Employment, Wage and Public Budget Effects of Minimum Wage Policy

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Abstract

We estimate the effect of the minimum wage for the entire wage distribution of workers. We implement a novel empirical approach that is particularly appropriate for nationwide changes in the minimum wage. Specifically, we use past wage distributions to develop a counterfactual in a difference-in-differences setting. We find negative effects on employment, large wage growth for affected workers, and significant wage increases further up on the distribution. The employment adjustment happens through an increase in layoffs and a decrease in entries. We analyze the impact on payroll taxation and unemployment benefit expenditure and measure positive net effects on the public budget.

Keywords: minimum wage, labor demand, labor costs, public budget.

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1 Introduction

Minimum wage policy continues to be very popular in both policy and academic debates. In the empirical literature, most of the evidence is based on US data, since state-mandated changes in the minimum wage (MW) have a natural control group in nearby unaffected counties (Cengiz et al., 2019; Dube et al., 2010). State-of-the-art evidence from other countries is more scant. In particular, for European countries most MW changes apply nationally and the construction of credible counterfactuals is more complicated. Notable recent exceptions are the cases of Dustmann et al. (2021) and Giupponi et al. (2022), who study the effects of the MW on the German and the UK labor market. To do so, they rely on two approaches. First, variation in exposure across individuals (Dustmann et al., 2021). A caveat of this empirical strategy is that we cannot measure the impact of the MW for all workers across the wage distribution, which Engbom and Moser (2022) have shown to be, potentially, very large. This of outmost importance for a correct measurement of the labor cost elasticity when MW reforms coincide with other changes in wages or other labor costs along the wage distribution. Second, regional heterogeneity in the bite of the MW (Dustmann et al., 2021; Giupponi et al., 2022). In this case, there is a concern that the employment estimates might be downward biased if regions that are less affected by a MW hike also experience negative effects on employment.

In this paper, we present a novel empirical strategy that allows us to overcome both issues. Moreover, we show results for a diverse set of outcome variables, some of them understudied in the literature: employment stocks and flows, wages, payroll tax collection and unemployment benefit expenditure. We focus on the MW changes that occurred in Spain in the years 2017, 2018 and 2019. The increases were of 6.9%, 2.8%, and 21.5% in real terms, respectively. At the same time the wage floor changed, the maximum basis for payroll taxation also increased. Relative to the salary of a MW worker, the increase in labor costs was of an additional 6%, 2.7% and 13% respectively. We construct the counterfactual with data from the years 2015-2016, when the MW stayed constant, and we use it as a control group in a difference-in-differences strategy. We place workers into one euro daily wage bins and measure the effects across the wage distribution, a quite recent approach that, as far as we know, has only been implemented in Cengiz et al. (2019) and Giupponi et al. (2022). We use high-quality administrative data for the estimations and obtain the following results.

In terms of employment, we show that MW policy creates a missing mass of workers for the wage bins affected by the reform. Most of these employees appear bunching at the new MW, though not all of them. We find significant negative effects for all three reforms equal to 4.5%, 10.2% and 16.5%. We do not measure significant changes in employment for the rest of the wage distribution. However, we do detect reallocation of workers in the upper part of the distribution. These movements do not reflect real changes in wages, but increases in the maximum basis for payroll taxation.

Next, we analyze the effects on wages. For each year, we detect significant wage growth for MW workers that is very similar to the expected real wage increase. Furthermore, we also detect significant wage growth, though smaller in magnitude for the rest of the wage distribution. For instance, for the 2019 reform, wage increases show a descending ladder pattern: for workers at the old MW, wage growth equals 18.6%. In the next bins, it is of 14.8%, 14.4%, 12.3%, and 10.1%. For employees earning one euro of daily wage less than the new MW, wage growth is of 9%, and effect which moves them slightly two bins above the new mandated floor. From then on, wage growth continues to decline until it reaches 3% for workers with wages ten bins above the new MW. All individuals above this wage level experience wage increases of around 3% on average. There are two possible interpretations of the wage effects higher up in the wage distribution. On one hand, they might reflect wage updates that coincide with the new year and are unrelated to MW policy. On the other hand, they might be a consequence of MW changes, which could help workers attain better outcomes both in collective and individual bargaining. Unfortunately, we cannot distinguish between these two channels. Nonetheless, they reflect significant increases in labor costs that need to be taken into account for the computation of labor demand elasticities. For instance, the minimum wage elasticity is quite large when we only consider the MW hike, -0.74, decreases significantly once we include the increase in payroll taxation, -0.31, and will decrease even more when we include wage growth over the whole distribution.

In order to understand better how the employment adjustment happens, we analyze the effects on flows. The results are similar across years and here we summarize the estimates for 2019. There are three main results. First, there is a significant increase in dismissals for workers under the new MW of 1.1%. The highest bin estimate is for workers just at the old MW, with an effect of 2.3%, which indicates that, of the affected jobs, those with the lowest wages are the most likely to break. This finding is consistent with the canonical Mortensen and Pissarides (1994) model and contrast with the negative effects documented in the empirical literature (Dube et al., 2016; Portugal and Cardoso, 2006; Brochu and Green, 2013). Second, we do not detect significant effects on quits, suggesting that the higher MW did not increase the workers' attachment to their jobs. This result is line with the analysis in Brochu and Green (2013). Third, the adjustment on employment also happens through a decrease in hires, as has been shown in previous papers (Dube et al., 2016; Portugal and Cardoso, 2006; Brochu and Green, 2013).

Lastly, we provide evidence of the effects of the MW on the public budget. In particular, we quantify its impact on payroll tax collection and unemployment benefit expenditure. For each policy change we focus on, there were positive effects on revenue -significant for 2017 and 2019, the two largest changes. Expenditure only increased significantly for the 2019 reform. Overall, the policy changes increased net public revenue, though the effect is only significant for 2019. These results suggest that MW policy, combined with other changes in labor costs, can be budget enhancing. As far as we know, we are the first to measure this type of public finance estimates.

We contribute to the literature in three main ways. First, we present a new empirical approach to construct a counterfactual for the whole wage distribution. The strategy is particularly suitable for contexts in which the MW is a national policy and it is not easy to find a good control for workers of all wages. Recently, impacts on the wage distribution have been analyzed in a standard difference-in-differences setting in Cengiz et al. (2019) and exploiting regional price variation (Giupponi et al., 2022). Instead, we use wage distributions from Spain in the past to construct a counterfactual also in a difference-in-differences setting. We find negative effects on employment, larger than those in similar papers (Cengiz et al., 2019; Giupponi et al., 2022). However, we also detect widespread effects on wages on the entire distribution. The increase in wages almost matches the mandated 2019 MW increase and declines for workers in higher wage bins, until it stabilizes around 3% of wage growth for workers earning around ten euros of daily salary above the new MW. The far-reaching wage impact highlights the importance of understanding effects for all workers regardless of their wage. For instance, the labor cost elasticity changes dramatically, ranging from -0.31 to -1.1, depending on whether we measure the consequences on labor costs only for MW workers or we quantify it for the entire distribution.

Second, we report results for several variables that have not received much attention in the literature. First of all, we document that MW policy, combined with other changes in labor costs, has positive effects on public net revenue. We are not aware of previous papers focusing on these variables. Second of all, we analyze the changes in employment flows that caused the adjustment in stocks. The MW hike increased layoffs and decreased hires, as predicted in the seminal Mortensen and Pissarides (1994) contribution, and consistent with some matches not being productive any more. The estimates for layoffs are different from those in previous papers, that detected reductions in dismissals after MW updates (Dube et al., 2016; Portugal and Cardoso, 2006; Brochu and Green, 2013). In terms of quit behavior, we do not find significant effects, similar to Brochu and Green (2013).

Third, our paper complements recent papers that evaluate the labor market effects of Spain's MW policy. Thanks to the empirical strategy implemented, we provide the cleanest evidence to date that the MW had negative employment effects, but that wages of affected workers increased significantly, and that this coincided with wage growth along the whole distribution. Furthermore, the increase in tax collection outweighed the increase in unemployment benefit expenditure. Relative to other papers, we do not need to restrict our sample to workers employed before the policy change (Barceló et al., 2021; Fernández-Baldor, 2022; Gorjón et al., 2022). Thus, we capture both employment destruction and lack of job creation.

The paper is organized as follows. Section 2.2 presents that data and the institutional context. Section 3 explains the empirical strategy. Section 4 shows the results. We conclude in section 5.

2 Data and Institutional Context

2.1 Data

This paper uses data from the the Continuous Sample of Work Lifes (MCVL), a dataset that combines administrative information from three main sources: the social security administration, the census and tax administration in Spain. A new edition of the sample is published every year since 2004. The sample is constructed in the following way: for each year, it contains a 4% of all individuals who had some relationship, that is, people who were working in the formal labor market, were collecting unemployment insurance or unemployment assistance, or were receiving pension benefits.[1] For each individual included, the data contains all information on her social security history. People who were sampled in a previous edition of the MCVL are included in the new samples unless their relation with social security ends, which means that they are either out of formal employment, or are not collecting unemployment benefits, or died. In that case, the worker is replaced with another randomly selected individual who is on a relation with the social security that year. If a person who droped out from the sample resumes its relation with the social security, she is included again in the sample again. In this paper, we use MCVL for the years 2014 to 2020.

The MCVL provides representative, unique and high quality data on the Spanish Labour Market. Crucially for our analysis, it contains monthly wages (bottom- and top-coded), an indicator of part-time work and the percentage of hours worked relative to a full-time contract, and the exact day of start and end of each employment spell. These three elements are essential for our analysis. There are two main reasons for that:

[1] Sampling was random, without any kind of stratification.

first, they allow us to put workers into one euro daily wage bins, corrected by part time work, and obtain the distibution of daily wages. Second, we can compute the changes in employment stocks and flows, wages, payroll taxes and unemployment benefits that occur across the wage distribution when the minimum wage changes.

The dataset has also information of the worker's characteristics: sex, age, nationality, etc. We can also know the firm's sector, its number of workers, its location, etc.

2.2 Institutional Context

Recent Evolution of the Minimum Wage

Figure I displays the real minimum wage in Spain since 2008. As can be seen, it remained quite stable between 2008-2016. For these years, there were no important nominal increases and inflation eroded the minimum wage. This trend was significantly reversed with three important increases of 8%, 4% and 22.3% in nominal terms that happened on the January 1st of 2017, 2018 and 2019, respectively. These policy changes are the focus of our analysis. A comparison of these increases with those analyzed in the literature is useful to put them in perspective. For instance, in Cengiz et al. (2019) the average real minimum wage change is of 10.1%, quite similar to the one implemented in Spain in 2017. The 2019 update is significantly larger and there are less papers studying the short-term effects of changes of such magnitude. A notable exception is Harasztosi and Lindner (2019), who investigate a 56.9% increase in Hungary.

Descriptive Evidence: The Daily Wage Distribution

In figure II, panels (a), (b) and (c), we plot the daily wage distributions for the months of January 2019, 2018 and 2017, respectively, together with the distribution in December of the previous year, just one month before each increase in the minimum wage. As is visually clear, in each month there is an important spike at the minimum wage level. Moreover, the distribution moves to the right every time the minimum wage is updated. Panel (d) depicts the distribution for December 2015 and January 2016, when there was no change. In this case, the two distributions are almost indistinguishable from each other.

Who Are the Minimum Wage Workers?

Table II provides descriptive statistics for those workers who were affected by each of the 2017, 2018 and 2019 MW hikes in December of the previous year, the month before the policy was introduced, and compares them to the rest of the workforce. In both December 2016 and 2017 around 12% of the workers earned below the new MW. In December 2018 it was around 16% of the workforce. In comparison to Cengiz et al. (2019), who study 138 minimum wage events in the US, each the new MW levels introduced in Spain between 2017 and 2019 affected a larger share of workers. In particular, in 2019 the share of workers below the new MW doubled the one they observe, however, the 2019 MW increase in Spain also doubled the average MW increase studied by Cengiz et al. (2019).

