Minimum Wage and Worker Productivity: Evidence from a large US retailer*

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Abstract

We study the effect of increasing the statutory minimum wage on 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 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 three distinct channels through which this productivity gain could arise: a demand increase, an incentive effect due to the change in compensation, and selective termination by the firm. We find evidence only for the second, that is, the compensation scheme channel. Intriguingly, this channel suggests an efficiency wage effect because a lump sum increase in base pay has incentive effects.

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1 Introduction

This paper studies the effect of increasing the minimum wage on 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 individual productivity of salespeople from a large US retailer.

Our firm operates across all 50 US States and employs roughly 8% of department store employees, or roughly 2% of employment in the entire US retail sector. We restrict the sample to salespeople whose hourly pay equals a fixed base plus a commission on sales per hour ("base + commission").

To estimate the productivity 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.'s (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, more than half of which have experienced at least one increase in the minimum wage. We find that a 65 cents increase in the minimum wage (one standard deviation) increases individual productivity (sales per hour) by 2% after controlling for worker fixed effects (Section **??**).

A number of possible 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 increases. Second, a compensation channel: increasing the statutory minimum wage should increase a worker's compensation, making the worker more attached to her current job and thus more willing to exert effort. Third, selection: as workers become more expensive, the firm might choose to terminate the least-productive workers, thus increasing average productivity.

To help discriminate between these channels, in Section **??** we present a simple model of a monopolistic firm setting a base+commission compensation scheme for workers with

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

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 then 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. Finally, if selective termination is responsible for the average productivity increase then the effect should disappear after conditioning on a worker's productivity level.

When we take these channels to the data (Section **??**) 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 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. And, finally, we find scant evidence for the selection channel: first, employment does not decrease at the store level, nor are the least-productive workers terminated more, after an increase in the minimum wage; second, the average productivity gains are even sharper after restricting the sample to employees who are never terminated during our sample period; third, the estimates of average productivity gains do not increase if we remove worker-fixed effects.

In Section **??** we examine, and ultimately rule out, two possible confounders of the estimated productivity effects. First,the finding that only low-productivity workers experience any gains could reflect a differential adjustment of the compensation scheme by productivity type. We find, however, that this pattern is not due to a discriminatory adjustment in the compensation scheme. The second confounder is worker migration from "control" to "treated" jurisdictions, which might confound our estimates if better workers are migrating. By analyzing the distance between each worker's home 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."

1.1 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 diff-in-diff strategy, with some nearby jurisdictions experiencing no minimum wage increase. Further, less significant differences are the following. The incentive scheme is different: Ku's (2017) pickers are paid piece-rate conditional on exceeding minimum wage, so that only workers with salaries close to the minimum wage are affected by the change in minimum wage; our workers instead are paid base plus commissions, so that when the base is increased (as it is in our data in response to a minimum wage increase), all workers *including the very productive ones* benefit. Finally, our richer data comprising more than 40 minimum-wage events allows for a richer set of covariates, e.g., unemployment level and home values. 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. 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 fixed portion of compensation.

- **Unemployment and worker productivity.** Lazear et al. (2016) study similar 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 un 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 **??** are fairly consistent with their finding.

- **Minimum wage and firm-level variables.** While none of the papers reviewed below studied individual worker productivity, some study firm-level productivity. 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.

2 Model

Time is discrete and infinite. There is a monopolistic firm and many workers (sales agents). A worker has a type $\sigma > 0$, where σ represents the hourly revenues generated by that worker if the worker exerts effort. We assume that σ is uniformly distributed on $[0, 1]$.

The index σ captures a variety of factors affecting 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 σ to $\delta\sigma$, with $\delta > 1$).

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

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

Here e represents effort exerted during a working hour (intensive margin), so this effort is not directly contractible or observable. It costs a worker $c \cdot e$ to exert effort e.

In each period, a worker of type σ is compensated with a base rate B plus a commission $R\sigma$ in case the agent was productive, with $R \in [0, 1]$. Note that total compensation is conditional on sales but not on worker type.

M represents the minimum wage. As in this model the worse-paid workers are paid B, it must be $B \geq M$. In what follows we maintain the assumption that the minimum wage is always binding, that is, $B \equiv M$.

An agent is terminated in period $t+1$ unless the agent was productive in period t, and even conditional on being productive he is only retained with probability $K \in [0, 1]$. The incentive parameters B, R, K are committed to by principal.[2]

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

$$V(\sigma) = \max_e [B + R\sigma \cdot \Pr(\sigma) - c \cdot e] + \beta [K \Pr(\sigma) V(\sigma) + (1 - K \Pr(\sigma)) \Omega],$$

where β is the economy-wide discount factor and Ω represents the value of the outside option if terminated.

Let $\Omega = \Omega(M, u)$ be a function of the minimum wage M and of unemployment, denoted by u. We will assume that $\Omega_2 \leq 0 \leq \Omega_1 \leq 1$, meaning that the outside option is worse with higher unemployment and better with a higher minimum wage. The assumption $\Omega_1 \leq 1$ ensures that the outside wage does not grow faster than the inside wage with an

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

increase in the minimum wage. We further assume that $\Omega_{12} \leq 0$, meaning that the higher the unemployment level, the lower the benefit of a higher minimum wage if the worker is fired. For example, we might specify that:

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

where $W(M)$ is an outside wage. It seems resonable that $\Pr(\text{finding another job}|u)$ is decreasing in u and $W(M)$ is increasing in M. Then indeed we have $\Omega_2 < 0 < \Omega_1$ and $\Omega_{12} < 0$.[3]

The firm chooses the compensation scheme to solve:

$$\max_{B,R,K} \sum_{t=0}^{\infty} \beta_0^{t1} \left[-B + \sigma(1-R) \Pr(\sigma|B, R, K)\right] d\sigma,$$

where $\Pr(\sigma|B, R, K) = \left(\frac{1}{2}\right) e^*(\sigma|B, R, K)$. This formulation of the firm's objective function fits exactly the case where σ represents the shift. In the case where σ represents worker skill, this formulation implies the assumption that a terminated worker of skill σ is replaced by a worker of the same skill; we accept this simplifying assumption as the price for tractability.

If some worker types are unproductive, the firm may well decide to fire them. The fired workers would likely be the low-σ type. We stop short of introducing worker retention explicitly in this model, but it is clear that an increase in the minimum wage may well tempt the firm to terminate some of the least productive workers. Next, we introduce a technical assumption that ensures that all worker types prefer employment to separation. This is a no-slavery assumption.

Maintained Assumption: $B > (1-\beta)\Omega$.

We start with a simple lemma which simplifies the firm's incentive-setting problem. All proofs are in the appendix.

Lemma 1. *Fix any pair of base + commission (B, R, K). Then it is optimal for the firm to set $K = 1$, that is, to re-hire the worker whenever she was productive.*

[3]Note that allowing Ω to depend on M and u is not necessary: all the results hold if the outside option is independent of the minimum wage and of the unemployment rate.

This result is intuitive: by choosing K as large as possible, the firm mazimizes the incentive value of continued employment. Next we characterize worker behavior for a given compensation scheme.

Proposition 2. ***(worker behavior for given compensation scheme)****. Fix any base + commission compensation scheme* $(B, R, 1)$*. Then all agents with type* σ *smaller than* $\overline{\sigma} = \frac{2c-\beta B+\beta(1-\beta)\Omega}{R}$ *exert zero effort and produce zero, all others exert maximum effort and produce* $\sigma/2$ *in expectation.*

Proposition **??** fully characterizes worker productivity. It makes sense that higher types are more willing to work because output is multiplicative function of σ and effort. The expression for $\overline{\sigma}$ has intuitive properties: workers are more willing to work if their commission rate R is higher, and if they receive a higher base B. The second effect is an efficiency-wage effect which is only present if $\beta > 0$.

We first explore what happens after a positive demand shock.

Proposition 3. ***(effect of demand increase, keeping the minimum wage constant)*** *Suppose a positive demand shock increases every worker's type* σ *to* $\delta\sigma$*, with* $\delta > 1$*. Then it is optimal for the firm to reduce the commission rate* R*. Regardless of whether* R *is optimally reduced or kept unchanged, the following results hold:*

1. *average employee productivity increases*
2. *consider the workers who before the demand increase are at the upper tail of the productivity distribution and put in full effort: after an increase in demand these workers become more productive.*

This proposition illustrates the complex effects of a demand shock on optimal compensation policy and then on worker behavior. After a positive demand shock it is optimal for the firm to reduce the commission rate R. The direct effect of reducing R is to depress worker effort. However, part **??** shows that in the optimal contract this direct effect is more than counteracted by the increase in demand. The productivity gains following a demand increase can be gleaned by comparing panels (a) and (b) in Figure **??**. Notice

particularly that, as stated in part **??**, 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 4. ***(effect of increasing the minimum wage, keeping demand constant)*** *Suppose the minimum wage M increases. Then it is optimal for the firm to reduce the commission rate R. Regardless of whether R is optimally reduced or kept unchanged, the following results hold:*

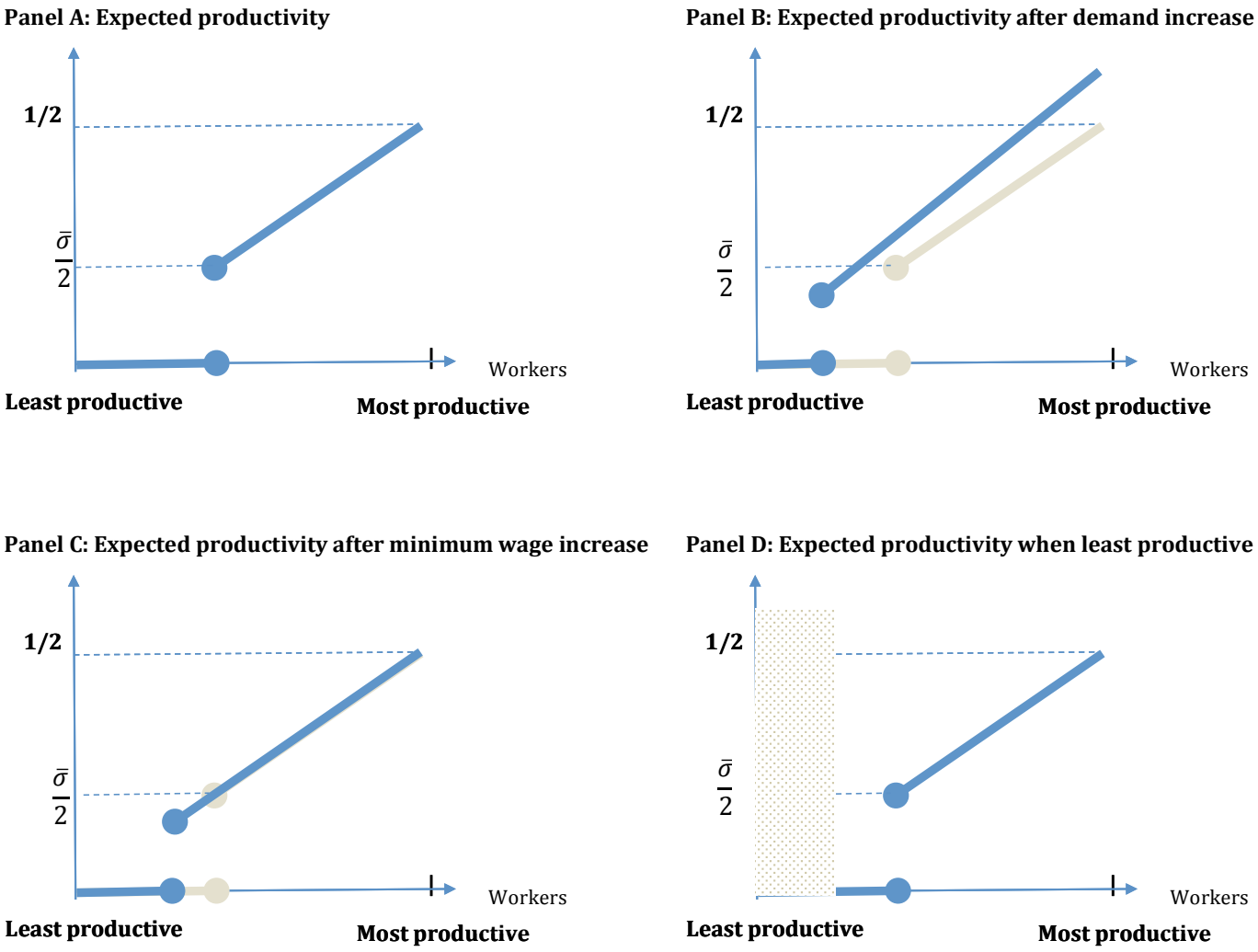
1. *average employee productivity increases*
2. *the effect on average productivity is sharper when unemployment is higher*
3. *consider the workers who before the increase in the minimum wage, are at the upper tail of the productivity distribution and put in full effort: these worker's productivity does not change after an increase in the minimum wage.*

