Does Minimum Wage Increase Labor Productivity? Evidence from Piece Rate Workers*

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Abstract

In a competitive model, there are two main pathways of adjustment to a minimum wage hike: firms can choose to dismiss (or not hire) workers whose productivity is below the new minimum wage, or subminimum wage workers can increase their efforts (and hence productivity) to preempt possible discharge. Whereas the first effect is the subject of extensive study, the second—incumbent workers' effort responses—is largely overlooked in the literature. Using unique data on a large number of piece rate workers who perform a homogenous task and whose individual productivity is rigorously recorded, we examine possible effort responses of workers to a minimum wage hike. By employing a difference-in-differences strategy that exploits the increase in Florida's minimum wage from $6.79 to $7.21 on January 1, 2009, and worker location on the pre-2009 productivity distribution, we provide evidence consistent with incumbent workers' positive effort responses.

Key words: minimum wage; incentive; effort; productivity

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1. Introduction

Each worker receives the value of his marginal product under competition. If a minimum wage is effective, it must therefore have one of two effects: first, workers whose services are worth less than the minimum wage are discharged (and thus forced into unregulated fields of employment, or into unemployment or retirement from the labor force); or, second, the productivity of low-efficiency workers is increased.

George J. Stigler (1946)

In his seminal discussion of the minimum wage, Stigler (1946) hypothesizes two possible effects: (i) when worker productivity is held constant, workers whose marginal product falls below the minimum wage will be discharged; (ii) the threat of discharge may induce formerly low productivity workers to increase their efforts to justify their continued employment to the employer, thereby offsetting the first effect. Although the literature on the minimum wage's (dis)employment effect is extensive,[3] it pays little attention to the minimum wage effect on worker *effort*. While plausible, identifying the minimum wage effect on worker effort is challenging. In most settings, productivity of *individual* workers is not observable. Establishment-level measures of labor productivity—if they can be inferred based on surveys—are likely convoluted with task and/or workforce composition. In addition, repeated observation on the same worker's productivity on a given task around a minimum wage hike is difficult to come by. Standard sources used in the literature such as the Current Population Survey (CPS) do not allow tracking the same workers and in high enough frequency to allow such comparison.

[3] For a review, see Card and Krueger (1995), Brown (1999) and Neumark, Salas and Wascher (2014).

In this paper, we employ a direct and high frequency measure of worker productivity on a homogenous task to examine possible worker effort responses to a minimum wage increase. Specifically, we use personnel records from a large tomato farm in Florida—where piece-rate workers hand-harvest tomatoes in the field—together with the change in the state minimum wage from $6.79 to $7.21 on January 1, 2009. In piece rate settings, the employer must make up any shortfall between a worker's raw productivity (output in dollars/hour) and the minimum wage for all work hours during a given pay period (in this context, one week).[4] Hence, when the worker productivity level is held constant, firm's compliance costs increase with the minimum wage. According to Stigler (1946)'s second hypothesis, the firm can then (threaten to) reduce (either at the extensive or intensive margin) the employment hours assigned to low productivity workers, which in turn may induce positive effort responses of low productivity workers.[5]

This is a unique setting conducive to examining worker *effort* responses to a minimum wage increase for several reasons. First, due to the pay scheme being piece-rate based, the productivity of individual workers is rigorously recorded. Not only do the workers clock in and out for each work spell, but an electronic system keeps track of their output in the field. Second, the minimum wage increase of January 1, 2009 occurs within a given harvesting season (autumn 2008 season), which allows us to compare the same worker's productivity before and after the hike. Third, the nature of the task and workforce allows us to rule out other potential determinants of worker productivity. In particular, hand-harvesting of fresh tomatoes is a low skilled, labor-

[4] Workers whose raw productivity (output in dollars/hour) is above the minimum wage get paid according to their actual output.

[5] Besides the threat of discharge, workers may respond to other concerns. For instance, a higher minimum wage may induce extra workers to participate and queue for a given job (Holger, Katz and Krueger 1991; Giuliano 2013), which increases competition even when the employer continues to hire the same number of workers as previously. Moreover, low productivity workers may respond to behavioral concerns such as gift exchange (Akerlof 1982; Fehr, Goette and Zehnder 2009), fairness (Akerlof and Yellen 1990; Falk, Fehr and Zehnder 2006), peer pressure (Kandel and Lazear 1992), or morale boost (Solow 1979) associated with the minimum wage.

intensive process and there is little scope for technological adjustments (e.g., shift towards capital) or innovation, at least in the short run (within season). In addition, due to the seasonal nature of the harvesting task and high workforce turnover, firm investment in worker training (Acemoglu and Pischke 1999, 2003; Arulampalam, Booth and Bryan 2004; Dustmann and Schönberg 2009) is virtually nonexistent and largely irrelevant in this sector.

In order to isolate the effects of worker effort from external determinants of labor productivity (e.g., field lifecycle or weather), we employ a difference-in-differences strategy. We first capture each worker's baseline productivity by estimating their fixed effects using data from outside our main estimation window. We then look for possibly differential productivity changes of individual workers around January 1, 2009 by their baseline productivity. Since low fixed effect workers are always more likely to fall below a minimum wage than high fixed effect workers when subject to the same production environment, to the extent there is a minimum wage effect on worker effort, we expect a disproportionate increase in observed productivity in the lower part of the fixed effects distribution when the minimum wage increases.

This strategy contrasts with the standard approach used in the literature in both analytic level and task uniformity. For example, Card and Krueger (1994), in their analysis of the employment effect of New Jersey's minimum wage hike on April 1, 1992, define their treatment status *at the (fast food) store level*, either dichotomously (New Jersey versus Pennsylvania) or as a "GAP"—the proportional increase in wages necessary to meet the new minimum wage.[6] We, in contrast, define the treatment status with respect to the new minimum wage *at the individual level*.

[6] Whereas Card and Krueger (1994) define their GAP measure based on store level *starting* wage, Draca, Machin and Van Reenen (2011), working in the UK context, use firm level *average* wage to determine a firm's treatment status with respect to the national minimum wage. In yet another approach to define the treatment status at the establishment level, Machin, Manning and Rahman (2003) use the *proportion* of workers at each care home paid the national minimum wage (NMW) before and after the introduction of the NMW in the UK.

Likewise, researchers using establishment level data typically evaluate an average outcome among all employees who may perform very different tasks (e.g., cashiers versus cooks), even though changes in the average outcome may reflect possible changes in task and/or workforce composition.[7] In our dataset, however, both the high and low productivity workers perform exactly the same task (tomato harvesting at the same piece rate), so individual workers' treatment status with respect to the minimum wage hike is not confounded by either task or worker qualifications. Any resulting productivity changes can thus be compared head to head.

We find evidence consistent with incumbent workers' positive effort responses. As the minimum wage increases by 6% ($6.79 to $7.21) on January 1, 2009, worker productivity (i.e., output per hour) in the bottom four deciles of the worker fixed effects distribution increases by 3-4% relative to that in the upper deciles. In contrast, we do not find any evidence of productivity changes around January 1 in the following year (autumn 2009 season) when the minimum wage remains at $7.25 (the federal minimum wage effective on July 24, 2009) throughout. Examining selective non-employment of low (versus high) productivity workers that may be attributed to the January 1, 2009 minimum wage hike, we find an increase in selectivity by *up to* 7-9 percentage points.[8] That this figure is at best quite modest and is nowhere near 100% may imply that despite the casual nature of the employment relationship in this setting, the firm cannot afford "discharging"—or "not hiring", to be more precise—*all* the low productivity workers as it needs to maintain the workforce above a certain size to meet the harvesting needs. Moreover, given our findings on worker efforts, the modest effect on employment is to some extent anticipated:

[7] Card and Kruger (1994) are explicit about the possibility of compositional changes in the store workforce and recognize that full time workers may be high productivity types. They therefore also examine the share of full time (versus part time) workers before and after New Jersey's minimum wage hike but find ambiguous effects on the share of full time workers in New Jersey restaurants.

[8] That is, workers in the bottom four deciles obtain up to 7-9% fewer hours of employment than those in the upper deciles.

According to Stigler (1946)'s logic, sufficiently large effort responses should obviate the firm's need to shed workers and in our case, worker productivity went up by 3-4% when the minimum wage rose by 6%.

These findings suggest that that while an exogenously higher minimum wage implies a higher labor cost for the firm, the rising cost can be (partly or fully) offset by the increased effort and productivity of (below minimum wage) workers.[9] Admittedly, this margin of adjustment can only work within relatively low ranges of the minimum wage as considered here. If the minimum wage continues to rise, we will reach a point where it is no longer feasible for (low productivity) workers to keep up their effort (and productivity) with the minimum wage. At that point, the firm may adopt an entirely different personnel policy than observed here and worker effort responses may no longer be a valid channel to absorb the rising labor cost associated with the minimum wage.

This paper provides concrete empirical evidence on Stigler (1946)'s second hypothesis—minimum wage's effect on worker *effort*—based on directly observed productivity data at the individual level on a homogenous task. By doing so, this paper adds to the recent and growing literature that explores alternative channels (other than employment) through which firms may absorb the rising labor cost associated with the minimum wage such as: an increase in prices (Aaronson 2001; Aaronson and French 2007); a decrease in profits (Draca, Machin and Van Reenen 2011; Bell and Machin 2016); increased worker retention and reduced turnover (Portugal and Cardoso 2006; Dube, Lester and Reich 2016); or labor-labor substitution (Lang and Kahn

[9] Note that increased productivity of workers who are above the minimum wage makes little difference for the firm's labor cost since compensation is purely piece-rate based, which means the total wage bill is determined by the total output (pieces) harvested and the piece rate only and *not* by the speed or productivity (output/hour) of (above minimum wage) workers.

1998; Portugal and Cardoso 2006; Fairris and Bujanda 2008; and Giuliano 2013).[10] In a recent study, Mayneris, Poncet and Zhang (2016) document in the context of China, minimum wage-induced increase in firm-level TFP, which is a revenue-based measure of firm efficiency. In contrast, we focus here specifically on labor productivity driven by worker effort, based on *observed* productivity data at the individual level.

This paper also relates to the personnel economics literature that explores how worker productivity may be related to the labor market conditions. In an earlier work, Rebitzer (1987) showed that the level of unemployment raises productivity growth using US data at two-digit manufacturing industries for 1960-1980. In addition, a recent work of Lazear, Shaw and Stanton (2016) shows—based on detailed productivity data for a large number of workers performing a homogenous task in a US firm—that incumbent workers may work harder during recession and when the unemployment rates are higher. While similar in the usage of personnel records from a US firm, the key difference between the present work and Lazear, Shaw and Stanton (2016) is that the latter study of recession effects focuses on the increased *cost* in case of discharge for workers with a relatively long employment contract, whereas our analysis of minimum wage effects concentrates on the increased *risk* of discharge—or not being picked up for daily employment—for workers operating in a casual labor market, where daily employment is decided on an ad hoc basis in the absence of any fixed-term contract.

The rest of the paper is organized as follows. The next section explains minimum wage operation in piece rate settings and describes the dataset used in the analysis. Section 3 discusses

[10] Hirsch, Kaufman and Zelenska (2015) simultaneously examine all the channels above as well as wage compression and raised performance standards based on a unique store-level dataset from quick-service restaurants in Georgia and Alabama.

the empirical strategy, after which Section 4 reports the results. Section 5 offers concluding comments.

2. Background and Data

2.1 Minimum Wage for Piece Rate Workers

For a given pay period (here, one calendar week), consider a worker i with a transaction profile of (h_i, Y_i), where h_i denotes the total field hours spent and Y_i the total output (in pieces) produced. Applying the constant piece rate (dollars/piece) p, the total output can be expressed as pY_i in dollars. This worker's average productivity then is $pY_i/h_i \equiv py_i$ (dollars per hour).

For all hours employed during the pay period, workers whose average raw productivity is above (below) the minimum wage are paid according to actual output (minimum wage). Hence, worker i's hourly wage is

$$Hourly\ wage_i = \begin{cases} py_i & \text{if } py_i \geq MW \\ MW & \text{if } py_i < MW \end{cases}$$

where MW denotes the minimum wage. Worker i's total weekly earnings are

$$Earnings_i = \begin{cases} pY_i & \text{if } py_i \geq MW \\ h_i MW & \text{if } py_i < MW. \end{cases}$$

so the firm's total wage bill is

$$\sum_j pY_j + \sum_{py_{j'} < MW} h_{j'}(MW - py_{j'})$$

where the first and second parts represent (i) the unadjusted wage bill for all workers and (ii) the compliance cost for the minimum wage expended on subminimum wage workers, respectively.

When worker productivity is held constant, firm's compliance costs increase with the minimum wage for two reasons: first, a higher minimum wage makes the minimum wage bite for more workers than previously, and second, it increases the gap between the minimum wage and the subminimum wage workers' raw productivity. A minimum wage increase thus creates an incentive for firms to dismiss (or not hire) subminimum wage workers. On the other hand, low productivity workers can preempt the firm's action by increasing their efforts and productivity, thereby (at least partially) relieving the firm of the expanding compliance cost. Whether either or both effects exist is examined empirically below.

2.2 Setting and Data

The setting of our analysis is a large tomato farm in Florida where piece-rate workers hand-harvest fresh tomatoes in the field. Our main data come from the personnel records of the farm covering the 12-week autumn harvesting season from November 2008 to January 2009. Because this firm uses one calendar week pay periods, the timeline in Figure 1 shows the harvesting periods by week. During the 9th week of this season, in particular on January 1, 2009, the state minimum wage rose from $6.79 to $7.21, an increase by 42 cents or 6% of the baseline minimum wage.