For all the years we study, compared to the rest of the workforce, workers affected by the MW increases are more likely to be female and less likely to be Spanish Citizens. Younger workers are also over represented and in general they also spend less years in formal education. Regarding the working conditions workers below the new MW are more likely to be on short term contracts and less likely to be on open-ended ones. Furthermore, they are also more likely to be employed in the agricultural sector or work as housekeepers and less likely to be in industry or service sector when compared to the rest of the workforce.

Other Contemporaneous Changes to Labor Costs

Every time the minimum wage increases, there are other changes in labor costs that happen contemporaneously, which need to be taken into account to compute the labor demand elasticity correctly. In particular, both the minimum and the maximum contribution basis for payroll taxes are updated. As far as we are aware, there are no previous papers analyzing minimum wage changes in Spain that incorporate simultaneous changes in labor costs other than the MW itself (Lacuesta et al., 2019; Barceló et al., 2021; Fernández-Baldor, 2022). Therefore, the elasticities reported in these papers overestimate the employment impact of the change.

Table I summarizes the contribution basis for 2015-2019. The minimum basis (top panel) differ depending on the worker's contribution group.[2] For the groups 4-11 the minimum basis is equal to the minimum wage. However, for groups 1-3 the minimum basis is above the minimum wage.[3] Finally, as can be seen in the bottom panel of table I, the maximum basis is the same for all contribution groups.[4] There are two remarks that highlight the relevance of changes in the maximum basis for a correct computation of the labor demand elasticity. First of all, the 2019 MW change was accompanied by an increase of 266.3 euros in the maximum basis. In terms of payroll taxation, it represents an increase of 96.5 euros or 13.12% relative to the 2018 MW. Second of all, in 2018 around 7.5% of the workforce was at the maximum basis.

3 Empirical Strategy

The key empirical challenge is to estimate how the wage distribution would have been if there had been no increase in the minimum wage. Cengiz et al. (2019) use MW state-level variation in the USA and construct the counterfactual distribution with a difference-in-differences strategy. Nonetheless, in Spain the minimum wage is a national policy and there is no variation across regions. One possibility to overcome this issue is to exploit regional variation in the bite of the minimum wage as in (Dustmann et al., 2021) or geographic differences in the price level (Giupponi et al., 2022) to construct the counterfactual. However, a limitation of this approach is that they capture relative employment effects and, hence, the estimates might be biased downwards.

Our identification strategy is based on a difference-in-differences, but with some particularities. Since all Spanish regions were affected by each MW change, we construct the counterfactual wage distribution using data from Spain before the wave of MW increases that started in 2017. If we go back in time, January 2016 is the first month of January when no change was approved. In fact, we construct the counterfactual for each change

[2] In this context, a worker group can be understood as a broad occupational category. For instance, worker group 1 is composed of employees with university education. However, there probably is misreporting of contribution groups, since there is not much monitoring.

[3] A worker in groups 1-3 can still earn a salary below its contribution basis and the minimum wage. Contribution basis only matter for payroll taxation, but the minimum wage is the only floor for all workers in terms of monthly salary.

[4] Groups 8-11 report daily earnings and hence have daily contribution basis.

using the data for 2015-2016. An advantage of this approach is that the control did not experience any increase in the MW. Therefore, the estimates are less likely to suffer from downward bias.

A first assessment of the validity of this approach is in figure III. In it, we plot the evolution of employment before and after the 2019 change (blue solid line), the 2018 change (red dashed line) and the 2017 change (green dashed line). For each case, the x axis represents the months that have passed since January of each year. The grey dashed line displays employment the months before and after January 2016. As can be seen, the labor market of each period was following a similar parallel trend.

A second assessment of the plausibility of the method is in figure IV. In it, we plot the share of employment in each daily wage bin, first differenced with respect to the share in December of the previous year. Panel (a) shows the evidence for the 2019 change, panel (b) for the 2018 change, panel (c) for the 2017 change, and panel (d) is for 2016. The movements associated to MW changes are very clear visually (blue dots in panels (a) to (c)), whereas not such oscillations exist in 2016 (panel (d)). Furthermore, the differences in shares between two consecutive months when no MW change occurred (green dots) are all near zero, suggesting that the number of workers in each bin was evolving proportionally. This last statement is true for all years and insinuates that the daily wage distribution of the 2015-2016 Spain can be used to construct a valid counterfactual for the other changes.

The estimation is based on the following specification:

$$\begin{aligned} y_{sjt} = \alpha + treatment_s + post_t + \sum_i \gamma_j 1[bin_j = i] + \sum_i \beta_j 1[bin_j = i] \times treatment_s \times post_t \\ + \theta_t + \mu_{sj} + \rho_{jt} + \epsilon_{sjt} \end{aligned} \tag{1}$$

where y_{sjt} is the fraction of workers in bin j and at month distance t from a minimum wage change. The subindex s refers to either treatment or control Spain. Specifically, $treatment_s$ is a dummy that equals one for Spain in the years 2018-2019, 2017-2018, and 2016-2017, and 0 for Spain in the years 2015-2016.[5] $post_t$ indicates a period after a minimum wage change. Thus, it is 1 whenever the time distance from an minimum wage hike is positive. bin_j is the wage in bin j. θ_t are month fixed effects, μ_{sj} are state-by-wage-bin fixed effects and ρ_{jt} are month-by-wage-bin fixed effects. ϵ_{sjt} is the error term. The specification is equivalent to Cengiz et al. (2019), the paper that we consider the closest to ours methodologically.

Measures of Employment Effects. The formulas we use to measure the missing (m_t) and excess (e_t) mass are:

$$m_t = \sum_{j<MW_t} \beta_j \quad (2) \qquad\qquad e_t = \sum_{MW_t \le j \le \overline{MB}_t} \beta_j \quad (3)$$

where MW_t is the new minimum wage at time t and $\overline{MB}_t$ is the new minimum contribution basis for group 1, that is, the highest new minimum contribution basis. The sum of the missing and excess mass is informative as to what extent the minimum wage might destroy employment: $s_t = m_t + e_t$. If we divide the effect on employment by the legal change in the minimum wage, we obtain the employment elasticity with respect to the minimum wage:

$$\frac{\%\Delta \text{Total Employment}_t}{\%\Delta MW_t} = \frac{s_t}{\%\Delta MW_t} \tag{4}$$

We define as affected employment the percentage change in employment relative to the fraction of workers below the minimum wage before treatment:

$$\%\Delta \text{Affected Employment}_t = \%ae_t = \frac{s_t}{\sum_{j<MW_t} n_j} \tag{5}$$

where n_j is the share of individuals working in bin j.

We use equation 1 to estimate the effects on three more outcome variables. First, wages. In that case, the outcome variable is the logarithm of the average wage of workers

[5] For the estimation of the effects of the 2017 change we focus on 6 months before and after the increase. We do so because otherwise the some of the control and the treatment months overlap.

who where at bin j before the reform. Second, labor costs. Third, payroll tax collection and unemployment insurance expenditure. Fourth, layoffs, quits and hires. Next, we explain why recovering each one these estimates is relevant.

Measures on Wage Effects. In the case of wages, it allows us to quantify the actual increase in wages and, consequently, the own-wage employment elasticity. We define the latter as:

$$\text{Own-wage employment elasticity} = \frac{\%\Delta \text{Affected Employment}_t}{\%\Delta \text{Affected Wage}_t} \tag{6}$$

where $\%\Delta\text{Affected Wage}_t = \%\Delta w = \frac{\Delta\text{Average Wage}_t}{\text{Average Wage}_{t-1}}$. In addition, we will measure the magnitude of wage spillovers.

The institutional characteristics of the Spanish labor market imply it is relevant to quantify the increase in labor costs as well. As explained in section 2.2, every time there is a minimum wage increase, there are also updates in both the minimum and the maximum basis of social security contributions, which increase payroll tax expenditure. Therefore, both the minimum wage and the own-wage labor demand elasticity might overestimate the impact on employment. It is for this reason that we also apply the method to understand the overall effect on labor costs. Moreover, wage spillovers also increase aggregate labor costs and are an additional motive to estimate the impact on them. For that matter, we will calculate:

Measures on Labor Costs Effects.

$$\Delta\text{Labor Costs}_t = \sum_j \beta_j \tag{7}$$

where β_j represents, in this case, the effect on absolute labor costs for bin j. The increase, relative the labor costs for minimum wage workers, can be expressed as:

$$\%\Delta\text{Labor Costs}_t = \frac{\Delta\text{Labor Costs}_t}{\sum_{j<MW_t}\text{Labor Costs}_{j,t-1}} \tag{8}$$

Then, the labor cost elasticity is:

$$\frac{\%\Delta\text{Total Employment}_t}{\%\Delta\text{Labor Costs}_t} = \frac{s_t}{\%\Delta\text{Labor Costs}_t} \tag{9}$$

Measures on effects on payroll tax and unemployment benefits. The effect on payroll taxes and unemployment insurance spending allows us to summarize the effect of the minimum wage on net public revenue. Specifically:

$$\Delta\text{Net Public Revenue}_t = \Delta npr_t = \frac{\Delta\text{Payroll Taxes}_t}{\Delta\text{UI}_t} \tag{10}$$

Therefore, a value of Δnpr_t higher than 1 means net public revenue increased, whereas a value lower than 1 would imply that the increase in UI expenditure outweighed the positive effects on tax collection.

Finally, the analysis on involuntary separations and quits allows us to locate for which bin exactly the employment losses happen.

4 Results

Employment Effects. We begin by estimating the effect of the minimum wage on the frequency distribution of daily wages. Figure V displays the results from our baseline specification (equation 1). The graphs on the left show the distribution around the minimum wage, and the ones on the right depict the complete distribution, which allows us to observe behavior around the maximum contribution basis. The top figures are for the largest change in 2019, the middle for the smallest change in 2018, and the bottom for the medium change in 2017. We report employment estimates averaged over the next 12 months over every post-treatment period, for each euro daily wage bin relative to the minimum wage. We reach several conclusions from this analysis.

First, for each change there is a significant drop in the number of jobs below the new minimum wage. It amounts to 7.9%, 4.2% and 5% for the 2019, 2018 and 2017 changes, respectively. Second, there is also a clear and significant increase in jobs just at the new minimum wage. Specifically, the excess mass represents 5.2% in 2019, 3% in 2018 and 4.4% in 2017. Third, the differences between the missing and excess mass are negative and significant for each case: -0.027pp in 2019, -0.013pp in 2018 and -0.005 in 2017. Fourth, the percentage of affected workers that lost their employment is 16.5% in 2019, 10.2% in 2018 and 4.5% in 2017. The estimates can also be consulted in table III. Fifth, there are no significant increases for wage bins above the new floor, apart from changes related to modifications in the maximum contribution basis. Sixth, responses in the upper part of the distribution correspond exactly with changes in the maximum contribution basis. Moreover, the differences between the excess and the missing mass in that area are not significantly different in any of the three years. Hence, we can conclude that increases in payroll tax collection for high-wage workers did not affect their employment. However, these movements will be important for the correct calculation of the change in labor costs.

Figure VI shows the excess and missing mass, and the difference between them, in an event study design for a few months before and after each change. We use an event-study implementation of equation 1 for this exercise. All the estimates are measured relative to changes in the month before treatment. We highlight several remarks from these figures. First, there is no indication of pretreatment trends. Therefore, these results provide a strong validation of the identification assumption of our approach. Namely, that the frequency distribution of daily wages in treatment and control Spain would have moved in parallel in the absence of the reforms. Second, we observe clear reductions in the jobs that pay below the minimum wage in the first month of treatment (solid grey line). The quick response shows that firms were complying with the minimum wage increases. Third, the estimates for the missing mass are very stable over time. Fourth, the excess mass displays very similar behavior, with the opposite sign, and slightly smaller in magnitude (dashed grey line). Fifth, the difference between the excess and missing mass is significant for each case. Furthermore, it grows with every change.

