and Vavra (2017) document that local house price movements have a strong effect on local retail demand.

Table 4: Minimum Wage Has No Effect on The Most Productive Salespersons

| Dep.Var | Sales/Hrs. | Sales/Hrs. | Sales/Hrs. | Sales/Hrs. |
|---|---|---|---|---|
| Threshold | 120% | 140% | 160% | 180% |
| | (1) | (2) | (3) | (4) |
| MinW | 0.192*** | 0.189*** | 0.190*** | 0.207*** |
| | (0.032) | (0.029) | (0.031) | (0.032) |
| $\mathbb{1}(> MW)$ | 0.219*** | 0.286*** | 0.341*** | 0.373*** |
| | (0.025) | (0.029) | (0.030) | (0.030) |
| $\mathbb{1}(>> MW)$ | 0.677*** | 0.947*** | 1.141*** | 1.264*** |
| | (0.040) | (0.047) | (0.056) | (0.061) |
| MinW $\cdot\mathbb{1}(> MW)$ | -0.074*** | -0.054** | -0.063*** | -0.078*** |
| | (0.022) | (0.021) | (0.021) | (0.021) |
| MinW $\cdot\mathbb{1}(>> MW)$ | -0.067*** | -0.095*** | -0.152*** | -0.218*** |
| | (0.022) | (0.025) | (0.025) | (0.030) |
| Observations | 167,060 | 167,060 | 167,060 | 167,060 |
| Units | Workers | Workers | Workers | Workers |
| R-squared | 0.467 | 0.483 | 0.493 | 0.492 |
| Mean Y | 2.125 | 2.125 | 2.125 | 2.125 |
| Eff.Wrkrs.at MW (%) | 18.19 | 17.92 | 18.01 | 19.58 |
| p-value | 0.001 | 0.001 | 0.001 | 0.001 |
| Eff.Wrkrs.just above MW (%) | 8.036 | 7.986 | 6.846 | 6.519 |
| p-value | 0.001 | 0.001 | 0.001 | 0.001 |
| Eff.Wrkrs.well above MW (%) | 5.292 | 3.628 | 1.366 | -0.387 |
| p-value | 0.001 | 0.001 | 0.210 | 0.730 |

Note: *Sales/Hrs.* are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its $ value. *MinW* is the monthly minimum wage in the jurisdiction in which the worker is located (in $). $\mathbb{1}(> MW)$ is an indicator for whether the worker's total pay in month *m-1* is between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). $\mathbb{1}(>> MW)$ is an indicator for whether the worker's total pay in month *m-1* is above 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.at MW* is the percent effect of one standard deviation increase in MinW on workers "at minimum wage." *Eff.Wrkrs.just above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.well above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated more than 120% of minimum wage (or 140%, 160%, 180%). All the regressions include county-unemployment, worker tenure, month FE, worker FE, department FE and state-specific trends. *** p<0.01, ** p<0.05, * p<0.1.

regression model:

$$Y_{slm} = \alpha + \beta MinW_{lm} + \phi State_l \cdot Month_m + \delta_s + \eta_m + \varepsilon_{slm}, \tag{4}$$

where $Y_{slm}$ is the median house price per square feet in the zipcode of store $s$ in month $m$. $\delta_s$ are store fixed effects, and all other variables are defined as before. Errors are clustered at the state level.

We find that minimum wage does not significantly affect house prices – see Table 5 col.1. Similarly, we test whether the minimum wage predicts unemployment. To do so, we run a regression at the county-level and find no effect – see col.2.[22] This lack of correlation may well be a convenient by-product of our bordering-county research design which, to the extent that retail shoppers cross over to purchase in neighboring counties, is expected to "difference out" any county-specific demand effect. We interpret this evidence as suggestive that increases in the minimum wage are not associated with demand shocks, at least in our bordering-counties sample. We discuss the possibility of worker migration (col.3) later in the paper, in Section 6.3.

Table 5: Minimum Wage Has No Effect on Bordering-Counties Demand

| Dep.Var | House prices<br>(1) | Unemployment<br>(2) | Distance from store<br>(3) |
|---|---|---|---|
| MinW | -18.795 | -0.083 | 0.060 |
| | (14.797) | (0.146) | (0.301) |
| Observations | 11,529 | 9,582 | 15,532 |
| Units | Stores | Counties | Stores |
| R-squared | 0.887 | 0.943 | 0.459 |
| Eff.MinW % | -9.401 | -0.966 | 0.461 |
| Mean Y | 155.2 | 6.463 | 10.51 |

Note: *House prices* is the Zillow monthly median price per square feet for listed houses in the zip-code of the store. These data are available only for a sub-sample of counties covered by Zillow. *Unemployment* is the monthly unemployment rate at the county level. *Distance from store* is the average worker distance from home zip code to work aggregated at the store level. Columns 1 and 3 include store FE, month FE and state-specific trends. col.2 includes county FE, month FE and state-specific trends. SEs clustered at the state level.*** p<0.01, ** p<0.05, * p<0.1.

[22] Note that the unemployment data is available at the county level. Therefore, the exact model we estimate is $U_{cm} = \alpha + \beta MinW_{cm} + \phi State_c \cdot Month_m + \delta_c + \eta_m + \varepsilon_{cm}$, where $U_{cm}$ is unemployment in county $c$ and month $m$; $MinW_{cm}$ is the average minimum wage in the county. Errors are clustered at the state level.

**Increased demand-per-worker?**

A more subtle channel might be that an increase in the minimum wage causes the number of salespeople to be reduced but the number of customers to stay the same. Then demand-per-worker increases, and individually each worker might well become more productive. However, in Section 7 we will show that salespeople actually slightly *increase* after a minimum wage increase, which leads us to discount this demand-per-worker channel.

In summary, in this section we have first asked who among the workers is mostly responsible for the productivity increase. We found that the most-productive workers are not responsible for the productivity gain; instead, it is the least productive workers who contribute a sizable productivity gain (between 18% and 20% relative to their base level). We interpret this finding as inconsistent with the demand channel – the notion that productivity increased because more customers walked through the door. Instead, this finding is consistent with a model where the productivity gains reflect increased effort by the least-productive workers. Next, we checked whether generally-accepted demand proxies, such as house prices and unemployment, are correlated with minimum wage levels and found that they are not. In other words, we failed to find evidence that the minimum wage correlates with demand proxies. Finally, we have ruled out increased demand-per-worker as a confounder of our estimates. Overall, we conclude that the demand channel is not responsible for the increased productivity.

## 6.2 Compensation Channel

A minimum wage increase affects compensation directly, when a worker's wage is propped up by higher "minimum wage adjustments" and, in addition, indirectly if the firm changes its base and/or commission rate. If changes in compensation are responsible, either directly or indirectly, for the productivity increase, then the theory provides two implications/tests. First, increasing the minimum wage should affect average productivity more sharply during high-unemployment spells. Second, the productivity effect should be disproportionately concentrated in the lower tail of the productivity distribution (refer to Proposition 3 and Corollary 4). In this section we show support for both predictions.

We then ask whether the firm changes its compensation scheme in response to minimum wage increases. Proposition 5 predicts that the firm should increase the base rate one-to-one with the minimum wage, but the theory abstracts from the fact that our firm is multi-jurisdictional. To the extent that national headquarters value wage uniformity across stores, we should expect a minimum wage increase in a single jurisdiction to have a more-muted than 1-1 effect on the base rate in that jurisdiction. Consistent with this expectation, in this section we estimate a positive but modest elasticity (0.14) of base pay to minimum wage, and no detectable elasticity of the commission rate to minimum wage. This endogenous wage change on the firm's part may, by itself, partly account for the observed productivity increase. However, it probably does not fully mediate the effect of minimum wage increases in our data because Corollary 4 indicates that a base pay adjustment alone, absent any concurrent increase in the minimum wage, would impact productivity in a way that is independent of the unemployment level. This is not what we see in our data.

**Are average productivity gains sharper during high-unemployment spells?**

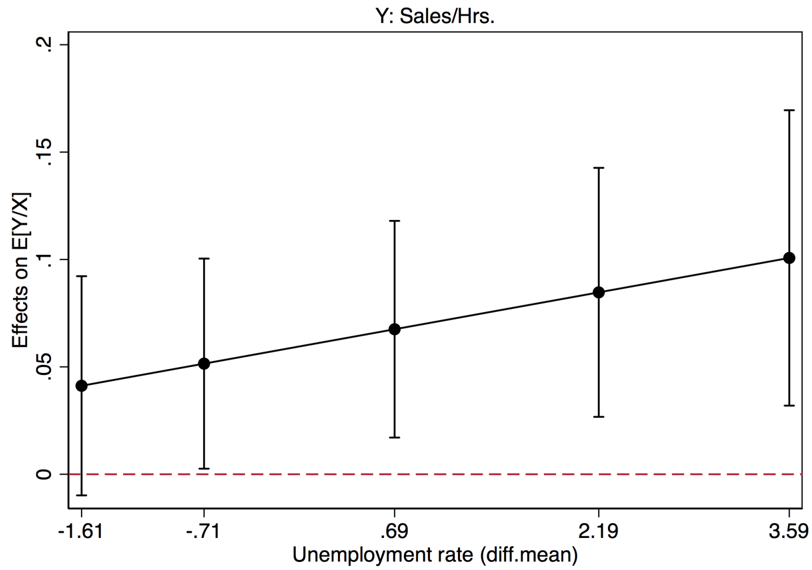
As indicated above, the compensation channel implies that increasing the minimum wage should affect average productivity more sharply during high-unemployment spells. We extend the original model to make use of differences in local labor market conditions:

$$Y_{wlm} = \alpha + \beta MinW_{lm} + \gamma U_{lm} + \mu MinW_{lm} \cdot U_{lm} + \zeta Tenure_{wm} + \phi State_l \cdot Month_m + \delta_w + \eta_m + \varepsilon_{wlm},$$

where $MinW_{lm} \cdot U_{lm}$ is an interaction term between unemployment and the minimum wage, and all the other variables are the same as above.

Table D.4 (col.1) reports the details of the estimates. The coefficient for $MinW_{sm} \cdot U_{sm}$ is statistically significant: a one standard deviation increase in unemployment (2%) increases the effect of minimum wage on productivity by 37%. Figure 4 plots the average effects of minimum wage (and the 95% confidence intervals) for productivity evaluated at the $10^{th}$, $25^{th}$, $50^{th}$, $75^{th}$, and $90^{th}$ percentiles of the unemployment rate distribution. The figure shows that most of the effect of the minimum wage on productivity accrues during periods of high unemployment, consistent with the theoretical predictions. Moving from the bottom to the top decile in unemployment more than doubles the effect of minimum wage on productivity.

Figure 4: Unemployment Sharpens The Effect of Minimum Wage




Note: Average effect on productivity (Y: Sales/Hrs.) of a variation in minimum wage at the $10^{th}$, $25^{th}$, $50^{th}$, $75^{th}$, and $90^{th}$ percentile of the difference from mean unemployment rate. Vertical bars are 95% confidence intervals.

### Are productivity gains greater for low-productivity workers?

Further evidence in favor of the compensation channel is the pattern of the productivity gain disaggregated by productivity type. Consistent with the model prediction and Figure 1 Panel (c), the estimates in Table 4 indicate that the productivity gains are greater for low-productivity workers and negligible for high-productivity workers.

### Does the firm adjust base and commission rates after a minimum wage increase?

Consistent with the theoretical predictions from Proposition 5, Table 6 provides some indication that the firm adjusts the base rate: a $1 increase in the minimum wage causes a $0.14 increase in the base rate (col.1). However, the commission rate does not change measurably (col.2). How, then, does the firm meet the higher minimum wage requirement?

In compliance with the minimum wage law, we find that the firm tops up workers in any week in which the average hourly pay falls short of the new minimum wage level. The percentage of workers who are topped-up each week of the month increases by 6pp (it more than doubles; see col.3), while the percentage of workers who receive no adjustment at all decreases by 16pp (not reported). A $1 increase in the minimum wage causes a $0.23 increase in the average adjustment pay per hour worked (col.5).