This proposition illustrates the complex effects of increasing the minimum wage on optimal compensation policy and then on worker behavior. As M increases, forcing an increase in the base rate, it is optimal for the firm to reduce the commission rate R. The reason this is optimal is that the firm replaces costlier static incentives (the rate R) with cheaper dynamic incentives (efficiency-wage effect). The direct effect of reducing R is to depress worker effort. However, parts **??** shows that in the optimal contract this direct effect is more than counteracted by the increase in dynamic incentives created by the increase in B. Put differently, the proposition shows the firm optimally chooses to decrease R not very much relative to the change in B. In other words, in the optimal contract the efficiency-wage incentive created to an exogenous increase in the minimum wage dominates the static disincentive effect due to the endogenous decrease in R. Part **??** is intuitive: when unemployment is higher the outside option Ω is relatively less attractive (recall that $\Omega_2 < 0$) than the inside option, and this gap grows as the minimum wage rises (recall that $\Omega_{12} < 0$).

The productivity gains following a minimum wage increase can be gleaned by comparing panels (a) and (c) in Figure **??**. As stated in part **??** 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 increase in minimum wage. This contrast will provide an 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 **??** 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 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 σ (empirically, this is achieved by introducing fixed effects in a regression), then there is no productivity gain for that type during their employment period.

Figure 1: Theory



3 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.

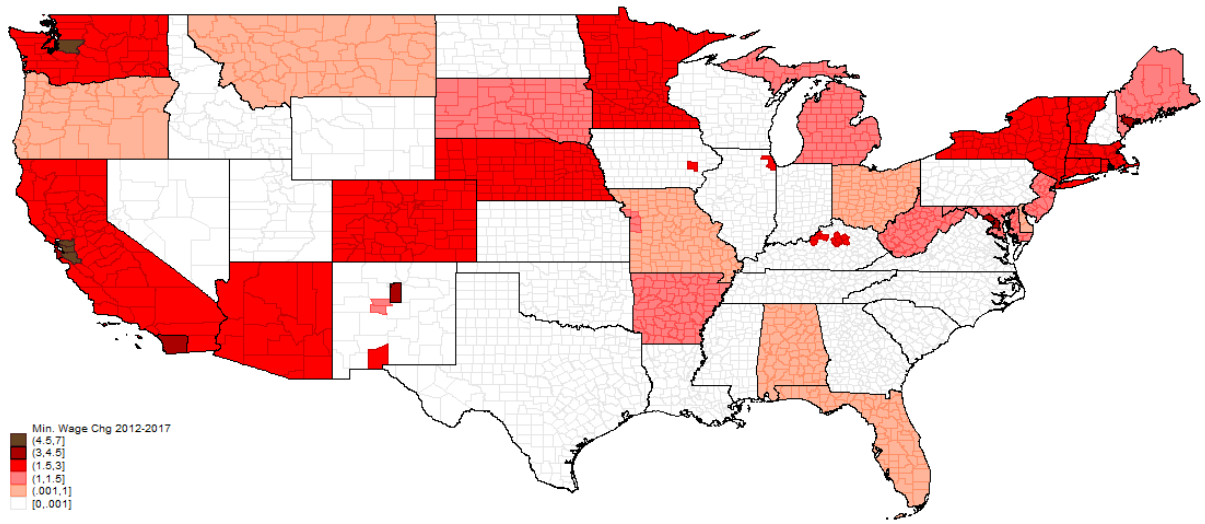
The sample consists of more than 40,000 hourly salespeople paid on base + commission, working in more than 500 stores across the United States. For each salesperson in our sample we observe monthly worker-level productivity (sales per hour) and earnings (hourly base and commission) between 2012m2 and 2015m6.

Every worker's hourly wages must exceed the jurisdictional minimum wage requirements averaged over the pay cycle (2 weeks). The average base pay level ($ 6.1 in our data, see Table **??**) is below the minimum wage: this makes sense for the firm, because the base is paid regardless of whether the wage exceeds the minimum wage. If a worker's wages (base + commissions) fall below the minimum wage in a pay cycle, the company will top them up.

Local jurisdictions differ in the minimum wage level. Our data also contains time-invariant information on the geographical location of stores (latitude and longitude), which are located in a great number of US states (the exact number of states cannot be revealed for confidentiality reasons). The data are matched with monthly county-level unemployment rates obtained form the BLS website, and with house-listing pricing data obtained from the Zillow website.

In Figure **??** we plot all variations in minimum wage between 2012-2017, including local jurisdictions. The data come from the public dataset maintained by the Washington Center for Equitable Growth. We extended this database to include the 2017 changes. In our data, variations in minimum wage take place at state, county and city levels. Over our sample period there are 37 variations at the city or county levels alone. The mean minimum wage during this sample period is 7.86 (see Table **??**) and the average increase after a minimum wage hike is $1.45. Most minimum wage changes occur in January, with a minority occurring in June, July, or other months. The exact timing of each minimum

Figure 2: Variations in Minimum Wage



Note: Store locations are withheld for confidentiality reasons.

wage change is reported in Table **??**, and Table **??** shows the states that had no change in their minimum wage during our sample period.

Our identification strategy will require us to restrict to stores located in bordering jurisdictions, some of which have experienced a minimum wage increase. The sample selection procedure is described in the next section. Tables **??** and **??** report descriptive statistics within this restricted sample Average hourly productivity (sales per hour) is approximately $200, see Table **??**. The average salesperson's total compensation equals $1,337 per month, which makes for an average of $12.2/h. Total compensation includes base ($ 6.1/h) + commission pay ($5.65/h), and in addition small amounts ($0.45/h) in benefits and occasional retention bonuses. We define the compensation scheme as base and commission hourly rates. The base rate is computed by dividing "total monthly regular earnings" by "hours worked." The commission rate is computed by dividing "commissions and incentives" by ("sales per hour" x "hours worked").[4] The table reveals considerable cross-worker variation in base and commission rates. The variation in these rates reflects cross-jurisdictional variation in minimum wage and other labor market conditions, and

[4]The actual incentive schemes encoded in the "pay from commission" is an aggregate of a number of corporate incentive programs tied to sales.

also within-store variation across departments. This variation will be controlled for by state- and department-fixed effects.

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 by 5%). Monthly unemployment (7%) is obtained from BLS data for the county where each store is located. Home value/sq. ft. ($164) is the monthly median residential housing list price per square foot at the zip code level, collected by Zillow.

Table 1: Descriptive statistics

Variable	mean	sd	p10	p50	p90
	(1)	(2)	(3)	(4)	(5)
Productivity: Sales/Hrs. (in 100$)	2.061	1.540	0.669	1.875	3.562
Base Rate: Reg.Pay/Hrs. (in $)	6.108	3.490	4.500	6	7
Comm.Rate: Var.Pay/Sales (in %)	3.295	3.013	1.069	2.276	6.926
Var.Pay/Hrs.(in$)	5.653	4.693	1.720	4.520	10.67
Tot.Pay.Rate: Tot.Pay/T.Hrs. (in $)	12.18	4.343	8.676	11.00	16.93
MinW (in $)	7.865	0.648	7.250	8	9
Tot.Pay (in $)	1,337	797.1	496.8	1,213	2,267
Termination (in %)	4.772	21.32	0	0	0
Tenure (in months)	46.82	66.71	3	21	124
Unemployment Rate (in %)	7.240	2.032	4.800	7.100	10
Home value/sq. ft. (in $)	163.5	99.11	77.74	131.2	293.9

Note: *Productivity: Sales/Hrs. (in 100$)* are the sales per hour worked (in 100$); *Base: Reg.Pay/Hrs.* is the monthly regular earning divided by hours worked $ per hour worked); *Comm.Rate: Var.Pay/Sales* is the monthly commission rate (in %) and it is obtained by dividing earning from commissions and incentives and sales; *Var.Pay/Hrs.* is the monthly hourly commission pay (in $ per hour); *Tot.Pay/T.Hrs.* is the monthly hourly rate (in $) from total compensations divided by total hours. *MinW (in $)* is the monthly minimum wage (in $ per hour) in the jurisdiction of the store of the employee. *Tot.Pay* is the monthly total compensation. *Termination (in %)* is the percent probability that an employee is terminated in a given month; *Tenure* is the employee's tenure based on worker's hiring date; *Unemployment Rate* is the monthly rate of unemployment in the store's county, from BLS data; *Home value/sq. ft. (in $)* is the monthly median residential housing list price per square foot at the zip code level, collected by Zillow.

4 Identification strategy: county-level border discontinuity design

We estimate the causal effect of a $1 increase in the minimum wage using Dube et al.'s (2010) approach. This approach compares outcomes for workers in stores where the minimum wage increased by a certain amount (treated) with workers in stores where it did not increase at all (control), before and after the changes in the minimum wage. Estimates of the overall impact of minimum wage are based on multiple variations in the minimum wage over time. In this approach all stores serve as controls before the change in the minimum wage and the treatment is a deviation from the previous minimum wage in the jurisdiction. In our sample the average change in minimum wage is $1.3.