Wage Effects. In figure VII we show that the minimum wage changes increased wages for low-wage workers. The top figure is for the change approved in January 2019, the middle figure for January 2018, and the bottom one for January 2017. The panels on the left display the percentage wage change between two consecutive months. In particular, December, the month before a change happens, and January, the first month after it, with respect to the change between December and November, when no increase in the minimum wage occurs. The figures on the right serve as a placebo test. They depict changes between February and January, both months after the minimum wage update is implemented, relative to the change between December and November. Hence, we do not expect to detect positive and significant effects.

For the change in January 2019 (panel (a)), workers with a wage below the new minimum wage (to the left of the first grey dashed line) experience substantially higher daily wage growth than workers earning wages above the minimum wage. There are four remarks worth highlighting: first, the increase for workers at the old minimum wage is slightly below the increase in real terms of 21.5%; second, for employees earning wages between the old and the new minimum wage, the increases are smaller the closer they are to the new minimum wage; third, for workers earning below the old minimum wage, we measure significant positive effects ranging between 9 and 12%; fourth, the average wage effect for workers earning below the new minimum wage is 15.1%; fifth, we detect significant increases in wages throughout the wage distribution. However, we should be cautious about relating this wage growth to the minimum wage change. While the new minimum wage policy could have triggered updates throughout the wage distribution, it is also plausible that wage increases for workers not in the minimum wage area reflect both the approval of new collective bargaining agreements or individual bargaining that coincides with the new year. In fact, 2019 was a year with an average wage growth of 2.33%, the highest since the Great Recession and 1.27pp higher than in 2016.

The pattern of wage growth we observe for the 2018 and 2017 changes is quite similar. The main difference is that the increase for 2018 is around 5pp larger than the actually mandated minimum wage change. For the 2017 case, the estimated increase is of a similar magnitude to the mandated increase of 8%.

Labor Costs. The increase in labor costs is displayed in figure VIII. As can be seen, the changes in labor costs that happen across the wage distribution correspond to the bins for which the employment changes occurred. Following formula 8, we compute that the labor costs, relative to labor cost below the new minimum wage, increased by 47.1%

in 2019, 32.3% in 2018, and 16.3%. The magnitude of the labor costs growth doubles the mandated increase in minimum wage for the years 2017 and 2019. For the year 2018 it is 8 times higher.

Elasticities. Now that we have quantified the effect of the minimum wage on employment, wages and labor costs we have all the factors that are necessary for the computation of the elasticities. In table III we report the employment elasticity taking into account different definitions of increases in labor costs. As can be seen, the MW elasticity is -0.74, quite large relative to previous results in the literature (Dube, 2019). However, when we take into account mandated increases in payroll taxation it equals -0.3, a number that is within the ranges documented in previous papers.

Employment Flows. The analysis of employment stocks has shown that the minimum wage change reduced the employment of affected workers. Thus, the adjustment could have taken place either by an increase in layoffs, or a decrease in hires, or both. Figure IX presents the evidence for layoffs (left panels) and quits (right panels). We begin by discussing the evidence for 2019 in panels (a) and (b). First, the only significant effect on dismissals is for workers at the old minimum wage, where we detect a 2.3% increase. Second, the estimates are larger for workers in the area affected by the update, though they are not significantly different from zero. Third, the average effect on firings in the area under the new minimum wage is 1.1%, significant at the 10% level.

Third, the effects on layoffs for 2018 and 2017 (panel (c) and (d), respectively) are quite similar to the ones just described for 2019, though less precisely estimated. Fourth, we do not detect any significant effect on quits for any of the years we focus on. Therefore, the evidence confirms that part of the employment adjustment happened via an increase of dismissals of employees below the new minimum wage.

In figure X we proceed to the analysis on hires. Note that, in this case, workers are placed in wage bins according to how much they earn in the new job. Hence, we expect that the increase in the MW decreases mechanically the amount of entries that happen below the new MW. In contrast, we expect that the hires that are absent below the new MW show up at the new legally binding MW. The evidence across the three years is similar: we detect the negative impact on hires below the new MW but we do not see any positive effect at the new MW, which indicates that entries were negatively affected by the reform. In particular, for the year 2019, the average decrease in hires below the new minimum wage is of -0.7pp, marginally significant at the 10%. If the employment adjustment did not take place through a reduction in hires, we would expect a symmetric effect on hires at the new minimum wage. Instead, we measure a reduction of -0.49pp, with upper bound of the 95% confidence interval equal to 0.036. Therefore, we can conclude that part of the adjustment in the employment stocks happened because firms decreased the hiring of affected workers. The figures also suggest that low-wage workers were being substituted by higher paid employees. This effect is perhaps more apparent for the 2017 change.

Payroll Tax Collection and Unemployment Insurance Expenditure. Next, we study the impact of MW policy on payroll tax collection and UI spending. The results are in figure XI and table IV. For this set of variables, we document the following results: first, as shown in the figures, the effects on UI and payroll taxes are concentrated in the bins where the changes in MW and the maximum contribution basis occur. This is true except for 2019, in which case UI spending increased also for several bins above the new MW. Second, we quantify the changes these magnitudes represent for the budget. We calculate two numbers: for workers under the new contribution basis (panel A in table IV) and for the entire distribution (panel B). We think both numbers are policy relevant but have different interpretations. We focus our discussion on the second number. It is presumably more relevant for international comparisons because it is informative about the overall budget effect. For the change in 2019, both payroll tax collection and UI expenditure increased significantly, with the former effect being much larger. We estimate that the revenue increase was around 2.27 times the increase in expenditure. Qualitatively, the effects are similar for 2018 and 2017, with an important remark. The net effect in 2017 is very significant, with earnings increase almost 20 times more than the expenses.

5 Conclusions

This paper studies the MW changes that occurred in Spain in the years 2017, 2018 and 2019. To do so, we employ a novel empirical strategy in the minimum wage literature, we use past wage distributions to develop a counterfactual in a difference-in-difference setting. Our results show that all three MW changes had a negative effect on employment on the part of the distribution affected by the reform, but no effects on the rest of the distribution. We also find that a significant effect in wages of a similar magnitude as the MW change mandate. Additionally wages increase further up on the distribution. Overall, we find a negative minimum wage elasticity of around -0.74 for 2019. However, this elasticity changes dramatically when we take into account the whole increase in labour costs and is of -0.3.

Additionally, in this paper we also show that the change in the employment stock is driven by both and increase in layoffs, concentrated on those workers who were at the old MW, and a decrease in layoffs. However, when we study how it affected public finances our results show that the MW policies in Spain, which occur at the same time that the updates in the contributions to Social Security, had a positive effect. Suggesting that government revenue increase. Hence, understanding how MW policy shift labour costs along the whole distribution when interacted whit other policies seems a prominent area for future research.

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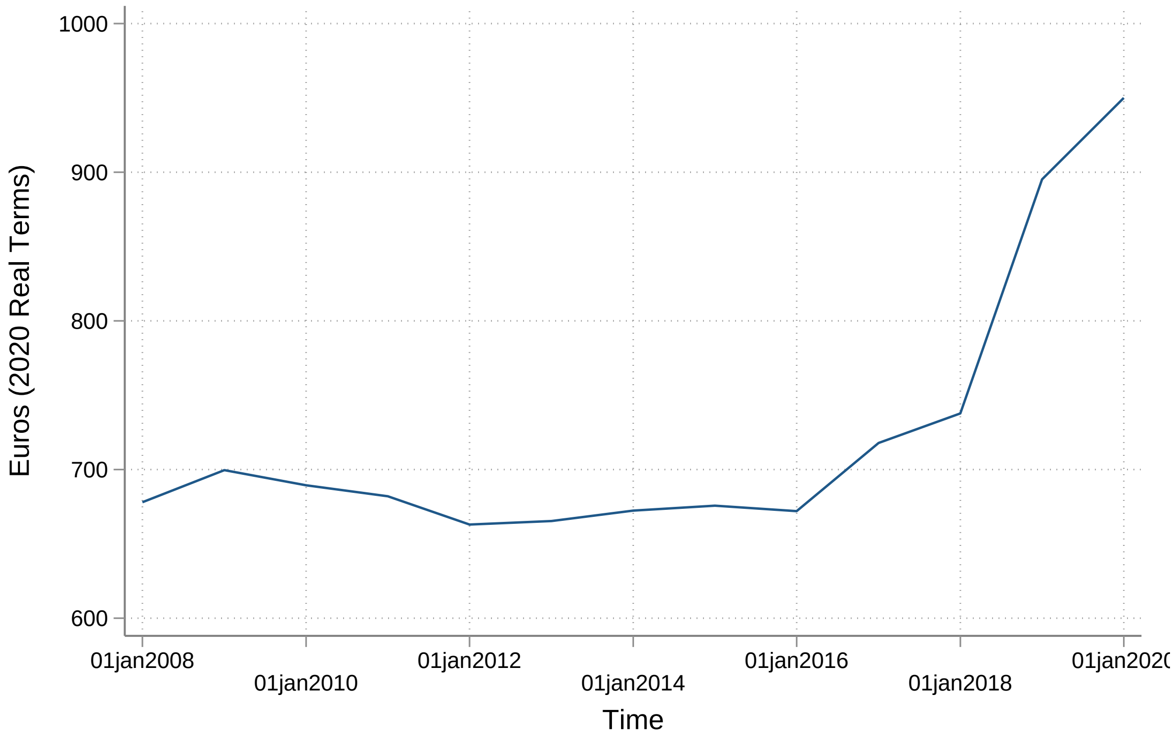
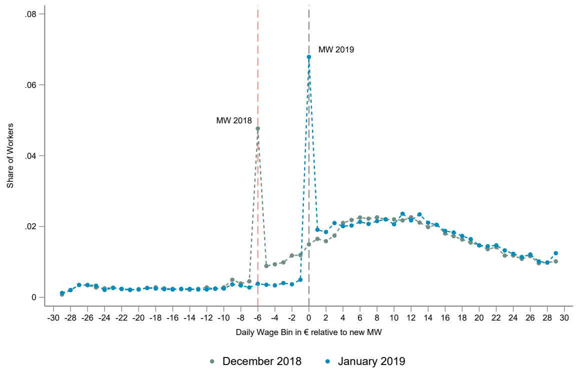
Figure I: Minimum Wage Evolution

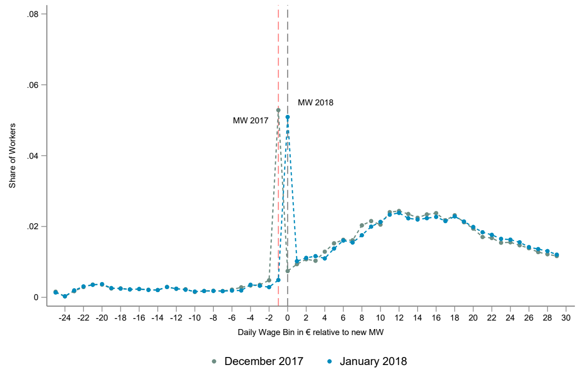


Note: This figure shows the evolution of the minimum wage in Spain between 2008 and 2020. Minimum wage is calculated in real euro terms with respect to 2020.