Table 6: Minimum Wage Increases Worker Compensation

| Var.Desc. | Compensation scheme | | MinW Adjustments | | | Compensation | |
|---|---|---|---|---|---|---|---|
| Dep.Var. | Base Rate: Reg.Pay/Hrs. | Comm. Rate: Var.Pay/Sales | Weekly Adj. | # Adj. | Adj.Pay/Hrs. | Tot.Pay/T.Hrs. | Tot.Pay |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| MinW | 0.136* | 0.024 | 0.061*** | 0.542*** | 0.227*** | 0.577*** | 0.452*** |
| | (0.078) | (0.025) | (0.007) | (0.024) | (0.026) | (0.104) | (0.104) |
| Observations | 179,046 | 170,337 | 179,046 | 179,046 | 179,045 | 179,046 | 179,046 |
| Units | Workers | Workers | Workers | Workers | Workers | Workers | Workers |
| R-squared | 0.110 | 0.520 | 0.321 | 0.523 | 0.149 | 0.610 | 0.723 |
| Mean Y | 6.108 | 3.301 | 0.0329 | 0.736 | 0.229 | 12.18 | 13.37 |
| Eff.MinW % | 1.445 | 0.476 | 120.2 | 47.72 | 64.46 | 3.070 | 2.190 |

Note: *Base: Reg.Pay/Hrs.* are monthly regular earnings per hour worked (in $ per hour). *Comm.Rate: Var.Pay/Sales* are earnings from commissions and incentives divided by sales (in %). *MinW* is the monthly minimum wage in the jurisdiction in which worker is located (in $). *Weekly Adj.* is a dummy for whether the worker received minimum wage adjustments each week of the month. *# Adj.* is the number of weekly adjustments per month. *Adj.Pay/Hrs* are monthly earnings from minimum wage adjustments divided by hours worked (in $ per hour). *Tot.Pay/T.Hrs.* is the monthly total pay from total take-home pay divided by total hours (in $ per hour). *Tot.Pay* is the monthly total pay from total take-home pay, and it is rescaled by a factor between $ 1/50 and 1/150 relative to its $ value. *Tenure* is the number of months of tenure. *Eff.MinW%* is the percent effect of one standard deviation increase in MinW ($0.65) on the outcomes. All the regressions include county-unemployment, worker tenure, month FE, worker FE, department FE and state-specific trends.*** p<0.01, ** p<0.05, * p<0.1.

## 6.3 Confounders and Robustness Checks

### Confounder: Worker selection

The estimated average productivity gains might be inflated by a selection effect whereby stores terminate less-productive workers, or hire from a better pool, following a minimum wage increase. We expect this confounder to have been largely controlled for by worker-fixed effects, but worker-fixed effects may not necessarily eliminate the entirety of the selection bias.[23] Lazear et al. (2016) suggest restricting the sample to a balanced panel containing only workers who are employed throughout the sample period. When we do this (Table 7), we find that the estimated productivity gain grows to 2.6% (this is true whether or not we control for worker-fixed effects). Therefore, we conclude that the estimates in our baseline specification are not inflated by selection.

Table 7: Productivity Effects Are Stronger in Balanced Sample

| Dep.Var. | Sales/Hrs. | Sales/Hrs. |
|---|---|---|
| Sample | Balanced sample | Balanced sample |
| | (1) | (2) |
| MinW | 0.097*** | 0.098*** |
| | (0.030) | (0.030) |
| Observations | 22,754 | 22,754 |
| Units | Workers | Workers |
| R-squared | 0.660 | 0.487 |
| Mean Y | 2.206 | 2.206 |
| Eff.MinW % | 2.642 | 2.668 |
| Worker FE | YES | NO |

Note: *Sales/Hrs.* are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its $ value. *MinW* is the monthly minimum wage in the jurisdiction in which the worker is located (in $). The sample is restricted to workers that never left the company and which we observe for all the months in the data (i.e., balanced sample). All the regressions include county-unemployment, worker tenure, month FE, department FE and state-specific trends. Odd (even) columns include workers (stores) FE. *** p<0.01, ** p<0.05, * p<0.1.

If any concerns remain that our productivity estimates are an artifact of selective termination of low-productivity workers after a minimum wage increase, Table D.5 should further reassure the reader: in a specification with worker fixed effects, we find no selective

[23] Adding worker fixed effects does not fully account for selection if the minimum wage affects the type of workers who exit/enter our panel. In this scenario, the effect of the minimum wage is confounded by the fact that the panel of "retained" workers may have changed after a minimum wage increase.

termination across productivity types. We remove the worker fixed effects and examine worker composition in Section 7.

### Confounder: Worker migration

The possibility of worker movement across jurisdictions raises the concern that "treated" jurisdictions (higher minimum wage) might attract workers from neighboring "control" jurisdictions (no change in minimum wage). If that were true then some of the productivity gains we find might reflect an improved hiring pool in treated jurisdictions, rather than greater effort on the part of incumbent workers. To investigate this possibility, we leverage unique data on the worker's home zip code and compute the average distance between workplace and home zip code for all of our salespeople in any given store. If workers cross jurisdictional boundaries in pursuit of higher wages, then we would expect work-home distance to increase in stores located in treated jurisdictions relative to control jurisdictions. To test for this possibility we estimate the store-level equation (4). Table 5 (col.3) tests for, and fails to find, an economically or statistically significant effect of the minimum wage on average work-home distance. Therefore we discount the possibility of systematic worker migration triggered by minimum wage changes.

### Robustness: Store distance from borders

In our main estimates we follow the existing literature (Card and Kruger (1994), Dube et al. (2010)) by restricting the sample to all stores located in counties that: (a) share a border and (b) whose centroids are closer than 75 km (46 miles). In this section we check the robustness of our results to using the exact location of a store rather than the centroid of the county in which it is located. We test whether our results are robust to further restricting our sample to only include stores whose distance from the county-border is less than 75 km; 37.5 km; and 18 km. Our results are broadly consistent across these specifications. See Tables D.6 - D.9 and Figure D.1.

# 7 Workforce Composition

While we have ruled out worker selection as a confounder in Section 6.3, worker composition has independent economic interest beyond its confounding effects on our estimates. In this section we explore the change in workforce composition and show that all the results are consistent with the model's predictions regarding termination.

Using the store-level specification (4), we find that a one standard deviation increase in the minimum wage increases total store employment by 1% (Table 8, col.1), and the effect is statistically significant. This effect appears to reflect a combination of lower hiring rates (-1.4%) and even lower termination rates (-2.3%), albeit these effects are not precisely estimated (cols. 2 and 3). Our base+commission salespeople remain constant as a fraction of total store employment (col.4).

Table 8: Minimum Wage Increases Store Employment

| Dep.Var | N.Wrkrs | % Hired | % Termin. | % Base+Comm. |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| MinW | 1.276** | -0.099 | -0.192 | -0.028 |
| | (0.529) | (0.091) | (0.237) | (0.313) |
| Observations | 15,609 | 15,609 | 15,609 | 15,609 |
| Units | Stores | Stores | Stores | Stores |
| R-squared | 0.955 | 0.418 | 0.226 | 0.656 |
| Eff.MinW % | 1.058 | -1.405 | -2.260 | -0.151 |

Note: N=Stores*Month. *N.Wrkrs* is the total number of workers in the store; *%Hired* is the percent of new workers hired in a month; *%Termin.* is the percent of workers terminated in a month; *%Base+Comm.* is the fraction of workers paid base+commission. *MinW* is the monthly minimum wage (in $) in the jurisdiction of the store. *Eff.MinW%* is the percent effect of one standard deviation increase in MinW ($0.65) on the outcomes. All regression include county-unemployment, store FE, month FE and state-specific trends. SEs clustered at the state level.*** p<0.01, ** p<0.05, * p<0.1.

Next, we ask whether the least-productive workers are terminated at a different rate. Because we are interested in the composition of workers who are terminated, we remove the worker-fixed effects and use store-fixed effects instead. The approach thus differs from Section 6.3. Table 9 shows that the least-productive workers are less likely to be terminated after a minimum wage increase. This is consistent with these workers becoming more productive and hence being terminated less frequently. In contrast, the minimum wage has no effect on the termination rates of intermediate and highly-productive workers.

Table 9: Minimum Wage Reduces Termination of The Least-Productive Workers

| Dep.Var | Termin. | Termin. | Termin. | Termin. | Termin. |
|---|---|---|---|---|---|
| Threshold | None | 120% | 140% | 160% | 180% |
| | (1) | (2) | (3) | (4) | (5) |
| MinW | -0.173 | -0.796** | -0.739* | -0.747** | -0.774** |
| | (0.216) | (0.378) | (0.377) | (0.368) | (0.368) |
| $\mathbb{1}(> MW)$ | | -0.759*** | -0.758*** | -0.902*** | -0.964*** |
| | | (0.278) | (0.255) | (0.255) | (0.255) |
| $\mathbb{1}(>> MW)$ | | -1.266*** | -1.657*** | -1.741*** | -1.826*** |
| | | (0.251) | (0.260) | (0.258) | (0.247) |
| MinW $\cdot \mathbb{1}(> MW)$ | | 0.459* | 0.462* | 0.507** | 0.507** |
| | | (0.243) | (0.250) | (0.249) | (0.245) |
| MinW $\cdot \mathbb{1}(>> MW)$ | | 0.547** | 0.437* | 0.435* | 0.588*** |
| | | (0.233) | (0.225) | (0.217) | (0.215) |
| Observations | 179,047 | 167,060 | 167,060 | 167,060 | 167,060 |
| Units | Workers | Workers | Workers | Workers | Workers |
| R-squared | 0.018 | 0.020 | 0.021 | 0.021 | 0.021 |
| Mean Y | 4.771 | 4.606 | 4.606 | 4.606 | 4.606 |
| Eff.MinW % | -2.350 | | | | |
| Eff.Wrkrs.at MW (%) | | -13.21 | -12.26 | -12.39 | -12.84 |
| p-value | | 0.041 | 0.057 | 0.049 | 0.042 |
| Eff.Wrkrs.just above (%) | | -6.29 | -5.27 | -4.75 | -5.44 |
| p-value | | 0.224 | 0.309 | 0.352 | 0.306 |
| Eff.Wrkrs.well above (%) | | -5.77 | -7.71 | -8.66 | -5.77 |
| p-value | | 0.395 | 0.303 | 0.385 | 0.602 |

Note: *Termin.* is the probability that a worker has been terminated in a given month $m$. *MinW* is the monthly minimum wage in the jurisdiction in which the worker is located (in \$). $\mathbb{1}(> MW)$ is an indicator for whether the worker's total pay in month *m-1* is between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). $\mathbb{1}(>> MW)$ is an indicator for whether the worker's total pay in month *m-1* is above 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.at MW* is the percent effect of one standard deviation increase in MinW on workers "at minimum wage." *Eff.Wrkrs.just above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.well above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated more than 120% of minimum wage (or 140%, 160%, 180%). All the regressions include county-unemployment, worker tenure, store FE, month FE, department FE and state-specific trends. *** p<0.01, ** p<0.05, * p<0.1.

# 8 Effect of Minimum Wage on Worker Pay and Firm Profits

In this section, we perform a back-of-the envelope calculation to quantify the effect of a higher minimum wage on worker pay and firm profits.

Table 6 shows that a $1 increase in the minimum wage increases workers' total hourly pay by $0.57 (col.6). This increase in worker pay reflects three components: a higher base (+$0.14/h; paid to all workers), higher minimum wage adjustments (+$0.23/h; paid to low-productive workers) and higher commissions (+$0.2/h). In our context, workers earn higher commissions because they become more productive (their sales go up by 0.06 per hour; see Table 3), while their commission rate remains stable at approximately 3.3%.

Using information on the average costs of our company's retail goods, we estimate that the extra 0.06 of sales per hour translate into $0.27 extra net revenue (sales minus costs).[24] A $1 increase in minimum wage thus effectively reduces profits by $0.3 per hour ($0.57/h - $0.27/h); while the average worker earns an additional $0.57 per hour.

Overall, an increase in minimum wage transfers money from firm to worker while generating higher worker productivity. The net effect is lower firm profits, and presumably higher worker welfare.

# 9 Conclusions

We have studied a base plus commission sales force from a large US retailer. Using a border-discontinuity research design, we have documented that a 65 cents (one standard deviation) increase in the statutory minimum wage increases individual productivity (sales per hour) by 2%.

Two channels might account for this productivity gain: a demand increase concurrent with minimum wage increases and an incentive effect due to the change in worker compensation. With the help of a model, we have sought evidence for both channels and found evidence only for the second, that is, the compensation channel.

[24] Details of this calculation are not reported to preserve confidentiality.

The compensation channel was further parsed out into two sub-channels. First, a higher statutory minimum wage directly increases a worker's compensation which, in our theory, might increase the incentives to exert effort through an efficiency-wage mechanism. We found support for this sub-channel because the impact on productivity is stronger during high-unemployment spells, as would be predicted by an efficiency-wage model. Second, we found some evidence that the firm endogenously adjusts its base rate following minimum wage increases. This adjustment would make sense theoretically because increasing the base rate incentivizes workers more cheaply than increasing commission pay. This second sub-channel may, by itself, partly account for the observed productivity increase. However, we have argued that this second sub-channel does not fully mediate the effect of minimum wage increases in our data.