[Figure 1]

The minimum wage increase comes from Article X, Section 24 of the Florida Constitution. Enacted in 2004 and first implemented in 2005, Florida's minimum wage is indexed to inflation. In particular, on September 30th of each year, an adjusted minimum wage rate is computed based on the current minimum wage and the inflation rate (based on CPI-W) during the twelve months prior to each September 1st, which is then published and takes effect on the following January 1st.[11] As Appendix Table A.1 shows, the minimum wage hike on January 1, 2009 is relatively large in absolute magnitude. This has to do with the high inflation rate that prevailed during the twelve months prior to September 1, 2008, as shown in Appendix Figure A.1.

Although the farm operates several different fields and grows different tomato varieties, due to a confidentiality agreement with the firm, this analysis is constrained to the harvesting of two main varieties, round and grape tomatoes, which represent over 70 percent of total man hours. All field workers are paid piece rate based on individual output, meaning no team element in production or compensation, and may be asked to pick either tomato variety depending on the day's harvesting requirements.

To track each worker's output and work hours electronically, an ID card with a magnetic chip is attached to each worker's bucket and scanned at the beginning and end of each work spell. Although a work day may comprise multiple work periods, there is typically a morning and afternoon work spell with a lunch break separating the two. During a work period, workers spread around the field to pick tomatoes from different rows of thick tall bushes and then carry their filled buckets to a truck parked in the middle of the field. Several "dumpers" standing on the back of the truck empty the full buckets into a large collection bin and scan the worker's ID card with a

[11] Specifically, part (c) of Article X, Section 24 of the Florida Constitution reads "MINIMUM WAGE. Employers shall pay Employees Wages no less than the Minimum Wage for all hours worked in Florida. Six months after enactment, the Minimum Wage shall be established at an hourly rate of $6.15. On September 30th of that year and on each following September 30th, the state Agency for Workforce Innovation shall calculate an adjusted Minimum Wage rate by increasing the current Minimum Wage rate by the rate of inflation during the twelve months prior to each September 1st using the consumer price index for urban wage earners and clerical workers, CPI-W, or a successor index as calculated by the United States Department of Labor. Each adjusted Minimum Wage rate calculated shall be published and take effect on the following January 1st. For tipped Employees meeting eligibility requirements for the tip credit under the FLSA, Employers may credit towards satisfaction of the Minimum Wage tips up to the amount of the allowable FLSA tip credit in 2003."

scanning device to add the output unit to the system. This procedure is repeated throughout the day until the day's designated fields are completely picked.

Output is measured in 32 pound bucket, for which the piece rate for round (grape) tomatoes is a constant $0.50 ($3.75) throughout. For ease of comparison, worker output is always converted to dollars (pieces times piece rate for the relevant variety), and productivity (output per hour) is expressed in dollars per hour. For each variety separately, we remove the transactions that fall in the bottom and top 1 percent of the productivity distribution to ensure that the results are not driven by outliers. Further, we focus on workers who worked for at least 35 hours during weeks 1-5. This results in 28,066 transactions for 768 unique workers. The average output per hour (dollars/hour) in the sample is $9.60 with a standard deviation of $3.64.[12] Because the January 1 minimum wage hike falls in week 9, weeks 1-8 and 9-12 comprise the pre and post periods, respectively.

To address the relevant question of how substantive this new $7.21 minimum wage is, the incidence and extent of the old and the new minimum wages are tabulated in Table 1. As the minimum wage rises from $6.79 to $7.21, the share of worker weekly paychecks for which the minimum wage binds rises from 11 to 15 percent. Moreover, the share of workers for whom the minimum wage will *ever* bite increases from 42 to 52 percent. At the same time, the share of farm-level employment hours (assigned to worker-weeks below the minimum wage) rises from 9 to 13 percent, and the minimum wage compliance cost increases from $6,522 to $10,606, which corresponds to an increase from 0.7 to 1.2 percent as a share of the farm's raw wage bill.

[Table 1]

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[12] The average output per hour (standard deviation) for round is $11.15 ($3.82) and that for grape is $8.10 ($2.72). In our data, 51 percent of all transactions is picking grape tomatoes. As mentioned above, workers do not specialize in any variety and are asked to pick either variety depending on the harvesting requirements of the farm. Appendix Figure A.2 shows that the share of grape variety in a worker's total hours worked is not systematically related to his productivity (measured by worker fixed effects).

2.3 Compliance

Minimum wage is part of the Fair Labor Standards Act (FLSA), which also sets overtime, recordkeeping, and child labor standards. Contrary to popular misconceptions, all agricultural workers on any but small farms, while exempt from the law's overtime pay provision, are covered by its minimum wage requirement.[13] Since the state of Florida has its own minimum wage, whichever one is higher binds between the federal and state minimum wages (see Appendix Table A.1).

As with any empirical research on minimum wage, one important concern here is noncompliance.[14] The most common violation of minimum wage regulation is manipulating the manual records of workers' compensable hours. The recordkeeping standards at the farm studied here, however, makes *ex post* manipulation of employment hours highly implausible. Workers are *clocked in and out* in the field by magnetic chips. Nevertheless, we perform several tests to eliminate this possibility, including an inspection of workers' actual paystubs to verify that subminimum wage workers were indeed paid the minimum wage. To illustrate, the worker whose weekly paystub is shown in Appendix Figure A.3 worked a total of 15.28 hours over two days during the reference week in 2008. Based on his output, his raw (unadjusted) earnings were $87.75 dollars ($29.00 + $7.50 + $11.25 + $40.00), which translates into an hourly productivity (dollars/hour) of $5.74. Because the relevant minimum wage for this period was $6.79, the worker was paid $6.79 and not $5.74 for all 15.28 hours worked, resulting in a total earnings of $103.75

[13] An agricultural employer who does not use more than 500 man days (days on which a worker provides at least one hour of agricultural work) in any calendar quarter of the preceding calendar year is exempt from the FLSA minimum wage provision for the current calendar year. The farm studied here hires 300–600 workers *per day* and thus is *not* exempt from the provision.

[14] See Ashenfelter and Smith (1979) for discussion on noncompliance in the context of the US federal minimum wage.

($6.79 times 15.28). The firm's compliance costs were thus $16 ($103.75 minus $87.75), which appears as a line item labeled "minimum wage."

We also check for any sign of *ex post* manipulation in the payroll data, in particular, any downward adjustment of employment hours for workers whose raw hourly productivity falls below the minimum wage. Appendix Figure A.4 plots the mean of worker-weekly total hours of employment by 5 cents bins of worker-weekly average productivity (output per hour) for a 2 dollar window around the relevant minimum wage. Data are pooled across weeks with week fixed effects controlled for. The plot for weeks 1-8 (minimum wage = $6.79) is in part (a) whereas that for weeks 9-12 (minimum wage = $7.21) is in part (b). As the figure illustrates, the individual work hours in any given (calendar week) pay period are smooth along the distribution of each worker's contemporaneous productivity. That is, there is no sign of a discontinuous drop in field hours for workers below the productivity threshold of $6.79 (or $7.21), which could be expected if the firm had adjusted subminimum wage workers' field hours downward.[15]

On the other hand, if the firm were to make a uniform downward adjustment to *everyone's* employment hours— either in response to a minimum wage hike or all the time— such adjustment could not be detected without having access to the unadulterated records. Even if such uniform downward adjustment were to happen—no matter the reason—it would not threaten the analysis because the difference-in-differences strategy used examines possible *differential* changes in the outcomes of low versus high productivity workers when both groups are exposed to the same

[15] Relatedly, Appendix Figure A.5 shows the McCrary plot, which tests for selective sorting around the threshold on the worker-weekly average productivity (output per hour). Consistent with no ex post manipulation of production records by the firm, the figure shows no discontinuity in the density of observations around the minimum wage either in the pre or in the post period.

shocks at the firm level. Such shocks would include both the January 1 minimum wage hike and the (highly unlikely) uniform downward adjustment of everyone's employment hours.

3. Empirical Strategy

Outdoor production of agricultural crops tends to be characterized by natural fluctuations in average productivity due to external factors such as weather conditions and the field lifecycle.[16] It is therefore tenuous to attribute to effort any changes in worker productivity observed before and after a minimum wage hike. To isolate the effects of worker effort from external determinants of labor productivity, we therefore employ a difference-in-differences strategy. We first capture each worker's baseline productivity by estimating their fixed effects using data from weeks 1-5 of the harvesting season. We then look for possibly differential productivity changes of individual workers from weeks 6-8 to weeks 9-12 (or weeks 10-12 excluding the transition week)—January 1, 2009 falls in week 9—by their baseline productivity. Since low fixed effect workers are always more likely to fall below a minimum wage than high fixed effect workers when subject to a common production environment, to the extent there is a minimum wage effect on worker effort, we expect a disproportionate increase in observed productivity in the lower part of the fixed effects distribution as the minimum wage increases.

Based on data from weeks 1-5, we first estimate the following regression:

$$(1)\quad y_{ivft} = \alpha_i + \phi_{vf} + \psi_t + \gamma_1 \boldsymbol{Z}_{it} + \gamma_2 \boldsymbol{X}_{vft} + u_{ivft},$$

where y_{ivft} denotes (log) worker i's output per hour for variety v in field f on day t. Worker fixed effects, which capture each worker's baseline productivity, are denoted by α_i. We further include

[16] Appendix Figure A.6 shows the farm-level daily productivity across harvesting days.

variety-field fixed effects (ϕ_{vf}) to capture any between-variety differences that are also field specific, and day fixed effects (ψ_t) to account for such day-specific common shocks as weather or crop density. As a result, the estimates of α_i capture the differences between workers who harvest the same variety in the same field while eliminating day-specific common shocks. Lastly, we include variety-field-day specific observed characteristics such as a cubic polynomial of the variety-field lifecycle,[17] supervisor fixed effects (collected in $\boldsymbol{X}_{vft}$), and a cubic polynomial of worker experience, measured as cumulative work hours from the beginning of the season to day t, $\boldsymbol{Z}_{it}$. Essentially, we want to capture in α_i worker's fixed characteristic, which we refer as baseline productivity, while accounting for other determinants of worker's observed productivity.

Next, based on the estimated fixed effects $\hat{\alpha}_i$, we classify workers into different bins (e.g., deciles), and then estimate the following regression (based on transactions over weeks 6–12):

$$(2)\quad y_{ivft} = \sum_{k=1}^{K} \delta_k \left(Post_t \times D_i^k\right) + \hat{\alpha}_i + \phi_{vf} + \psi_t + \beta_1 \boldsymbol{Z}_{it} + \beta_2 \boldsymbol{X}_{vft} + e_{ivft},$$

where y_{ivft} again denotes (log) worker i's output per hour for variety v in field f on day t. The variable $Post_t$ assumes the value of unity if day t belongs to weeks 9-12 and zero otherwise, while D_i^k indicates whether worker i is in the kth decile on the (pre-estimated) worker fixed effects distribution. The omitted categories are deciles $K+1$ through 10. We include the pre-estimated worker fixed effects $\hat{\alpha}_i$ and day fixed effects ψ_t. As in equation (1), we also control for variety-field fixed effects ϕ_{vf}, and for the variables in $\boldsymbol{Z}_{it}$ and $\boldsymbol{X}_{vft}$. The diff-in-diff estimate δ_k measures the disproportionate productivity changes of lower productivity workers in decile k relative to workers in the upper deciles ($K+1$ through 10). All standard errors are clustered by day.

[17] The variety-field lifecycle is computed as the number of days the variety has been picked in that field by day t divided by the total number of days it has been harvested in that field during the season.

We first compare the productivity changes in the bottom five deciles ($K = 5$) with those in the upper deciles and then gradually refine the treatment and comparison groups. Because the deciles are based on predefined characteristics (i.e., worker fixed effects in weeks 1-5), this method of classifying treatment status is exogenous to workers' actual effort choices during the analytic window (weeks 6-12). In practice, we also take a non-parametric approach by estimating local linear regressions of worker productivity along the distribution of the (pre-estimated) worker fixed effects and comparing the estimates from weeks 6-8 and weeks 9-12, respectively. This allows us to see where the productivity increase (from the pre to the post periods) appears without arbitrarily specifying the location of the "treated" workers along the distribution. The identifying assumption for either approach is that conditioning on the included controls, in particular, the harvesting day fixed effects that capture farm-level common shocks specific to each day (e.g., weather or crop density), there are no significant changes on or around January 1, 2009, other than the new minimum wage that might *differentially* influence the effort choices of workers in the lower versus higher part of the worker fixed effects distribution. That is, low versus high fixed effect workers would have the same productivity growth (i.e., the same change in log productivity) around January 1 in the absence of the minimum wage hike.

4. Results

4.1 Worker Fixed Effects

For our identification strategy, it is important that the estimated worker fixed effects (from weeks 1-5) are a good proxy for worker's baseline productivity. If the fixed effects are noisy, for instance, picking up the effects of initial bad draws of otherwise high ability workers (or the effects of initial excess efforts by otherwise low ability workers who may want to appear high productivity), then there may be a mechanical negative relationship between the (noisy) fixed effects and productivity growth in later periods due to mean reversion. We take several approaches to ensure that this would not be the case. First, we check whether our estimated fixed effects (based on weeks 1-5) are indeed informative and a good predictor of worker productivity *outside* its estimation window, in particular for weeks 6-8 (i.e., the "pre" period with respect to the January 1, 2009 minimum wage hike). Second, we find no systematic productivity changes along the fixed effects distribution in the placebo year (autumn 2009), when the minimum wage remained constant throughout.