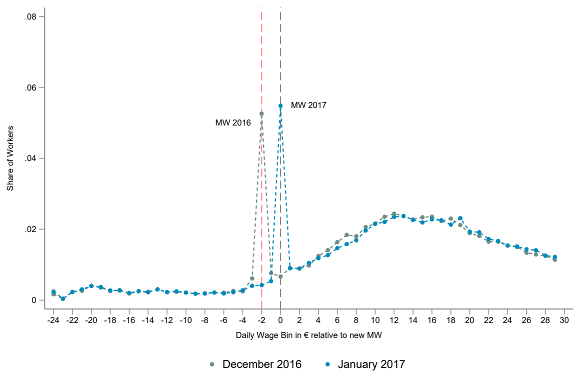
Figure II: Daily Wage Distribution Around the Minimum Wage



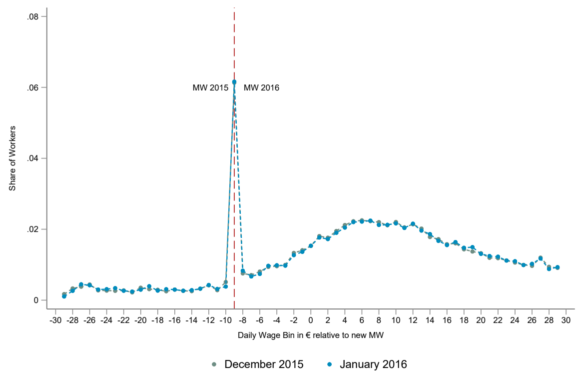
(a)



(b)



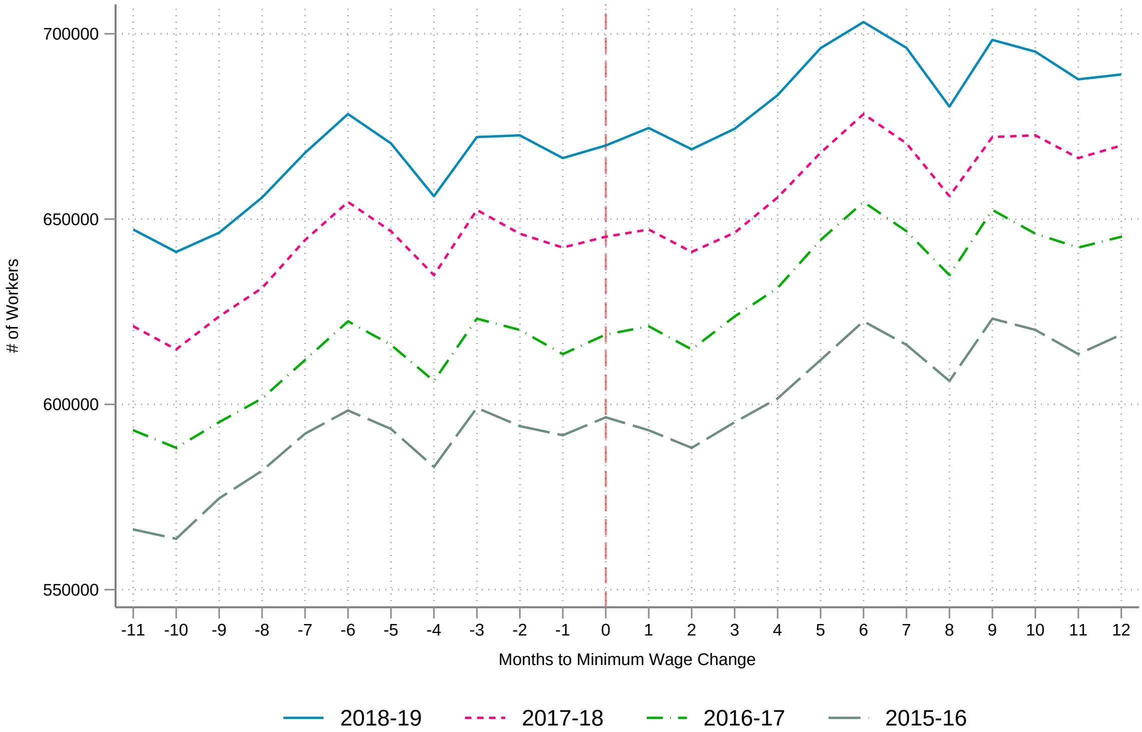
(c)



(d)

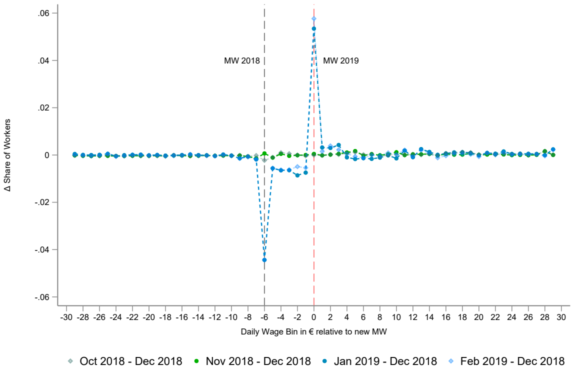
Note: This Figure shows the frequency distribution of the daily base pay of salaried workers in December in a certain year, t, and January of the next year, $t+1$. Panel (a) plots the distributions from December 2018 and January 2019. Panel (b) plots the distributions from December 2017 and December 2018. Panel (c) plots the distributions from December 2015 and 2016. Finally, panel (d) plots the distributions from 2015 and 2016. The vertical lines represent the daily minimum wage level. The red dashed lines corresponds to the daily MW level in year t and the gray dashed line the daily MW year in year $t+1$. The bins have a width of 1€and daily wage is calculated in relation to the new daily MW i.e. the MW level of 2019, 2018 and 2017 in panels (a), (b) and (c) respectively. The bins from panel (d) are also set in relation to the MW level from 2019. The distributions are truncated at 30 euros above the daily MW.

Figure III: Total Number of Workers Before and After Minimum Wage Change

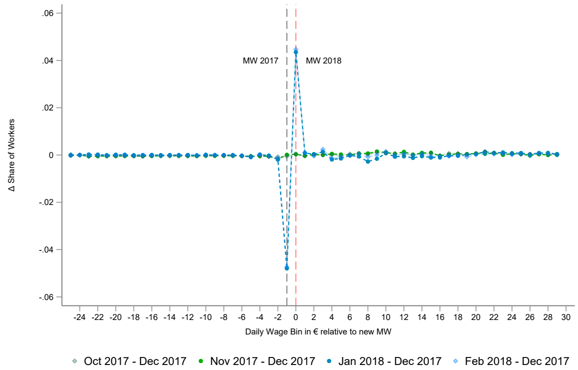


Note: This figure shows the evolution of the total number of workers affiliated to the social security 11 months before and 12 months after there is a minimum wage change.

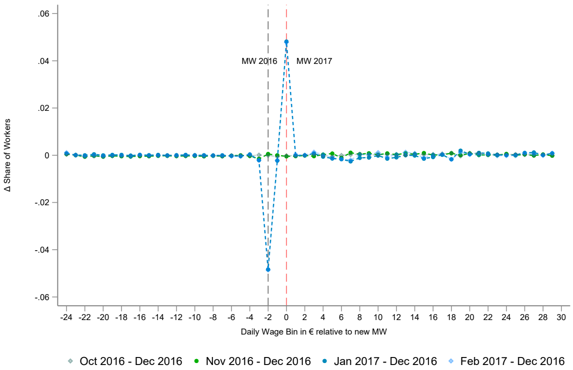
Figure IV: Daily Wage Distribution: Differentiated with respect to December



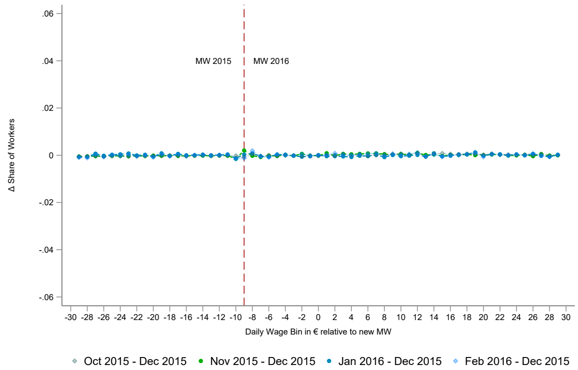
(a)



(b)



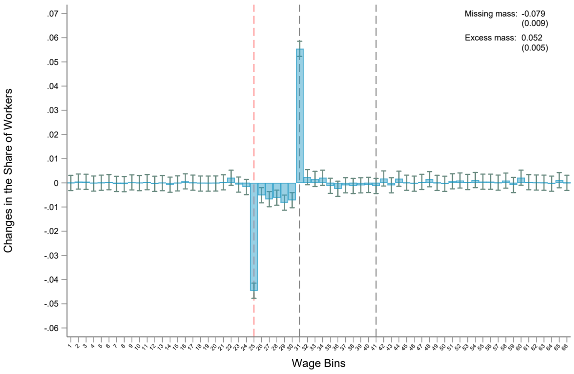
(c)



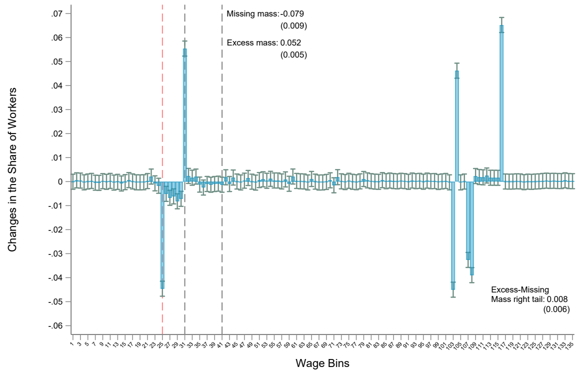
(d)

Note: This Figure shows the frequency distribution differentiated with respect to December of year t of the daily base pay of salaried workers in the months before and after December. In particular it shows the differentiated frequency distributions from October and November in year t, and January and February in year $t+1$ Panel (a) plots the distributions differentiated with respect from December 2018. Panel (b) plots the distributions differentiated with respect from December 2017. Panel (c) plots the distributions differentiated with respect from December 2016. Finally, panel (d) plots the distributions differentiated with respect from December 2015. The vertical lines represent the daily minimum wage level. The red dashed lines corresponds to the daily MW level in year t and the gray dashed line the daily MW year in year $t+1$. The bins have a width of 1€and daily wage is calculated in relation to the new daily MW i.e. the MW level of 2019, 2018 and 2017 in panels (a), (b) and (c) respectively. The bins from panel (d) are also set in relation to the MW level from 2019. The distributions are truncated at 30 euros above the daily MW.