We found that, after a minimum wage increase: employment increases slightly in a store, and this effect was driven by lower termination among low-productivity types. Both effects are consistent with the model's predictions. Finally, we performed a back-of-the envelope calculation which suggests that an increase in minimum wage transfers money from firm to worker while generating higher worker productivity. The net effect is lower firm profits (and, presumably higher worker welfare).

We believe this to be the first study that combines productivity and wage data to examine the impact of minimum wage increases. The workers we study labor under a base+commission contract. We provide the first theoretical model, to our knowledge, that studies the complex interaction of this contract with the minimum wage. The model helps organize our empirical findings, and ultimately points to an efficiency-wage logic as playing a significant role in shaping worker incentives.

If confirmed by other studies, the idea that increasing the minimum wage might increase productivity through an incentive effect, as opposed to selective termination, might provide an additional argument for minimum-wage proponents.

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# Appendices

## A Appendix: Theory

**Proof of Lemma 1.**

*Proof.* The function $V^W(\sigma)$ is flat for $B + R\sigma < M$ in $\sigma$ and strictly increasing for $B + R\sigma > M$. If $V^W(\sigma)$ meets $V^S$ it must be at a $\sigma$ where $B + R\sigma > M$ and then the $\overline{\sigma}$ at which they meet solves:

$$\begin{aligned} 2(1-\beta)\max[M,B] + 2(1-\beta)\beta\Omega(M,u) &= \max[M,B] + B + R\sigma - 2c \\ (1-2\beta)\max[M,B] + 2(1-\beta)\beta\Omega(\sigma,M,u) - B + 2c &= R\sigma. \end{aligned}$$

Solving for $\sigma$ yields:

$$\overline{\sigma} = \frac{(1-2\beta)\max[M,B] + 2(1-\beta)\beta\Omega(M,u) - B + 2c}{R}.$$

Our assumption that $V^W(\varepsilon) < V^S$ implies that $\overline{\sigma} > \varepsilon$. ■

**Proof of Proposition 2**

*Proof.* Now workers exert effort if $V^W((1+\delta)\sigma) > V^S$, and so there is a threshold $\overline{\sigma}_\delta$ that solves:

$$(1+\delta)\overline{\sigma}_\delta = \frac{(1-2\beta)\max[M,B] + 2(1-\beta)\beta\Omega(M,u) - B + 2c}{R}.$$

All types $\sigma$ below $\overline{\sigma}_\delta$ exert zero effort, all others types exert maximum effort. As $\delta$ increases above zero $\overline{\sigma}_\delta$ must decrease, so more workers exert effort. In addition the high types in a neighborhood of $\sigma = 1$ exert effort both before and after the demand increase. Thus these workers' productivity increases approximately by $\delta$ (from 1 to $1+\delta$). ■

**Proof of Proposition 3 and of Corollary 4**

*Proof.* The change in average (and total) productivity is:

$$\frac{\partial}{\partial M}\left(\frac{1}{2}\int_{\overline{\sigma}}^{1} \sigma f(\sigma)\, d\sigma\right) = -\frac{1}{2}\overline{\sigma} f(\overline{\sigma})\frac{\partial\overline{\sigma}}{\partial M} = -\frac{K}{2}\frac{\partial\overline{\sigma}}{\partial M}.$$

Therefore, any changes in average and total productivity are due to workers in the neighborhood of $\overline{\sigma}$, which is the upper bound of the least-productive workers. This proposition assumes that as $M$ changes the compensation scheme is unchanged, however, we can allow for greater generality and suppose that as $M$ changes the incentive scheme also becomes more generous at rate: $[\partial B/\partial M \geq 0, \partial R/\partial M \geq 0]$, so that:

$$\frac{\partial \overline{\sigma}}{\partial M} = \frac{(1-2\beta)\,\mathbb{I}_{B\leq M} + (1-2\beta)\,\frac{\partial B}{\partial M}\mathbb{I}_{B>M} + 2\,(1-\beta)\,\beta\Omega_1 - \frac{\partial B}{\partial M}}{R} - \frac{\overline{\sigma}}{R}\frac{\partial R}{\partial M}.$$

Rearrange to isolate $\partial\overline{\sigma}/\partial M$ :

$$R\frac{\partial \overline{\sigma}}{\partial M} = (1-2\beta)\,\mathbb{I}_{B\leq M} + 2\,(1-\beta)\,\beta\Omega_1 + ((1-2\beta)\,\mathbb{I}_{B>M} - 1)\,\frac{\partial B}{\partial M} - \overline{\sigma}\frac{\partial R}{\partial M} \tag{5}$$

Therefore, $\partial\overline{\sigma}/\partial M$ has the same sign as the RHS of (5).

**Case** $B \leq M$. In this case the RHS of (5) reads:

$$(1-2\beta) + 2\,(1-\beta)\,\beta\Omega_1 - \frac{\partial B}{\partial M} - \overline{\sigma}\frac{\partial R}{\partial M}.$$

Since $\partial B/\partial M, \partial R/\partial M \geq 0$, this expression is negative (as desired) if:

$$\begin{aligned} & (1-2\beta) + 2\,(1-\beta)\,\beta\Omega_1 \\ < \; & (1-2\beta) + 2\,(1-\beta)\,\beta \\ = \; & 1 - 2\beta^2 < 0, \end{aligned}$$

i.e., if $\beta > \sqrt{1/2}$.

**Effect of unemployment.** The change in average (and total) productivity is mediated by unemployment as follows:

$$\frac{\partial^2}{\partial M \partial u}\left(\frac{1}{2}\int_{\overline{\sigma}}^{1} \sigma f(\sigma)\, d\sigma\right) = -\frac{K}{2}\left[\frac{\partial^2 \overline{\sigma}}{\partial M \partial u}\right]$$

Differentiating (5) with respect to $u$ under the assumption that $\partial R/\partial M = 0$, one gets:

$$R\frac{\partial^2 \overline{\sigma}}{\partial M \partial u} = 2\,(1-\beta)\,\beta\Omega_{12}. \tag{6}$$

The RHS is negative because $\Omega_{12}$, i.e., if $B \leq M$ the beneficial effect of increasing the minimum wage on productivity is sharper during times of high unemployment.

**If base pay increases without any change in $M$ then the effects on productivity are independent of the unemployment level.**

$$\begin{aligned} \frac{\partial \overline{\sigma}}{\partial B} &= \frac{(1-2\beta)\,\mathbb{I}_{B>M} - 1}{R} \\ \frac{\partial^2 \overline{\sigma}}{\partial B \partial u} &= 0. \end{aligned}$$

■

# B Optimal Compensation Scheme

We assume that the firm chooses the compensation scheme $(B, R)$ to maximize revenues minus labor costs, taking into account that the choice of $(B, R)$ affects the types of workers that exert effort. Formally, the firm maximizes:

$$\int_0^{\overline{\sigma}} -\max[M,B]\, f(\sigma)\, d\sigma + \frac{1}{2}\int_{\overline{\sigma}}^{1} \left[-\max[M,B] + (\sigma - \max[M, B + R\sigma])\right] f(\sigma)\, d\sigma$$

$$\int_0^{\overline{\sigma}} -\max[M,B]\, f(\sigma)\, d\sigma + \frac{1}{2}\int_{\overline{\sigma}}^{1} \left[-2\max[M,B] + \max[M,B] + (\sigma - \max[M, B + R\sigma])\right] f(\sigma)\, d\sigma$$

$$\int_0^{\overline{\sigma}} -\max[M,B]\, f(\sigma)\, d\sigma + \int_{\overline{\sigma}}^{1} -\max[M,B]\, f(\sigma)\, d\sigma + \frac{1}{2}\int_{\overline{\sigma}}^{1} \left[\max[M,B] + (\sigma - \max[M, B + R\sigma])\right] f\,($$

$$-\max[M,B] + \frac{1}{2}\int_{\overline{\sigma}}^{1} \left[\max[M,B] + (\sigma - \max[M, B + R\sigma])\right] f(\sigma)\, d\sigma.$$

Since the scheme $(B, R)$ is now endogenous, it might be optimal to have all of the workers, or none of them, exert effort. If *all* the workers *strictly preferred* to exert effort, or not to exert effort, marginally tweaking the incentive scheme would have no effect on productivity, and in that case the firm would optimize by reducing the generosity of the compensation scheme until either $(B^* = R^* = 0)$ or until some worker is indifferent between exerting effort or not. This implies that, in our search for the optimal compensation scheme we can restrict attention to, and to the closure of, the space of schemes where a marginal change in the scheme impacts productivity. This is the space where $M \leq B + R\overline{\sigma}$. In this case the firm's objective function simplifies as follows:

$$-\max[M,B] + \frac{1}{2}\int_{\overline{\sigma}}^{1} \left[\max[M,B] - B + (1-R)\,\sigma\right] f(\sigma)\, d\sigma. \tag{7}$$

Note that this function is continuous in $B$ at $B = M$. Also note that this function is decreasing in $\overline{\sigma}$ as long as $R < 1$. Let $B^*, R^*$ solve the problem of maximizing (7).

**Lemma 6.** *Fix* $(B, R)$ *and suppose* $\overline{\sigma} \in (\varepsilon, 1)$. *Then:*

$$\frac{\partial \overline{\sigma}}{\partial B} = -\frac{1 + (2\beta - 1)\,\mathbb{I}_{B>M}}{R}$$

$$\frac{\partial \overline{\sigma}}{\partial R} = -\frac{\overline{\sigma}}{R}.$$

*Thus productivity is increasing in $B$ and in $R$.*

*Proof.* From (2) we have:

$$\overline{\sigma} = \frac{(1-2\beta)\max[M,B] + 2(1-\beta)\beta\Omega(M,u) - B + 2c}{R}$$

So:

$$\frac{\partial\overline{\sigma}}{\partial B} = \frac{(1-2\beta)\,\mathbb{I}_{B>M} - 1}{R},$$

and:

$$\frac{\partial\overline{\sigma}}{\partial R} = -\frac{\overline{\sigma}}{R}.$$

■

**Lemma 7.** ***(schemes that do not incentivize effort)*** *If $B^* < M$ is optimal then $R^* = 0$. Any such scheme is essentially equivalent to $(B^* = R^* = 0)$.*

*Proof.* Suppose $\sigma^*$ is interior. The derivatives of (7) with respect to $B$ and $R$ are, respectively:

$$\begin{aligned}
\text{wrt } B &: \quad -\mathbb{I}_{B>M} - \frac{1}{2}\frac{\partial\overline{\sigma}}{\partial B}\left[\max[M,B] - B + (1-R)\overline{\sigma}\right] f(\overline{\sigma}) + \frac{1}{2}\left(\mathbb{I}_{B>M} - 1\right)\left(1 - F(\overline{\sigma})\right) \\
\text{wrt } R &: \quad -\frac{1}{2}\frac{\partial\overline{\sigma}}{\partial R}\left[\max[M,B] - B + (1-R)\overline{\sigma}\right] f(\overline{\sigma}) - \frac{1}{2}\int_{\overline{\sigma}}^{1} \sigma f(\sigma)\, d\sigma
\end{aligned}$$

$$\begin{aligned}
\text{wrt } B &: \quad -\frac{1}{2}\frac{\partial\overline{\sigma}}{\partial B}\left[\max[M,B] - B + (1-R)\overline{\sigma}\right] f(\overline{\sigma}) - \mathbb{I}_{B>M} - \frac{1}{2}\left(1 - \mathbb{I}_{B>M}\right)\left(1 - F(\overline{\sigma})\right) \\
\text{wrt } R &: \quad -\frac{1}{2}\frac{\partial\overline{\sigma}}{\partial R}\left[\max[M,B] - B + (1-R)\overline{\sigma}\right] f(\overline{\sigma}) - \frac{1}{2}\int_{\overline{\sigma}}^{1} \sigma f(\sigma)\, d\sigma
\end{aligned}$$

Multiply through by 2:

$$\begin{aligned}
\text{wrt } B &: \quad -\frac{\partial\overline{\sigma}}{\partial B}\left[\max[M,B] - B + (1-R)\overline{\sigma}\right] f(\overline{\sigma}) - 2\mathbb{I}_{B>M} - \left(1 - \mathbb{I}_{B>M}\right)\left(1 - F(\overline{\sigma})\right) \\
\text{wrt } R &: \quad -\frac{\partial\overline{\sigma}}{\partial R}\left[\max[M,B] - B + (1-R)\overline{\sigma}\right] f(\overline{\sigma}) - \int_{\overline{\sigma}}^{1} \sigma f(\sigma)\, d\sigma
\end{aligned}$$