Following the approach developed by Card and Krueger (1994, 2000), Dube et al.(2010, 2016), Allegretto et al.'s (2011), and Addison et al. (2012, 2014), we control for possible non-parallel pre-trends between treated and control jurisdictions by including state-specific trends. Following Dube et al (2015), we further restrict the sample to jurisdictions that share a border and whose centroid are within 75km of each other (see Figure **??**).[5] Note that some of the minimum wage variation in Figure **??** comes from within-state jurisdictions, such as counties or cities. Figure **??** shows the example of California. Accounting for these substate variations increases the number of jurisdictions exposed to border discontinuities, thereby increasing our sample size by approximately 15%. Our final sample contains more than 300 stores located in counties sharing a border and half of them experience variation in minimum wage.

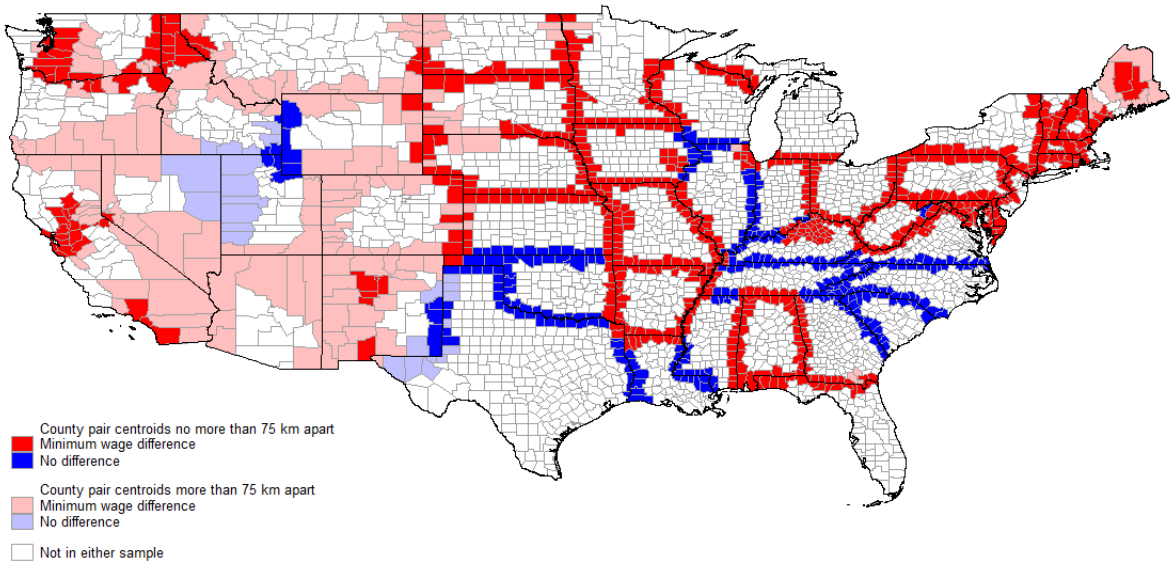
We follow Allegretto et al. (2013), Card and Krueger (2000) and Dube et al. (2010, 2016) by estimating the following model:

$$Y_{wm} = \alpha + \beta MinW_{sm} + \zeta Tenure_{wm} + \gamma U_{sm} + \phi State_s \cdot Month_m + \delta_w + \eta_m + \varepsilon_{wm}, \quad (1)$$

where: Y are monthly worker-level outcomes. These are the compensation scheme: base pay, commission rate; productivity: sales per hour; total pay per hour and total

[5] Dube et al. (2015) show that this procedure ensures that stores located in bordering jurisdictions face similar economic conditions except for minimum wage policies. We later refine this approach by considering *stores* whose distance is less than 75km from the border.

Figure 3: Variations in minimum wage in bordering counties



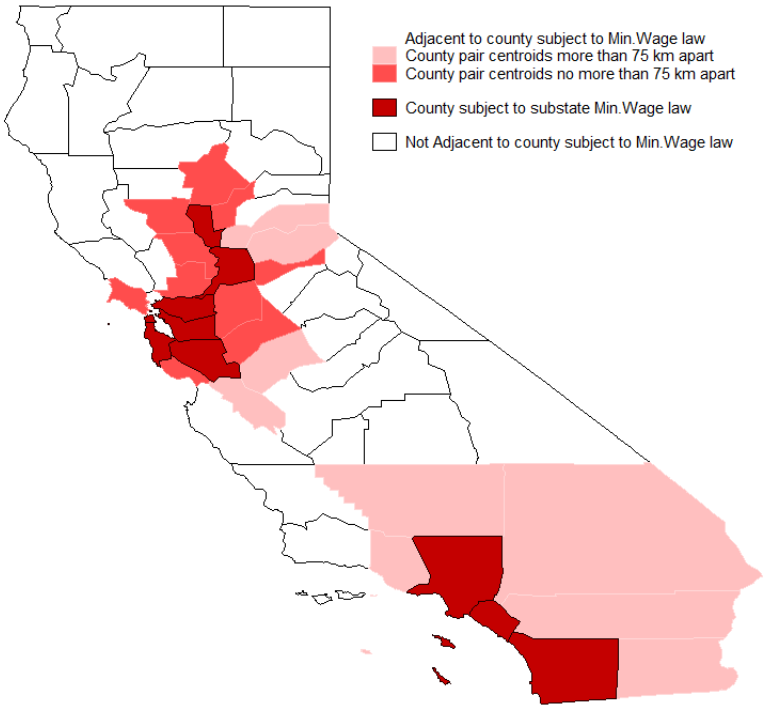
Note: Store locations are withheld for confidentiality reasons.

pay. In the model,w is a worker and m is a month. $MinW_{sm}$ is the minimum wage in the jurisdiction; *Tenure* is the employee's tenure; U is the monthly unemployment rate at county level. $State_s \cdot Month_m$ are state-specific trends, δ_w and η_m are worker- and month-fixed effects. The model also includes department fixed effects. Since most of the variations in the minimum wage are at the state level we cluster standard errors at the state level.

5 Results: Effects of minimum wage on productivity

The theory considers three channels through which average productivity could respond to the minimum wage. First, a "compensation scheme" channel. The theory assumes that an increase in the minimum wage forces the firm to increase base pay, and predicts that this increase will cause average worker productivity to increase. Also, the theory predicts that the firm would react by reducing the commission rate, but this reduction is modest in the sense that it is not strong enough to overturn the positive effect on

Figure 4: Variations in minimum wage in California between 2012-2017



Note: Store locations are withheld for confidentiality reasons.

productivity. The second channel is an increase in demand caused by an increase in the minimum wage. The third is a selection channel whereby unproductive workers are fired and/or more-productive workers are hired.

Table **??** presents evidence that is consistent with the compensation-scheme channel: a \$0.65 (one standard deviation) increase in the minimum wage causes a statistically significant 5% increase in base pay (col. 1), consistent with the theory's assumption. Consistent with the theory's prediction, the effect on the commission rate is negative, though the effect it is not statistically significant (col. 2). Productivity (within-worker sales per hour) increases by 2% (col. 3), again as predicted by the theory.

For descriptive interest, columns 4 and 5 report the effect of the minimum wage on hourly and monthly compensation, which includes benefits. A \$0.65 increase in the minimum wage increases hourly pay by 3.2% and total pay by 2.27%, respectively.

Table 2: Minimum wage affects compensation scheme, productivity, and compensation

Var.Desc.	Compensation scheme		Productivity	Compensation	
	Base Rate	Comm. Rate			
Dep.Var.	Reg.Pay/Hrs.	Var.Pay/Sales	Sales/Hrs.	Tot.Pay/T.Hrs.	Tot.Pay
	(1)	(2)	(3)	(4)	(5)
MinW	0.470**	-0.144	0.0636**	0.602***	46.84***
	(0.227)	(0.0921)	(0.0258)	(0.109)	(10.67)
Observations	179,046	170,337	179,046	179,046	179,046
R-squared	0.103	0.518	0.415	0.610	0.723
State FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
VBU FE	YES	YES	YES	YES	YES
Worker FE	YES	YES	YES	YES	YES
StateXYear FE	YES	YES	YES	YES	YES
Mean Y	6.108	3.301	2.061	12.18	1337
Eff.MinW %	4.986	-2.818	2	3.203	2.271

Note: *Base Rate: Reg.Pay/Hrs.* is the monthly regular earning divided by hours worked $ per hour worked); *Comm.Rate: Var.Pay/Sales* is the monthly commission rate (in %) and it is obtained by dividing earning from commissions and incentives and sales; *Sales/Hrs.* are the monthly sales divided by hours worked (in $ per hour); *Tot.Pay/T.Hrs.* is the monthly hourly rate (in $) from total compensations divided by total hours. *Tot.Pay* is the monthly total pay (in $) from total take home pay. *MinW* is the monthly minimum wage (in $) in the jurisdiction of the store of the employee. *Eff.MinW%* is the percent effect of one standard deviation increase in MinW on the outcomes. All the regressions include county-unemployment and employee tenure. *Time FE* are month FEs. *VBU FE* are FE for employees departments. *State·Year FE* are state specific trends. SEs clustered at the state level.*** p<0.01, ** p<0.05, * p<0.1.

While consistent with the compensation-scheme channel, this evidence does not rule out the demand or selection channels. The relative contribution of these channels to the productivity increase is evaluated next.

6 Channels

6.1 Demand channel

The productivity gains might result from a demand channel, if increasing the minimum wage increased 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.[6] In this section we explore this question within our sample.

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,[7] are predicted by minimum wage levels, controlling for county- and month-fixed effects and including state specific trends (like in our main specification). We find they aren't – see Table **??** col. 2. Similarly, we find that a jurisdiction's minimum wage level does not predict unemployment – see Table **??** col. 1. This lack of correlation may well be a convenient feature of our neighboring-jurisdiction research design which, to the extent that retail shoppers cross over to purchase in neighboring jurisdictions, is expected to "difference out" any jurisdiction-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-jurisdictions 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

[6] Aaronson et al. (2012, Table 3) shows 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 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.

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

Table 3: Minimum wage has no effect on bordering-counties demand proxies and worker migration

Dep.Var	Unemployment	House prices	Distance from store
	(1)	(2)	(3)
MinW	0.138	-6.667	0.857
	(0.114)	(5.427)	(0.544)
Observations	7,338	6,179	7,338
R-squared	0.948	0.985	0.530
Eff.MinW %	1.303	-3.283	5.214
Mean Y	6.907	132.5	10.72
Mean MinW	7.703	7.675	7.703
County FE	YES	YES	YES
Time FE	YES	YES	YES
State·Year FE	YES	YES	YES

Note: *Unemployment* is the monthly unemployment rate at the county level; *House prices* is the ZILLOW monthly median price per square feet for listed houses in the zip-code of the stores aggregated (mean) at the county-month level. This data is available for the sub-set of bordering counties covered by ZILLOW. *Distance from store* is the average worker distance from home to work aggregated at the county level. *State·Year FE* are state specific trends. SEs clustered at the state level.*** p<0.01, ** p<0.05, * p<0.1.

assumption is embedded in our theory: see Figure **??**, panel B). To explore whether this is the case after a minimum wage increase in month m we need to operationalize a worker's productivity in month m-1. We proxy for it by creating three categories, corresponding to productivity levels in m-1: workers who at m-1 are paid exactly the minimum wage (the least productive types); intermediate types who are paid more than the minimum wage but less than 120% of the minimum wage (we also explore specifications with 140%, 160%, 180% thresholds); and the rest, i.e., the most productive types. Table **??** reports the month-m average productivity of these three categories.[8] We use these categories to stratify the productivity gains following a minimum wage increase. Despite its roughness, this proxy turns out to consistently correlate (negatively) with productivity gains.