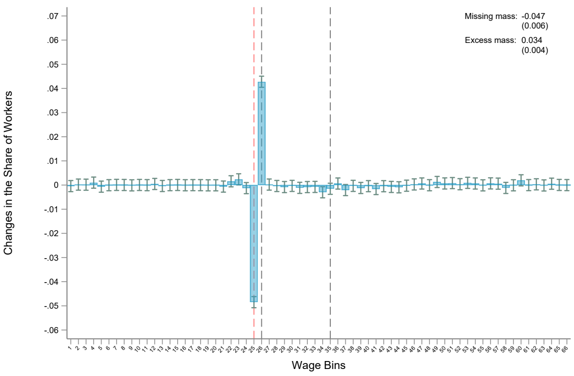
Figure V: Employment Effects of the Minimum Wage Increase



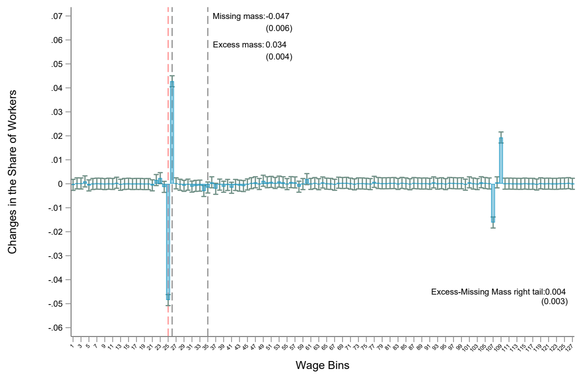
(a) 2019 MW Increase



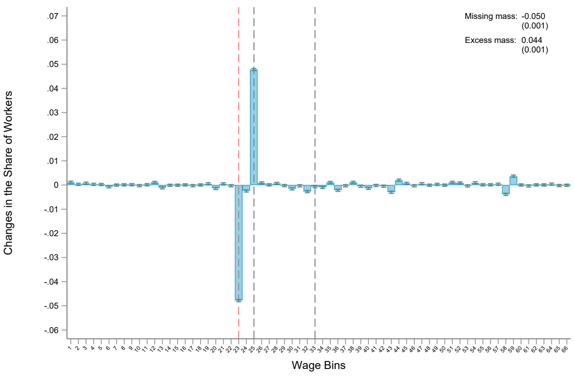
(b) 2019 MW Increase (Complete Distribution)



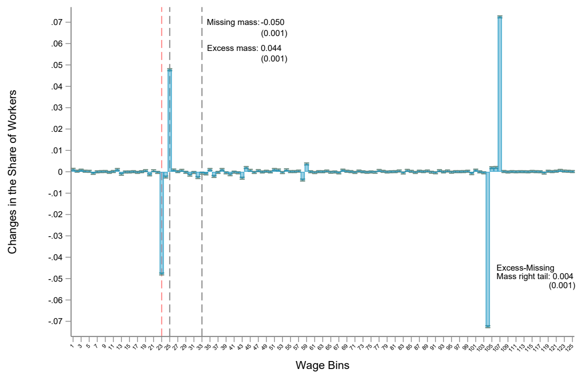
(c) 2018 Increase



(d) 2018 MW Increase (Complete Distribution)



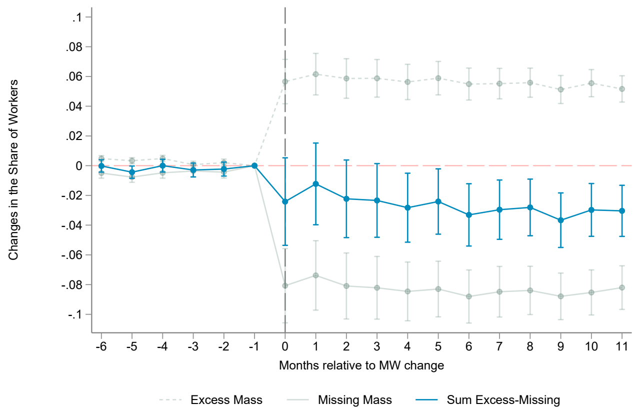
(e) 2017 MW Increase



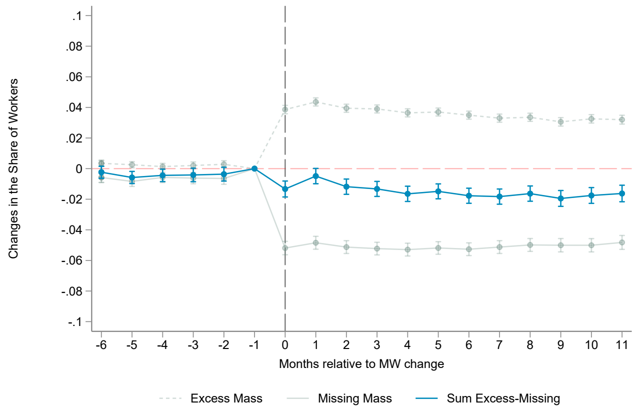
(f) 2017 MW Increase (Complete Distribution)

Note: This figure shows the main results from the difference-in-difference specification (see equation 1) on employment. Panel (a) and (b) show the results for the 2019 MW increase. Panel (c) and (d) show the results for the 2018 MW increase. Panel (e) and (f) show the results for the 2017 MW increase. In panels (a), (c) and (e) we show the results only for the bottom part of the distribution and in panels (b), (d) and (f) we show the effects along the complete distribution. The blue bars show for each euro bin, relative to the minimum wage, the estimated average employment changes in that bin during the twelve months after the minimum wage increase. The error bars show the 95% confidence interval clustered at ?. The vertical dashed read line indicates the MW level before the increase and the vertical dashed gray lines indicate the new MW level and the new minimum contribution base for the highest contribution group respectively.

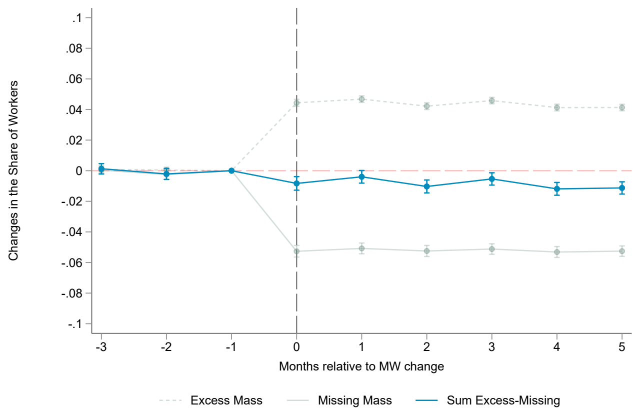
Figure VI: Employment Effects of the Minimum Wage Increase: Event Study



(a) 2019 MW Increase



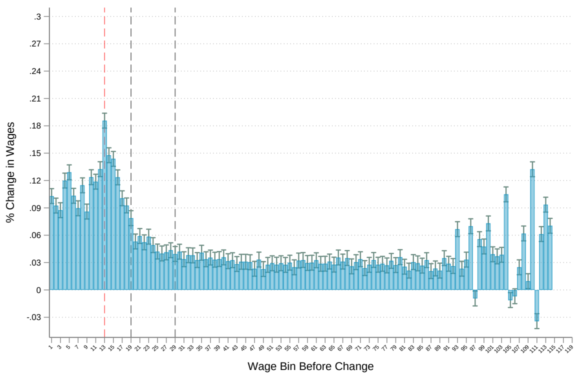
(b) 2018 Increase



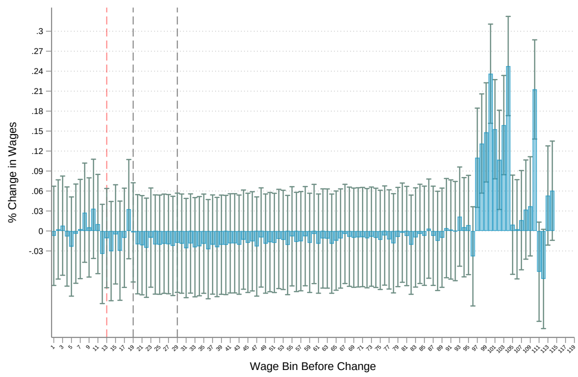
(c) 2017 MW Increase

Note: This figure shows the main results from the event-study specification (see equation 1) on employment. Panel (a) shows the results for the 2019 MW increase. Panel (b) shows the results for the 2018 MW increase. Panel (c) shows the results for the 2017 MW increase. The figure shows the effect of a minimum wage increase on the excess and missing jobs below and above the new minimum wage (gray dotted line and gray line respectively) and the sum of this excess and missing mass (blue solid line). The vertical lines represent the 95% confidence intervals. For 2018 and 2019 we show the effect for eleven months after the minimum wage increase and six month before it. For 2017 we show the effects for five month after the increase and three months before.

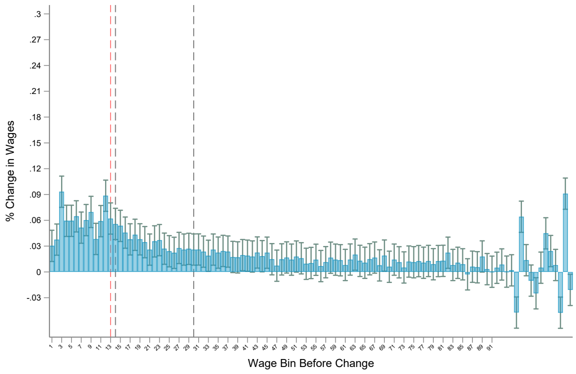
Figure VII: Wage Effects of the Minimum Wage Increase



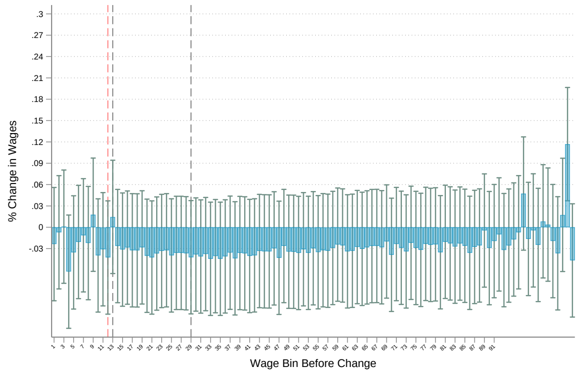
(a) 2019 MW Increase



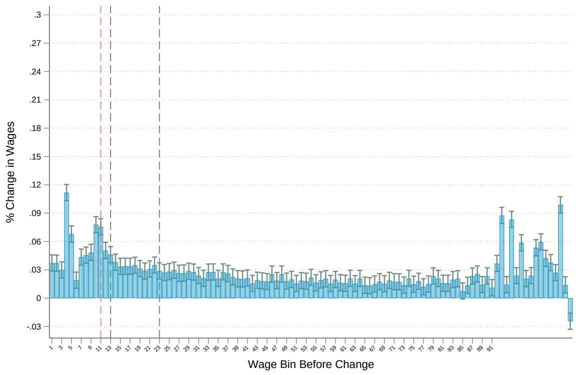
(b) One Month After 2019 Increase



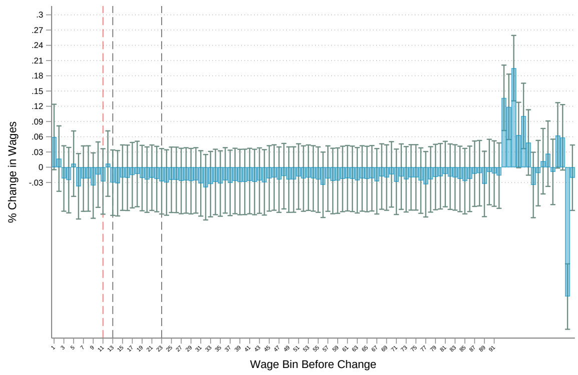
(c) 2018 Increase



(d) One Month After 2018 Increase



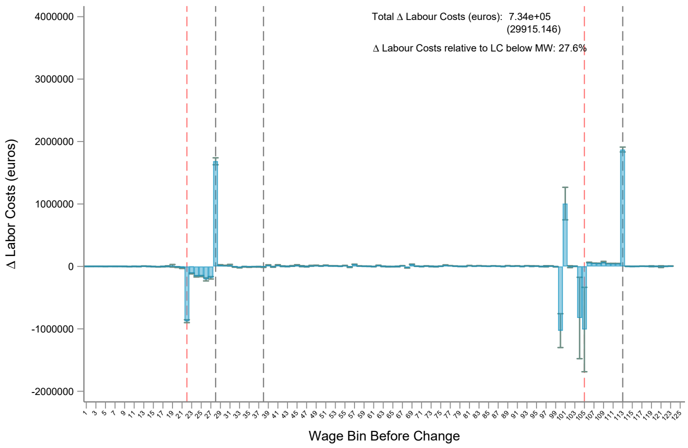
(e) 2017 MW Increase



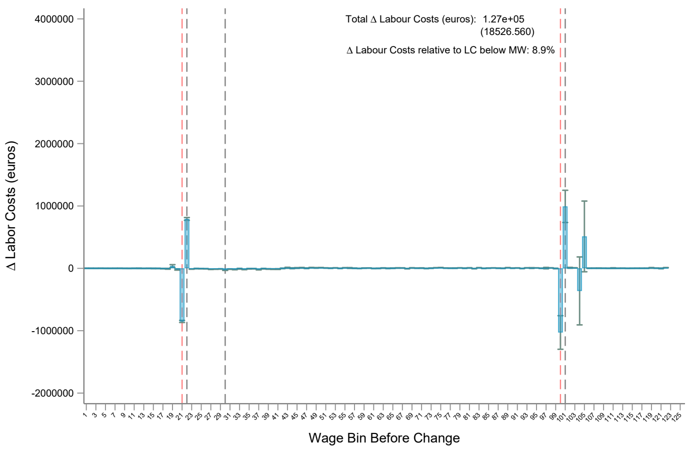
(f) One Month After 2017 Increase

Note: This figure shows the main results from the difference-in-difference specification (see equation 1) on wages. Panels (a), (c) and (e) show the result for the wage change between December, the month before the minimum wage is updated, and January, the month after. Panels (b), (d) and (f) show the effect on the wage change between January and February after the MW increase. The blue bars show for each euro bin, relative to the minimum wage, the estimated average change in wages in that bin. The error bars show the 95% confidence interval clustered at month level. The vertical dashed read line indicates the MW level before the increase and the vertical dashed gray lines indicate the new MW level and the new minimum contribution base for the highest contribution group respectively.