Divide each through by $-\frac{\partial\overline{\sigma}}{\partial B}$ and $-\frac{\partial\overline{\sigma}}{\partial R}$ respectively; this operation preserves the signs:

$$\begin{aligned}
\text{wrt } B &: \quad \left[\max[M,B] - B + (1-R)\overline{\sigma}\right] f(\overline{\sigma}) + \frac{1}{\frac{\partial\overline{\sigma}}{\partial B}}\left[2\mathbb{I}_{B>M} + \left(1 - \mathbb{I}_{B>M}\right)\left(1 - F(\overline{\sigma})\right)\right] \\
\text{wrt } R &: \quad \left[\max[M,B] - B + (1-R)\overline{\sigma}\right] f(\overline{\sigma}) + \frac{1}{\frac{\partial\overline{\sigma}}{\partial R}}\int_{\overline{\sigma}}^{1} \sigma f(\sigma)\, d\sigma
\end{aligned}$$

Substituting into the derivatives we get:

$$\text{wrt } B \quad : \quad [\max[M,B] - B + (1-R)\overline{\sigma}] f(\overline{\sigma}) - R\frac{1}{1-(1-2\beta)\mathbb{I}_{B>M}} [2\mathbb{I}_{B>M} + (1-\mathbb{I}_{B>M})(1-F(\overline{\sigma}))] \quad (8)$$

$$\text{wrt } R \quad : \quad [\max[M,B] - B + (1-R)\overline{\sigma}] f(\overline{\sigma}) - R\frac{1}{\overline{\sigma}} \int_{\overline{\sigma}}^{1} \sigma f(\sigma)\, d\sigma \quad (9)$$

In the case $B \leq M$ these expressions reduce to:

$$\text{wrt } B \quad : \quad [M - B + (1-R)\overline{\sigma}] f(\overline{\sigma}) - R(1-F(\overline{\sigma})) \quad (10)$$

$$\text{wrt } R \quad : \quad [M - B + (1-R)\overline{\sigma}] f(\overline{\sigma}) - R\frac{1}{\overline{\sigma}} \int_{\overline{\sigma}}^{1} \sigma f(\sigma)\, d\sigma. \quad (11)$$

Suppose by contradiction $0 < B^* < M$ is an interior solution. Then this solution must satisfy the first order conditions with respect to $B$, which requires $[M - B + (1-R)\overline{\sigma}] \geq 0$. Since

$$(1-F(\overline{\sigma})) = \frac{1}{\overline{\sigma}} \int_{\overline{\sigma}}^{1} \overline{\sigma} f(\sigma)\, d\sigma < \frac{1}{\overline{\sigma}} \int_{\overline{\sigma}}^{1} \sigma f(\sigma)\, d\sigma,$$

the derivative with respect to $B$ always exceeds the derivative with respect to $R$, and so if an interior $0 < B^* < M$ is optimal then it must be $R^* = 0$. In this case for all $\sigma$ we have: $B^* + R^*\sigma < M$, which means that the firm-provided incentive scheme is irrelevant to the worker and to the firm. ■

**Lemma 8.** *When $B > M$ the objective function is a linear function of $B$ that achieves a maximum either at $M$ or at the smallest $B^*$ that incentivizes all workers to exert effort. In the latter case $\overline{\sigma}^* = \varepsilon$. In either case $R^* = \overline{\sigma}^*$.*

*Proof.* In the case $B > M$ (8) and (9) reduce to:

$$\text{wrt } B \quad : \quad [(1-R)\overline{\sigma}] f(\overline{\sigma}) - R\frac{1}{\beta}$$

$$\text{wrt } R \quad : \quad [(1-R)\overline{\sigma}] f(\overline{\sigma}) - R\frac{1}{\overline{\sigma}} \int_{\overline{\sigma}}^{1} \sigma f(\sigma)\, d\sigma.$$

Since $f(\sigma) = K/\sigma$ we get:

$$\text{wrt } B \quad : \quad (1-R)K - R\frac{1}{\beta} \quad (12)$$

$$\text{wrt } R \quad : \quad (1-R)K - R\frac{K}{\overline{\sigma}}(1-\overline{\sigma}). \quad (13)$$

By comparing (13) with (11) we see that the derivative with respect to $R$ is continuous around $B = M$. The derivative with respect to $R$ can be expressed as:

$$\frac{K}{\overline{\sigma}}\left[(1-R)\,\overline{\sigma} - R\,(1-\overline{\sigma})\right].$$

When $R$ converges to zero this expression is positive, when $R$ converges to 1 this expression is negative. Thus the optimum must be interior, and so it must be characterized by the first order conditions, which require:

$$\frac{(1-R^*)}{R^*} = \frac{(1-\overline{\sigma})}{\overline{\sigma}}, \tag{14}$$

leading to $R^* = \overline{\sigma}$.

By comparing (12) with (10) we see that the derivative with respect to $B$ is not continuous around $B = M$ because:

$$\frac{1}{\beta} > (1 - F(\overline{\sigma})).$$

Thus, the derivative with respect to $B$ drops discontinuously at $B = M$. The derivative (12) is independent of $B$, so the objective function is a linear function of $B$ in the region $B > M$. This means that the objective function achieves a maximum either at $B^* = M$ or at the highest value $B^*$ that is compatible with $V^W(\varepsilon) < V^S$. ■

**Proposition 9.** ***(characterization of the optimal compensation scheme)*** *The optimal compensation scheme can take three forms:*

***Scheme 1.*** $B^* = R^* = 0$. *In this case for all $\sigma$ we have: $B^* + R^*\sigma < M$, i.e., no worker is ever paid above minimum wage.*

***Scheme 2.*** $B^* = M$, $R^* = \overline{\sigma}^*$. *In this case some, but not all workers exert effort, the optimal base pay $B^*$ is increasing in $M$, the optimal commission rate $R^*$ is decreasing in $M$ and productivity is increasing in $M$.*

***Scheme 3.*** $B^* = (1-\beta)\,\Omega(M,u) + \frac{1}{\beta}\left(c - \frac{\varepsilon^2}{2}\right) > M, R^* = \overline{\sigma}^* = \varepsilon$. *In this case all workers exert effort, the optimal base pay $B^*$ is increasing in $M$, the optimal commission rates and productivity are independent of $M$.*

*Proof.* **Scheme 1:** Lemma 7 indicates that two types of base pay can be optimal, based on $R$. Either $B^* = R^* = 0$ or $R^* > 0$ and then it must be $B^* > M$. Together, these results partition the set of optimal incentive schemes into two types: $B^* = R^* = 0$ and $(B^* \geq M, R^* > 0)$.

**Scheme 2:** Rewrite (14) as follows:

$$\frac{(1-R^*)}{R^*} = \frac{1 - \left[(1-2\beta)\max[M,B] + 2(1-\beta)\,\beta\Omega(M,u) - B + 2c\right]}{(1-2\beta)\max[M,B] + 2(1-\beta)\,\beta\Omega(M,u) - B + 2c}.$$

Since $B^* = M$ this equation rewrites as:

$$\begin{aligned}\frac{(1-R^*)}{R^*} &= \frac{1-[(1-2\beta)M + 2(1-\beta)\beta\Omega(M,u) - M + 2c]}{(1-2\beta)M + 2(1-\beta)\beta\Omega(M,u) - M + 2c} \\ &= \frac{1-[2(1-\beta)\beta\Omega(M,u) - 2\beta M + 2c]}{2(1-\beta)\beta\Omega(M,u) - 2\beta M + 2c}.\end{aligned}$$

The derivative of the numerator of the RHS with respect to $M$ is:

$$\begin{aligned}& -2(1-\beta)\beta\Omega_1 + 2\beta \\ =\ & 2\beta[1-(1-\beta)\Omega_1] \\ >\ & 2\beta[1-(1-\beta)] \\ =\ & 2\beta^2 > 0.\end{aligned}$$

where the inequality holds because $\Omega_1 < 1$. The derivative of the denominator of the RHS with respect to $M$ is:

$$\begin{aligned}& 2(1-\beta)\beta\Omega_1 - 2\beta \\ <\ & 2(1-\beta)\beta - 2\beta \\ =\ & 2\beta[(1-\beta)-1] \\ =\ & -2\beta^2 < 0.\end{aligned}$$

Since the numerator of the RHS of (14) is increasing in $M$ and the denominator is decreasing in $M$, the entire RHS is increasing in $M$. The LHS of (14) is decreasing in $R$ and does not vary with $M$. Therefore, as $M$ increases $R^*$ must decrease to preserve the equality in (14). But then by (14) $\overline{\sigma}^*$ must decrease, i.e., productivity increases. The rest of the statement reflects Lemma 8.

**Scheme 3:** In this case Lemma 8 indicates that $R^* = \overline{\sigma}^* = \varepsilon$, and that $B^*$ takes the highest value that is compatible with $V^W(\varepsilon) < V^S$.

$$\begin{aligned}V^S &= \max[M, B^*] + \beta\Omega(M,u) \\ &= B^* + \beta\Omega(M,u),\end{aligned}$$

where the second equality holds because we are looking at the case $B^* > M$. Now, $V^W(\varepsilon)$ reads:

$$
\begin{aligned}
V^W(\varepsilon) &= \frac{1}{2(1-\beta)}[\max[M,B^*]+\max[M,B^*+R^*\varepsilon]-2c] \\
&= \frac{1}{2(1-\beta)}\left[\max[M,B^*]+\max\left[M,B^*+\varepsilon^2\right]-2c\right] \\
&= \frac{1}{2(1-\beta)}\left[B^*+B^*+\varepsilon^2-2c\right] \\
&= \frac{1}{(1-\beta)}\left[B^*-c+\frac{\varepsilon^2}{2}\right].
\end{aligned}
$$

The requirement that $V^W(\varepsilon) < V^S$ rewrites as:

$$
\begin{aligned}
\frac{1}{(1-\beta)}\left[B^*-c+\frac{\varepsilon^2}{2}\right] &< B^*+\beta\Omega(M,u) \\
B^*-c+\frac{\varepsilon^2}{2} &< (1-\beta)B^*+(1-\beta)\beta\Omega(M,u) \\
\beta B^* &< (1-\beta)\beta\Omega(M,u)+c-\frac{\varepsilon^2}{2} \\
B^* &< (1-\beta)\Omega(M,u)+\frac{1}{\beta}\left(c-\frac{\varepsilon^2}{2}\right).
\end{aligned}
$$

The smallest $B^*$ that violates this inequality is the optimal base pay. ■

**Lemma 10.** *There exist parameter constellations such that scheme 2 yields higher profits than scheme 1 and 3.*

*Proof.* The parameter constellation that is sufficient to ensure that scheme 2 is superior to schemes 1 and 3 is that $\varepsilon$ be close to zero and that the statistic $\overline{\sigma}_2^*$ defined in (16) is not be close to zero.

**Scheme 2.** Since $B^* = M$ and $R^* = \overline{\sigma}^*$ the firm's payoff reads:

$$
\begin{aligned}
& -\max[M,B^*]+\frac{1}{2}\int_{\overline{\sigma}^*}^{1}[\max[M,B^*]-B^*+(1-R^*)\sigma]f(\sigma)d\sigma \\
= \quad & -M+\frac{1}{2}\int_{\overline{\sigma}^*}^{1}(1-\overline{\sigma}^*)Kd\sigma \\
= \quad & -M+\frac{K}{2}(1-\overline{\sigma}_2^*)^2, \qquad (15)
\end{aligned}
$$

where $\overline{\sigma}_2^*$ denotes the worker who is indifferent between working and not working when

$B^* = M$ and $R^* = \overline{\sigma}^*$. We can solve for $\overline{\sigma}_2^*$ explicitly by solving:

$$\begin{aligned}
\overline{\sigma}_2^* &= \frac{(1-2\beta)\max[M,B^*] + 2(1-\beta)\beta\Omega(M,u) - B^* + 2c}{R^*} \\
&= \frac{(1-2\beta)M + 2(1-\beta)\beta\Omega(M,u) - M + 2c}{\overline{\sigma}_2^*} \\
&= \frac{-2\beta M + 2(1-\beta)\beta\Omega(M,u) + 2c}{\overline{\sigma}_2^*},
\end{aligned}$$

hence:

$$\overline{\sigma}_2^* = \sqrt{-2\beta M + 2(1-\beta)\beta\Omega(M,u) + 2c}. \tag{16}$$

This threshold $\overline{\sigma}_2^*$ exceeds $\varepsilon$ if

$$\begin{aligned}
-2\beta M + 2(1-\beta)\beta\Omega(M,u) + 2c &> \varepsilon^2 \\
2(1-\beta)\beta\Omega(M,u) + 2c - \varepsilon^2 &> 2\beta M \\
M &< (1-\beta)\Omega(M,u) + \frac{1}{\beta}\left(c - \frac{\varepsilon^2}{2}\right).
\end{aligned} \tag{17}$$