To keep as close as possible to our main specification (**??**) and to the spirit of Allegretto

[8]Low-productivity type produce 92$/hr; medium-productivity types between 142 and 182$/hr; and high-productivity types between 237 and 276$/hr, depending on the definition of most-productive types (120% to 180%). The 120% level follows Aaronson (2012). Numerosity is not a problem: even at the 180% threshold the most productive types represent 20% of the observations.

et al. (2013), Card and Krueger (2000) and Dube et al. (2010, 2016), we estimate the following model:

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

where: Y is sales per hour; $\mathbb{1}(W_{wm-1} > MinW_{m-1})$ and $\mathbb{1}(W_{wm-1} >> MinW_{m-1})$ are lagged indicators for workers paid between the minimum wage and 120% (140%, 160%, 180%) of the minimum wage, and more than 120% (140%, 160%, 180%) of the minimum wage, respectively, in any given month previous to month m. Workers paid at the minimum wage are the omitted group. In this specification, $MinW_{sm}$ is centered around the sample mean; the other variables are as in equation (**??**). The effect of a \$1 increase in the minimum wage for the "most productive" group, for example, is given by $\beta_1 + \beta_3$.

Table **??** shows the estimated effects of a \$1 increase in minimum wage on the productivity of the three productivity types, as a function of different thresholds (120% to 180%). The effect on low-productivity type is given by the estimate for β_1, which is consistently between 12.5% and 14.5% of their average productivity, and statistically significant. The effect on medium-productivity types ($\beta_1 + \beta_2$) is between 6.5% and 8.6% of their average productivity, and statistically significant.[9] 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.[10]

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. This lack of effect touches a non-negligible part of the sample: at the 180% threshold, the "most productive" comprise a full 20% of the sample. Mean reversion is an unlikely explanation for this phenomenon because the estimated coefficient

[9]Statistical significance is based on the sum of the estimated coefficients, standard errors computed with the delta method.

[10]This finding is consistent with Ku's (2017) results. A possible spurious cause of this heterogeneity might be that compensation is adjusted differentially across productivity types. In Section **??** we explore, and ultimately dismiss, this concern.

for $\mathbb{1}(W_{wm-1} >> MinW_{m-1})$, β_5, 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.

Table 4: Minimum wage has no effect on the most productive salespersons

Dep.Var	Sales/ Hrs.	Sales/ Hrs.	Sales/ Hrs.	Sales/ Hrs.
Most-productive definition	>120%	>140%	>160%	>180%
	(1)	(2)	(3)	(4)
MinW	0.125***	0.115***	0.120***	0.134***
	(0.039)	(0.033)	(0.032)	(0.032)
MinW $\cdot \mathbb{1}(> MW)$	-0.002	0.017	0.006	-0.007
	(0.025)	(0.025)	(0.025)	(0.024)
MinW $\cdot \mathbb{1}(>> MW)$	0.001	-0.021	-0.080**	-0.143***
	(0.038)	(0.041)	(0.037)	(0.041)
$\mathbb{1}(> MW)$	0.217***	0.264***	0.316***	0.350***
	(0.033)	(0.036)	(0.037)	(0.037)
$\mathbb{1}(>> MW)$	0.690***	0.931***	1.121***	1.243***
	(0.050)	(0.054)	(0.062)	(0.067)
Observations	167,060	167,060	167,060	167,060
R-squared	0.467	0.483	0.492	0.491
State FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
VBU FE	YES	YES	YES	YES
Store FE	NO	NO	NO	NO
Worker FE	YES	YES	YES	YES
StateXYear FE	YES	YES	YES	YES
Mean Y	2.061	2.061	2.061	2.061
Eff.Wrkrs.at MW (%)	13.56	12.50	12.94	14.49
p-value	0.003	0.001	0.0005	0.0001
Eff.Wrkrs.just above MW (%)	8.586	7.951	6.851	6.535
p-value	0.001	0.001	0.001	0.001
Eff.Wrkrs.well above MW (%)	5.335	3.646	1.433	-0.332
p-value	0.001	0.001	0.205	0.774

Note: *Sales/Hrs.* represents workers performance measured by monthly sales over total monthly hours. *MinW* is the monthly minimum wage (in $) in the jurisdiction of the store of the employee. *Eff.Wrkrs.at MW* is the percent effect of one dollar increase in MinW on the outcomes on workers earning minimum wage. *Eff.Wrkrs.just above MW (%)* is the percent effect of one dollar increase in MinW on productivity for workers that in month *m-1* compensated between 100 and 120% of minimum wage (20% threshold). *Eff.Wrkrs.well above MW (%)* is the percent effect of one dollar increase in MinW on productivity for workers compensated more than 120% of minimum wage. Col.1-Col4. present calculation for the 20-80% thresholds. *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 and employee tenure. *Time FE* are month FEs. *VBU FE* are FE for employees departments. *State·Year FE* are state specific trends. SEs clustered at the state level. *** p<0.01, ** p<0.05, * p<0.1.

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 each worker might well become more productive. However, in Section **??** 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 checked first 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. Second, we 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 12% and 14% 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. We now explore this channel.

6.2 Compensation channel

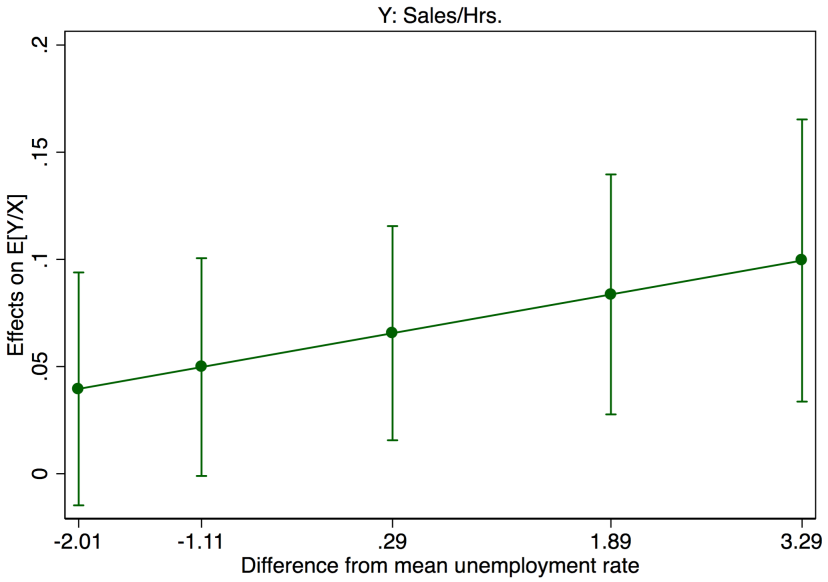
The productivity gains might result from a compensation channel, that is, a channel whereby workers work harder due to a chance in the compensation scheme. Proposition **??** provides two comparative static results that are uniquely associated to the compensation channel. First, that the effect of the minimum wage on average productivity should be sharper during high-unemployment spells. Second, that the productivity effect is disproportionately concentrated at the lower tail of the productivity distribution. We now examine these two predictions in turn.

Are average productivity gains sharper during high-unemployment spells? We extend the original model to make use of differences in local labor market conditions. We estimate the following model:

$$Y_{sm} = \alpha + \mu MinW_{sm} \cdot U_{sm} + \beta MinW_{sm} + \gamma U_{sm} + \phi State_s \cdot Month_m + \delta_s + \eta_m + \varepsilon_{sm}$$

where, U_{sm} is the monthly unemployment rate measured at the county level, $MinW_{sm} \cdot U_{sm}$ is an interaction term between unemployment and the minimum wage, and all the other variables are the same as the one discussed above. Table **??** reports the estimates. Figure **??** plots the average effects of minimum wage for productivity evaluated at the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles of the unemployment rate distribution. The figure also reports 95% confidence intervals computed with the delta method for each of the percentiles of unemployment rate. The figure shows that most of the effect of the minimum wage on productivity accrues during periods of high unemployment, consistent with Proposition **??**, part **??**.

Figure 5: Effects of MinW for During Periods of High Unemployment



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 computed with the delta method.

Are productivity gains are 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 Proposition **??** (part **??**) and Figure **??** panel c, the estimates in Table **??** indicate that the productivity gains are greater for low-productivity workers and negligible for high-productivity workers.[11]

6.3 Selection channel

The productivity gains might result from a selection channel whereby stores terminate worse workers, or hire from a better pool, following a minimum wage increase. To explore this possibility we test whether, after a minimum wage increase: 1) employment decreases in a store; 2) the least productive workers are more likely to be terminated. Finally: 3) we repeat our basic analysis in a full-balance sample including only workers who are present throughout our sample period.

1. Does employment decrease at the store level? Lazear et al. (2016) argues that a decrease in employment after a minimum wage increase might signal that some workers, possibly the least-productive ones, are being let go, lending support to the selection channel. In this spirit, we estimate the following model with store-level data and store-FEs:

$$Y_{cm} = \alpha + \beta MinW_{cm} + \phi State_s \cdot Month_m + \delta_c + \eta_m + \varepsilon_{cm} \tag{2}$$

where Y_{cm} is: number of store employees; new hires, new terminations, and number of salespeople, as a fraction of store employees. β is the main coefficient of interest of the effect of the minimum wage. [12]

We find that a minimum wage increase actually *increases* total employment slightly (1%, see col.1 of Table **??**). This effect appears to reflect a combination of lower hiring rates (-1.2%) and even lower termination rates (-1.9%), albeit these effects not precisely estimated. Finally, our base+commission salespeople remain constant as a fraction of total store employment. We conclude that, at the store level, we do not find evidence that our salespeople are being terminated more often following a minimum wage increase.

[11] These heterogeneous effects do not reflect heterogeneity in compensation after a minimum wage increase, see Section **??**.

[12] $State_s \cdot Month_m$ are state-specific trends, δ_c and η_m are stores and month fixed-effects. We cluster standard errors at the state level since most of the changes in the minimum wage are determined by state laws. We estimate this model for the same sample of "bordering" stores as in previous sections.

Table 5: Minimum wage affects store employment but not composition

Dep.Var	N.Wrkrs	%Hired	%Termin.	% Base
	(1)	(2)	(3)	(4)
MinW	1.341**	-0.072	-0.147	-0.085
	(0.553)	(0.094)	(0.239)	(0.337)
Observations	15,609	15,609	15,609	15,609
R-squared	0.955	0.418	0.225	0.656
StoreFE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
StateXYear FE	YES	YES	YES	YES
Controls	YES	YES	YES	YES
Eff.MinW %	1.110	-1.022	-1.735	-0.454

Note: In this table the unit of observation is a store-month. *N.Wrkrs* is the number of workers; *%Hired* is the percent of new workers hired in a month; *%Termin.* is the percent of workers terminated in a month; *%Base* is the fraction of salesperson paid base+commission. *MinW* is the monthly minimum wage (in $) in the jurisdiction of the store. *Controls* include county-unemployment. *Eff.MinW%* is the percent effect of one standard deviation increase in MinW on the outcomes. *Time FE* are month FEs. *Store FE* are store FE. *State·Year FE* are state specific trends. SEs clustered at the state level.*** p<0.01, ** p<0.05, * p<0.1.