We focus on workers who worked for at least 35 hours during weeks 1-5, which results in a sample of 768 unique employees with a mean of 17 work spells.[18] Based on the estimated fixed effects (from weeks 1-5), whose mean is (obviously) zero with a standard deviation of 0.17, we classify workers into different bins (quintiles, deciles, or percentiles). We then examine the relationship between worker's observed productivity in weeks 6-8 (the "pre" period with respect to the minimum wage hike) and their baseline productivity. Below we present a series of evidence that the pre-estimated fixed effects are indeed a good predictor of worker's productivity and hence the risk of falling below the minimum wage. In the graphical analysis below, we use worker-weekly as the unit of observation—the unit at which paychecks are issued and minimum wage adjustments are made—without using additional controls. In our regression analysis on worker efforts, we use a finer variation with an extensive list of controls to account for external determinants of productivity.

Figure 2 plots the worker-weekly productivity distribution for weeks 6–8 by the quintiles of worker fixed effects. Because of such external factors as weather and field lifecycle, there is a

[18] For robustness, we also use a cutoff of 50 hours (fewer workers but more spells) and 20 hours (more workers but fewer spells) to estimate worker fixed effects.

fair amount of dispersion in worker productivity even for the same quintiles. However, *on average*, workers in the lower quintiles tend to have lower productivity, suggesting that the estimated worker fixed effects (from weeks 1-5) are indeed informative. The monotonic relationship between worker productivity (in weeks 6-8) and the pre-estimated worker fixed effects is also visualized in Figure 3, which displays the percentile-weekly mean productivity (collapsed from worker-weekly observations) against the percentile of worker fixed effects.

[Figures 2 and 3]

Given the monotonicity in Figure 3, it is easy to imagine that workers in the lower part of the fixed effects distribution are more likely to fall below the new (and old) minimum wage than those in the upper part. In Figure 4 illustrates this. Based on worker-weekly productivity observations (from weeks 6-8), we compute for each percentile of worker fixed effects, the share of observations that fall below the current and new minimum wages. As shown, the probability to fall below the minimum wage is greater at the lower part of the distribution than in the higher part. Moreover, the probability shifts upwardly as we apply the new minimum wage to the same productivity data.

[Figure 4]

Based on these figures, the pre-estimated worker fixed effects (based on weeks 1-5) seem to be a reasonable proxy for workers' baseline productivity, which we use to define workers' treatment status with respect to the minimum wage. In particular, we hypothesize that low fixed effect workers have a greater incentive to increase effort than high fixed effect workers when both are subject to the minimum wage hike on January 1, 2009.

4.2 Minimum Wage Effect on Worker Effort

4.2.1 Main results

In Figure 5, we present the results of a local linear regression of the residual log output per hour against the percentiles of worker fixed effects, where the residual log output per hour is obtained by controlling for all external factors that contribute to observed productivity (day FE, variety-field FE, a cubic of variety-field lifecycle, and supervisor FE). The vertical difference in the estimates for the post (weeks 9-12) and the pre (weeks 6-8) periods is plotted in Figure 5. The 95 percent confidence intervals are bootstrapped by harvesting day, based on 500 draws. The figure reveals a disproportionate increase in productivity around and below the 40th percentile relative to the upper part of the distribution.

[Figure 5]

Next, we examine this in a regression framework. The estimates of equation (2) are given in Table 2, which contrasts the effort responses of workers in the lower deciles with those of workers further up the distribution. The estimates in column 1, which compare the productivity change in the bottom half (deciles 1-5) of the worker fixed effects distribution with that of the top half (deciles 6-10), reveal that the productivity change in decile 5 is no different from that in the control group (deciles 6-10). On the other hand, worker productivity in the lower four deciles (1-4) increases disproportionately relative to the above median deciles, a 3 to 8 percent increase in the post period relative to the pre period. Column 2 then restricts the comparison to deciles 1-4 against deciles 5-8, which leads to estimates similar to column 1. In column 3, we estimate the average changes among deciles 1-4 relative to deciles 5-8. The estimates show that the output per hour for workers in the bottom four deciles increases a disproportionate 4 percent relative to workers in the comparison group (deciles 5-8).[19]

[Table 2]

Columns 4 through 9 report the results of several robustness checks, the first three of which exclude transition week 9 from the sample (columns 4–6), and the second three of which restrict the analysis to weeks 7–11, making this sample the most homogenous around the minimum wage hike (columns 7–9). The magnitude of these estimates changes only slightly.

Further, to investigate whether the effects detected might result from changes in worker composition, we repeat this analysis using a balanced sample of workers who worked in both the pre (weeks 6–8) and post (weeks 9–12) periods. In these estimates, reported in Table 3, the sample size becomes slightly smaller, but the patterns are very similar to those in Table 2. Thus, the increase in output per worker detected is unlikely to be driven by compositional changes.

[Table 3]

Given the minimum wage increase of 6% (from $6.79 to $7.21), the productivity increase of about 3-4% among the bottom four deciles seems reasonable. That is, while the higher minimum wage is costly for the firm, a part of that can be offset by productivity increases. As an aside, had the productivity increase been more than proportionate to the minimum wage increase (i.e., larger than 6%), that would suggest the high minimum wage as an efficiency wage (Shapiro and Stiglitz 1984; Rebitzer and Taylor 1995), which the firm should volunteer for regardless of the government regulation. Clearly, this is not the case and the high minimum wage is still costly for the firm even after taking the productivity increases into account.

[19] The results are similar when deciles 5-10 are used as the comparison group.

4.2.2 Robustness and placebo

Our baseline sample consists of workers who worked for at least 35 hours during weeks 1–5 (768 unique workers with a mean number of work spells of 17). We also use a cutoff of 50 hours (556 workers and a mean of 18 spells) and 20 hours (963 workers and a mean of 16 spells) to estimate worker fixed effects. As shown in Appendix Table A.2, our key results (in Tables 2 and 3) are invariant to the more and less restrictive sample choices. We also estimate equation (2) separately by tomato varieties: Appendix Table A.3. The effects are similar to our baseline although the estimates are less precise.

To corroborate our main findings, we also perform a placebo analysis by conducting the same investigation for the autumn 2009 season, which spans 12 weeks from October 2009 to January 2010.[20] Throughout this season, the piece rates are exactly the same as before, with a constant minimum wage of $7.25 (the federal minimum wage effective on July 24, 2009). We assume a hypothetical minimum wage hike beginning either in the week of January 1 (week 11 in this context) or week 9.

Figure 6 presents the results of local linear regressions. The upper panel treats the week of January 1 or later as the post period, and the lower panel uses week 9 or later as the post period. No disproportionate increase in productivity is observable among workers at the lower end of the distribution under either definition of post period. This finding is also confirmed in Table 4, which reports the results of examining worker efforts in a regression framework by treating either the week of January 1 or later (i.e., week 11 or later in this context) or week 9 or later as the post period (in panels A and B, respectively). In neither case does any significant increase in

[20] The average output per hour (dollar/hour) during this period is $8.79 with a standard deviation of $3.59, which is based on 16,197 transactions for 452 unique workers.

productivity emerge among lower decile workers relative to workers in the upper part of the distribution.

[Figure 6]

[Table 4]

Overall, the results of the placebo analyses indicate that the results of our main analysis for the autumn 2008 season, rather than merely reflecting a January 1 or week 9 effect possible in any year irrespective of minimum wage hike, are likely due to the January 1, 2009 increase in the minimum wage. They also rule out mean reversion as a driver of our main results.

4.3 Employment Outcomes

The positive effort responses of workers are consistent with both the competitive motive in Stigler (1946)—i.e., workers try to preempt the (perceived or real) threat of discharge—and behavioral motives (e.g., Akerlof 1982; Fehr, Goette and Zehnder 2009)—i.e., workers feel bad when own productivity is too far below the (minimum) wage even if there are no risks of discharge. Distinguishing the two motives is not straightforward. In particular, to rule out the behavioral motive in favor of the competitive motive, one needs to show that the threat of discharge is indeed real. However, even if we are operating in the world of Stigler (1946), actual discharges will occur only in the absence of worker effort responses. That is, sufficient worker effort responses obviate the firm's need to shed workers, resulting in no discharge even when the *threat* is alive and well.

While we are agnostic about either interpretation for worker motives, it is nonetheless of empirical interest whether there are any changes in worker employment outcomes in relation to the minimum wage hike. Before we proceed, it is worthwhile understanding the evolution of farm-level employment during the season. As panel (a) of Figure 7 shows, the farm's lifecycle (and hence its labor demand cycle) is such that workers are added towards the middle of the season and workers are shed after the peak of the season. This can be shown in a different way. Panel (b) of Figure 7 plots the ratio of workers employed in the previous week to workers employed in the present week, which is a proxy for the tightness of the intra-firm labor market. This number tends to exceed 1 in our main estimation window (weeks 6-12), indicating that there is some room for downward adjustments in worker employment status.

[Figure 7]

The question is how the scarce employment opportunities are allocated between the low versus high productivity workers, which we examine below. Consider the following equation:

$$(3)\quad employment_{it} = \eta_1 D_i + \eta_2 (Post_t \times D_i) + \psi_t + \omega_{it},$$

where $employment_{it}$ is worker i's employment outcome on day t. The variable D_i indicates whether worker i is in the bottom four deciles in the (pre-estimated) fixed effects distribution. The variable $Post_t$ assumes the value of unity if day t belongs to weeks 9-12 and zero otherwise. Day fixed effects are absorbed in ψ_t. As before, the treatment status D_i is based on the worker's pre-determined characteristic (from weeks 1-5) and is orthogonal to his/her contemporaneous decisions.

In the absence of the second term, the equation estimates the simple difference between low versus high productivity workers. The coefficient η_1 measures whether low productivity workers are *in general* employed less frequently than high productivity workers. Once we include the interaction term ($Post_t \times D_i$), the coefficient η_2 picks up the excess selectivity in the post period (weeks 9-12) *relative to* the pre period (weeks 6-8). Depending on what we think of the timing of the firm's employment adjustments—even before the new minimum wage kicks in or only after—both the simple and double differences are of interest.

We present two sets of results: unconditional—using all workers—and conditional on the worker having worked in the previous week. The coefficients from the unconditional estimation may reflect both workers' voluntary quits and the firm's firing (non-hiring) decisions. The coefficients from the conditional estimation are likely more reflective of the firm's decision since workers who were present and working in the previous week are likely those who are available and are hoping for employment in the present week.

Figure 8 displays the daily total hours of employment—zero hours are assigned in case of non-employment—by low (deciles 1-4) versus high (deciles 5-10) fixed effect workers across different weeks. Panel (a) uses all workers in our sample and panel (b) restricts attention to workers who were employed in the preceding week. In both panels, the line for low fixed effect workers is generally below that for high fixed effect workers. In panel (b), the separation appears more pronounced in the post period (weeks 9-12).

[Figure 8]

The pattern in Figure 8 can be examined in a regression framework. Table 5 displays the estimates of equation (3) without and with the interaction term ($Post_t \times D_i$), corresponding to the single and double differences, respectively. Panel A shows the unconditional estimates based on all workers and panel B the conditional—on the worker having worked in the previous week—estimates. All regressions include day fixed effects. The dependent variable in columns 1-2 is the total hours worked by each worker per day (zero hours are assigned for workers not working that day). Columns 3-4 focus on the extensive margin (i.e. 1 if working that day and 0 otherwise) and columns 5-6 on the intensive margin (i.e., total hours worked conditional on working that day).

[Table 5]

Take the estimate in column 1 of panel A. It shows that *in general*, workers in the bottom four deciles obtain 0.345 fewer hours of employment per day than those in upper deciles, which is about 14% (0.345/2.482) of the mean employment hours, but this may be driven by both worker and firm choices. Looking at column 1 in panel B, which conditions on workers who worked in the previous week, we find that the corresponding selectivity is about 7% (0.242/3.365). This effect comes from both the extensive and intensive margins (columns 3 and 5) though the former channel appears more dominant. Next turning to the double difference estimator ($Post_t \times D_i$) in column 2, we find that the excess selectivity in the post period *relative to* the pre period is 7% (0.166/2.482 in Panel A) to 9% (0.307/3.365 in Panel B) of the mean employment hours, which is driven mostly by the extensive margin (column 4).

As a way of comparison, we also conduct a similar analysis for the autumn 2009 season, where we impose a hypothetical minimum wage increase in week 9. Table 6 displays the simple and double differences for the placebo year. Column 1 shows that *in general* workers in the bottom four deciles obtain 6% (0.220/3.430) fewer hours of employment than those in the upper deciles, which is very similar to that for the program year (as presented in Table 5). Looking at the coefficient on $Post_t \times D_i$ in column 2, workers in lower deciles appear to obtain more employment hours (Panel A) in the post period, but this can be driven by both worker and firm behavior. To get closer to firm's behavior, focus on panel B, which conditions on workers who worked in the previous week and hence are more likely to be available in the present week. In Column 2 of Panel B, we do not find any evidence of excess selectivity in the hypothetical "post" period *relative to* the hypothetical "pre" period, whereas the corresponding diff-in-diff estimate in Table 5 was about 9%.