**Scheme 3.** Since $B^* = (1-\beta)\Omega(M,u) + \frac{1}{\beta}\left(c - \frac{\varepsilon^2}{2}\right) > M, R^* = \overline{\sigma}^* = \varepsilon$ we have:

$$\begin{aligned}
&-\max[M,B^*] + \frac{1}{2}\int_{\overline{\sigma}^*}^{1} [\max[M,B^*] - B^* + (1-R^*)\sigma] f(\sigma)\, d\sigma \\
&-B^* + \frac{1}{2}\int_{\varepsilon}^{1} (1-\varepsilon) K d\sigma \\
&-B^* + \frac{K}{2}(1-\varepsilon)^2.
\end{aligned}$$

**Comparison 3-2.** For the payoff to be larger in scheme 2 than in scheme 3 it must be:

$$\begin{aligned}
-M + \frac{K}{2}(1-\overline{\sigma}_2^*)^2 &> -B^* + \frac{K}{2}(1-\varepsilon)^2 \\
B^* - M &> \frac{K}{2}\left[(1-\varepsilon)^2 - (1-\overline{\sigma}_2^*)^2\right] \\
(1-\beta)\Omega(M,u) + \frac{1}{\beta}\left(c - \frac{\varepsilon^2}{2}\right) - M &> \frac{K}{2}\left[(1-\varepsilon)^2 - (1-\overline{\sigma}_2^*)^2\right]
\end{aligned}$$

Since:

$$
\begin{aligned}
& (1-\beta)\,\Omega\,(M,u)+\frac{1}{\beta}\left(c-\frac{\varepsilon^2}{2}\right)-M \\
= \;& \frac{1}{2\beta}\left[2\,(1-\beta)\,\beta\Omega\,(M,u)+2\left(c-\frac{\varepsilon^2}{2}\right)-2\beta M\right] \\
= \;& \frac{1}{2\beta}\left[2\,(1-\beta)\,\beta\Omega\,(M,u)+2c-2\beta M-\varepsilon^2\right] \\
= \;& \frac{1}{2\beta}\left[\overline{\sigma}_2^{*2}-\varepsilon^2\right],
\end{aligned}
$$

for the payoff to be larger in scheme 2 than in scheme 3 it must be:

$$
\begin{aligned}
\frac{1}{2\beta}\left[\overline{\sigma}_2^{*2}-\varepsilon^2\right] &> \frac{K}{2}\left[(1-\varepsilon)^2-(1-\overline{\sigma}_2^{*})^2\right] \\
&= \frac{K}{2}\left[1+\varepsilon^2-2\varepsilon-\left(1+\overline{\sigma}_2^{*2}-2\overline{\sigma}_2^{*}\right)\right] \\
&= \frac{K}{2}\left[\varepsilon^2-2\varepsilon-\overline{\sigma}_2^{*2}+2\overline{\sigma}_2^{*}\right] \\
&= \frac{K}{2}\left[2\left(\overline{\sigma}_2^{*}-\varepsilon\right)-\left(\overline{\sigma}_2^{*2}-\varepsilon^2\right)\right],
\end{aligned}
$$

or equivalently:

$$
\begin{aligned}
\frac{1}{2\beta}\left[\overline{\sigma}_2^{*2}-\varepsilon^2\right] &> \frac{K}{2}\left[2\left(\overline{\sigma}_2^{*}-\varepsilon\right)-\left(\overline{\sigma}_2^{*2}-\varepsilon^2\right)\right] \\
\frac{1}{\beta K}\left[\overline{\sigma}_2^{*2}-\varepsilon^2\right] &> 2\left(\overline{\sigma}_2^{*}-\varepsilon\right)-\left(\overline{\sigma}_2^{*2}-\varepsilon^2\right) \\
\left(\frac{1}{\beta K}+1\right)\left[\overline{\sigma}_2^{*2}-\varepsilon^2\right] &> 2\left(\overline{\sigma}_2^{*}-\varepsilon\right) \\
\left(\frac{1}{\beta K}+1\right)\left(\overline{\sigma}_2^{*}-\varepsilon\right)\left(\overline{\sigma}_2^{*}+\varepsilon\right) &> 2\left(\overline{\sigma}_2^{*}-\varepsilon\right) \\
\left(\frac{1}{\beta K}+1\right)\left(\overline{\sigma}_2^{*}+\varepsilon\right) &> 2
\end{aligned}
$$

where $K=-1/\log(\varepsilon)$. Now, if $\varepsilon$ is close to 0 then $K$ is close to zero and then the inequality is true for sure provided that the parameters are such that $\overline{\sigma}_2^{*}>0$.

**Scheme 1.** Suppose $\overline{\sigma}_2^{*}>\varepsilon$, i.e., the conditions in (17) hold. Then some, but not all workers, exert effort under scheme $\left(B^*=M,R^*=\overline{\sigma}_2^{*}\right)$. Then no worker would exert effort under scheme $\left(B^*=M,R^*=0\right)$. The latter scheme is equivalent both for workers and for the firm to scheme 1, $\left(B^*=R^*=0\right)$. Therefore under scheme 1 profits equal $-M$ which is below the (15), the profits in scheme 2. ■

# C Variations in minimum wage

Table C.1: States With No Changes in Minimum Wage since January 2012

| State with no change | State Abr. |
|---|---|
| Georgia | GA |
| Iowa | IA |
| Idaho | ID |
| Illinois | IL |
| Indiana | IN |
| Kansas | KS |
| Kentucky | KY |
| Louisiana | LA |
| Mississippi | MS |
| North Carolina | NC |
| North Dakota | ND |
| New Hampshire | NH |
| New Mexico | NM |
| Nevada | NV |
| Oklahoma | OK |
| Pennsylvania | PA |
| South Carolina | SC |
| Tennessee | TN |
| Texas | TX |
| Utah | UT |
| Virginia | VA |
| Wisconsin | WI |
| Wyoming | WY |

## Table C.2: Minimum Wages since January 2012

| *State* | State | Date C.1 | $W_{t-1}$ | $W_t$ | Date C.2 | $W_{t-1}$ | $W_t$ | Date C.3 | $W_{t-1}$ | $W_t$ | Date C.4 | $W_{t-1}$ | $W_t$ | Date C.5 | $W_{t-1}$ | $W_t$ | Date C.6 | $W_{t-1}$ | $W_t$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alaska | AK | 2015m2 | 7.75 | 8.75 | 2016m1 | 8.75 | 9.75 | 2017m1 | 9.75 | 9.8 | | | | | | | | | |
| Alabama | AL | 2016m8 | 7.25 | 7.75 | | | | | | | | | | | | | | | |
| Arkansas | AR | 2015m1 | 7.25 | 7.5 | 2016m1 | 7.5 | 8 | 2017m1 | 8 | 8.5 | | | | | | | | | |
| Arizona | AZ | 2012m1 | 7.35 | 7.65 | 2013m1 | 7.65 | 7.8 | 2014m1 | 7.8 | 7.9 | 2015m1 | 7.9 | 8.05 | 2017m1 | 8.05 | 10 | | | |
| California | CA | 2014m7 | 8 | 9 | 2016m1 | 9 | 10 | 2017m1 | 10 | 10.5 | | | | | | | | | |
| Colorado | CO | 2012m1 | 7.36 | 7.64 | 2013m1 | 7.64 | 7.78 | 2014m1 | 7.78 | 8 | 2015m1 | 8 | 8.23 | 2016m1 | 8.23 | 8.31 | 2017m1 | 8.31 | 9.3 |
| Connecticut | CT | 2014m1 | 8.25 | 8.7 | 2015m1 | 8.7 | 9.15 | 2016m1 | 9.15 | 9.6 | 2017m1 | 9.6 | 10.1 | | | | | | |
| DC | DC | 2014m7 | 8.25 | 9.5 | 2015m7 | 9.5 | 10.5 | 2016m7 | 10.5 | 11.5 | | | | | | | | | |
| Delaware | DE | 2014m6 | 7.25 | 7.75 | 2015m6 | 7.75 | 8.25 | | | | | | | | | | | | |
| Florida | FL | 2012m1 | 7.31 | 7.67 | 2013m1 | 7.67 | 7.79 | 2014m1 | 7.79 | 7.93 | 2015m1 | 7.93 | 8.05 | 2017m1 | 8.05 | 8.1 | | | |
| Hawaii | HI | 2015m1 | 7.25 | 7.75 | 2016m1 | 7.75 | 8.5 | 2017m1 | 8.5 | 9.25 | | | | | | | | | |
| Massachusetts | MA | 2015m1 | 8 | 9 | 2016m1 | 9 | 10 | 2017m1 | 10 | 11 | | | | | | | | | |
| Maryland | MD | 2015m1 | 7.25 | 8 | 2015m7 | 8 | 8.25 | 2016m7 | 8.25 | 8.75 | | | | | | | | | |
| Maine | ME | 2017m1 | 7.5 | 9 | | | | | | | | | | | | | | | |
| Michigan | MI | 2014m9 | 7.4 | 8.15 | 2016m1 | 8.15 | 8.5 | 2017m1 | 8.5 | 8.9 | | | | | | | | | |
| Minnesota | MN | 2014m8 | 7.25 | 8 | 2015m8 | 8 | 9 | | | | | | | | | | | | |
| Missouri | MO | 2013m1 | 7.25 | 7.35 | 2014m1 | 7.35 | 7.5 | 2015m1 | 7.5 | 7.65 | 2017m1 | 7.65 | 7.7 | | | | | | |
| Montana | MT | 2012m1 | 7.35 | 7.65 | 2013m1 | 7.65 | 7.8 | 2014m1 | 7.8 | 7.9 | 2015m1 | 7.9 | 8.05 | 2017m1 | 8.05 | 8.15 | | | |
| Nebraska | NE | 2015m1 | 7.25 | 8 | 2016m1 | 8 | 9 | | | | | | | | | | | | |
| New Jersey | NJ | 2014m1 | 7.25 | 8.25 | 2015m1 | 8.25 | 8.38 | 2017m1 | 8.38 | 8.44 | | | | | | | | | |
| New York | NY | 2013m12 | 7.25 | 8 | 2014m12 | 8 | 8.75 | 2015m12 | 8.75 | 9 | 2017m1 | 9 | 9.7 | | | | | | |
| Ohio | OH | 2012m1 | 7.4 | 7.7 | 2013m1 | 7.7 | 7.85 | 2014m1 | 7.85 | 7.95 | 2015m1 | 7.95 | 8.1 | 2017m1 | 8.1 | 8.15 | | | |
| Oregon | OR | 2012m1 | 8.5 | 8.8 | 2013m1 | 8.8 | 8.95 | 2014m1 | 8.95 | 9.1 | 2015m1 | 9.1 | 9.25 | 2017m1 | 9.25 | 9.75 | | | |
| Rhode Island | RI | 2013m1 | 7.4 | 7.75 | 2014m1 | 7.75 | 8 | 2015m1 | 8 | 9 | 2016m1 | 9 | 9.6 | | | | | | |
| South Dakota | SD | 2015m1 | 7.25 | 8.5 | 2016m1 | 8.5 | 8.55 | 2017m1 | 8.55 | 8.65 | 2012m1 | 8.15 | 8.46 | 2013m1 | 8.46 | 8.6 | | | |
| Vermont | VT | 2014m1 | 8.6 | 8.73 | 2015m1 | 8.73 | 9.15 | 2016m1 | 9.15 | 9.6 | 2017m1 | 9.6 | 10 | | | | | | |
| Washington | WA | 2012m1 | 8.67 | 9.04 | 2013m1 | 9.04 | 9.19 | 2014m1 | 9.19 | 9.32 | 2015m1 | 9.32 | 9.47 | 2017m1 | 9.47 | 11 | | | |
| West Virginia | WV | 2015m1 | 7.25 | 8 | 2016m1 | 8 | 8.75 | | | | | | | | | | | | |

| *County* | State | Date C.1 | $W_{t-1}$ | $W_t$ | Date C.2 | $W_{t-1}$ | $W_t$ | Date C.3 | $W_{t-1}$ | $W_t$ | Date C.4 | $W_{t-1}$ | $W_t$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bernalillo | NM | 2013m7 | 7.5 | 8 | 2014m1 | 8 | 8.5 | 2015m1 | 8.5 | 8.65 | 2017m1 | 8.65 | 8.7 |
| Johnson | IA | 2015m11 | 7.25 | 8.2 | 2016m5 | 8.2 | 9.15 | 2017m1 | 9.15 | 10.1 | | | |
| Los Angeles | CA | 2014m7 | 8 | 9 | 2016m1 | 9 | 10 | 2016m7 | 10 | 10.5 | | | |
| Montgomery | MD | 2014m10 | 7.25 | 8.4 | 2015m10 | 8.4 | 9.55 | 2016m10 | 9.55 | 10.75 | | | |
| Prince George's | MD | 2014m10 | 7.25 | 8.4 | 2015m10 | 8.4 | 9.55 | 2016m10 | 9.55 | 10.75 | | | |
| Santa Fe | NM | 2014m4 | 7.5 | 10.66 | 2015m3 | 10.66 | 10.84 | 2016m3 | 10.84 | 10.91 | | | |