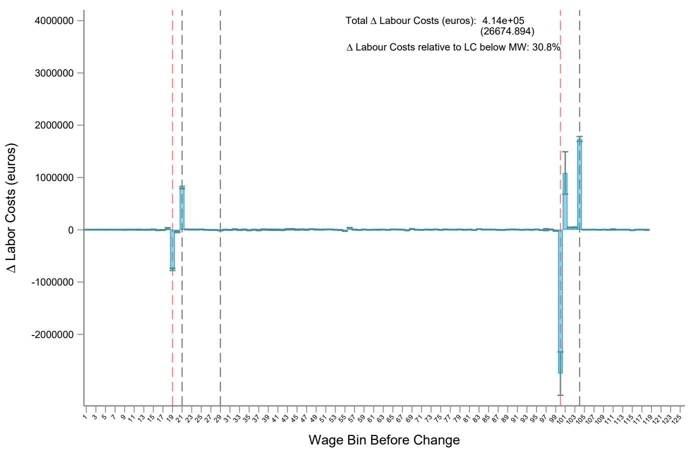
Figure VIII: Effects on Labour Costs of the Minimum Wage Increase



(a) 2019 MW Increase



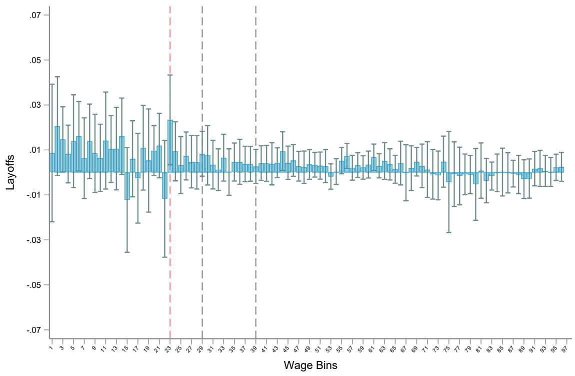
(b) 2018 Increase



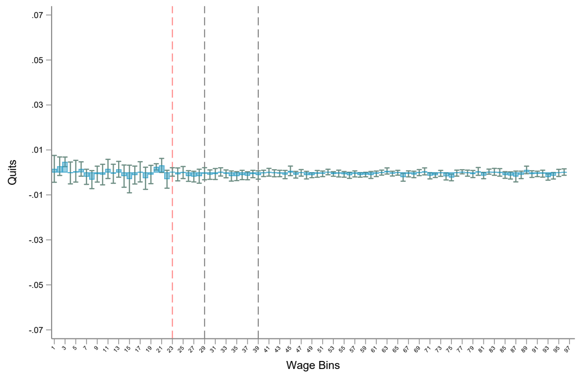
(c) 2017 MW Increase

Note:

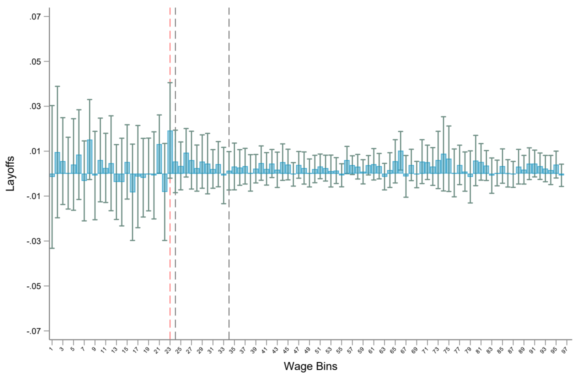
Figure IX: Effects on Layoffs and Quits of the Minimum Wage Increase



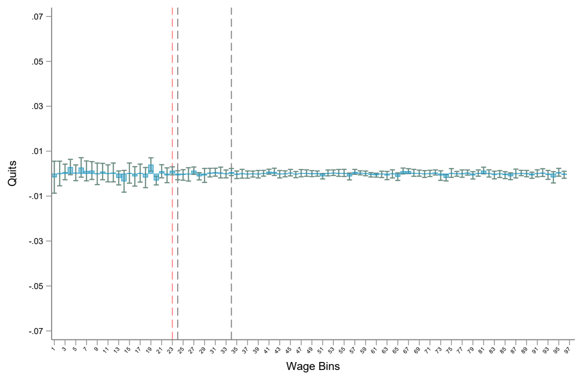
(a) 2019, Layoffs



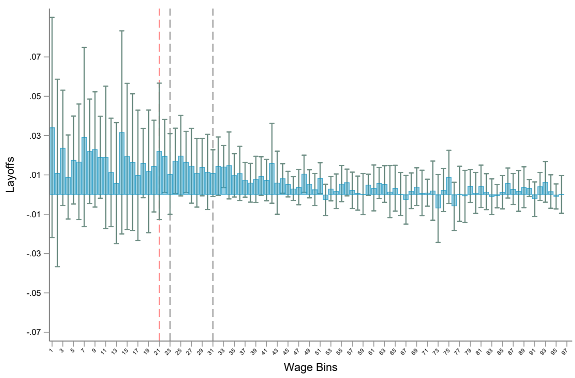
(b) 2019, Quits



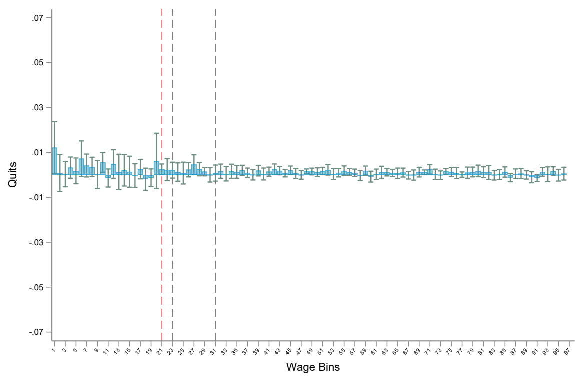
(c) 2018, Layoffs



(d) 2018, Quits



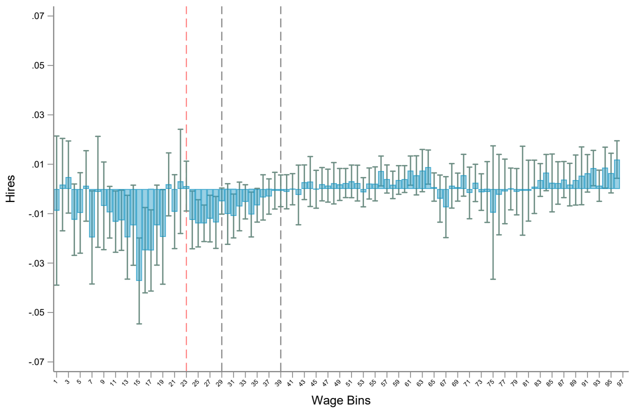
(e) 2017, Layoffs



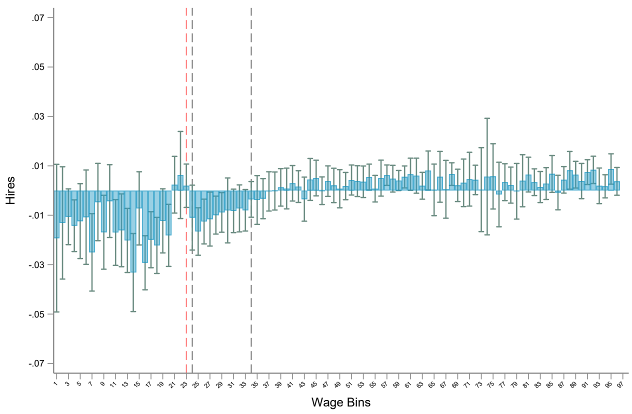
(f) 2017, Quits

Note: This figure shows the main results from the difference-in-difference specification (see equation 1) on layoffs and quits. Panel (a) and (b) show the results for the 2019 MW increase. Panel (c) and (d) show the results for the 2018 MW increase. Panel (e) and (f) show the results for the 2017 MW increase. In panels (a), (c) and (e) we show the results on layoffs and in panels (b), (d) and (f) we show the results on quits. The blue bars show for each euro bin, relative to the minimum wage, the average percentage change in either layoffs or quits in that bin during the twelve months after the minimum wage increase. The error bars show the 95% confidence interval clustered at month level. The vertical dashed read line indicates the MW level before the increase and the vertical dashed gray lines indicate the new MW level and the new minimum contribution base for the highest contribution group respectively.

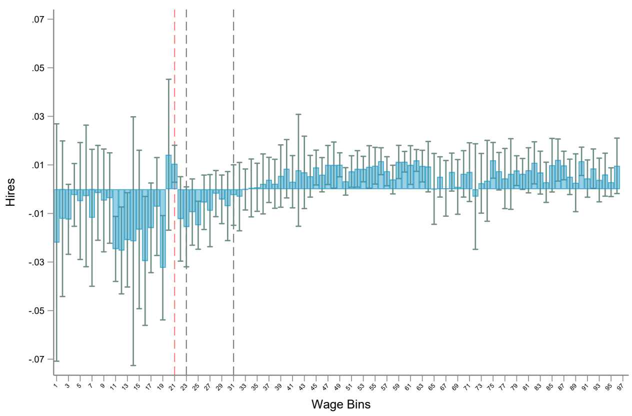
Figure X: Effects on Hires of the Minimum Wage Increase



(a) 2019 MW Increase



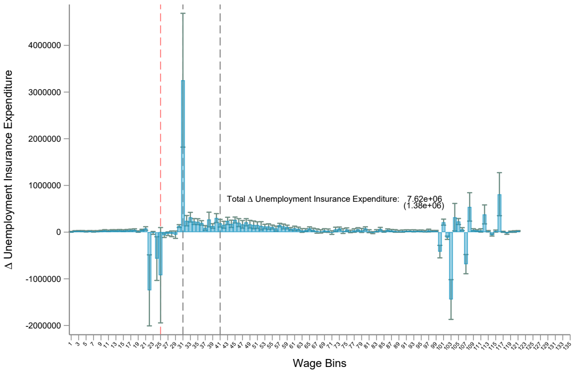
(b) 2018 Increase



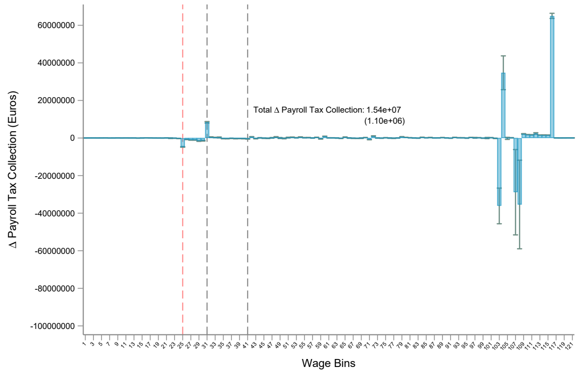
(c) 2017 MW Increase

Note: This figure shows the main results from the difference-in-difference specification (see equation 1) on hires. Panel (a) shows the results for the 2019 MW increase. Panel (b) shows the results for the 2018 MW increase. Panel (e) shows the results for the 2017 MW increase. The blue bars show for each euro bin, relative to the minimum wage, the average percentage change in hires in that bin during the twelve months after the minimum wage increase. The error bars show the 95% confidence interval clustered at month level. The vertical dashed read line indicates the MW level before the increase and the vertical dashed gray lines indicate the new MW level and the new minimum contribution base for the highest contribution group respectively.