[Table 6]

Based on Tables 5 and 6 and depending on the measure of selectivity (simple or double difference), we could argue that the increased selectivity due to the January 1, 2009 minimum wage hike (relative to the selectivity that is operative anyway even in the comparison year) is up to 7-9 percentage points, *with the caveat* that the underlying labor demand cycles are not identical for autumn 2008 and autumn 2009 seasons (or for any two years). As shown in Appendix Figure A.7, the intra-firm labor market (for weeks 6-12) in autumn 2009 appears overall less tight than that in autumn 2008. This means in autumn 2008, there is *more* scope for selective non-employment of low productivity workers than for the placebo year. Therefore, the 7-9 percentage points increase in selectivity we report is likely the *upper bound* of the effect attributable to the minimum wage hike.

That the change in selectivity—i.e., selective non-hiring of low productivity workers—is rather modest (up to 7-9 percentage points) and is nowhere near 100% may imply that despite the casual nature of the employment relationship in this setting, the firm cannot afford "discharging"—or "not hiring", to be more precise—*all* the low productivity workers as it needs to maintain the workforce above a certain size to meet the harvesting needs. Moreover, given our findings on worker efforts, the modest effect on employment is to some extent anticipated: According to Stigler (1946)'s logic, sufficiently large effort responses should obviate the firm's need to shed workers and in our case, worker productivity went up by 3-4% when the minimum wage rose by 6%.

4.4 Discussion

The results of our analysis above indicate that in response to the January 1, 2009 minimum wage hike, the productivity of workers in the bottom four deciles of the productivity distribution increases disproportionately relative to workers in the higher deciles. For the minimum wage increase of 6% (from $6.79 to $7.21), the productivity increase was about 3-4%.

In the absence of such worker responses, a higher minimum wage means a higher labor cost for the firm because of higher associated compliance costs. If, however, some subminimum wage workers increase their efforts, it may (at least partially) offset these rising costs. We examine these alternatives using the counterfactual exercise reported in Table 7, which is based on data for weeks 1–8, [21] when the prevailing minimum wage is $6.79 and the compliance cost incurred by subminimum wage workers is $6,522.

[Table 7]

We consider the consequences of a minimum wage hike from $6.79 to $7.21. In the absence of worker effort responses the minimum wage hike will raise the firm's compliance cost to $10,606. However, as earlier analyses show, some workers may increase their efforts, which would bring the firm's compliance cost down to $8,625, which is $1,981 less than the projected cost of $10,606. The exercise above, however, takes only worker responses into account. Once an additional response by the firm is added in—namely, less frequent hiring of subminimum wage workers—the firm's compliance cost may be lowered even further. For instance, if the firm reduces the employment probability of workers in the bottom four deciles by 7 percent, then the compliance cost in columns 2 and 3 of Table 7 would decrease to $9,980 and $8,138, respectively (see columns 4 and 5). Overall, therefore, this exercise shows that both worker and firm responses, if present, can to some extent offset the increased compliance cost burden as the minimum wage increases.

[21] For this counterfactual exercise, we fix the production schedule at the period of pre-MW hike so as not to confound the minimum wage effect with a seasonality effect.

One issue we have so far been silent about is whether the higher minimum wage helps the workers. From the perspective of (subminimum wage) workers, the highest rent could be earned if he/she can still keep the job and get paid the minimum wage (which is above his/her productivity) without increasing effort. In reality, however, as the benefit (i.e., the minimum wage) increases, the cost (i.e., worker effort cost) also increases. Therefore, it is *a priori* unclear how much rent can stay with the (subminimum wage) workers. Abstracting away from such issues as the shape of the workers' cost function, risk aversion or the insurance value of the minimum wage, consider a very rough calculation of worker gains in purely monetary terms. For a minimum wage increase of 6%, worker productivity increased by 4% with an associated risk of discharge by up to 9%. Assume the *worst case scenario* that workers earn nothing if losing employment at this farm (although in reality, they may land a minimum wage job elsewhere with a nonzero probability). Then, the net gain for workers is roughly 1.5-2 percent of the baseline minimum wage ($6.79 per hour) or about 10-14 cents per hour. [22] Therefore, even in this worst case scenario, an average (subminimum wage) worker has some modest gains, albeit smaller than the full 42 cents increase in the minimum wage (due to their effort responses). Although based on a very crude calculation, this is consistent with the observation of Holzer, Katz and Krueger (1991) that *ex ante* rents generated for employees by the minimum wage tend not to be completely dissipated by measures available to the employer.

5. Conclusions

By employing a direct and high frequency measure of individual-level productivity on a homogenous task in the context of Florida's minimum wage hike on January 1, 2009 (from $6.79

[22] The net gain is {0.06*(1-0.09) + 0.00*(0.09)} – 0.04 = 0.015 if assumes 9% excess selectivity and 0.06*(1) – 0.04 = 0.02 if assumes zero excess selectivity.

to $7.21), we examined the minimum wage effect on worker effort. We find that in response to the 6% increase in the minimum wage, worker productivity (i.e., output per hour) in the bottom four deciles of the (pre-estimated) worker fixed effects distribution increased by 3-4% relative to that in the upper deciles, suggesting that productivity increases driven by worker *effort* may help mitigate the higher labor costs associated with the minimum wage.

Several cautions are warranted. First, this margin of adjustment can only work within relatively low ranges of the minimum wage. If the minimum wage continues to rise to a higher level, workers may no longer be able to keep up their effort (and productivity) with the minimum wage due to physical or cognitive limits. At that point, the firm may adopt an entirely different personnel policy than observed here and worker effort responses may no longer be a valid channel to absorb the rising labor cost associated with the minimum wage.

Second, we focus here on workers who do not have a long-term contract and are hired on a day-to-day basis within a harvesting season. If workers had extended-term contract, the incentive structure in place may look quite different. One the one hand, the fact that the job is more or less guaranteed—at least for the fixed term—may reduce the incentive to increase effort in response to the minimum wage. On the other hand, the job is worth more (in present discounted values) than a daily laboring, hence the workers may find a greater incentive to increase effort to keep it. Although not in the context of minimum wage, the incumbent workers' effort responses as documented in Lazear, Shaw and Stanton (2016) seem to suggest that the latter effect likely dominates.

Although a plausible channel of adjustment to the minimum wage, incumbent workers' effort responses have been largely overlooked in the literature, probably because in most settings, measuring individual-level productivity around a minimum wage hike—without convolution with task and workforce composition—is difficult. This work, although focused on a particular firm in a particular industry, opens a new avenue for future research, particularly in terms of whether labor productivity serves as a mechanism for adjusting to the minimum wage in other firms or industries.

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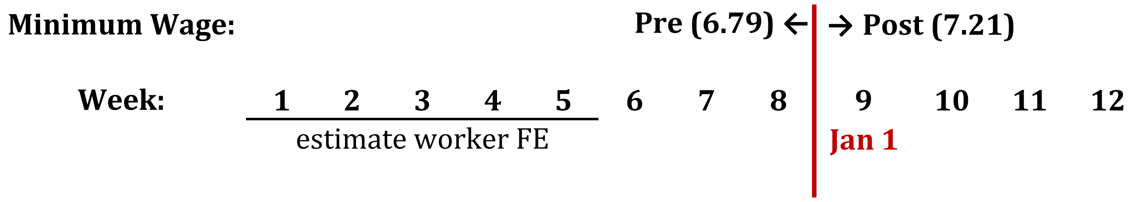
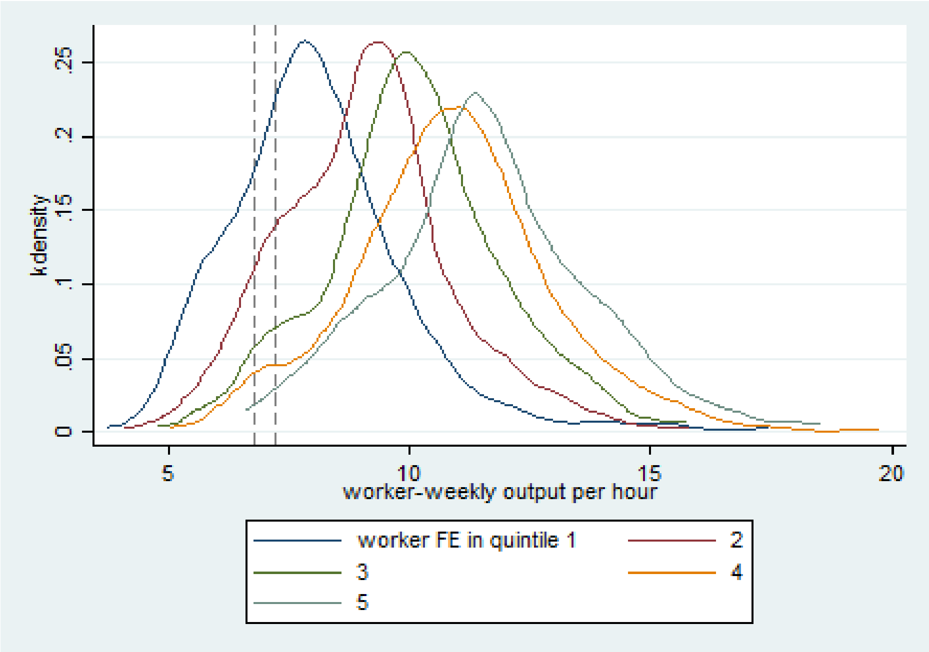
Figure 1: Timeline of the 2009 minimum wage hike



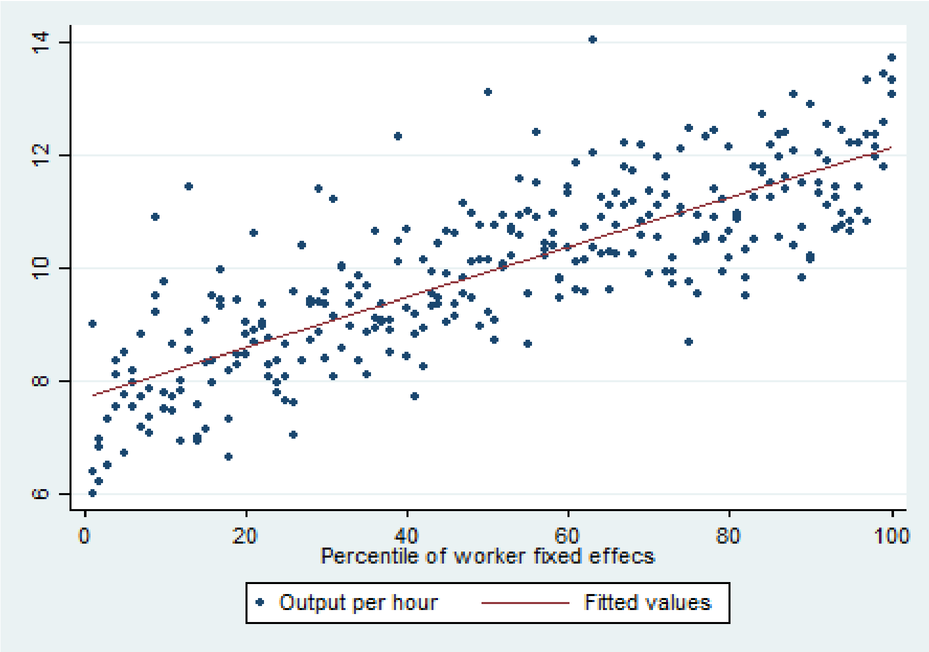
The harvesting season being investigated spans 12 weeks from November 2008 to January 2009, during which Florida's state minimum wage rose from $6.79 to $7.21 on January 1, 2009, a date that falls in week 9 of the analytic window. The pre period is defined as weeks 1-8; the post period as weeks 9-12 (or weeks 10-12, when transition week 9 is excluded). The estimation of worker fixed effects is based on transactions during the initial 5 weeks; that of worker effort responses on those during weeks 6-12.

Figure 2: Distribution of worker productivity by quintiles of worker fixed effects



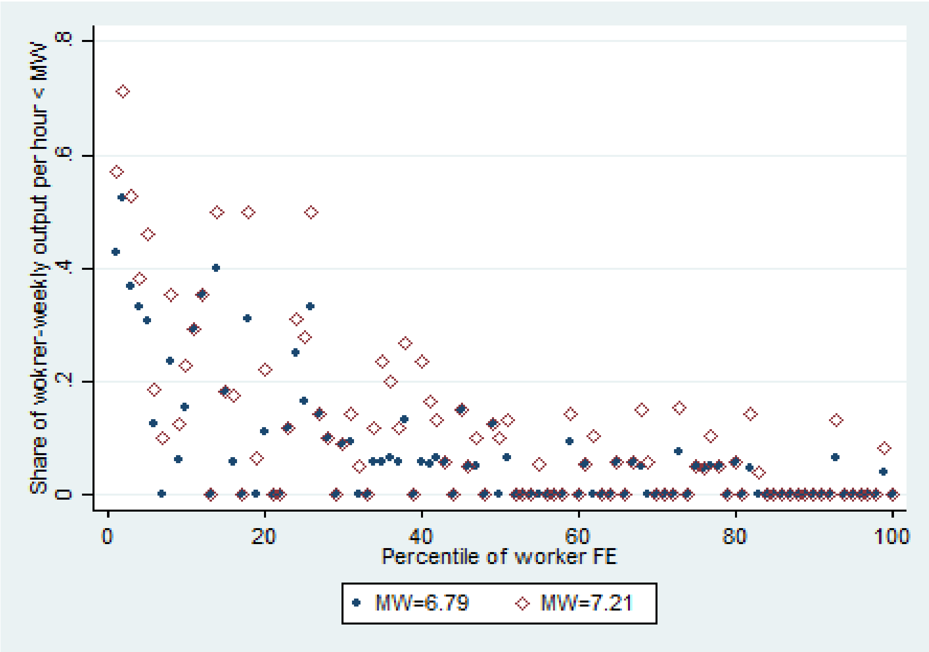
Worker-weekly output per hour during weeks 6-8. The worker fixed effects as estimated by equation (1) using transactions during weeks 1-5. The dashed vertical line indicates the old and new minimum wages of $6.79 and $7.21, respectively.