| *City* | State | Date C.1 | $W_{t-1}$ | $W_t$ | Date C.2 | $W_{t-1}$ | $W_t$ | Date C.3 | $W_{t-1}$ | $W_t$ | Date C.4 | $W_{t-1}$ | $W_t$ | Date C.5 | $W_{t-1}$ | $W_t$ | Date C.6 | $W_{t-1}$ | $W_t$ | Date C.7 | $W_{t-1}$ | $W_t$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alburquerque | NM | 2013m1 | 7.5 | 8.5 | 2014m1 | 8.5 | 8.6 | 2015m1 | 8.6 | 8.75 | 2017m1 | 8.75 | 8.8 | | | | | | | | | |
| Bangor | ME | 2017m1 | 7.5 | 8.25 | | | | | | | | | | | | | | | | | | |
| Berkeley | CA | 2014m7 | 8 | 9 | 2014m10 | 9 | 10 | 2015m10 | 10 | 11 | 2016m10 | 10 | 12.53 | | | | | | | | | |
| Chicago | IL | 2016m7 | 8.25 | 10.5 | | | | | | | | | | | | | | | | | | |
| El Cerrito | CA | 2014m7 | 8 | 9 | 2016m1 | 9 | 10 | 2016m7 | 10 | 11.6 | 2017m1 | 11.6 | 12.25 | | | | | | | | | |
| Emeryville | CA | 2014m7 | 8 | 9 | 2015m7 | 9 | 14.44 | 2016m7 | 14.44 | 14.82 | | | | | | | | | | | | |
| Kansas City* | MO | 2015m8 | 7.65 | 8.5 | | | | | | | | | | | | | | | | | | |
| Las Cruces | NM | 2015m1 | 7.5 | 8.4 | 2017m1 | 8.4 | 9.2 | | | | | | | | | | | | | | | |
| Lexington | KY | 2016m7 | 7.25 | 9.15 | | | | | | | | | | | | | | | | | | |
| Long Beach | CA | 2014m7 | 8 | 9 | 2016m1 | 9 | 10 | 2017m1 | 10 | 10.5 | | | | | | | | | | | | |
| Los Angeles | CA | 2014m7 | 8 | 9 | 2016m1 | 9 | 10 | 2016m7 | 10 | 10.5 | | | | | | | | | | | | |
| Louisville | KY | 2015m7 | 7.25 | 8.1 | 2016m7 | 8.1 | 9.15 | | | | | | | | | | | | | | | |
| Mountain View | CA | 2014m7 | 8 | 9 | 2015m7 | 9 | 10.3 | 2016m1 | 10.3 | 11 | 2017m1 | 11 | 13 | | | | | | | | | |
| Oakland | CA | 2014m7 | 8 | 9 | 2015m3 | 9 | 12.25 | 2016m1 | 12.25 | 12.55 | 2017m1 | 12.55 | 12.86 | | | | | | | | | |
| Palo Alto | CA | 2014m7 | 8 | 9 | 2016m1 | 9 | 11 | 2017m1 | 11 | 12 | | | | | | | | | | | | |
| Portland | ME | 2016m1 | 7.5 | 10.1 | 2017m1 | 10.1 | 10.68 | | | | | | | | | | | | | | | |
| Richmond | CA | 2014m7 | 8 | 9 | 2015m1 | 9 | 9.6 | 2016m1 | 9.6 | 11.52 | 2017m1 | 11.52 | 12.3 | | | | | | | | | |
| Sacramento | CA | 2014m7 | 8 | 9 | 2016m1 | 9 | 10 | 2017m1 | 10 | 10.5 | | | | | | | | | | | | |
| San Diego | CA | 2014m7 | 8 | 9 | 2015m1 | 9 | 9.75 | 2016m1 | 9.75 | 10.5 | 2017m1 | 10.5 | 11.5 | | | | | | | | | |
| San Francisco | CA | 2012m1 | 9.92 | 10.24 | 2013m1 | 10.24 | 10.55 | 2014m1 | 10.55 | 10.74 | 2015m1 | 10.74 | 11.05 | 2015m5 | 11.05 | 12.25 | 2016m7 | 12.25 | 13 | | | |
| San Jose | CA | 2013m3 | 8 | 10 | 2014m1 | 10 | 10.15 | 2015m1 | 10.15 | 10.3 | 2017m1 | 10.3 | 10.5 | | | | | | | | | |
| Santa Clara | CA | 2014m7 | 8 | 9 | 2016m1 | 9 | 11 | 2017m1 | 11 | 11.1 | | | | | | | | | | | | |
| Santa Fe | NM | 2012m3 | 9.5 | 10.29 | 2013m3 | 10.29 | 10.51 | 2014m3 | 10.51 | 10.66 | 2015m3 | 10.66 | 10.84 | 2016m3 | 10.84 | 10.91 | | | | | | |
| Santa Monica | CA | 2014m7 | 8 | 9 | 2016m1 | 9 | 10 | 2016m7 | 10 | 10.5 | | | | | | | | | | | | |
| SeaTac | WA | 2012m1 | 8.67 | 9.04 | 2013m1 | 9.04 | 9.19 | 2014m1 | 9.19 | 15 | 2015m10 | 15 | 15.24 | 2017m1 | 15.24 | 15.34 | | | | | | |
| Seattle | WA | 2012m1 | 8.67 | 9.04 | 2013m1 | 9.04 | 9.19 | 2014m1 | 9.19 | 9.32 | 2015m1 | 9.32 | 9.47 | 2015m4 | 9.47 | 11 | 2016m1 | 11 | 13 | 2017m1 | 13 | 15 |
| Sunnyvale | CA | 2014m7 | 8 | 9 | 2015m1 | 9 | 10.3 | 2016m7 | 10.3 | 11 | 2017m1 | 11 | 13 | | | | | | | | | |
| Tacoma | WA | 2012m1 | 8.67 | 9.04 | 2013m1 | 9.04 | 9.19 | 2014m1 | 9.19 | 9.32 | 2015m1 | 9.32 | 9.47 | 2016m2 | 9.47 | 10.35 | 2017m1 | 10.35 | 11.15 | | | |
| Washington | DC | 2014m7 | 8.25 | 9.5 | 2015m7 | 9.5 | 10.5 | 2016m7 | 10.5 | 11.5 | | | | | | | | | | | | |

*Was reversed by state court but still honored by retailer.

# D Additional Tables and Figures

Table D.1: Distribution of Workers in Different Wage Groups

| | Wage group | | |
|---|---|---|---|
| | At MinW | Just Above MinW | Well Above MinW |
| Threshold | (1) | (2) | (3) |
| 120% | 4.06% | 20.96% | 74.98% |
| 140% | 4.06% | 44.62% | 51.32% |
| 160% | 4.06% | 62.77% | 33.17% |
| 180% | 4.06% | 74.58% | 21.36% |

Note: Row 1: *At MinW* is the proportion of workers paid at the minimum wage. *Just Above MinW* is the proportion of workers paid between the minimum wage and 120% of the minimum wage (120% threshold); *Well Above MinW* is the proportion of workers paid more than 120% of the minimum wage. Row 2-Row 4 present statistics for the 140-180% thresholds.

Table D.2: Productivity For Workers in Different Wage Groups

| | Wage group | | |
|---|---|---|---|
| | At MinW | Just Above MinW | Well Above MinW |
| Threshold | (1) | (2) | (3) |
| 120% | 1.056 | 1.469 | 2.37 |
| 140% | 1.056 | 1.691 | 2.59 |
| 160% | 1.056 | 1.859 | 2.76 |
| 180% | 1.056 | 1.975 | 2.85 |

Note: *Productivity* is the worker monthly sales per hour. Row 1: *At MinW* is the proportion of workers paid at the minimum wage. *Just Above MinW* is the proportion of workers paid between the minimum wage and 120% of the minimum wage (120% threshold); *Well Above MinW* is the proportion of workers paid more than 120% of the minimum wage. Row 2-Row 4 present statistics for the 140-180% thresholds.

Table D.3: Minimum Wage Has No Effect on The Most Productive Salespersons, Based on the Productivity in the First Month on the Job

| Dep.Var | Sales/Hrs. | Sales/Hrs. | Sales/Hrs. | Sales/Hrs. |
|---|---|---|---|---|
| Threshold | 120% | 140% | 160% | 180% |
| | (1) | (2) | (3) | (4) |
| MinW | 0.197** | 0.196** | 0.194** | 0.198** |
| | (0.084) | (0.083) | (0.084) | (0.084) |
| MinW * $\mathbb{1}(> MW)$ | -0.113 | -0.107 | -0.114 | -0.140* |
| | (0.077) | (0.078) | (0.078) | (0.070) |
| MinW * $\mathbb{1}(>> MW)$ | -0.156** | -0.186*** | -0.212*** | -0.158** |
| | (0.065) | (0.056) | (0.050) | (0.068) |
| Observations | 167,060 | 167,060 | 167,060 | 167,060 |
| Units | Workers | Workers | Workers | Workers |
| R-squared | 0.456 | 0.456 | 0.456 | 0.456 |
| Mean Y | 2.125 | 2.125 | 2.125 | 2.125 |
| Eff.Wrkrs.at MW (%) | 18.70 | 11.28 | 11.18 | 11.39 |
| p-value | 0.0231 | 0.0237 | 0.0253 | 0.0227 |
| Eff.Wrkrs.just above MW (%) | 5.760 | 4.381 | 3.840 | 2.742 |
| p-value | 0.001 | 0.001 | 0.001 | 0.007 |
| Eff.Wrkrs.well above MW (%) | 1.764 | 0.441 | -0.760 | 1.799 |
| p-value | 0.109 | 0.777 | 0.735 | 0.455 |

Note: *Sales/Hrs.* are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its $ value. *MinW* is the monthly minimum wage in the jurisdiction in which the worker is located (in $). $\mathbb{1}(> MW)$ is an indicator for whether the worker's total pay in month *1* (first month on the job) is between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). $\mathbb{1}(>> MW)$ is an indicator for whether the worker's total pay in month *1* (first month on the job) is above 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.at MW* is the percent effect of one standard deviation increase in MinW on workers "at minimum wage." *Eff.Wrkrs.just above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.well above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated more than 120% of minimum wage (or 140%, 160%, 180%). All the regressions include county-unemployment, worker tenure, month FE, worker FE, department FE and state-specific trends. *** p<0.01, ** p<0.05, * p<0.1.

Table D.4: Robustness: Unemployment Sharpens The Effects of Minimum Wage on Individual Workers Productivity

| Var.Desc. | Productivity | Productivity | Productivity | Productivity |
|---|---|---|---|---|
| Dep.Var. | Sales/Hrs. | Sales/Hrs. | Sales/Hrs. | Sales/Hrs. |
| Sample | All stores | Stores dist.jur.: 75km | Stores dist.jur. 37.5km | Stores dist.jur.: 18.75km |
| | (1) | (2) | (3) | (4) |
| MinW | 0.060** | 0.063** | 0.074*** | 0.084*** |
| | (0.025) | (0.026) | (0.027) | (0.027) |
| Unemployment | 0.012 | 0.011 | 0.005 | 0.007 |
| | (0.014) | (0.014) | (0.014) | (0.017) |
| MinW·Unemployment | 0.011* | 0.013** | 0.013* | 0.012 |
| | (0.006) | (0.007) | (0.007) | (0.008) |
| Observations | 179,046 | 177,743 | 165,265 | 115,030 |
| Units | Workers | Workers | Workers | Workers |
| R-squared | 0.415 | 0.415 | 0.413 | 0.409 |
| Mean Y | 2.061 | 2.062 | 2.069 | 2.068 |

Note: The dependent variable is *Sales/Hrs* which are the total monthly sales divided by the total hours. *MinW* is the monthly minimum wage (in $) in the city/county/state of the store of the employee. *Unemployment* is the unemployment rate at the county level (difference to the mean). All the regressions include county-unemployment, worker tenure, month FE, worker FE, department FE and state-specific trends. Samples with stores within 75km, 37.5km and 18.75km include stores located within 75km/37.5km/18.75km of another jurisdiction with its own minimum wage law. All regressions include month FE, worker FE, department FE, and state-specific trends. *** p<0.01, ** p<0.05, * p<0.1.