2. Are the least productive workers more likely to be terminated? In Table **??** we check whether workers are more likely to be terminated in month m if they were less productive in month m-1, based on the productivity categories developed in Section **??**. To avoid the econometrics problem associated with estimated a model with discrete dependent variable we estimate equation **??** adding store fixed effect instead of workers fixed effects. None of the interaction coefficients (those in rows 2 and 3) are significant, suggesting that the least productive workers are neither more nor less likely to be terminated after an increase in the minimum wage.

Table 6: Differential effect of minimum wage on terminations by workers' past exposure to minimum wage for salespersons

Dep.Var	Termin.	Termin.	Termin.	Termin.	Termin.
Most-productive definition	None	> 120%	>140%	>160%	> 180%
	(1)	(2)	(3)	(4)	(5)
MinW	-0.130	0.354	0.423	0.409	0.378
	(0.227)	(0.810)	(0.817)	(0.802)	(0.802)
MinW $\cdot \mathbb{1}(> MW)$		-0.744	-0.706	-0.644	-0.634
		(0.641)	(0.659)	(0.664)	(0.653)
MinW $\cdot \mathbb{1}(>> MW)$		-0.548	-0.677	-0.679	-0.521
		(0.645)	(0.648)	(0.565)	(0.585)
$\mathbb{1}(> MW)$		-1.324**	-1.327**	-1.466**	-1.529**
		(0.608)	(0.618)	(0.609)	(0.612)
$\mathbb{1}(>> MW)$		-1.872***	-2.236***	-2.313***	-2.397***
		(0.621)	(0.602)	(0.622)	(0.608)
Observations	179,046	167,060	167,060	167,060	167,060
R-squared	0.018	0.020	0.021	0.021	0.021
State FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
VBU FE	YES	YES	YES	YES	YES
Worker FE	NO	NO	NO	NO	NO
StateXYear FE	YES	YES	YES	YES	YES
Mean Y	4.771	4.606	4.606	4.606	4.606
Eff.Wrkrs.at MW (%)	7.865	5.029	6.008	5.809	5.377
p-value		0.664	0.607	0.613	0.640
Eff.Wrkrs.just above (%)		-7.230	-5.357	-4.633	-5.171
p-value		0.151	0.293	0.361	0.329
Eff.Wrkrs.well above (%)		-4.485	-6.482	-7.491	-4.402
p-value		0.510	0.395	0.458	0.693

Note: *Termin.* is the probability that a worker has been terminated in a given month. *MinW* is the monthly minimum wage (in $) in the jurisdiction of the store of the employee. *Eff.Wrkrs.at MW (%)* is the percent effect of one dollar increase in MinW on the outcomes on workers earning minimum wage. *Eff.Wrkrs.just above MW (%)* is the percent effect of one dollar increase in MinW on productivity for workers that in month *m-1* compensated between 100 and 120% of minimum wage (20% threshold). *Eff.Wrkrs.well above MW (%)* is the percent effect of one dollar increase in MinW on productivity for workers compensated more than 120% of minimum wage. Col.2-Col.5 present calculation for the 20-80% thresholds. *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 and employee tenure. *Time FE* are month FEs. *VBU FE* are FE for employees departments. *State·Year FE* are state specific trends. SEs clustered at the state level. *** p<0.01, ** p<0.05, * p<0.1.

Two diagnostic tests for selection inspired by Lazear et al. (2016) Lazear (2016) performs several tests as diagnostics of a selection effect. First, he argues that if selection was a major confounder, introducing worker-fixed effects should decrease the magnitude and significance of the estimated effect. Contrary to this hypothesis, in our sample comparing the first two columns in Table **??** reveals that the presence of worker-fixed effects actually *increases* the size and significance of the estimated coefficient. Second, to remove the confounding effect of selection 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 (col. 3), we find that the estimated productivity gain, if anything, grows slightly to 2.74%. Therefore, the estimates in our baseline specification are not an artifact of worker turnover.

Table 7: Effects of minimum wage on productivity of stayers and leavers

Dep.Var.	Sales/Hrs.	Sales/Hrs.	Sales/Hrs.	Sales/Hrs.
Sample	All workers	All workers	Balance sample	Balance sample
	(1)	(2)	(3)	(4)
MinW	0.0636**	0.0362	0.100***	0.102***
	(0.0258)	(0.0259)	(0.0310)	(0.0310)
Observations	179,046	179,046	22,754	22,754
R-squared	0.415	0.218	0.660	0.487
State FE	YES	YES	YES	YES
Time FE	YES	YES	YES	YES
VBU FE	YES	YES	YES	YES
Store FE	NO	YES	NO	YES
Worker FE	YES	NO	YES	NO
StateXYear FE	YES	YES	YES	YES
Mean Y	2.061	2.061	2.206	2.206
Mean MinW	7.865	7.865	7.844	7.844
Eff.MinW %	2.001	1.139	2.736	2.778

Note: *Sales/Hrs.* represents workers performance measured by monthly sales over total monthly hours. *MinW* is the monthly minimum wage (in $) in the jurisdiction of the store of the employee. Col.3 and Col.4 restrict the analysis to workers that never left the company and we observe for all the months in the data (i.e., balance sample). Odd (even) columns include workers (stores) FE. All the regressions include county-unemployment and employee tenure. *Time FE* are month FEs. *VBU FE* are FE for employees departments. *State· Year FE* are state specific trends. SEs clustered at the state level. *** p<0.01, ** p<0.05, * p<0.1.

7 Confounders and robustness checks

7.1 Confounder: wage discrimination

In Sections **??** and **??** we have disaggregated the the productivity improvement by productivity type, and the observed pattern (high for low-productivity worker, absent for high-productivity workers) has been interpreted as supporting the compensation channel over the demand channel. A concern with this argument might be that the observed differentials by productivity types are due to wage discrimination, namely, that the firm might differentially adjust incentives for different productivity groups after a minimum wage increase. In this section we explore, and ultimately dismiss this mechanism. Table **??** shows that the base pay is essentially the same across different productivity types, and Table **??** that the percentage increase is also the same across productivity types. Therefore, we find no evidence that the minimum wage increase is translated differentially on the base pay of different productivity types. The picture is more complex for the commission rate, but comparing Table **??** and Table **??** shows that, if anything, decreases in commission rate are larger, in absolute value, for low-productivity types following an increase in the minimum wage. Therefore, if a minimum wage increase is translated differential on any productivity type, the low-productivity types experience a *greater* reduction in commission rate, which should decrease their incentives to work. This finding suggests that the observed relative productivity improvements of low productivity types cannot be explained by wage discrimination in the commission rate. Overall, the disaggregated evidence suggests that if low-productivity types become more productive after a minimum wage increase, this is not due to a discriminatory adjustment of the compensation scheme.

7.2 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 a improvement in the pool of potential hires, rather than greater effort on the part of incumbent workers. To investigate this possibility, we compute

the average distance between workplace and home for all of our salespeople in a given jurisdiction. If workers cross jurisdictional boundaries in pursuit of higher wages, then we would expect the work-home distance to increase in treated jurisdictions relative to control jurisdictions. To test for this possibility we estimate the following model with county FE:

$$Y_{cm} = \alpha + \beta MinW_{cm} + \phi State_s \cdot Month_m + \delta_c + \eta_m + \varepsilon_{cm} \tag{3}$$

where Y_{cm} is average work-home distance among jurisdiction c's workers in month m. Table **??** column 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.

7.3 Robustness: store distance from jurisdictional borders

In this section we explore the robustness of our estimates to different definitions of treated and control stores. In our main estimates we follow the existing literature,[13] in defining stores to be close to each other if they are located in neighboring jurisdictions whose centroids are closer than 75 kilometers (46 miles). We checked the robustness of our results by further restricting this sample to only include stores whose distance from the jurisdictional border is less than: 75 km; 37.5 km; and 18 km. Our results are broadly consistent across these specifications. See Table **??** (col.2-col.4), Tables **??**-**??** and Figure **??**.

8 Conclusions

Within a workforce of base+commission salespeople from a large US retailer, and using a border-discontinuity research design, we have documented that a 65 cents increase in the minimum wage increases individual productivity (sales per hour) by 2%.

This productivity gain could arise through several channels: a demand increase, an incentive effect due to the change in compensation, and selective termination by the firm. With the help of a model, we have sought evidence for each channel and found evidence

[13] Card and Kruger (1994), Dube et al. (2016)

only for the second, that is, the compensation scheme channel. Intriguingly, this channel suggests an efficiency wage effect because a lump sum increase in base pay has incentive effects.

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

A.1 Static model without efficiency-wage effect ($\beta = 0$)

This section studies a static model where neither firm nor workers look to the future. In this section, then, workers do not contemplate the possibility of being terminated at the end of the period and so, according to our definition, there cannot be an efficiency-wage effect. Instead, workers are incentivized solely through the commission rate. The following proposition characterizes the firm's optimal contract, and worker behavior, as the minimum wage changes.

Proposition 5. ***(absent a concern for the future, an increase in the minimum wage has no effect on worker productivity)*** *Suppose $\beta = 0$. Then it is optimal for the firm to set the base rate B as low as possible, and so the minimum wage M is binding for the firm. An increase in M will therefore force an increase in B, but the firm's optimal choice of commission rate R and the workers' effort choices will remain unchanged.*

Proof. In a single-period model the agent solves:

$$\max_e \left[B + R\sigma \cdot \Pr(\sigma) - c \cdot e\right]$$

An agent will put in maximum effort $e = 1$ if $R\sigma/2 > c$, else the worker puts in effort $e = 0$ (refer to the graph). Note that the parameter B does not impact the worker's decision. The firm maximizes:

$$\begin{aligned} & {}_0^1 \left[-B + \sigma(1-R)\Pr(\sigma)\right] d\sigma \\ = \; & -B + (1-R)_0^1 \sigma \Pr(\sigma)\, d\sigma \\ = \; & -B + (1-R)_{2c/R}^1 \sigma \frac{1}{2} d\sigma \end{aligned}$$

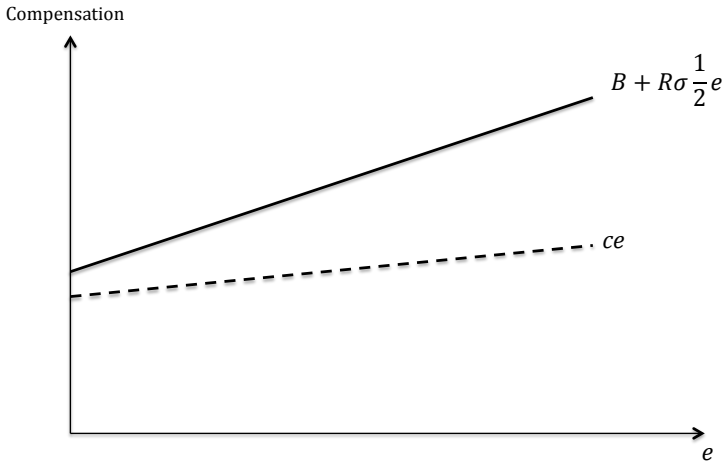
Since B does not affect the worker's decision it is optimal for the firm to set $B = M$. Furthermore, the firm's optimal choice of R is independent of B. ■

The previous proposition shows that worker behavior does not respond to an increase in the base rate. This feature of optimal worker behavior can be gleaned graphically in Figure **??**[14] The solid line represents the compensation scheme of a type-σ worker; this

[14] This figure is an adaptation of Figure 1 in the classic Lazear (2000) "Safelite" paper.

is the locus of achievable combinations of worker effort and compensation. The dashed line represents the worker's indifference locus between compensation and effort. Any point above the dashed line delivers greater utility to the worker than any point below the dashed line. The worker will choose the point on the solid line that delivers the highest utility. Workers assigned to a σ larger than $2c/R$ will prefer the right-most end on the solid line, corresponding to maximal effort; workers assigned to lower σ's will prefer the left-most point on the solid line, corresponding to no effort. But this choice between extremes is unaffected by the level of the solid line, that is, by the base hourly pay.