Figure 3: Average productivity by percentiles of worker fixed effects



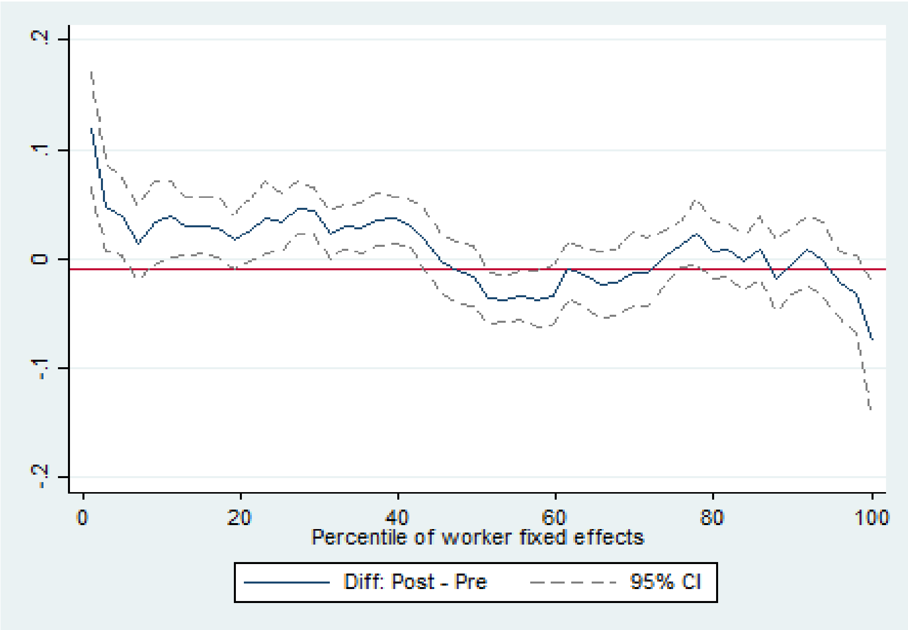
This figure plots the average weekly productivity of workers in different percentiles of the worker fixed effects during weeks 6-8. Percentile-weekly mean productivity is obtained by taking the mean of worker-weekly observations in that percentile. The worker fixed effects are estimated by equation (1) using transactions during weeks 1-5. The coefficient (SE) of the fitted line is 0.044 (0.002) and the R-squared is 0.65, based on 300 observations.

Figure 4: Propensity to fall below the minimum wage by percentiles of worker fixed effects



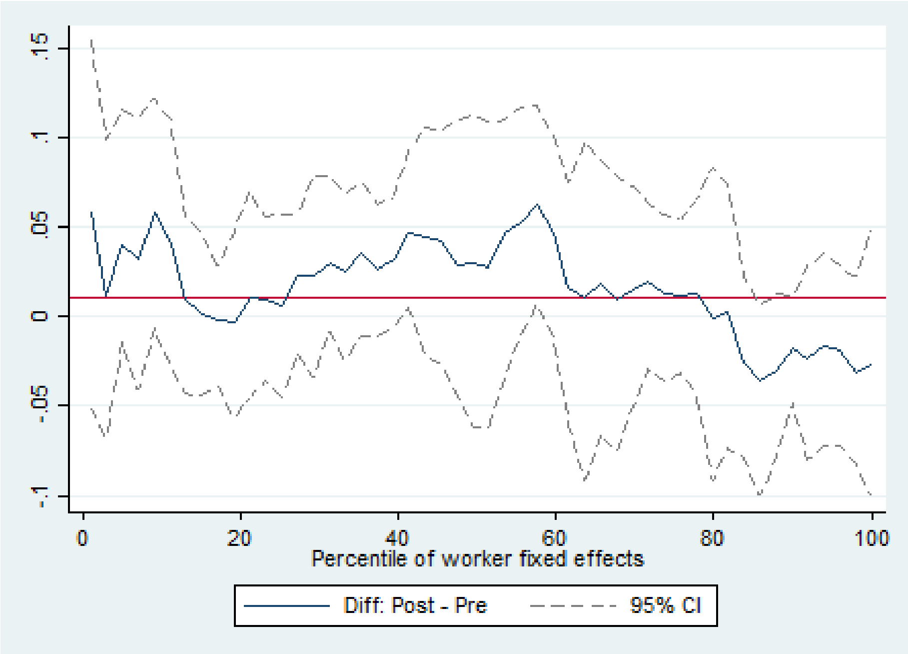
This figure plots for each percentile of worker fixed effects, the share of worker-weekly productivity observations during weeks 6-8 that fall below the current ($6.79) and new ($7.21) minimum wages, respectively. The worker fixed effects are estimated by equation (1) using transactions during weeks 1-5.

Figure 5: Local linear regression of transaction-level output per hour against worker fixed effects

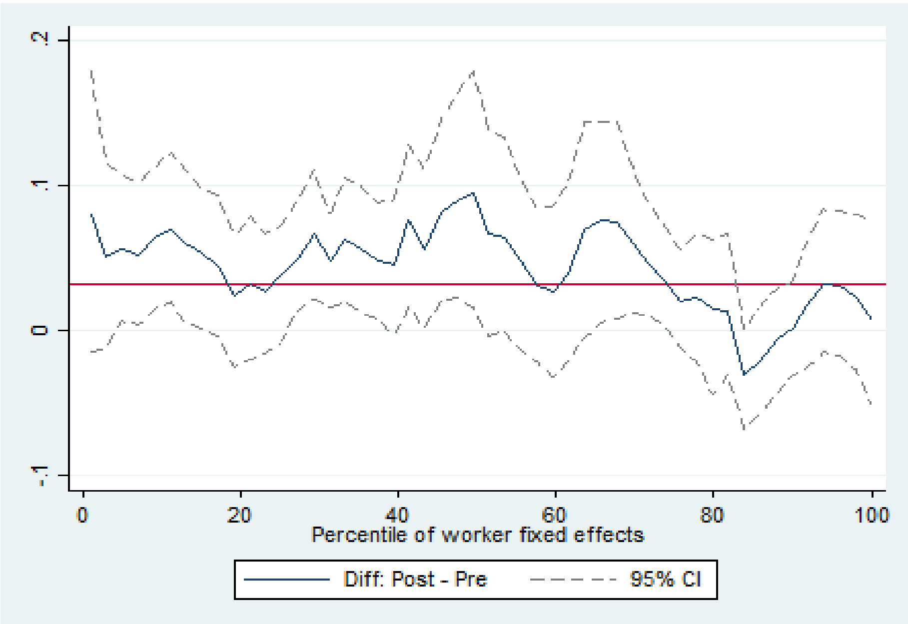


Local linear regression of the residual log output per hour on the percentiles of the pre-estimated worker fixed effects is estimated separately by the pre and post periods, and the post- pre difference is plotted. The kernel is rectangular and the bandwidth is 1/20th of the range of percentile scores. The residual log output per hour is obtained after day FE, variety-field FE, a cubic of variety-field lifecycle and supervisor FE are controlled for. Worker fixed effects are estimated based on equation (1) using data from weeks 1-5. The 95% confidence intervals are bootstrapped by harvesting day based on 500 draws. The horizontal line represents the mean of the difference in the upper half (deciles 6-10) of the productivity distribution.

Figure 6: Local linear regression of transaction-level output per hour against worker fixed effects: Placebo year



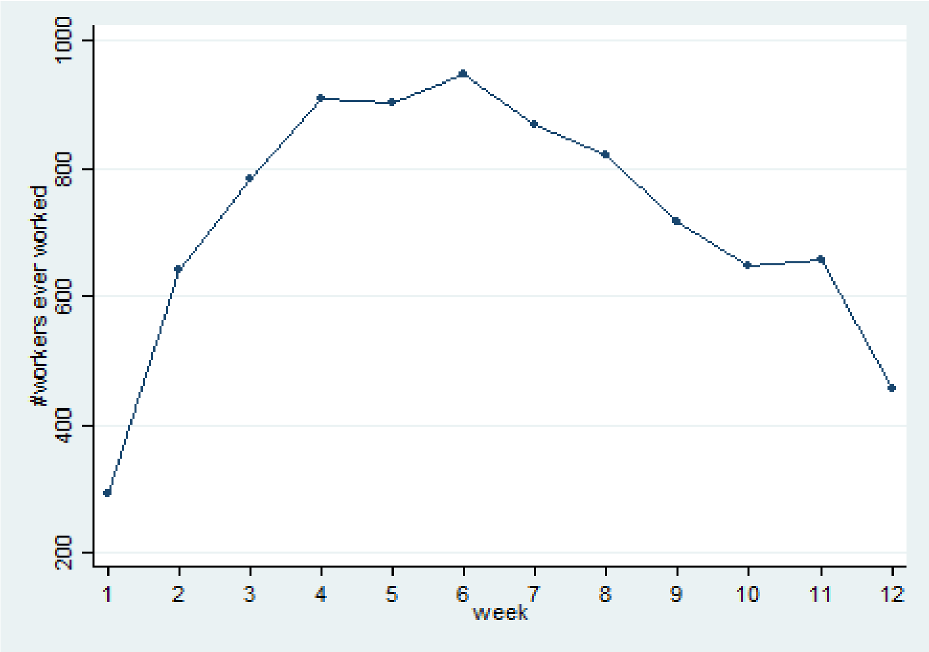
(a) week of January 1 or later as Post



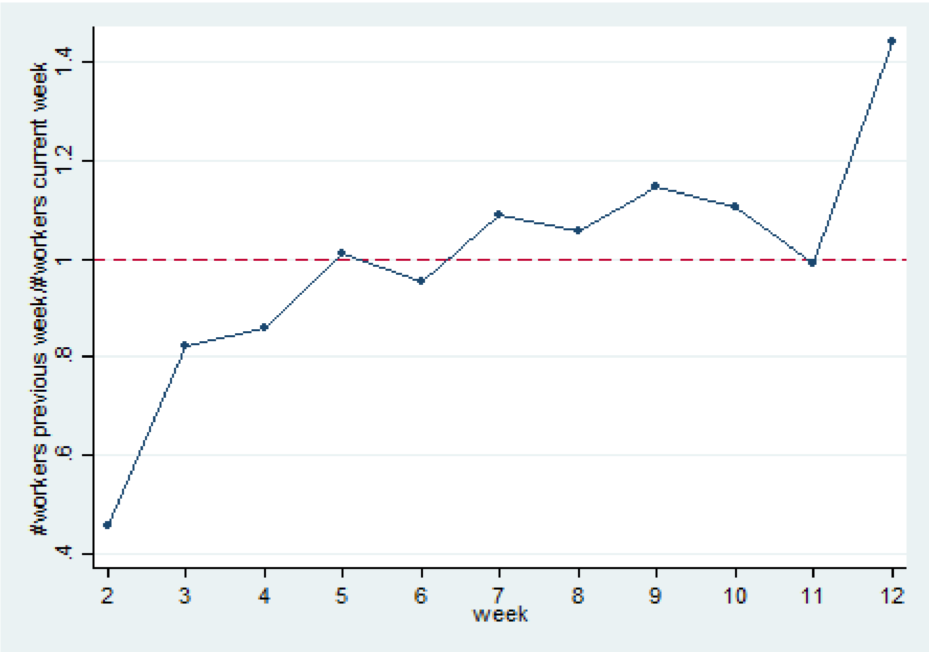
(b) week 9 or later as Post

Local linear regression of the residual log output per hour on the percentiles of the pre-estimated worker fixed effects is estimated separately by the pre and post periods, and the post- pre difference is plotted. The kernel is rectangular and the bandwidth is 1/20th of the range of percentile scores. The residual log output per hour is obtained after day FE, variety-field FE, a cubic of variety-field lifecycle and supervisor FE are controlled for. Worker fixed effects are estimated based on equation (1) using data from weeks 1-5. The 95% confidence intervals are bootstrapped by harvesting day based on 500 draws. The horizontal line represents the mean of the difference in the upper half (deciles 6-10) of the productivity distribution. Panel (a) uses the week of January 1 or later as the post period and panel (b) uses week 9 or later as the post period.