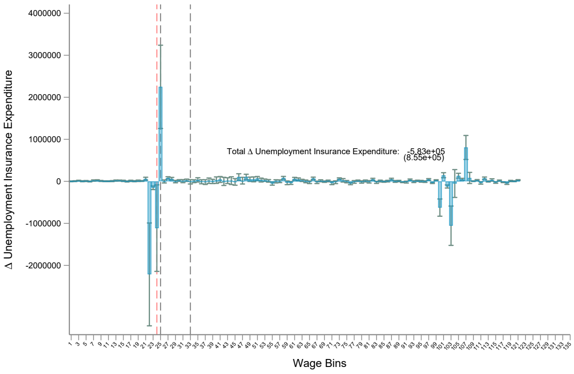
Figure XI: Effects on Unemployment Insurance and Payroll Tax Collection of the MW Increase



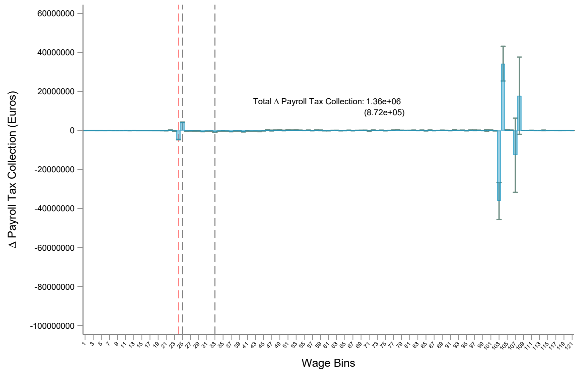
(a) 2019, Unemployment Insurance



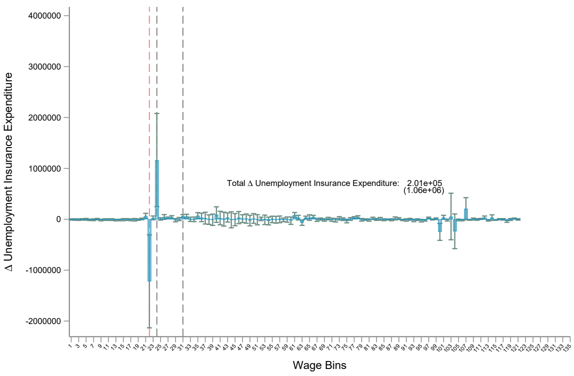
(b) 2019, Payroll Taxes



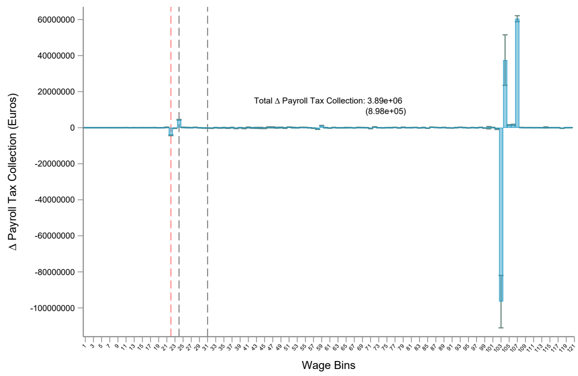
(c) 2018, Unemployment Insurance



(d) 2018, Payroll Taxes



(e) 2017, Unemployment Insurance



(f) 2017, Payroll Taxes

Note:

Table I: Contribution Basis 2015-2020

	Minimum Basis				
Worker Group	2015	2016	2017	2018	2019
1	1056.9	1067.4	1152.9	1199.10	1466.40
2	876.6	885.3	956.1	994.20	1215.90
3	762.6	770.1	831.6	864.90	1057.80
4-7	756.6	764.4	825.6	858.6	1050
8-11 (1)	25.22	25.48	27.52	28.62	35
	Maximum Basis				
Worker Group	2015	2016	2017	2018	2019
1-7	3606.00	3642.00	3751.2	3803.70	4070.10
8-11 (1)	120.2	121.4	125.04	126.79	135.67

Notes: This table shows the minimum and maximum social security contribution basis for several years. Source:

Table II: Summary Statistics

	December 2016		December 2017		December 2018	
	Below 2017 MW (1)	Rest of the Workers (2)	Below 2018 MW (3)	Rest of the Workers (4)	Below 2019 MW (5)	Rest of the Workers (6)
A. Demographic Characteristics						
Female	0.571	0.472	0.575	0.471	0.574	0.465
Spanish Citizens	0.771	0.917	0.772	0.913	0.774	0.913
By age:						
Share less than 24	0.023	0.010	0.023	0.012	0.014	0.006
Share 24-44	0.363	0.453	0.337	0.442	0.322	0.411
Share 45-65	0.394	0.411	0.389	0.391	0.358	0.404
B. Socioeconomic Characteristics						
By education:						
Share less than HS	0.347	0.137	0.343	0.137	0.317	0.133
Completed HS	0.543	0.565	0.546	0.566	0.562	0.564
Some Higher Education	0.081	0.264	0.082	0.262	0.092	0.267
C. Contract Characteristics						
Open Ended	0.552	0.624	0.544	0.619	0.526	0.634
Short-Term	0.447	0.284	0.453	0.288	0.471	0.268
Public Worker	0.001	0.093	0.003	0.092	0.003	0.098
Full Time	0.929	0.821	0.927	0.824	0.875	0.832
Agriculture	0.174	0.034	0.190	0.029	0.181	0.026
Industry	0.025	0.138	0.024	0.138	0.030	0.141
Construction	0.011	0.053	0.009	0.056	0.011	0.060
Services	0.534	0.782	0.527	0.783	0.602	0.778
Housekeeping	0.229	0.005	0.229	0.004	0.177	0.002
Share of workers	0.126	0.873	0.122	0.878	0.164	0.836

Notes: This table shows summary statistics for workers affected and not affected by a minimum wage increase.

Table III: Effects of Minimum Wage Increase on Employment and Wages

	2017 MW increase	2018 MW increase	2019 MW increase
	(1)	(2)	(3)
Sum excess and missing mass	-0.005***	-0.013*	-0.027***
	(0.001)	(0.007)	(0.027)
% Δe	-0.045***	-0.102***	-0.165***
	(0.010)	(0.05)	(0.0173)
% Δw	0.062***	0.062***	0.151***
	(0.004)	(0.009)	(0.004)
% $\Delta labourcosts$	0.308	0.089	0.276
Employment elasticity w.r.t MW	-0.565***	-2.571***	-0.742***
	(0.135)	(1.469)	(0.077)
Own Wage Employment elasticity	-0.729***	-1.658**	-1.096**
	(0.174)	(0.948)	(0.428)
Employment elasticity w.r.t Labour Costs	-.205***	-1.008**	-0.310**
	(0.049)	(0.576)	(0.121)
Own Labour Cost Employment elasticity	-0.146***	-1.155**	-0.600**
	(0.035)	(0.660)	(0.234)
Share below new MW December $t-1$	0.126	0.122	0.164
Increase in the MW	0.08	0.04	0.223
Increase in mandated LC	0.222	0.102	0.533

Note:

Table IV: Change in Unemployment Insurance and Payroll Taxes

A. Distribution around the new MW until new Minimum Contribution Basis G1

	2017 MW and Contribution Basis Change	2018 MW and Contribution Basis Change	2019 MW and Contribution Basis Change
Δ in Payroll Tax (PT) Collection	230,582	-3,902,908	-3,693,508
	(680,427.5)	(461,823.7)	(680,556.8)
Δ in Unemployment Insurance (UI) Payments	70,284.39	-809,089.4	3,298,810
	(269,286.5)	(256,447.8)	(561,552.6)
Net Difference	160,297.71	-3,093,819	-6,992,318
	()	(550,619.8)	(1,014,689)
Δ PT Collection/Δ UI Payments	3.28	4.82	-1.12

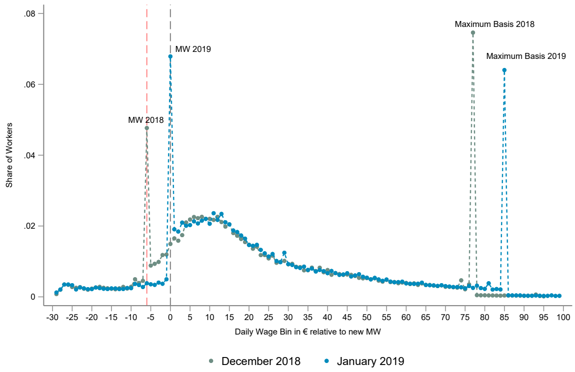
B. Complete Distribution

	2017 MW and Contribution Basis Change	2018 MW and Contribution Basis Change	2019 MW and Contribution Basis Change
Δ in Payroll Tax (PT) Collection	3,888,711.8	1,362,852.9	15,446,283
	(897,849.51)	(871,690.78)	(1,097,826.1)
Δ in Unemployment Insurance (UI) Payments	201,433.85	-583,337	7,619,240.4
	(1,064,531.6)	(855,183.55)	(1,381,735.9)
Net Difference	3,687,277.95	1,946,190	7,827,043
	()	(1,359,690)	(1,713,304)
Δ PT Collection/Δ UI Payments	19.31	-2,33	2.27

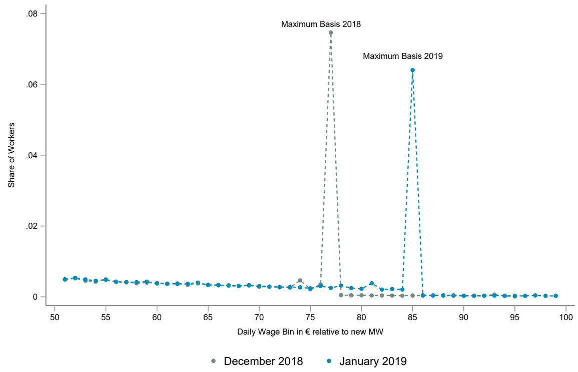
Notes: This table shows the minimum and maximum social security contribution basis for several years. Source:

A Additional Tables and Figures

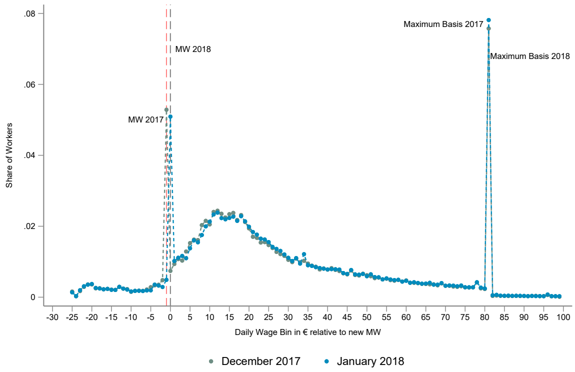
Figure A1: Daily Wage Distribution: Complete Distribution and Right Tail



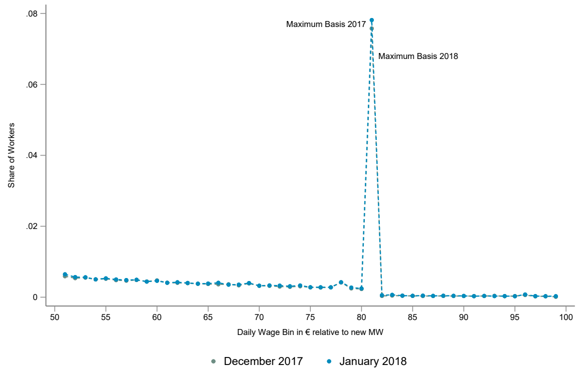
(a) Complete Distribution (Dec 2018- Jan 2019)