Figure 6: Static model



A.2 Dynamic model featuring efficiency-wage effect ($\beta > 0$)

Proof of Lemma ??

Proof. The problem of a type-σ agent is:

$$\begin{aligned} V(\sigma) &= \max_e \left[B + \sigma R \cdot \frac{1}{2} e - c \cdot e \right] + \beta \left[\frac{1}{2} eKV(\sigma) + \left(1 - \frac{1}{2} eK \right) \Omega \right] \\ &= \max_e B + \beta\Omega + e \left[\frac{\sigma R}{2} - c + K \frac{\beta}{2} (V(\sigma) - \Omega) \right]. \end{aligned}$$

As this payoff is linear in e, the agent will choose effort equal to 1 if:

$$\frac{\sigma R}{2} - c + K \frac{\beta}{2} (V(\sigma) - \Omega) \geq 0, \tag{4}$$

else the agent will exert zero effort. If $V(\sigma) > \Omega$ then increasing K increases effort and does not cost the principal anything; since higher effort increases principal's payoff, the principal optimally sets $K = 1$. So it is optimal for the principal to set $K = 1$ as long as $V(\sigma) > \Omega$ for all σ; as we will see from the proof of Proposition **??**, this is the case if $B + \beta\Omega > \Omega$. ■

Proof of Proposition ??

Condition (**??**) is a single-crossing condition: fixing B, R, there must be a threshold $\overline{\sigma}$ above which all agents exert full effort and below which all agents exert zero effort. Then for $\sigma < \overline{\sigma}$ we have:

$$V(\sigma) = B + \beta\Omega. \tag{5}$$

For $\sigma > \overline{\sigma}$ we have:

$$\begin{aligned} V(\sigma) &= B + \beta\Omega + \frac{\sigma R}{2} - c + \frac{\beta}{2} (V(\sigma) - \Omega) \\ \left(1 - \frac{\beta}{2} \right) V(\sigma) &= B + \beta\Omega + \frac{\sigma R}{2} - c - \frac{\beta}{2} \Omega \\ V(\sigma) &= \frac{2}{2 - \beta} \left(B + \beta\Omega + \frac{\sigma R}{2} - c - \frac{\beta}{2} \Omega \right) \end{aligned}$$

This expression is increasing in σ. We identify $\overline{\sigma}$ as that value that makes $V(\sigma) = B + \beta\Omega$.

Then $\overline{\sigma}$ solves:

$$\begin{aligned}
\frac{2}{2-\beta}\left(B+\beta\Omega+\frac{\overline{\sigma}R}{2}-c-\frac{\beta}{2}\Omega\right) &= B+\beta\Omega \\
\left(B+\beta\Omega+\frac{\overline{\sigma}R}{2}-c-\frac{\beta}{2}\Omega\right) &= \frac{(2-\beta)}{2}\left(B+\beta\Omega\right) \\
\frac{\overline{\sigma}R}{2}-c-\frac{\beta}{2}\Omega &= \left(\frac{(2-\beta)}{2}-1\right)\left(B+\beta\Omega\right) \\
\frac{\overline{\sigma}R}{2}-c &= -\frac{\beta}{2}\left(B+\beta\Omega\right)+\frac{\beta}{2}\Omega \\
\frac{\overline{\sigma}R}{2}-c &= -\frac{\beta}{2}B+\frac{\beta\left(1-\beta\right)}{2}\Omega \\
\overline{\sigma}R-2c &= -\beta B+\beta\left(1-\beta\right)\Omega \\
\overline{\sigma} &= \frac{2c-\beta B+\beta\left(1-\beta\right)\Omega}{R}
\end{aligned}$$

Note that for all σ we have $V(\sigma)\geq B+\beta\Omega$. Thus the sufficient condition $V(\sigma)>\Omega$ on which the proof of Lemma **??** relies is met if $B+\beta\Omega>\Omega$.

Proof of Proposition ??

Proof. Let us first show that R is optimally reduced as demand increases. Consistent with the assumption that $B\equiv M$, we fix B. Denote by $\overline{\sigma}(\delta)$ the threshold type above which all workers exert effort. Then following the steps in the proof of Proposition **??** we get:

$$\overline{\sigma}(\delta)=\frac{1}{\delta}\frac{2c-\beta B+\beta\left(1-\beta\right)\Omega}{R}.$$

The principal solves:

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

The FOCs for R are:

$$\begin{aligned}
0 &= -\int_{\overline{\sigma}(\delta)}^{1}\frac{\sigma}{2}d\sigma-\frac{(1-R)}{2}\overline{\sigma}(\delta)\frac{\partial\overline{\sigma}(\delta)}{\partial R}=-\int_{\overline{\sigma}}^{1}\frac{\sigma}{2}d\sigma+\frac{(1-R)}{2}\frac{1}{R}\left(\overline{\sigma}(\delta)\right)^{2} \\
&= -\frac{1}{4}\left[\sigma^{2}\right]_{\overline{\sigma}(\delta)}^{1}+\frac{(1-R)}{2}\left(\overline{\sigma}(\delta)\right)^{2}\frac{1}{R}=\frac{1}{4}\left[\left(\overline{\sigma}(\delta)\right)^{2}-1\right]+\frac{(1-R)}{2}\left(\overline{\sigma}(\delta)\right)^{2}\frac{1}{R} \\
&= -\frac{1}{4}+\frac{\left(\overline{\sigma}(\delta)\right)^{2}}{2}\left(\frac{1}{2}+\frac{(1-R)}{R}\right)
\end{aligned}$$

First, observe that both $\left(\overline{\sigma}(\delta)\right)^{2}$ and the term in parenthesis are positive and decreasing in R, so FOCs are decreasing in R, whence concavity in R is guaranteed. Thus the first order

conditions indeed identify the optimal R. Next, the first order conditions that identify the optimal $R(\delta)$ can be expressed as:

$$\left(\frac{1}{2}+\frac{(1-R)}{R}\right)=\frac{R^2}{2}\frac{\delta^2}{\left[2c-\beta M+\beta(1-\beta)\Omega\right]^2}. \tag{6}$$

The LHS is a decreasing function of R, while the RHS is an increasing function of R. Thus if $\delta>1$ then $R(\delta)<R(1)$.

1. Suppose first that the commission rate is optimally reduced. At $R(\delta)$ the LHS is higher than before, which means that the RHS is also higher. Since the RHS equals $1/2\left[\overline{\sigma}(\delta)\right]^2$, it follows that $\overline{\sigma}(\delta)<\overline{\sigma}(1)$. Since average productivity is:

$$\int_{\overline{\sigma}(\delta)}^{1}\frac{\delta\sigma}{2}dF(\sigma),$$

which is strictly decreasing in $\overline{\sigma}(\delta)$, the proof result is proved. Suppose now the commission rate does not change. Then fixing $R\equiv R(1)$ the only change after the demand shock is that

$$\overline{\sigma}(\delta)=\frac{1}{\delta}\frac{2c-\beta B+\beta(1-\beta)\Omega}{R}<\overline{\sigma}(1),$$

which means that some the set of high-effort types is now larger, leading to increased individual productivity for every worker in this set, and thus to higher average productivity.

2. Regardless of whether the commission rate is optimally reduced or not, any worker of type σ who put in full effort produced on average $\sigma/2$ before the demand increase. By part (**??**), this same worker still puts in full effort after the positive demand shock, and now produces on average $\delta\sigma/2$.

■

Proof of Proposition ??

Proof. Let us first show that R is optimally reduced as the minimum wage increases. Denote by $R^*(M,u)$ the R that solves (**??**) with $\delta=1$. Now define

$$\phi(M,u)=\left[2c-\beta M+\beta(1-\beta)\Omega(M,u)\right].$$

We need to stipulate that $\phi(M,u) > 0$ for all M, u in order to have $R^*(M,u) > 0$. Since $\Omega_2 < 0$, $u < u'$ implies:

$$0 < \phi(M,u') < \phi(M,u). \tag{7}$$

Since $\Omega_1 \leq 1$ we have:

$$\phi_1(M,u) = -\beta + \beta(1-\beta)\Omega_1(M,u) < -\beta + \beta(1-\beta) \leq 0.$$

Since $\Omega_{12} < 0$, $u < u'$ implies:

$$\phi_1(M,u') < \phi_1(M,u) < 0. \tag{8}$$

In light of (**??**) and (**??**) we have:

$$0 < \frac{\partial}{\partial M}\frac{1}{[\phi(M,u)]^2} = -2\frac{1}{[\phi(M,u)]^3}\phi_1(M,u) < -2\frac{1}{[\phi(M,u')]^3}\phi_1(M,u') = \frac{\partial}{\partial M}\frac{1}{[\phi(M,u')]^2}. \tag{9}$$

From (**??**), the first inequality in (**??**) implies that as M increases to M', the entire RHS of (**??**) as a function of R shifts upward. The LHS of (**??**) is a decreasing function of R which does depend on M. Hence, for any u, the crossing point $R^*(M',u)$ between the two functions is to the left of $R^*(M,u)$. This establishes that as M increases to M' then R^* decreases.

1. Suppose first that the commission rate is optimally reduced. To see that $\overline{\sigma}$ increases, observe that because $R^*(M',u) < R^*(M,u)$, the LHS of (**??**) assumes a higher value at $R^*(M',u)$ than at $R^*(M,u)$. Therefore the RHS is also higher. And since the RHS is inversely related to $\overline{\sigma}^2$, it follows that $\overline{\sigma}$ gets smaller. Therefore every worker works no less hard as M increases to M'. Suppose now that the optimal rate is not optimally reduced and so R does not change with the minium wage. Then from the expression for $\overline{\sigma}$ from Proposition **??**, and recalling that $B \equiv M$, we have:

$$\begin{aligned}\frac{\partial}{\partial M}\overline{\sigma} &= \frac{1}{R}\left[-\beta - \beta^2\Omega_1(M,u)\right] \\ &= -\frac{1}{R}\beta\left[1 + \beta\Omega_1(M,u)\right] < 0,\end{aligned}$$

   where the last inequality holds because $\Omega_1 \geq 0$ by assumption. Therefore, more types work hard after an increase in the minimum wage.