Figure 7: Labor demand cycle and tightness of intra-firm labor market



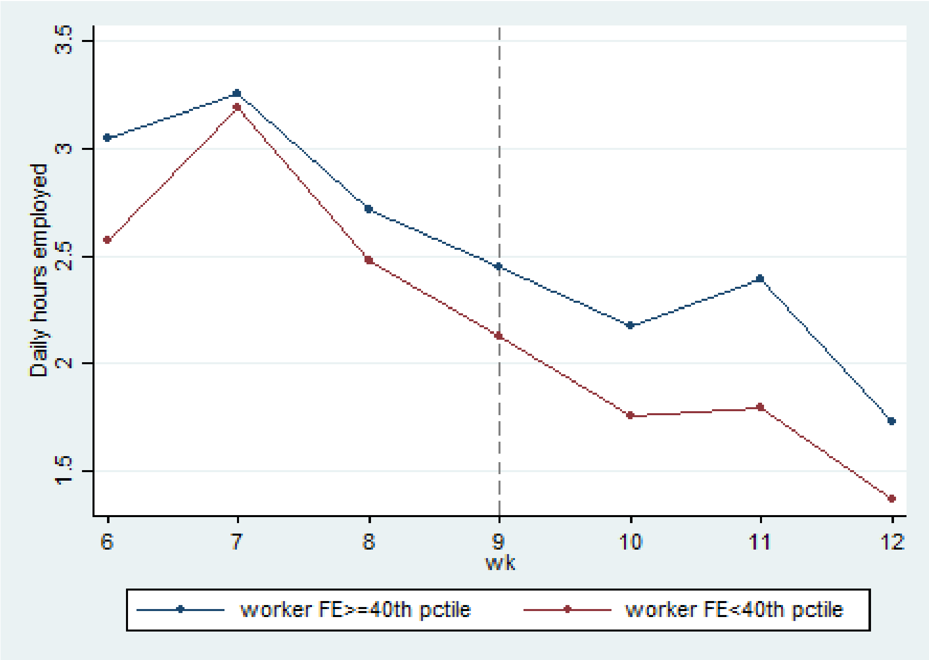
(a) Labor demand cycle



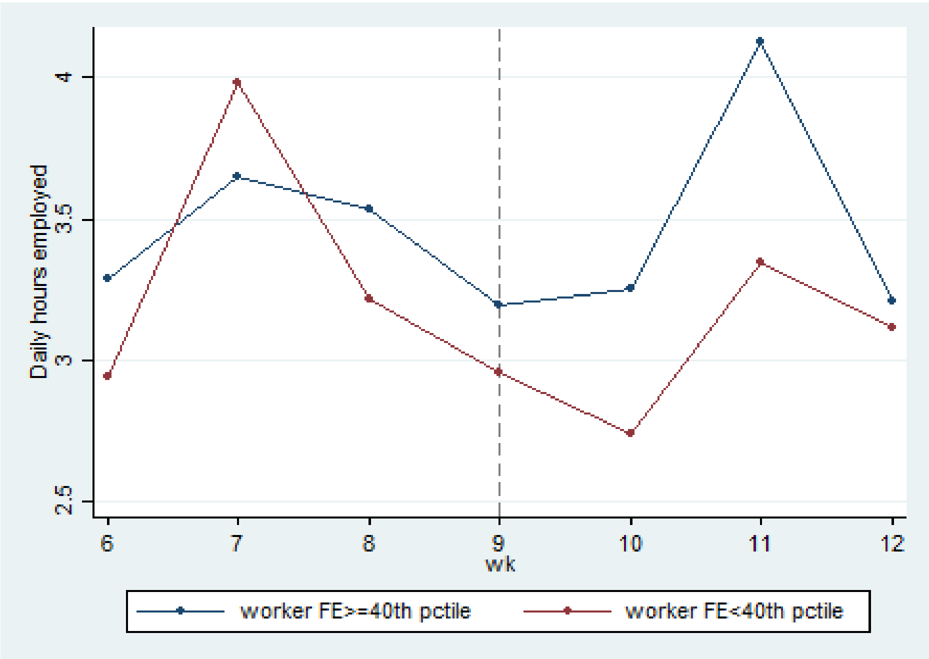
(b) Tightness of intra-firm labor market

Panel (a) shows the total number of workers employed in each week. Panel (b) shows the ratio of the number of workers employed in the previous week to that in the present week, which is a rough proxy for the tightness of the intra-firm labor market.

Figure 8: Employment outcomes of high versus low fixed effects workers



(a) Unconditional



(b) Conditional on workers who worked in the previous week

Dependent variable is the number of hours employed per day (zero hours if not employed). Panel (a) includes all workers in the worker FE sample. For panel (b), the sample for each week t includes workers who worked in the previous week (week t-1). The blue line shows the mean for workers with worker FE above the 40th percentile and the red line shows that for workers with worker FE below the 40th percentile, where worker fixed effects are as estimated by equation (1) using transactions during weeks 1-5. The vertical dashed line divides the weeks into the pre and post-minimum wage hike periods.

Table 1: Incidence and extent of the new minimum wage

	MW=$6.79	MW=$7.21
Minimum wage bites for the following share of:		
worker-weekly paychecks	0.109	0.147
workforce (for whom MW ever bites)	0.419	0.520
employment hours	0.090	0.128
Minimum wage compliance cost:		
in dollars	6522	10606
as share of raw wage bill	0.007	0.012

Notes: Both columns are based on 4644 worker-weekly observations (768 unique workers) for weeks 1-8. The first column applies the low MW of $6.79 (the current MW in weeks 1-8) and the second column applies the high MW of $7.21 (the new MW to take effect in weeks 9-12).

Table 2: Worker output per hour by deciles of worker fixed effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Dependent var.: Log (output per hour)								
Reference group	D6-D10	D5-D8	D5-D8	D6-D10	D5-D8	D5-D8	D6-D10	D5-D8	D5-D8
	All			*Exclude week 9*			*Weeks 7-11*		
Post x Deciles 1-4			0.040***			0.039***			0.032***
			(0.010)			(0.011)			(0.011)
Post x Decile 1	0.080***	0.072***		0.085***	0.079***		0.074***	0.068***	
	(0.021)	(0.018)		(0.021)	(0.017)		(0.024)	(0.020)	
Post x Decile 2	0.038**	0.035***		0.043**	0.040**		0.021	0.020	
	(0.015)	(0.012)		(0.020)	(0.015)		(0.016)	(0.012)	
Post x Decile 3	0.056***	0.053***		0.050***	0.046***		0.043***	0.042***	
	(0.013)	(0.011)		(0.016)	(0.014)		(0.013)	(0.010)	
Post x Decile 4	0.035***	0.034***		0.023*	0.022**		0.027**	0.029**	
	(0.012)	(0.010)		(0.013)	(0.009)		(0.013)	(0.011)	
Post x Decile 5	0.018			0.018			0.010		
	(0.014)			(0.019)			(0.015)		
Observations	16,157	12,499	12,499	13,811	10,689	10,689	12,051	9,289	9,289
R-squared	0.560	0.549	0.549	0.563	0.551	0.550	0.546	0.537	0.536

Notes: Based on transactions during weeks 6-12. Post=1 if week 9 or later. The deciles are based on the worker fixed effects estimated based on equation (1) using data from weeks 1-5. Columns 1, 4, and 7 use the full sample. All other columns exclude deciles 9 and 10. All regressions include pre-estimated worker FE, day FE, a cubic polynomial of worker experience, variety-field FE, a cubic polynomial of variety-field life-cycle, and supervisor FE. Robust standard errors clustered by day in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Worker output per hour by deciles of worker fixed effects: Balanced sample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Dependent var.: Log (output per hour)								
Reference group	D6-D10	D5-D8	D5-D8	D6-D10	D5-D8	D5-D8	D6-D10	D5-D8	D5-D8
	All			*Exclude week 9*			*Weeks 7-11*		
Post x Deciles 1-4			0.042***			0.041***			0.035***
			(0.010)			(0.011)			(0.011)
Post x Decile 1	0.087***	0.075***		0.092***	0.082***		0.083***	0.074***	
	(0.020)	(0.017)		(0.020)	(0.017)		(0.023)	(0.020)	
Post x Decile 2	0.043***	0.037***		0.048**	0.043***		0.028*	0.025**	
	(0.015)	(0.012)		(0.019)	(0.015)		(0.015)	(0.012)	
Post x Decile 3	0.061***	0.055***		0.054***	0.048***		0.048***	0.045***	
	(0.012)	(0.011)		(0.015)	(0.014)		(0.012)	(0.010)	
Post x Decile 4	0.037***	0.034***		0.025*	0.023**		0.031**	0.030***	
	(0.012)	(0.010)		(0.013)	(0.009)		(0.013)	(0.011)	
Post x Decile 5	0.021			0.020			0.014		
	(0.014)			(0.018)			(0.015)		
Observations	14,815	11,396	11,396	12,469	9,586	9,586	11,400	8,751	8,751
R-squared	0.565	0.550	0.549	0.569	0.550	0.550	0.550	0.538	0.537

Notes: The balanced sample includes workers who worked in both the pre (weeks 6-8) and post (weeks 9-12) periods. The deciles are based on the worker fixed effects estimated based on equation (1) using data from weeks 1-5. Columns 1, 4, and 7 use the full sample. All other columns exclude deciles 9 and 10. All regressions include pre-estimated worker FE, day FE, a cubic polynomial of worker experience, variety-field FE, a cubic polynomial of variety-field life-cycle, and supervisor FE. Robust standard errors clustered by day in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Worker output per hour by deciles of worker fixed effects: Placebo year

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent var.: Log (output per hour)					
Reference group	D6-D10	D5-D8	D5-D8	D6-D10	D5-D8	D5-D8
	A. Post=1 if week of Jan 1 or later			*B. Post=1 if week 9 or later*		
Post x Deciles 1-4			0.004			0.010
			(0.024)			(0.017)
Post x Decile 1	0.047	0.038		0.024	0.024	
	(0.040)	(0.039)		(0.026)	(0.029)	
Post x Decile 2	0.018	0.004		0.025	0.019	
	(0.029)	(0.027)		(0.021)	(0.023)	
Post x Decile 3	0.014	-0.010		0.017	0.004	
	(0.028)	(0.026)		(0.017)	(0.019)	
Post x Decile 4	0.023	0.001		0.012	0.000	
	(0.016)	(0.014)		(0.009)	(0.009)	
Post x Decile 5	0.021			0.021		
	(0.020)			(0.016)		
Observations	10,133	7,953	7,953	10,133	7,953	7,953
R-squared	0.513	0.496	0.495	0.513	0.496	0.496

Notes: Based on transactions during weeks 6-12. In Panel A, Post=1 if week of Jan 1 (week 11 in this case) or later. In panel B, Post=1 if week 9 or later. The deciles are based on the worker fixed effects estimated based on equation (1) using data from weeks 1-5. Balanced sample includes workers who worked in both the pre (weeks 6-10) and post (weeks 11-12) periods. Columns 1 and 4 use the full sample. All other columns exclude deciles 9 and 10. All regressions include pre-estimated worker FE, day FE, a cubic polynomial of worker experience, variety-field FE, a cubic polynomial of variety-field life-cycle, and supervisor FE. Robust standard errors clustered by day in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Employment outcomes by low versus high fixed effects workers

	(1)	(2)	(3)	(4)	(5)	(6)
	Daily hours worked, unconditional		Employed		Daily hours worked, conditional	
	A. Unconditional					
Mean of D.V.	2.482		0.439		5.656	
Post x Deciles 1-4		-0.166*		-0.021*		-0.034
		(0.086)		(0.012)		(0.088)
Deciles 1-4	-0.345***	-0.260***	-0.049***	-0.038***	-0.122**	-0.109
	(0.045)	(0.066)	(0.006)	(0.009)	(0.047)	(0.069)
Observations	28,416	28,416	28,416	28,416	12,468	12,468
R-squared	0.120	0.120	0.119	0.120	0.342	0.342
	B. Conditional on working previous week					
Mean of D.V.	3.365		0.594		5.660	
Post x Deciles 1-4		-0.307**		-0.045**		-0.017
		(0.130)		(0.019)		(0.096)
Deciles 1-4	-0.242***	-0.108	-0.028***	-0.009	-0.114**	-0.107
	(0.072)	(0.101)	(0.010)	(0.014)	(0.052)	(0.075)
Observations	20,239	20,239	20,239	20,239	12,031	12,031
R-squared	0.165	0.165	0.129	0.129	0.340	0.340

Notes: All regressions include day FE. Based on data for weeks 6-12. Post=1 if week 9 or later. The deciles are based on the worker fixed effects estimated based on equation (1) using data from weeks 1-5. Panel (a) includes all workers in the worker FE sample. For panel (b), the sample for each week t includes workers who worked in the previous week (week t-1). Robust standard errors clustered by day in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Employment outcomes by low versus high fixed effects workers: Placebo year

	(1)	(2)	(3)	(4)	(5)	(6)
	Daily hours worked, unconditional		Employed		Daily hours worked, conditional	
			A. Unconditional			
Mean of D.V.	2.733		0.494		5.529	
Post x Deciles 1-4		0.314**		0.045**		0.067
		(0.132)		(0.018)		(0.119)
Deciles 1-4	-0.163**	-0.337***	-0.012	-0.037***	-0.171***	-0.203***
	(0.071)	(0.097)	(0.010)	(0.013)	(0.059)	(0.073)
Observations	16,272	16,272	16,272	16,272	8,043	8,043
R-squared	0.136	0.137	0.131	0.131	0.253	0.253
			B. Conditional on working previous week			
Mean of D.V.	3.430		0.620		5.534	
Post x Deciles 1-4		0.172		0.024		0.036
		(0.151)		(0.021)		(0.119)
Deciles 1-4	-0.220***	-0.306***	-0.018*	-0.030**	-0.167***	-0.184**
	(0.077)	(0.104)	(0.011)	(0.014)	(0.059)	(0.069)
Observations	12,620	12,620	12,620	12,620	7,822	7,822
R-squared	0.196	0.196	0.195	0.195	0.252	0.252

Notes: All regressions include day FE. Based on data for weeks 6-12. Post=1 if week 9 or later. The deciles are based on the worker fixed effects estimated based on equation (1) using data from weeks 1-5. Panel (a) includes all workers in the worker FE sample. For panel (b), the sample for each week t includes workers who worked in the previous week (week t-1). Robust standard errors clustered by day in parentheses. *** p<0.01, ** p<0.05, * p<0.1