Table D.5: Minimum Wage Involves No Selective Termination with Worker Fixed Effects

| Dep.Var | Termin. | Termin. | Termin. | Termin. | Termin. |
|---|---|---|---|---|---|
| Threshold | None | 120% | 140% | 160% | 180% |
| | (1) | (2) | (3) | (4) | (5) |
| MinW | -0.0468 | 0.085 | 0.019 | -0.039 | -0.085 |
| | (0.196) | (0.408) | (0.403) | (0.414) | (0.411) |
| $\mathbb{1}(> MW)$ | | -0.017 | 0.408 | 0.486 | 0.528 |
| | | (0.419) | (0.411) | (0.422) | (0.422) |
| $\mathbb{1}(> MW)$ | | 1.186** | 1.054** | 1.125** | 1.057** |
| | | (0.447) | (0.482) | (0.441) | (0.465) |
| MinW * $\mathbb{1}(> MW)$ | | 0.706** | 0.424 | 0.325 | 0.258 |
| | | (0.309) | (0.305) | (0.308) | (0.313) |
| MinW * $\mathbb{1}(>> MW)$ | | -0.282 | -0.458 | -0.498 | -0.399 |
| | | (0.360) | (0.406) | (0.508) | (0.517) |
| Observations | 179,046 | 167,060 | 167,060 | 167,060 | 167,060 |
| Units | Workers | Workers | Workers | Workers | Workers |
| R-squared | 0.189 | 0.187 | 0.187 | 0.187 | 0.187 |
| Mean Y | 4.771 | 4.606 | 4.606 | 4.606 | 4.606 |
| Eff.MinW % | -0.635 | | | | |
| Eff.Wrkrs.at MW (%) | | 1.404 | 0.307 | -0.653 | -1.403 |
| p-value | | 0.837 | 0.964 | 0.925 | 0.838 |
| Eff.Wrkrs.just above (%) | | 14.75 | 8.406 | 5.667 | 3.520 |
| p-value | | 0.002 | 0.044 | 0.192 | 0.404 |
| Eff.Wrkrs.well above (%) | | -4.579 | -11.22 | -14.92 | -14.94 |
| p-value | | 0.368 | 0.094 | 0.107 | 0.187 |

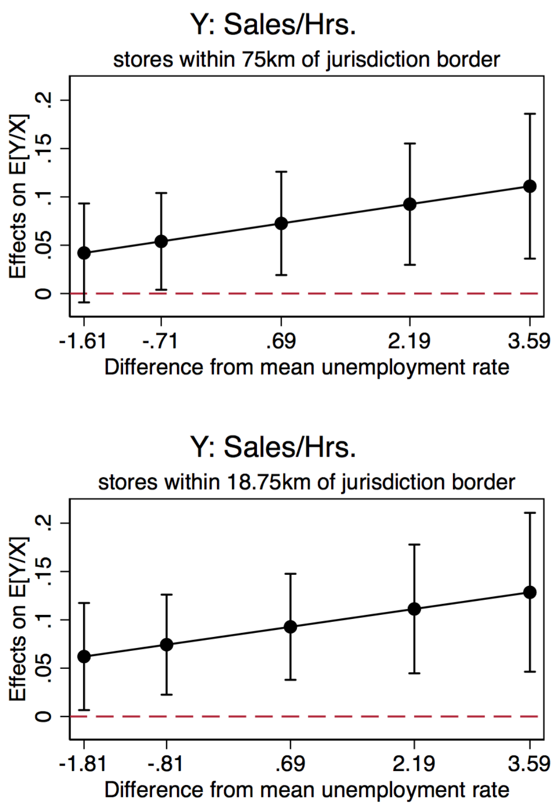
Note: *Termin.* is the probability that a worker has been terminated in a given month. *MinW* is the monthly minimum wage in the jurisdiction in which the worker is located (in $). $\mathbb{1}(> MW)$ is an indicator for whether the worker's total pay in month *m-1* is between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). $\mathbb{1}(>> MW)$ is an indicator for whether the worker's total pay in month *m-1* is above 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.at MW* is the percent effect of one standard deviation increase in MinW on workers "at minimum wage." *Eff.Wrkrs.just above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.well above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated more than 120% of minimum wage (or 140%, 160%, 180%). All the regressions include county-unemployment, worker tenure, worker FE, month FE, department FE and state-specific trends. *** p<0.01, ** p<0.05, * p<0.1.

Table D.6: Robustness: Minimum Wage Increases Individual Worker Productivity, and Worker Compensation

| Var.Desc. | Productivity | Compensation scheme | | MinW Adjustments | | | Compensation | |
|---|---|---|---|---|---|---|---|---|
| Dep.Var. | Sales/Hrs. | Base Rate: Reg.Pay/Hrs. | Comm. Rate: Var.Pay/Sales | Weekly Adj. | # Adj. | Adj.Pay/Hrs. | Tot.Pay/T.Hrs. | Tot.Pay |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | Stores distance from jurisdiction: 75km | | | | | | | |
| MinW | 0.0647** | 0.133* | 0.0200 | 0.0616*** | 0.542*** | 0.226*** | 0.576*** | 0.451*** |
| | (0.0267) | (0.0781) | (0.0258) | (0.00753) | (0.0246) | (0.0262) | (0.105) | (0.105) |
| Observations | 177,743 | 177,743 | 169,104 | 177,743 | 177,743 | 177,742 | 177,743 | 177,743 |
| Mean Y | 2.062 | 6.107 | 3.304 | 0.0326 | 0.735 | 0.228 | 12.19 | 13.37 |
| Eff.MinW % | 2.035 | 1.416 | 0.391 | 122.4 | 47.84 | 64.27 | 3.065 | 2.188 |
| | Stores distance from jurisdiction: 37.5km | | | | | | | |
| MinW | 0.0753*** | 0.120 | 0.0174 | 0.0608*** | 0.532*** | 0.218*** | 0.600*** | 0.489*** |
| | (0.0273) | (0.0782) | (0.0233) | (0.00781) | (0.0202) | (0.0276) | (0.123) | (0.138) |
| Observations | 165,265 | 165,265 | 157,172 | 165,265 | 165,265 | 165,264 | 165,265 | 165,265 |
| Units | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers |
| Mean Y | 2.069 | 6.104 | 3.300 | 0.0323 | 0.728 | 0.227 | 12.19 | 13.37 |
| Eff.MinW % | 2.385 | 1.291 | 0.344 | 123.5 | 47.91 | 62.91 | 3.226 | 2.396 |
| | Stores distance from jurisdiction: 18.75km | | | | | | | |
| MinW | 0.0860*** | 0.0961 | 0.0242 | 0.0628*** | 0.537*** | 0.208*** | 0.643*** | 0.437** |
| | (0.0269) | (0.0680) | (0.0273) | (0.00962) | (0.0213) | (0.0253) | (0.145) | (0.188) |
| Observations | 115,030 | 115,030 | 109,478 | 115,030 | 115,030 | 115,029 | 115,030 | 115,030 |
| Units | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers |
| Mean Y | 2.062 | 6.107 | 3.304 | 0.0326 | 0.735 | 0.228 | 12.19 | 13.37 |
| Eff.MinW % | 2.035 | 1.416 | 0.391 | 122.4 | 47.84 | 64.27 | 3.065 | 2.188 |

Note: *Sales/Hrs.* are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its $ value. *Base: Reg.Pay/Hrs.* are monthly regular earnings per hour worked (in $ per hour). *Comm.Rate: Var.Pay/Sales* are earnings from commissions and incentives divided by sales (in %). *MinW* is the monthly minimum wage in the jurisdiction in which worker is located (in $). *Weekly Adj.* is a dummy for whether the worker received minimum wage adjustments each week of the month. *# Adj.* is the number of weekly adjustments per month. *Adj.Pay/Hrs* are monthly earnings from minimum wage adjustments divided by hours worked (in $ per hour). *Tot.Pay/T.Hrs.* is the monthly total pay from total take home pay divided by total hours (in $ per hour). *Tot.Pay* is the monthly total pay from total take home pay, and it is rescaled by a factor between $ 1/50 and 1/150 relative to its $ value. *Tenure* is the number of months of tenure. All the regressions include county-unemployment, worker tenure, month FE, worker FE, department FE and state-specific trends.*** p<0.01, ** p<0.05, * p<0.1.

Figure D.1: Robustness: Effects of Minimum Wage on Individual Workers Productivity During Periods of High Unemployment




Note: Average effect of a variation in minimum wage for individual worker productivity measured with sales per hour (Y) at the $10^{th}$, $25^{th}$, $50^{th}$, $75^{th}$, and $90^{th}$ percentile of unemployment rate. Vertical bars are 95% confidence intervals.

Table D.7: Robustness: Differential Effect of Minimum Wage on Individual Workers Productivity by Workers' Past Exposure to Minimum Wage

| Dep.Var | Sales/ Hrs. | Sales/ Hrs. | Sales/ Hrs. | Sales/ Hrs. | Sales/ Hrs. | Sales/ Hrs. | Sales/ Hrs. | Sales/ Hrs. | Sales/ Hrs. | Sales/ Hrs. | Sales/ Hrs. | Sales/ Hrs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Store dist.jurisdiction (km) | 75 | 75 | 75 | 75 | 37.5 | 37.5 | 37.5 | 37.5 | 18.75 | 18.75 | 18.75 | 18.75 |
| Threshold | 120% | 140% | 160% | 180% | 120% | 140% | 160% | 180% | 120% | >140% | 160% | 180% |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| MinW | 0.198*** | 0.195*** | 0.197*** | 0.214*** | 0.208*** | 0.204*** | 0.204*** | 0.222*** | 0.239*** | 0.225*** | 0.220*** | 0.236*** |
| | (0.034) | (0.031) | (0.031) | (0.032) | (0.030) | (0.028) | (0.030) | (0.032) | (0.032) | (0.033) | (0.035) | (0.040) |
| $\mathbb{1}(> MW)$ | 0.223*** | 0.290*** | 0.346*** | 0.378*** | 0.223*** | 0.289*** | 0.344*** | 0.378*** | 0.189*** | 0.266*** | 0.321*** | 0.353*** |
| | (0.023) | (0.026) | (0.027) | (0.028) | (0.024) | (0.028) | (0.029) | (0.029) | (0.034) | (0.036) | (0.038) | (0.038) |
| $\mathbb{1}(>> MW)$ | 0.681*** | 0.951*** | 1.146*** | 1.269*** | 0.681*** | 0.948*** | 1.143*** | 1.267*** | 0.663*** | 0.920*** | 1.113*** | 1.239*** |
| | (0.037) | (0.044) | (0.054) | (0.058) | (0.038) | (0.045) | (0.054) | (0.059) | (0.044) | (0.052) | (0.060) | (0.068) |
| MinW $\cdot\mathbb{1}(> MW)$ | -0.077*** | -0.057*** | -0.066*** | -0.081*** | -0.075*** | -0.057** | -0.066*** | -0.082*** | -0.054* | -0.051 | -0.065** | -0.080** |
| | (0.021) | (0.020) | (0.020) | (0.020) | (0.023) | (0.023) | (0.023) | (0.023) | (0.032) | (0.031) | (0.030) | (0.031) |
| MinW $\cdot\mathbb{1}(>> MW)$ | -0.070*** | -0.099*** | -0.157*** | -0.222*** | -0.074*** | -0.102*** | -0.158*** | -0.222*** | -0.105*** | -0.134*** | -0.176*** | -0.232*** |
| | (0.022) | (0.027) | (0.027) | (0.031) | (0.021) | (0.024) | (0.024) | (0.029) | (0.025) | (0.023) | (0.025) | (0.032) |
| Observations | 165,847 | 165,847 | 165,847 | 165,847 | 154,152 | 154,152 | 154,152 | 154,152 | 107,359 | 107,359 | 107,359 | 107,359 |
| Units | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers |
| R-squared | 0.467 | 0.483 | 0.492 | 0.491 | 0.463 | 0.479 | 0.489 | 0.488 | 0.465 | 0.480 | 0.489 | 0.489 |
| Mean Y | 2.125 | 2.125 | 2.125 | 2.125 | 2.133 | 2.133 | 2.133 | 2.133 | 2.130 | 2.130 | 2.130 | 2.130 |
| Eff.Wrkrs.at MW (%) | 18.76 | 18.55 | 18.68 | 20.28 | 19.77 | 19.36 | 19.37 | 21.12 | 21.83 | 20.52 | 20.03 | 21.55 |
| p-value | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.0018 | 0.001 | 0.001 |
| Eff.Wrkrs.just above (%) | 8.250 | 8.202 | 7.063 | 6.735 | 9.080 | 8.720 | 7.405 | 7.094 | 12.64 | 10.36 | 8.374 | 7.965 |
| p-value | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Eff.Wrkrs.well above (%) | 5.373 | 3.724 | 1.441 | -0.295 | 5.634 | 3.905 | 1.636 | -0.004 | 5.670 | 3.522 | 1.559 | 0.149 |
| p-value | 0.001 | 0.001 | 0.191 | 0.793 | 0.001 | 0.001 | 0.125 | 0.997 | 0.001 | 0.002 | 0.128 | 0.901 |

Note: *Sales/Hrs.* are the sales per hour rescaled by a factor between 1/50 and 1/150 relative to its $ value. *MinW* is the monthly minimum wage in the jurisdiction in which the worker is located (in $). $\mathbb{1}(> MW)$ is an indicator for whether the worker's total pay in month *m-1* is between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). $\mathbb{1}(>> MW)$ is an indicator for whether the worker's total pay in month *m-1* is above 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.at MW* is the percent effect of one standard deviation increase in MinW on workers "at minimum wage." *Eff.Wrkrs.just above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.well above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated more than 120% of minimum wage (or 140%, 160%, 180%). All the regressions include county-unemployment, worker tenure, month FE, worker FE, department FE and state-specific trends.*** p<0.01, ** p<0.05, * p<0.1.