2. The second inequality in (**??**) implies that as M increases to M', the entire RHS of (**??**) as a function of R shifts upwards more sharply when u is large. Therefore the effect of increasing M on on R and on productivity is sharper the higher u is.

3. As shown in part **??**, every worker works no less hard after the increase in minimum wage. The most productive workers were working their hardest before the increase in the minimum wage, so their productivity stays unchanged.

■

B Variations in minimum wage

Table B.1: States with no changes in minimum wage between January 2012 and January 2017

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 B.2: Minimum Wages between January 2012 and January 2017

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

C Additional Tables and Figures

Table C.1: Productivity for workers in different wage groups

	Wage group		
Most-productive definition (threshold)	At MinW (1)	Just Above MinW (2)	Well Above MinW (3)
120%	0.92	1.42	2.37
140%	0.92	1.65	2.59
160%	0.92	1.82	2.76
180%	0.92	1.82	2.76

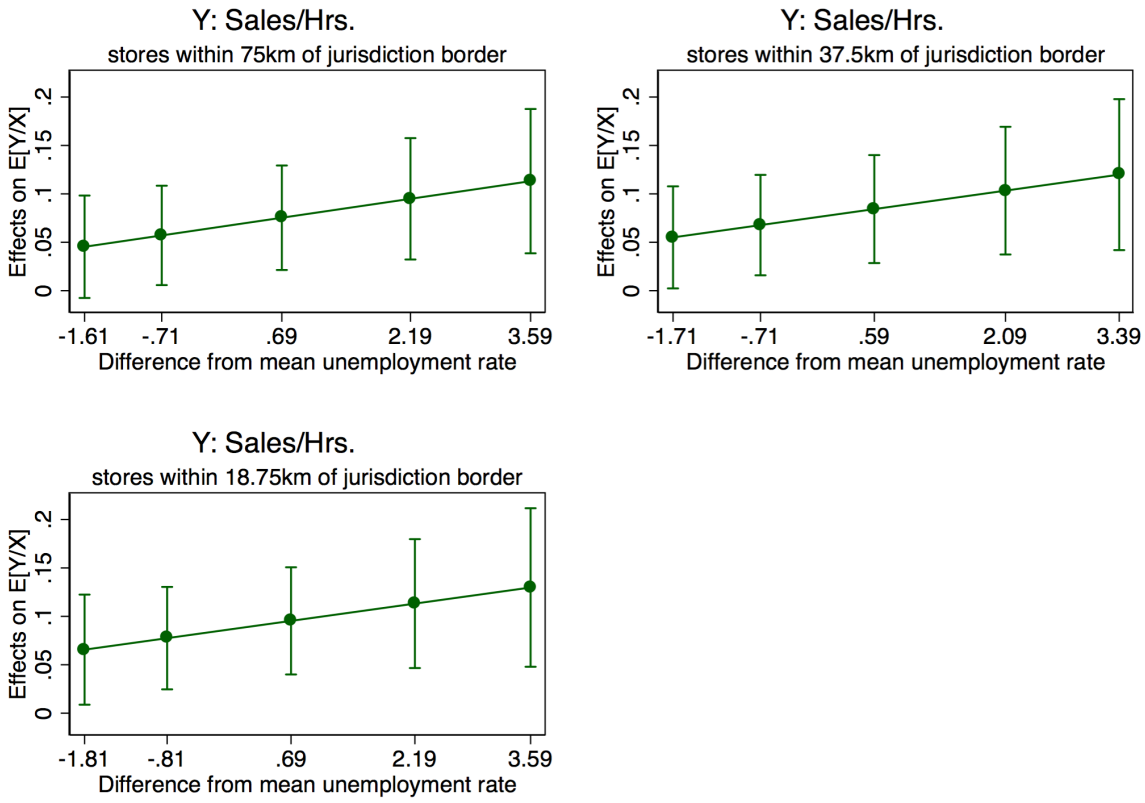
Note: *Productivity* is the worker level monthly sales per hour. *At MinW* is the average monthly productivity (Sales/Hours) for workers paid at the minimum wage. *Just Above MinW* is the average monthly productivity (Sales/Hours) for workers paid between 100 and 120% of the minimum wage (120% threshold); *Well Above MinW* is the average monthly productivity (Sales/Hours) for workers paid between more than 120% of the minimum wage. Row 2-Row 4 present statistics for the 140-180% thresholds.

Table C.2: Unemployment sharpens the effects of MinW

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·U	0.011*	0.013*	0.013*	0.012
	(0.006)	(0.007)	(0.007)	(0.008)
MinW	0.062**	0.066**	0.077***	0.087***
	(0.025)	(0.026)	(0.027)	(0.027)
U	0.012	0.011	0.005	0.006
	(0.014)	(0.014)	(0.014)	(0.017)
Observations	179,046	177,743	165,265	115,030
R-squared	0.415	0.415	0.413	0.409
Mean Y	2.063	2.062	2.069	2.068
Time FE	YES	YES	YES	YES
VBU FE	YES	YES	YES	YES
Worker FE	YES	YES	YES	YES
StateXYear FE	YES	YES	YES	YES

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. *U* is the unemployment rate at the county level (difference to the mean) All the regressions include county-unemployment and employee tenure. *Time FE* are month FEs. *VBU FE* are FE for employees departments. *State·Year FE* are state specific trends. SEs clustered at the state level. Samples with stores within 75km and 18.75km include stores located within 75km/18.75km of another jurisdiction with its own minimum wage law. *** p<0.01, ** p<0.05, * p<0.1.

Figure C.1: Robustness: Effects of MinW for During Periods of High Unemployment



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

Table C.3: Terminations for workers in different wage groups

Most-productive definition (threshold)	Wage group: At MinW (1)	Just Above MinW (2)	Well Above MinW (3)
120%	7.13	5.48	4.34
140%	7.13	5.35	3.94
160%	7.13	5.12	3.61
180%	7.13	4.99	3.25

Note: *Termination* is the worker level monthly probability of termination (in %). *At MinW* is the average monthly productivity (Sales/Hours) for workers paid at the minimum wage. *Just Above MinW* is the average monthly productivity (Sales/Hours) for workers paid between 100 and 120% of the minimum wage (120% threshold); *Well Above MinW* is the average monthly productivity (Sales/Hours) for workers paid between more than 120% of the minimum wage. Row 2-Row 4 present statistics for the 140-180% thresholds.

Table C.4: Compensation scheme for workers in different wage groups

Most-productive definition (threshold)	Wage group: At MinW (1)	Just Above MinW (2)	Well Above MinW (3)
	Base pay		
120%	5.97	6.20	6.04
140%	5.97	6.16	6.01
160%	5.97	6.15	5.95
180%	5.97	6.14	5.86
	Commission rate		
120%	3.92	3.12	3.33
140%	3.92	2.97	3.56
160%	3.92	2.93	3.94
180%	3.92	2.96	4.44

Note: *Base pay: Reg.Pay/Hrs.* is the monthly level regular earning divided by hours worked $ per hour worked); *Commission rate: Var.Pay/Sales* is the monthly level commission rate (in %) and it is obtained by dividing earning from commissions and incentives and sales. *At MinW* is the average monthly productivity (Sales/Hours) for workers paid at the minimum wage. *Just Above MinW* is the average monthly productivity (Sales/Hours) for workers paid between 100 and 120% of the minimum wage (120% threshold); *Well Above MinW* is the average monthly productivity (Sales/Hours) for workers paid between more than 120% of the minimum wage. Rows present statistics for the 140-180% thresholds.

Table C.5: Differential effect of minimum wage on base pay and incentives by workers' past exposure to minimum wage for salespersons

Dep.Var	Reg.Pay/Hrs.	Var.Pay/Sales	Reg.Pay/Hrs.	Var.Pay/Sales	Reg.Pay/Hrs.	Var.Pay/Sales	Reg.Pay/Hrs.	Var.Pay/Sales
Most-prod.Def.	>120%	>120%	>140%	>140%	>160%	>160%	>180%	>180%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MinW	0.499**	-0.607***	0.495**	-0.494***	0.500**	-0.453***	0.504**	-0.443***
	(0.193)	(0.146)	(0.194)	(0.144)	(0.194)	(0.147)	(0.195)	(0.144)
MinW $\cdot \mathbb{1}(> MW)$	-0.041	0.155*	-0.037	0.283***	-0.033	0.335***	-0.031	0.354***
	(0.069)	(0.090)	(0.071)	(0.097)	(0.071)	(0.098)	(0.071)	(0.100)
MinW $\cdot \mathbb{1}(>> MW)$	-0.010	0.454***	0.011	0.281***	-0.003	0.103	-0.013	-0.093
	(0.104)	(0.106)	(0.119)	(0.099)	(0.144)	(0.105)	(0.181)	(0.113)
$\mathbb{1}(> MW)$	0.136*	-0.678***	0.136*	-0.900***	0.139*	-0.986***	0.140**	-1.023***
	(0.069)	(0.088)	(0.070)	(0.097)	(0.069)	(0.097)	(0.069)	(0.098)
$\mathbb{1}(>> MW)$	0.165**	-1.676***	0.192**	-1.838***	0.213**	-2.040***	0.239*	-2.254***
	(0.081)	(0.103)	(0.089)	(0.098)	(0.104)	(0.099)	(0.127)	(0.102)
Observations	167,060	163,988	167,060	163,988	167,060	163,988	167,060	163,988
R-squared	0.104	0.534	0.104	0.537	0.104	0.538	0.104	0.539
State FE	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES
VBU FE	YES	YES	YES	YES	YES	YES	YES	YES
Worker FE	YES	YES	YES	YES	YES	YES	YES	YES
StateXYear FE	YES	YES	YES	YES	YES	YES	YES	YES
Mean Y	6.082	3.286	6.082	3.286	6.082	3.286	6.082	3.286
Eff.Wrkrs.at MW (%)	8.353	-15.45	8.284	-12.59	8.377	-11.54	8.435	-11.27
p-value	0.0133	0.0002	0.0145	0.0014	0.0137	0.0036	0.0134	0.0038
Eff.Wrkrs.just above (%)	7.376	-14.48	7.419	-7.090	7.600	-4.034	7.699	-3.007
p-value	0.0331	0.0001	0.0367	0.0280	0.0341	0.220	0.0322	0.307
Eff.Wrkrs.well above (%)	8.081	-4.577	8.407	-5.995	8.366	-8.865	8.370	-12.07
p-value	0.0440	0.0642	0.0449	0.0223	0.0567	0.0013	0.0775	0.0001

Note: *Base pay: Reg.Pay/Hrs.* is the monthly regular earning divided by hours worked $ per hour worked; *Comm.Rate: Var.Pay/Sales* is the monthly commission rate (in %) and it is obtained by dividing earning from commissions and incentives and sales; *MinW* is the monthly minimum wage (in $) in the jurisdisction of the store of the employee. *Eff.Wrkrs.at MW (%)* is the percent effect of one dollar increase in MinW on the outcomes on workers earning minimum wage. *Eff.Wrkrs.just above MW (%)* is the percent effect of one dollar increase in MinW on productivity for workers that in month *m-1* compensated between 100 and 120% of minimum wage (20% threshold). *Eff.Wrkrs.well above MW (%)* is the percent effect of one dollar increase in MinW on productivity for workers compensated more than 120% of minimum wage. Col.1-Col.2 (Col.3-Col.4) [Col.5-Col.6] {Col.7-Col.8} present calculation for the 120% (140%) [160%] {180%} thresholds. *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 and employee tenure. *Time FE* are month FEs. *VBU FE* are FE for employees departments. *State·Year FE* are state specific trends. SEs clustered at the state level. *** p<0.01, ** p<0.05, * p<0.1.