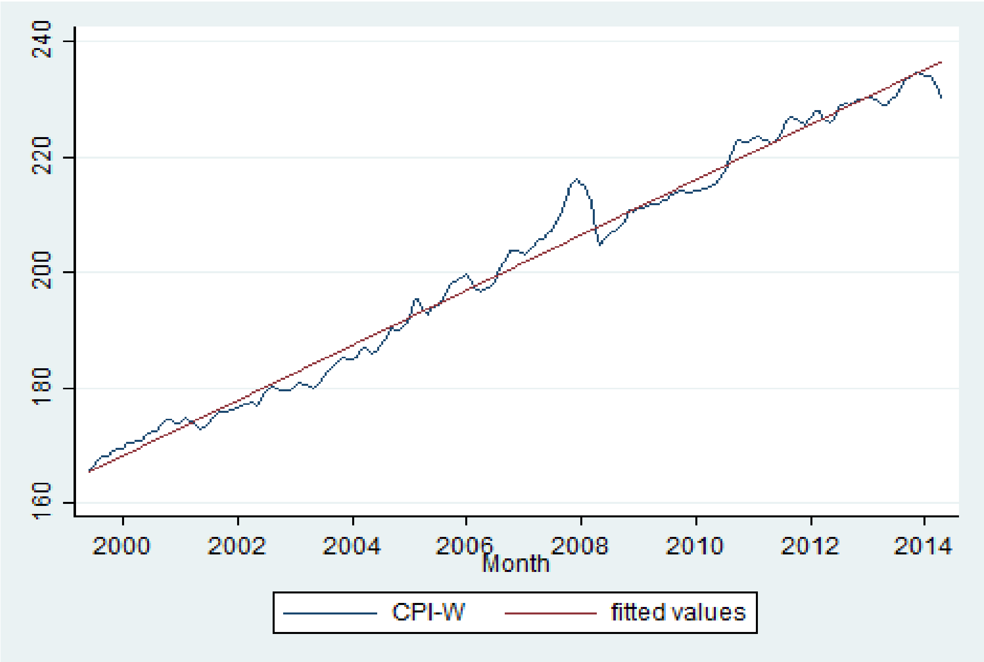
Table 7: Implication of worker effort responses on the firm's minimum wage compliance cost

	(1)	(2)	(3)	(4)	(5)
	MW=6.79	MW=7.21		MW=7.21	
Effort response:		**None**	**Positive**	**None**	**Positive**
Firm response:		**None**		**Yes**	
Minimum wage compliance cost ($)	6,522	10,606	8,625	9,980	8,138
Reduction in compliance cost due to effort response ($)			1,981		
Reduction in compliance cost due to effort + firm response ($)				626	2,468

Notes: Based on 4644 worker-weekly observations (768 unique workers) for weeks 1-8. Effort response: None assumes the scenario of no effort response. Effort response: Positive applies productivity increase of 4 percent for workers in deciles 1-4. Firm response: Yes applies decreased share of employment hours of workercers in deciles 1-4 by 7 percent.

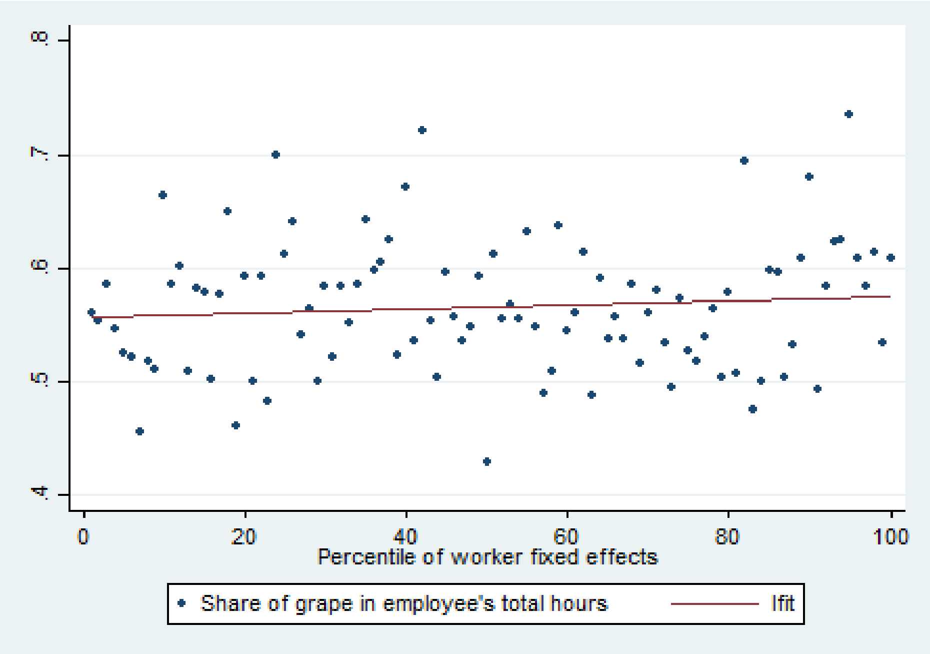
Appendix A

Figure A.1: Monthly Consumer Price Index for urban wage earners and clerical workers (CPI-W)



1982-84=100. August for each year is marked on the horizontal axis.
Source: US Bureau of Labor Statistics (Series ID: CWUR0000SA0).

Figure A.2: Share of grape in total hours worked versus worker fixed effects



This figure plots the share of grape (versus round) in a worker's total hours worked during weeks 6-12 against worker fixed effects. The worker fixed effects are estimated by equation (1) using transactions during weeks 1-5.

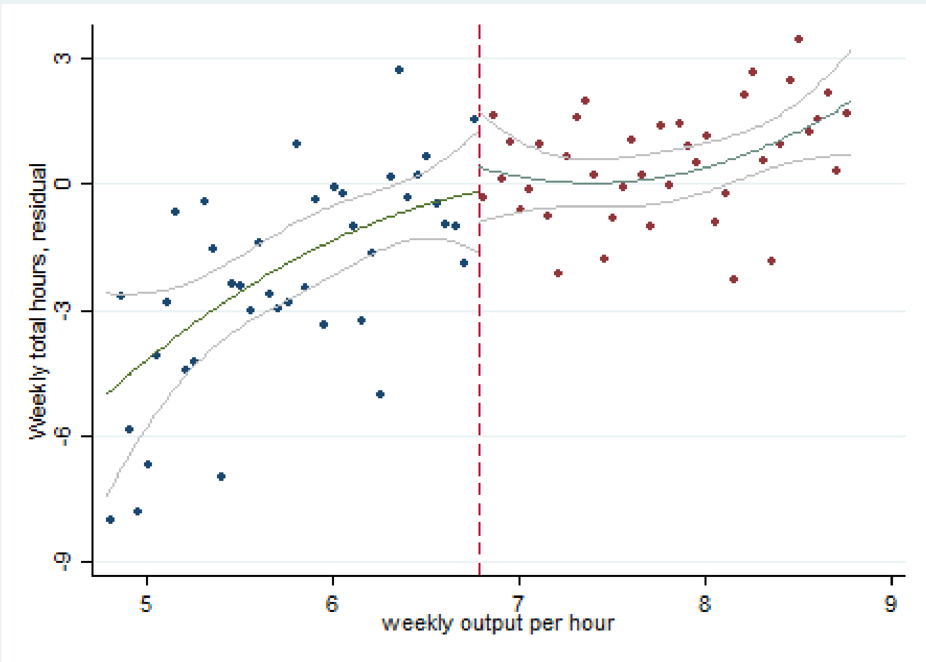
Figure A.3: Example worker paystub

Employee ID: ABCXYZ

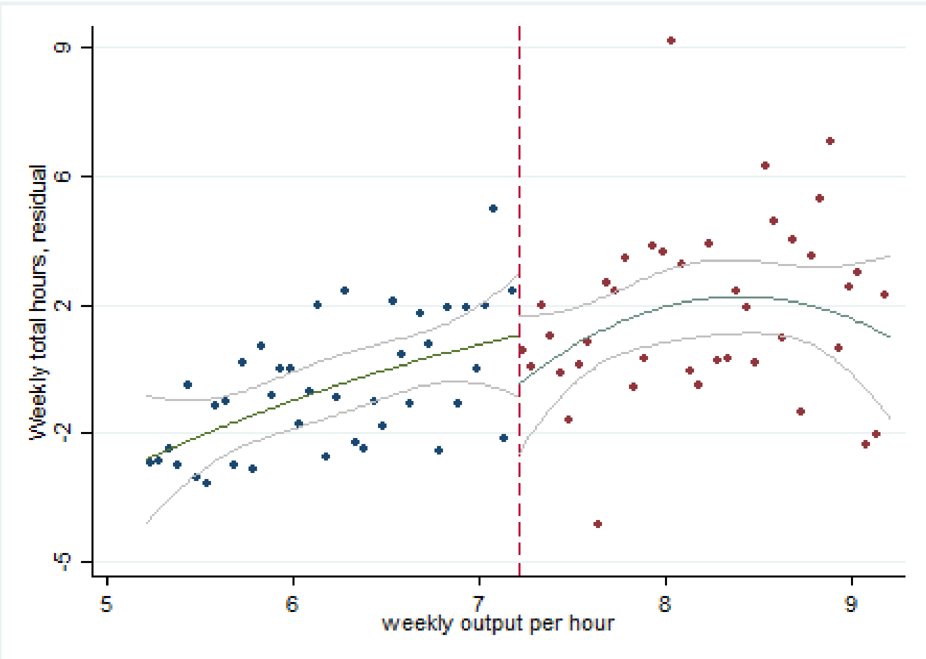
From: Nov 16, 2008 To: Nov 22, 2008

Date	Type	Hours	Rate	Pieces	Earnings
Nov 16, 2008	Minimum Wage				16.00
Nov 16, 2008	Round	5.33	0.5	58	29.00
Nov 16, 2008	Grape	1.67	3.75	2	7.50
Nov 17, 2008	Grape	3.65	3.75	3	11.25
Nov 17, 2008	Round	4.63	0.5	80	40.00
Total		15.28			103.75

Figure A.4: Worker-weekly total hours of employment against worker-weekly average productivity



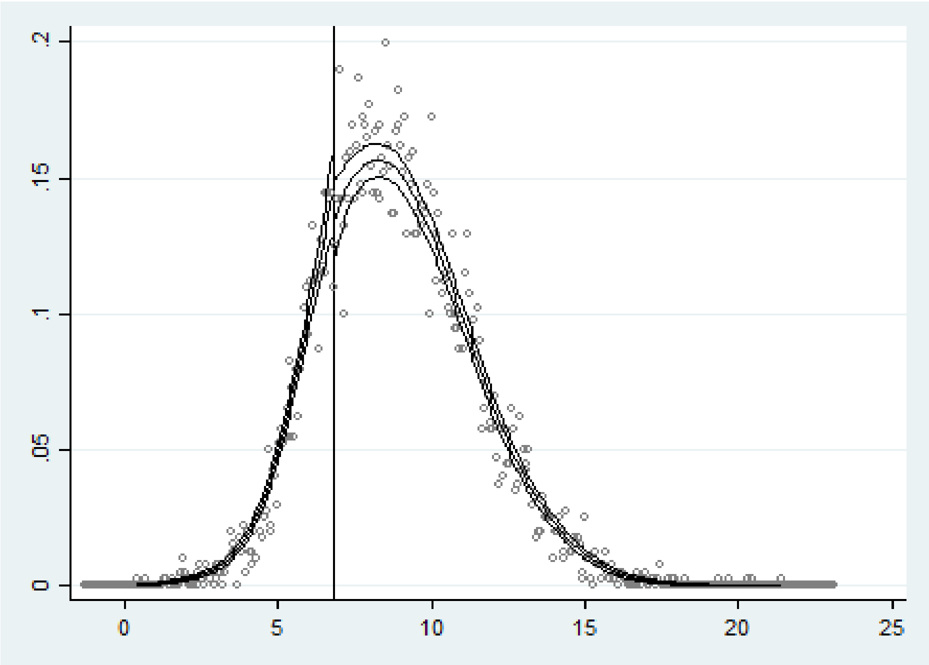
(a) weeks 1-8 (MW=$6.79)



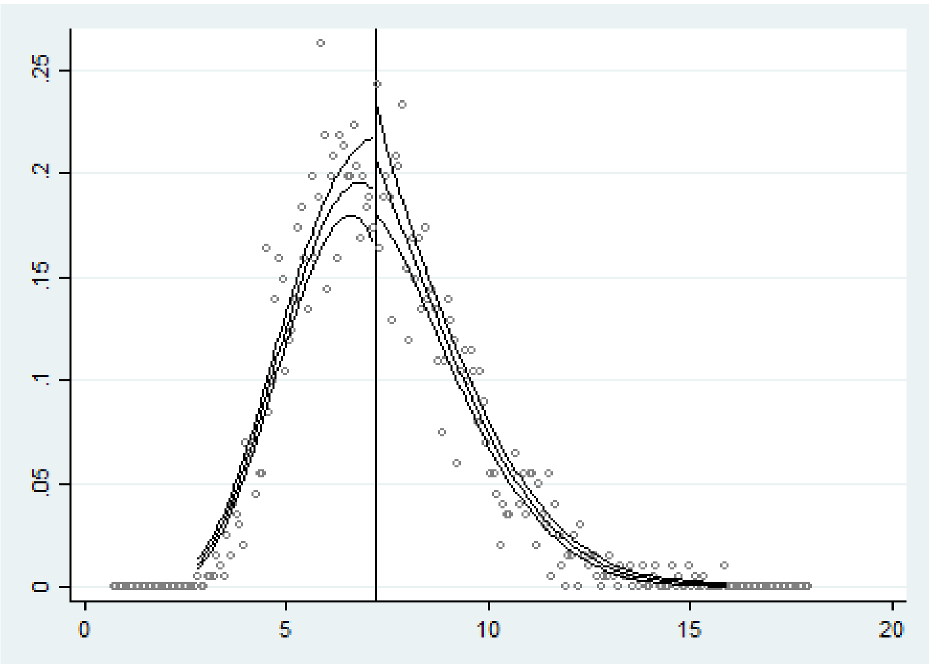
(b) weeks 9-12 (MW=$7.21)

This figure plots the mean of residual of worker-weekly total hours of employment (after accounting for week fixed effects) by 5 cents bins of worker-weekly average productivity (output per hour) for a 2 dollar window around the relevant minimum wage ($6.79 in panel (a) and $7.21 in panel (b)). Quadratic fit with 95 percent confidence interval is shown on either side of the minimum wage. It shows that the employment hours in the record are smooth around the minimum wage with no sign of a discontinuous drop before the minimum wage.