Table D.8: Robustness: Differential Effect of Minimum Wage on Terminations by Workers' Past Exposure to Minimum Wage

| Dep.Var | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Store dist.jurisdiction (km) | 75 | 75 | 75 | 75 | 75 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 |
| Threshold | None | 120% | 140% | 160% | 180% | None | 120% | 140% | 160% | 180% | None | 120% | 140% | 160% | 180% |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| MinW | -0.212 | -0.837** | -0.781* | -0.788* | -0.816** | -0.124 | -0.753* | -0.689* | -0.703* | -0.734* | -0.049 | -0.564 | -0.495 | -0.516 | -0.547 |
| | (0.265) | (0.404) | (0.403) | (0.393) | (0.394) | (0.273) | (0.378) | (0.379) | (0.367) | (0.368) | (0.334) | (0.455) | (0.459) | (0.450) | (0.452) |
| $\mathbb{1}(> MW)$ | | -0.802*** | -0.799*** | -0.944*** | -1.007*** | | -0.851*** | -0.793*** | -0.959*** | -1.022*** | | -0.748* | -0.677* | -0.829** | -0.899** |
| | | (0.273) | (0.256) | (0.256) | (0.257) | | (0.293) | (0.274) | (0.275) | (0.276) | | (0.405) | (0.388) | (0.391) | (0.396) |
| $\mathbb{1}(>> MW)$ | | -1.311*** | -1.704*** | -1.794*** | -1.880*** | | -1.303*** | -1.742*** | -1.778*** | -1.856*** | | -1.119** | -1.526*** | -1.561*** | -1.552*** |
| | | (0.259) | (0.262) | (0.271) | (0.258) | | (0.281) | (0.291) | (0.312) | (0.308) | | (0.420) | (0.437) | (0.468) | (0.460) |
| MinW $\cdot\mathbb{1}(> MW)$ | | 0.496* | 0.493* | 0.538** | 0.537** | | 0.505* | 0.472* | 0.517** | 0.513** | | 0.317 | 0.327 | 0.359 | 0.368 |
| | | (0.262) | (0.268) | (0.267) | (0.263) | | (0.267) | (0.255) | (0.254) | (0.252) | | (0.376) | (0.348) | (0.338) | (0.329) |
| MinW $\cdot\mathbb{1}(>> MW)$ | | 0.572** | 0.463* | 0.456** | 0.611*** | | 0.526** | 0.396* | 0.411 | 0.565** | | 0.455 | 0.318 | 0.402 | 0.584* |
| | | (0.245) | (0.236) | (0.221) | (0.217) | | (0.230) | (0.226) | (0.258) | (0.254) | | (0.275) | (0.266) | (0.308) | (0.317) |
| Observations | 177,744 | 165,847 | 165,847 | 165,847 | 165,847 | 165,266 | 154,152 | 154,152 | 154,152 | 154,152 | 115,031 | 107,359 | 107,359 | 107,359 | 107,359 |
| Units | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers |
| R-squared | 0.020 | 0.021 | 0.021 | 0.021 | 0.021 | 0.020 | 0.021 | 0.021 | 0.021 | 0.021 | 0.020 | 0.021 | 0.021 | 0.021 | 0.021 |
| Mean Y | 4.769 | 4.602 | 4.602 | 4.602 | 4.602 | 4.797 | 4.626 | 4.626 | 4.626 | 4.626 | 4.761 | 4.600 | 4.600 | 4.600 | 4.600 |
| Mean MinW | 7.862 | | | | | 7.845 | | | | | 7.835 | | | | |
| Eff.MinW % | -2.888 | | | | | -1.698 | | | | | -0.680 | | | | |
| Eff.Wrkrs.at MW (%) | | -13.89 | -12.96 | -13.07 | -13.54 | | -12.41 | -11.35 | -11.59 | -12.09 | | -9.344 | -8.190 | -8.539 | -9.049 |
| p-value | | 0.045 | 0.059 | 0.052 | 0.045 | | 0.053 | 0.076 | 0.063 | 0.053 | | 0.223 | 0.288 | 0.260 | 0.234 |
| Eff.Wrkrs.just above (%) | | -6.375 | -5.470 | -4.948 | -5.684 | | -4.641 | -4.084 | -3.679 | -4.460 | | -4.651 | -3.195 | -3.114 | -3.658 |
| p-value | | 0.225 | 0.303 | 0.344 | 0.297 | | 0.374 | 0.465 | 0.504 | 0.435 | | 0.442 | 0.622 | 0.637 | 0.595 |
| Eff.Wrkrs.well above (%) | | -6.152 | -8.111 | -9.222 | -6.339 | | -5.222 | -7.436 | -8.032 | -5.142 | | -2.536 | -4.494 | -3.102 | 1.094 |
| p-value | | 0.380 | 0.293 | 0.371 | 0.578 | | 0.495 | 0.359 | 0.478 | 0.685 | | 0.795 | 0.685 | 0.831 | 0.946 |

Note: The dependent variable is the probability that a worker has been terminated in a given month. *MinW* is the monthly minimum wage in the jurisdiction in which the worker is located (in \$). $\mathbb{1}(> MW)$ is an indicator for whether the worker's total pay in month *m-1* is between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). $\mathbb{1}(>> MW)$ is an indicator for whether the worker's total pay in month *m-1* is above 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.at MW* is the percent effect of one standard deviation increase in MinW on workers "at minimum wage." *Eff.Wrkrs.just above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.well above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated more than 120% of minimum wage (or 140%, 160%, 180%). col.1, col.6, col.11 present average effects, while col.2-col.4 (col.7-col.10; col.12-col.15) present calculation for the 120-180% thresholds. col.1-5 (col.6-10) [col.11-15] consider stores 75km (37.5km) [18.75km] away from jurisdictions. *p-value* indicates the statistical significance of the test computed with the delta method when the sum of estimated coefficients is involved. All the regressions include county-unemployment, worker tenure, month FE, store FE, department FE and state-specific trends. *** p<0.01, ** p<0.05, * p<0.1.

Table D.9: Robustness: Minimum Wage Involves No Selective Termination with Worker Fixed Effects

| Dep.Var | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. | Term. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Store dist.jurisdiction (km) | 75 | 75 | 75 | 75 | 75 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 18.75 | 18.75 | 18.75 | 18.75 | 18.75 |
| Threshold | None | 120% | 140% | 160% | 180% | None | 120% | 140% | 160% | 180% | None | 120% | 140% | 160% | 180% |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) | (14) | (15) |
| MinW | -0.079 | -0.004 | -0.068 | -0.125 | -0.172 | -0.036 | 0.022 | -0.038 | -0.112 | -0.164 | 0.152 | 0.815* | 0.777 | 0.695 | 0.633 |
| | (0.195) | (0.387) | (0.382) | (0.391) | (0.388) | (0.210) | (0.422) | (0.413) | (0.429) | (0.425) | (0.243) | (0.473) | (0.479) | (0.484) | (0.477) |
| $\mathbb{1}(> MW)$ | | -0.060 | 0.365 | 0.444 | 0.485 | | -0.180 | 0.288 | 0.349 | 0.391 | | 0.347 | 0.850 | 0.922 | 0.965* |
| | | (0.397) | (0.390) | (0.401) | (0.400) | | (0.428) | (0.428) | (0.437) | (0.436) | | (0.561) | (0.544) | (0.550) | (0.551) |
| $\mathbb{1}(>> MW)$ | | 1.138** | 1.005** | 1.075** | 1.009** | | 1.051** | 0.832* | 0.965** | 0.903* | | 1.694*** | 1.506** | 1.667*** | 1.694*** |
| | | (0.423) | (0.457) | (0.416) | (0.438) | | (0.462) | (0.485) | (0.449) | (0.467) | | (0.580) | (0.616) | (0.591) | (0.586) |
| MinW $\cdot \mathbb{1}(> MW)$ | | 0.756** | 0.476 | 0.378 | 0.310 | | 0.825** | 0.512 | 0.411 | 0.340 | | 0.184 | -0.091 | -0.206 | -0.284 |
| | | (0.294) | (0.289) | (0.292) | (0.296) | | (0.312) | (0.320) | (0.321) | (0.326) | | (0.397) | (0.363) | (0.353) | (0.352) |
| MinW $\cdot \mathbb{1}(>> MW)$ | | -0.223 | -0.400 | -0.439 | -0.332 | | -0.254 | -0.467 | -0.475 | -0.365 | | -0.804** | -1.125*** | -1.070* | -0.819 |
| | | (0.333) | (0.377) | (0.474) | (0.479) | | (0.389) | (0.411) | (0.560) | (0.585) | | (0.358) | (0.401) | (0.536) | (0.557) |
| Observations | 177,743 | 165,847 | 165,847 | 165,847 | 165,847 | 165,265 | 154,152 | 154,152 | 154,152 | 154,152 | 115,030 | 107,359 | 107,359 | 107,359 | 107,359 |
| Units | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers | Workers |
| R-squared | 0.189 | 0.187 | 0.187 | 0.187 | 0.187 | 0.190 | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.189 | 0.188 | 0.188 | 0.188 |
| Mean Y | 4.768 | 4.602 | 4.602 | 4.602 | 4.602 | 4.796 | 4.626 | 4.626 | 4.626 | 4.626 | 4.760 | 4.600 | 4.600 | 4.600 | 4.600 |
| Mean MinW | 7.862 | | | | | 7.845 | | | | | 7.835 | | | | |
| Eff.MinW % | -1.081 | | | | | -0.490 | | | | | 2.118 | | | | |
| Eff.Wrkrs.at MW (%) | | -0.0708 | -1.129 | -2.080 | -2.862 | | 0.370 | -0.624 | -1.840 | -2.696 | | 13.48 | 12.86 | 11.50 | 10.48 |
| p-value | | 0.991 | 0.859 | 0.750 | 0.659 | | 0.958 | 0.927 | 0.796 | 0.702 | | 0.0937 | 0.114 | 0.160 | 0.193 |
| Eff.Wrkrs.just above (%) | | 14.04 | 7.754 | 5.006 | 2.804 | | 15.82 | 8.920 | 5.908 | 3.574 | | 18.78 | 13.05 | 9.733 | 7.150 |
| p-value | | 0.00231 | 0.0597 | 0.242 | 0.501 | | 0.000897 | 0.0379 | 0.190 | 0.408 | | 0.00180 | 0.0133 | 0.0731 | 0.163 |
| Eff.Wrkrs.well above (%) | | -5.271 | -11.94 | -15.70 | -15.58 | | -5.319 | -12.84 | -16.12 | -16.13 | | 0.239 | -8.845 | -10.27 | -5.518 |
| p-value | | 0.305 | 0.0785 | 0.0935 | 0.170 | | 0.335 | 0.0604 | 0.116 | 0.215 | | 0.975 | 0.334 | 0.421 | 0.735 |

Note: The dependent variable is the probability that a worker has been terminated in a given month. *MinW* is the monthly minimum wage in the jurisdiction in which the worker is located (in \$). $\mathbb{1}(> MW)$ is an indicator for whether the worker's total pay in month *m-1* is between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). $\mathbb{1}(>> MW)$ is an indicator for whether the worker's total pay in month *m-1* is above 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.at MW* is the percent effect of one standard deviation increase in MinW on workers "at minimum wage." *Eff.Wrkrs.just above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated between the minimum wage and 120% of minimum wage (or 140%, 160%, 180%). *Eff.Wrkrs.well above MW (%)* is the percent effect of one standard deviation increase in MinW on workers compensated more than 120% of minimum wage (or 140%, 160%, 180%). col.1, col.6, col.11 present average effects, while col.2-col.4 (col.7-col.10; col.12-col.15) present calculation for the 120-180% thresholds. col.1-5 (col.6-10) [col.11-15] consider stores 75km (37.5km) [18.75km] away from jurisdictions. *p-value* indicates the statistical significance of the test computed with the delta method when the sum of estimated coefficients is involved. All the regressions include county-unemployment, worker tenure, month FE, worker FE, department FE and state-specific trends. *** p<0.01, ** p<0.05, * p<0.1.