Table C.6: Robustness: Minimum wage affects compensation scheme, productivity, and compensation, for stores close to jurisdictions' borders

Var.Desc.	Compensation scheme		Productivity	Compensation	
	Base Rate	Comm. Rate			
Dep.Var.	Reg.Pay/Hrs.	Var.Pay/Sales	Sales/Hrs.	Tot.Pay/T.Hrs.	Tot.Pay
	(1)	(2)	(3)	(4)	(5)
	Stores distance from jurisdiction: 75km				
MinW	0.465**	-0.148	0.0674**	0.600***	46.98***
	(0.228)	(0.0945)	(0.0271)	(0.110)	(10.85)
Observations	177,743	169,104	177,743	177,743	177,743
Mean Y	6.107	3.304	2.062	12.19	1337
Eff.MinW %	4.934	-2.902	2.119	3.195	2.278
	Stores distance from jurisdiction: 37.5km				
MinW	0.437*	-0.144	0.0774***	0.626***	50.67***
	(0.227)	(0.0887)	(0.0278)	(0.129)	(14.06)
Observations	165,265	157,172	165,265	165,265	165,265
Mean Y	6.104	3.300	2.069	12.19	1337
Eff.MinW %	4.694	-2.856	2.454	3.370	2.485
	Stores distance from jurisdiction: 18.75km				
MinW	0.412**	-0.143	0.0884***	0.677***	45.76**
	(0.203)	(0.0920)	(0.0272)	(0.151)	(18.83)
Observations	115,030	109,478	115,030	115,030	115,030
Mean Y	6.119	3.296	2.068	12.20	1339
Eff.MinW %	4.473	-2.866	2.839	3.681	2.269
State FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
VBU FE	YES	YES	YES	YES	YES
Worker FE	YES	YES	YES	YES	YES
StateXYear FE	YES	YES	YES	YES	YES

Note: *Base Rate: Reg.Pay/Hrs.* is the monthly regular earning divided by hours worked $ per hour worked); *Comm.Rate: Var.Pay/Sales* is the monthly commission rate (in %) and it is obtained by dividing earning from commissions and incentives and sales; *Sales/Hrs.* are the monthly sales divided by hours worked (in $ per hour); *Tot.Pay/T.Hrs.* is the monthly hourly rate (in $) from total compensations divided by total hours. *Tot.Pay* is the monthly total pay (in $) from total take home pay. *MinW* is the monthly minimum wage (in $) in the jurisdiction of the store of the employee. *Eff.MinW%* is the percent effect of one standard deviation increase in MinW on the outcomes. All the regressions include county-unemployment and employee tenure. *Time FE* are month FEs. *VBU FE* are FE for employees departments. *State·Year FE* are state specific trends. SEs clustered at the state level.*** p<0.01, ** p<0.05, * p<0.1.

Table C.7: Robustness: Differential effect of minimum wage on productivity by workers' past exposure to minimum wage for salespersons

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
Most-productive definition	> 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	0.132***	0.123***	0.127***	0.142***	0.145***	0.133***	0.136***	0.153***	0.186***	0.160***	0.155***	0.173***
	(0.042)	(0.035)	(0.033)	(0.033)	(0.039)	(0.033)	(0.033)	(0.033)	(0.038)	(0.035)	(0.034)	(0.037)
MinW $\cdot \mathbb{1}(> MW)$	-0.005	0.014	0.003	-0.010	-0.007	0.012	0.001	-0.013	0.004	0.013	-0.002	-0.017
	(0.024)	(0.024)	(0.024)	(0.023)	(0.026)	(0.026)	(0.026)	(0.026)	(0.038)	(0.038)	(0.037)	(0.036)
MinW $\cdot \mathbb{1}(>> MW)$	-0.004	-0.025	-0.085**	-0.148***	-0.010	-0.030	-0.088**	-0.150***	-0.050	-0.067	-0.110**	-0.166***
	(0.039)	(0.043)	(0.039)	(0.042)	(0.037)	(0.040)	(0.036)	(0.039)	(0.046)	(0.050)	(0.046)	(0.053)
$\mathbb{1}(> MW)$	0.228***	0.275***	0.328***	0.361***	0.221***	0.265***	0.317***	0.353***	0.237***	0.288***	0.339***	0.376***
	(0.029)	(0.031)	(0.032)	(0.031)	(0.036)	(0.039)	(0.040)	(0.040)	(0.057)	(0.058)	(0.059)	(0.060)
$\mathbb{1}(>> MW)$	0.701***	0.942***	1.132***	1.255***	0.694***	0.930***	1.120***	1.245***	0.723***	0.948***	1.135***	1.264***
	(0.044)	(0.049)	(0.055)	(0.060)	(0.053)	(0.058)	(0.065)	(0.070)	(0.072)	(0.077)	(0.082)	(0.091)
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
R-squared	0.466	0.482	0.491	0.490	0.463	0.479	0.488	0.487	0.464	0.480	0.489	0.488
State FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
VBU FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Worker FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
StateXYear FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
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 (%)	14.48	13.44	13.94	15.53	15.57	14.25	14.56	16.39	19.15	16.43	16	17.85
p-value	0.0034	0.0012	0.0005	0.0001	0.0007	0.0003	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001
Eff.Wrkrs.just above (%)	8.925	8.244	7.132	6.805	9.766	8.768	7.483	7.180	13.31	10.44	8.472	8.090
p-value	0.0009	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Eff.Wrkrs.well above (%)	5.437	3.763	1.532	-0.216	5.695	3.945	1.729	0.0820	5.723	3.553	1.644	0.243
p-value	0.0001	0.0009	0.180	0.852	0.0001	0.0005	0.120	0.942	0.0001	0.0026	0.128	0.846

Note: *Sales/Hrs.* represents workers performance measured by monthly sales over total monthly hours. *MinW* is the monthly minimum wage (in $) in the jurisdiction of the store of the employee. *Eff. Wrkrs.at MW* is the percent effect of one dollar increase in MinW on the outcomes on workers earning minimum wage. *Eff.Wrkrs.just above MW (%)* is the percent effect of one dollar increase in MinW on productivity for workers that in month *m-1* compensated between 100 and 120% of minimum wage (20% threshold). *Eff.Wrkrs.well above MW (%)* is the percent effect of one dollar increase in MinW on productivity for workers compensated more than 120% of minimum wage. Column present calculation for the 20-80% thresholds. Col.1-4 (Col.5-8) [Col.9-12] 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 and employee tenure. *Time FE* are month FEs. *VBU FE* are FE for employees departments. *State·Year FE* are state specific trends. SEs clustered at the state level. *** p<0.01, ** p<0.05, * p<0.1.

Table C.8: Robustness: Differential effect of minimum wage on terminations by workers' past exposure to minimum wage for salespersons

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
Most-productive definition	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	-0.141	0.306	0.374	0.361	0.329	-0.03	0.480	0.559	0.536	0.502	0.083	0.595	0.681	0.654	0.617
	(0.264)	(0.846)	(0.853)	(0.837)	(0.838)	(0.268)	(0.852)	(0.862)	(0.842)	(0.844)	(0.319)	(0.918)	(0.932)	(0.919)	(0.922)
MinW $\cdot \mathbb{1}(> MW)$		-0.691	-0.657	-0.595	-0.586		-0.755	-0.750	-0.686	-0.678		-0.801	-0.775	-0.728	-0.710
		(0.673)	(0.689)	(0.695)	(0.683)		(0.716)	(0.711)	(0.715)	(0.701)		(0.811)	(0.809)	(0.800)	(0.783)
MinW $\cdot \mathbb{1}(>> MW)$		-0.507	-0.635	-0.642	-0.481		-0.620	-0.771	-0.755	-0.594		-0.585	-0.744	-0.659	-0.470
		(0.672)	(0.676)	(0.588)	(0.611)		(0.663)	(0.679)	(0.584)	(0.608)		(0.695)	(0.682)	(0.616)	(0.641)
$\mathbb{1}(> MW)$		-1.229**	-1.232*	-1.374**	-1.439**		-1.305*	-1.253*	-1.419**	-1.485**		-1.040	-0.971	-1.123	-1.199
		(0.607)	(0.614)	(0.606)	(0.608)		(0.709)	(0.705)	(0.698)	(0.697)		(0.743)	(0.742)	(0.739)	(0.743)
$\mathbb{1}(>> MW)$		-1.786***	-2.151***	-2.234***	-2.320***		-1.806**	-2.214***	-2.248***	-2.327***		-1.455*	-1.830**	-1.865**	-1.860**
		(0.614)	(0.599)	(0.614)	(0.601)		(0.689)	(0.678)	(0.684)	(0.673)		(0.748)	(0.745)	(0.760)	(0.741)
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
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
State FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
VBU FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Store FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
StateXYear FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
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
Eff.Wrkrs.at MW (%)	-1.915	4.438	5.431	5.237	4.783	-0.407	6.865	7.995	7.665	7.179	1.151	8.731	10	9.597	9.057
p-value		0.720	0.663	0.669	0.696		0.576	0.520	0.528	0.555		0.521	0.469	0.481	0.508
Eff.Wrkrs.just above (%)		-7.142	-5.343	-4.619	-5.197		-5.084	-3.572	-2.931	-3.546		-3.838	-1.780	-1.468	-1.890
p-value		0.158	0.300	0.369	0.334		0.294	0.495	0.575	0.515		0.488	0.768	0.813	0.771
Eff.Wrkrs.well above (%)		-4.654	-6.648	-7.810	-4.693		-3.214	-5.390	-6.011	-2.802		0.218	-1.596	-0.151	4.357
p-value		0.503	0.393	0.450	0.681		0.662	0.497	0.587	0.820		0.981	0.880	0.991	0.779

Note: The dependent variable is the probability that a worker has been terminated in a given month. *MinW* is the monthly minimum wage (in $) in the jurisdiction of the store of the employee. *Eff.Wrkrs.at MW (%)* is the percent effect of one dollar increase in MinW on the outcomes on workers earning minimum wage. *Eff.Wrkrs.just above MW (%)* is the percent effect of one dollar increase in MinW on productivity for workers that in month *m-1* compensated between 100 and 120% of minimum wage (20% threshold). *Eff.Wrkrs.well above MW (%)* is the percent effect of one dollar increase in MinW on productivity for workers compensated more than 120% of minimum wage. 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 20-80% 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 and employee tenure. *Time FE* are month FEs. *VBU FE* are FE for employees departments. *State·Year FE* are state specific trends. SEs clustered at the state level. *** p<0.01, ** p<0.05, * p<0.1.