Figure A.5: McCrary test: density of worker-weekly productivity around the minimum wage threshold



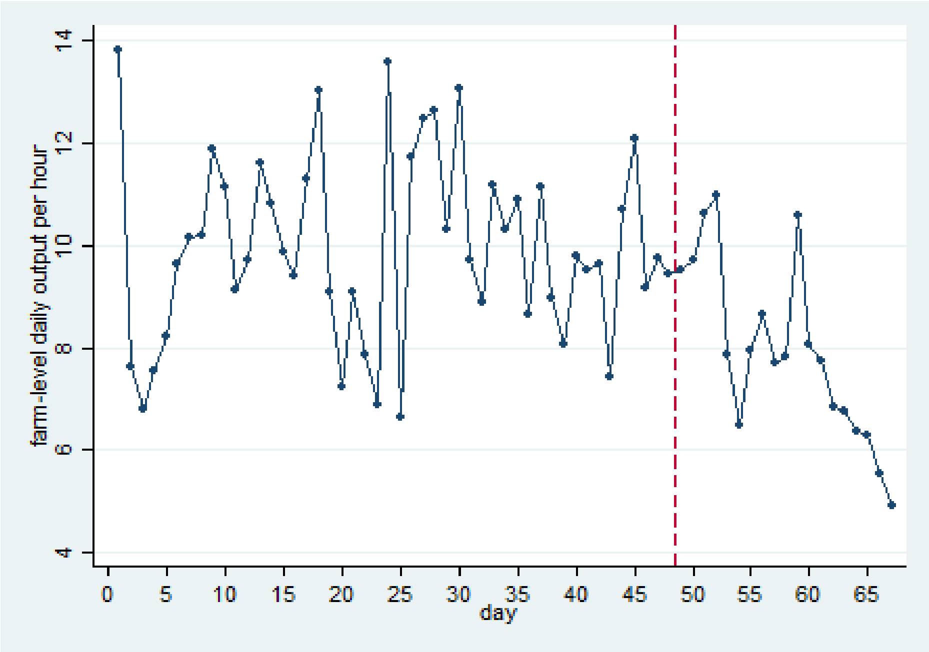
(a) weeks 1-8 (MW=$6.79)



(b) weeks 9-12 (MW=$7.21)

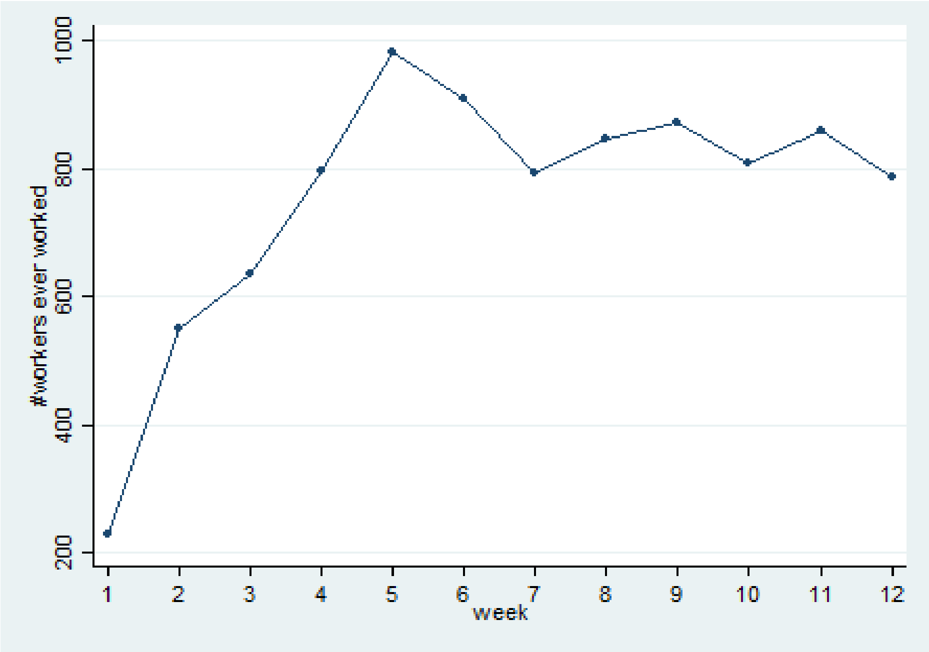
This figure shows the McCrary plot, which tests for selective sorting around the threshold on the worker-weekly average productivity (output per hour). The vertical line is the relevant minimum wage, $6.79 in panel (a) and $7.21 in panel (b). The figure shows no discontinuity in the density of observations around the minimum wage.

Figure A.6: Farm-level daily productivity on different harvesting days

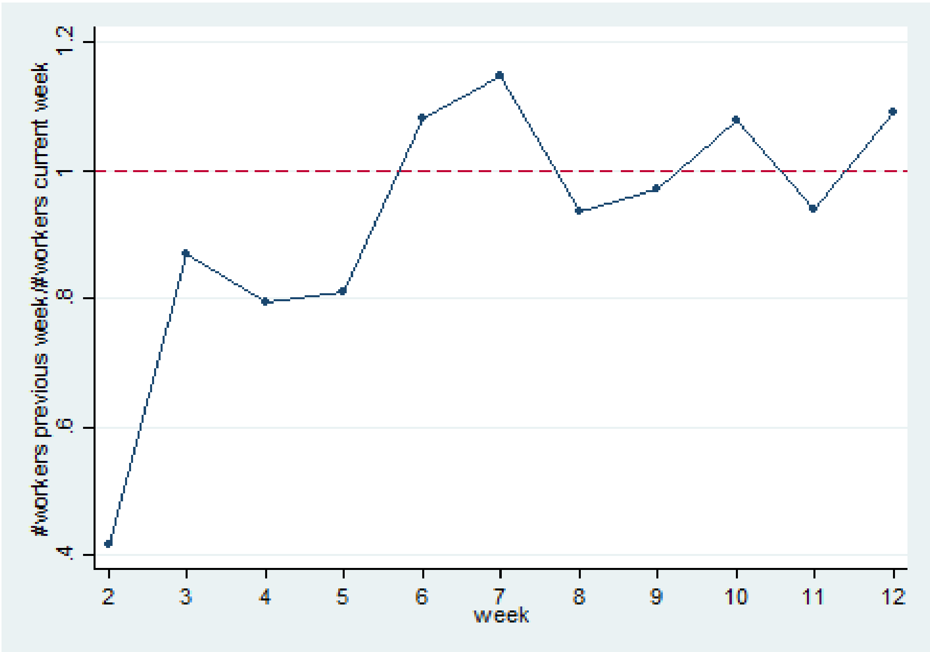


Farm-level daily output per hour is computed as the farm's aggregate output (in dollars) across all tomato varieties divided by the total manhours of employment that day. The horizontal axis shows the harvesting day.

Figure A.7: Labor demand cycle and tightness of intra-firm labor market - Placebo year



(a) Labor demand cycle



(b) Tightness of intra-firm labor market

Panel (a) shows the total number of workers employed in each week. Panel (b) shows the ratio of the number of workers employed in the previous week to that in the present week, which is a rough proxy for the tightness of the intra-firm labor market.

Table A.1: Minimum wage in Florida, 2000-2015

		Federal Minimum Wage	**Florida Minimum Wage**	**Change in Florida Minimum Wage**	**Florida Effective Date**	
*	2000	$5.15	$5.15			
	2001	$5.15	$5.15	$0.00		
	2002	$5.15	$5.15	$0.00		
	2003	$5.15	$5.15	$0.00		
	2004	$5.15	$5.15	$0.00		
**	2005	$5.15	$6.15	$1.00	05/02/2005	12/31/2005
	2006	$5.15	$6.40	$0.25	01/01/2006	12/31/2006
	2007	$5.85	$6.67	$0.27	01/01/2007	12/31/2007
	2008	$6.55	$6.79	$0.12	01/01/2008	12/31/2008
	2009	**$6.55**	**$7.21**	**$0.42**	**01/01/2009**	**7/23/2009**
***	2009	$7.25	$7.25	$0.04	7/24/2009	12/31/2009
***	**2010**	**$7.25**	**$7.25**	**$0.00**	**01/01/2010**	**12/31/2010**
***	2011	$7.25	$7.25	$0.00	01/01/2011	5/31/2011
****	2011	$7.25	$7.31	$0.06	06/01/2011	12/31/2011
	2012	$7.25	$7.67	$0.36	01/01/2012	12/31/2012
	2013	$7.25	$7.79	$0.12	01/01/2013	12/31/2013
	2014	$7.25	$7.93	$0.14	01/01/2014	12/31/2014
	2015	$7.25	$8.05	$0.12	01/01/2015	12/31/2015

Source: Florida Department of Economic Opportunity, October 2015

* 2000-2004, The Federal Minimum Wage

** 2005, Florida enacted a state minimum wage (Florida Minimum Wage Amendment approved through election ballot on November 2, 2004).

*** Florida defaulted to the Federal minimum wage

**** Legal ruling raising the minimum wage to $7.31

Table A.2: Worker output per hour by deciles of worker fixed effects: Choice of WFE sample

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent var.: Log (output per hour)					
Reference group	D6-D10	D5-D8	D5-D8	D6-D10	D5-D8	D5-D8
	A. WFE if hours>50			*B. WFE if hours>20*		
Post x Deciles 1-4			0.040***			0.035***
			(0.010)			(0.010)
Post x Decile 1	0.058**	0.061***		0.073***	0.064***	
	(0.022)	(0.020)		(0.019)	(0.017)	
Post x Decile 2	0.008	0.015		0.025	0.020	
	(0.018)	(0.016)		(0.017)	(0.014)	
Post x Decile 3	0.057***	0.063***		0.064***	0.061***	
	(0.018)	(0.016)		(0.015)	(0.013)	
Post x Decile 4	0.042***	0.049***		0.044***	0.041***	
	(0.012)	(0.010)		(0.010)	(0.008)	
Post x Decile 5	-0.016			0.012		
	(0.011)			(0.014)		
Observations	12,686	9,763	9,763	18,333	14,326	14,326
R-squared	0.561	0.552	0.551	0.557	0.542	0.541

Notes: Estimations are based on transactions during weeks 6-12. Post=1 if week 9 or later. The deciles are based on the worker fixed effects estimated based on equation (1) using data from weeks 1-5. In columns 1-3, the sample includes workers who worked for at least 50 hours during weeks 1-5 (556 unique workers and a mean of 18 spells). In columns 4-6, the sample includes workers who worked for at least 20 hours during weeks 1-5 (963 unique workers and a mean of 16 spells). All regressions include preestimated worker FE, day FE, a cubic polynomial of worker experience, variety-field FE, a cubic polynomial of variety-field life-cycle, and supervisor FE. Robust standard errors clustered by day in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A.3: Worker output per hour by deciles of worker fixed effects - Round and Grape separately

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent var.: Log (output per hour)					
Reference group	D6-D10	D5-D8	D5-D8	D6-D10	D5-D8	D5-D8
	A. Round			*B. Grape*		
Post x Deciles 1-4			0.034*			0.034***
			(0.019)			(0.011)
Post x Decile 1	0.099***	0.088***		0.063**	0.056***	
	(0.031)	(0.030)		(0.025)	(0.020)	
Post x Decile 2	0.027	0.018		0.020	0.022*	
	(0.024)	(0.021)		(0.017)	(0.012)	
Post x Decile 3	0.064***	0.054**		0.041**	0.045***	
	(0.021)	(0.020)		(0.015)	(0.014)	
Post x Decile 4	0.012	0.004		0.031**	0.038***	
	(0.021)	(0.018)		(0.014)	(0.013)	
Post x Decile 5	0.047*			-0.008		
	(0.023)			(0.016)		
Observations	6,975	5,452	5,452	9,182	7,047	7,047
R-squared	0.593	0.574	0.572	0.539	0.535	0.535

Notes: Based on transactions during weeks 6-12. Post=1 if week 9 or later. The deciles are based on the worker fixed effects estimated based on equation (1) using data from weeks 1-5. Columns 1-3 include round tomatoes only and columns 4-6 grape tomatoes only. All regressions include pre-estimated worker FE, day FE, a cubic polynomial of worker experience, variety-field FE, a cubic polynomial of variety-field life-cycle, and supervisor FE. Robust standard errors clustered by day in parentheses. *** p<0.01, ** p<0.05, * p<0.1