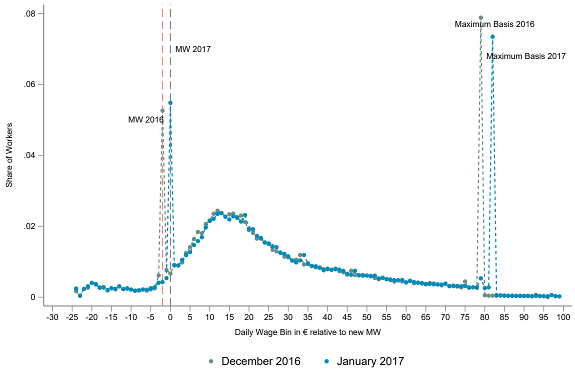
(b) Right Tail (Dec 2018- Jan 2019)



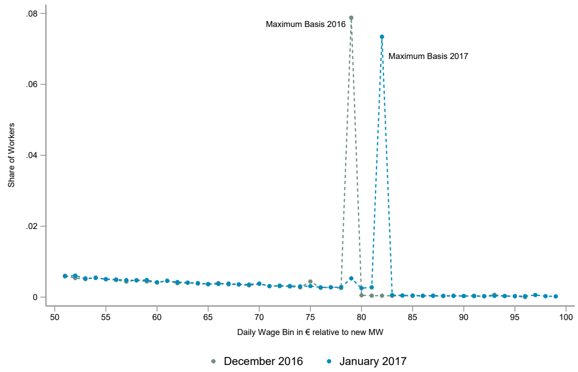
(c) Complete Distribution (Dec 2017- Jan 2018)



(d) Right Tail (Dec 2017- Jan 2018)



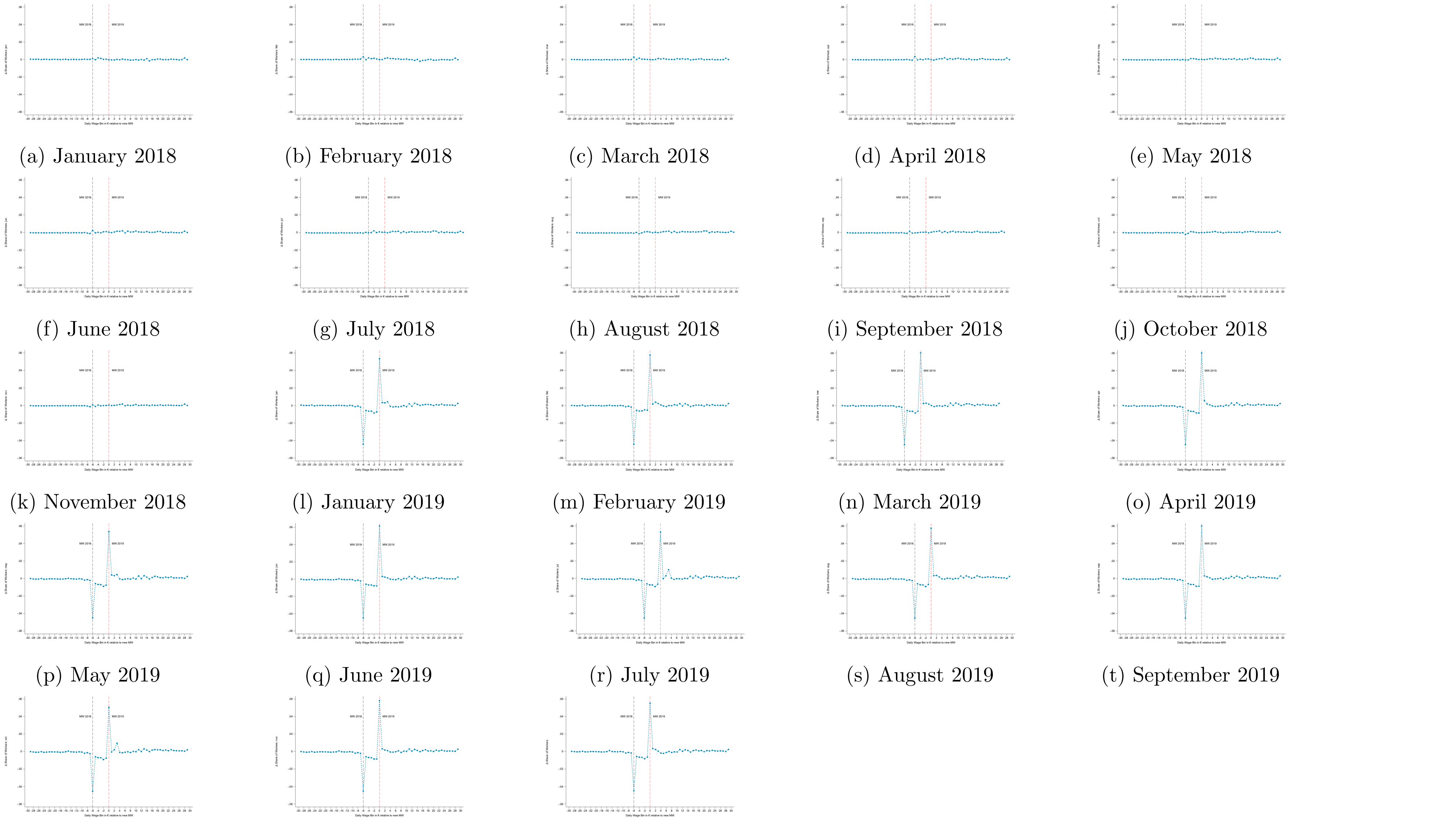
(e) Complete Distribution (Dec 2016- Jan 2017)



(f) Right Tail (Dec 2016- Jan 2017)

Note: This Figure shows the complete frequency distribution of the daily base pay of salaried workers in December in a certain year, t, and January of the next year, $t+1$ and the right tail of those same distributions. Panel (a) and (b) plot the distributions from December 2018 and January 2019. Panel (c) and (d) plot the distributions from December 2017 and December 2018. Panel (e) and (f) plot the distributions from December 2015 and 2016. The vertical lines represent the daily minimum wage level. The red dashed lines corresponds to the daily MW level in year t and the gray dashed line the daily MW year in year $t+1$. The bins have a width of 1€and daily wage is calculated in relation to the new daily MW i.e. the MW level of 2019, 2018 and 2017 in panels (a) and (b), (c) and (d), and (e) and (f) respectively.

Figure A2: Month by Month Daily Wage Distributions: Differentiated with respect to December 2018



(a) January 2018 (b) February 2018 (c) March 2018 (d) April 2018 (e) May 2018

(f) June 2018 (g) July 2018 (h) August 2018 (i) September 2018 (j) October 2018

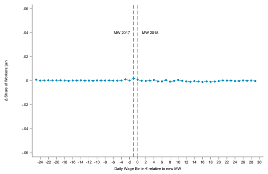
(k) November 2018 (l) January 2019 (m) February 2019 (n) March 2019 (o) April 2019

(p) May 2019 (q) June 2019 (r) July 2019 (s) August 2019 (t) September 2019

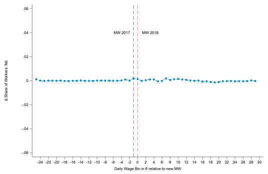
(u) October 2019 (v) November 2019 (w) December 2019

Note: This Figure shows the frequency distribution of all the months in 2018 and 2019 differentiated with respect to December of 2018 of the daily base pay of salaried workers.

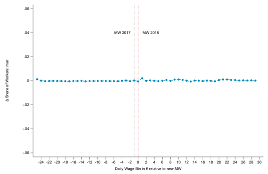
Figure A3: Month by Month Daily Wage Distributions: Differentiated with respect to December 2017



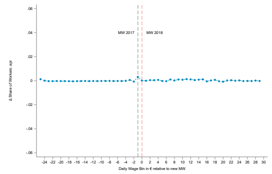
(a) January 2017



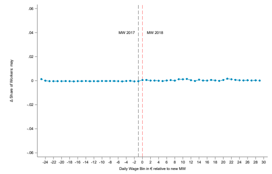
(b) February 2017



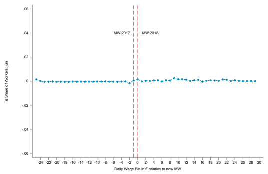
(c) March 2017



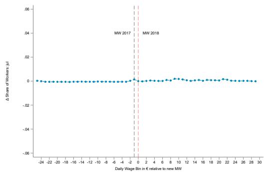
(d) April 2017



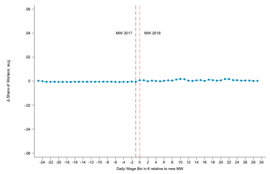
(e) May 2017



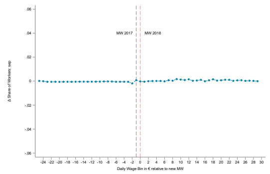
(f) June 2017



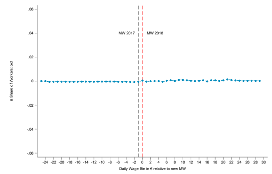
(g) July 2017



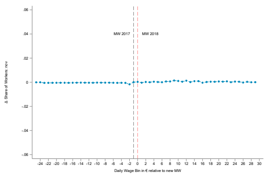
(h) August 2017



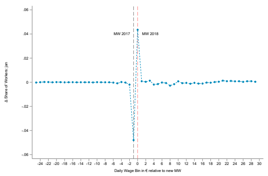
(i) September 2017



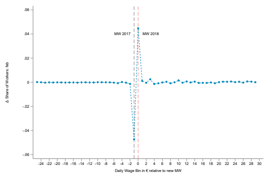
(j) October 2017



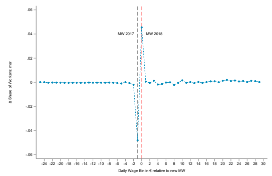
(k) November 2017



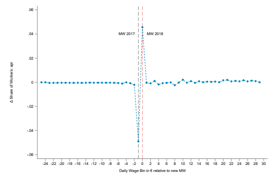
(l) January 2018



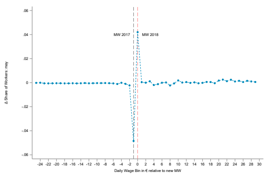
(m) February 2018



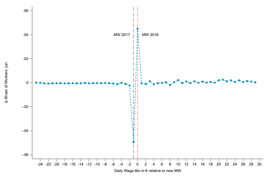
(n) March 2018



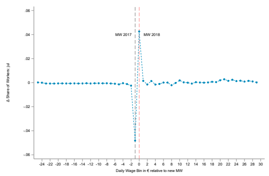
(o) April 2018



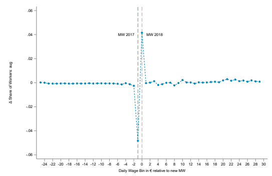
(p) May 2018



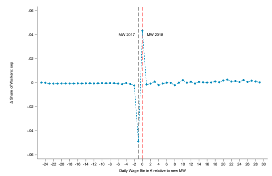
(q) June 2018



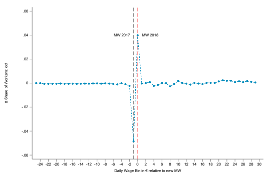
(r) July 2018



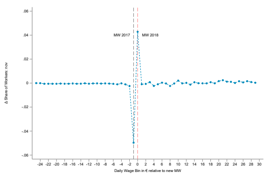
(s) August 2018



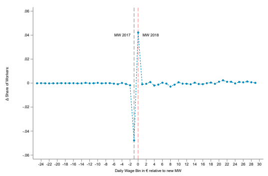
(t) September 2018



(u) October 2018



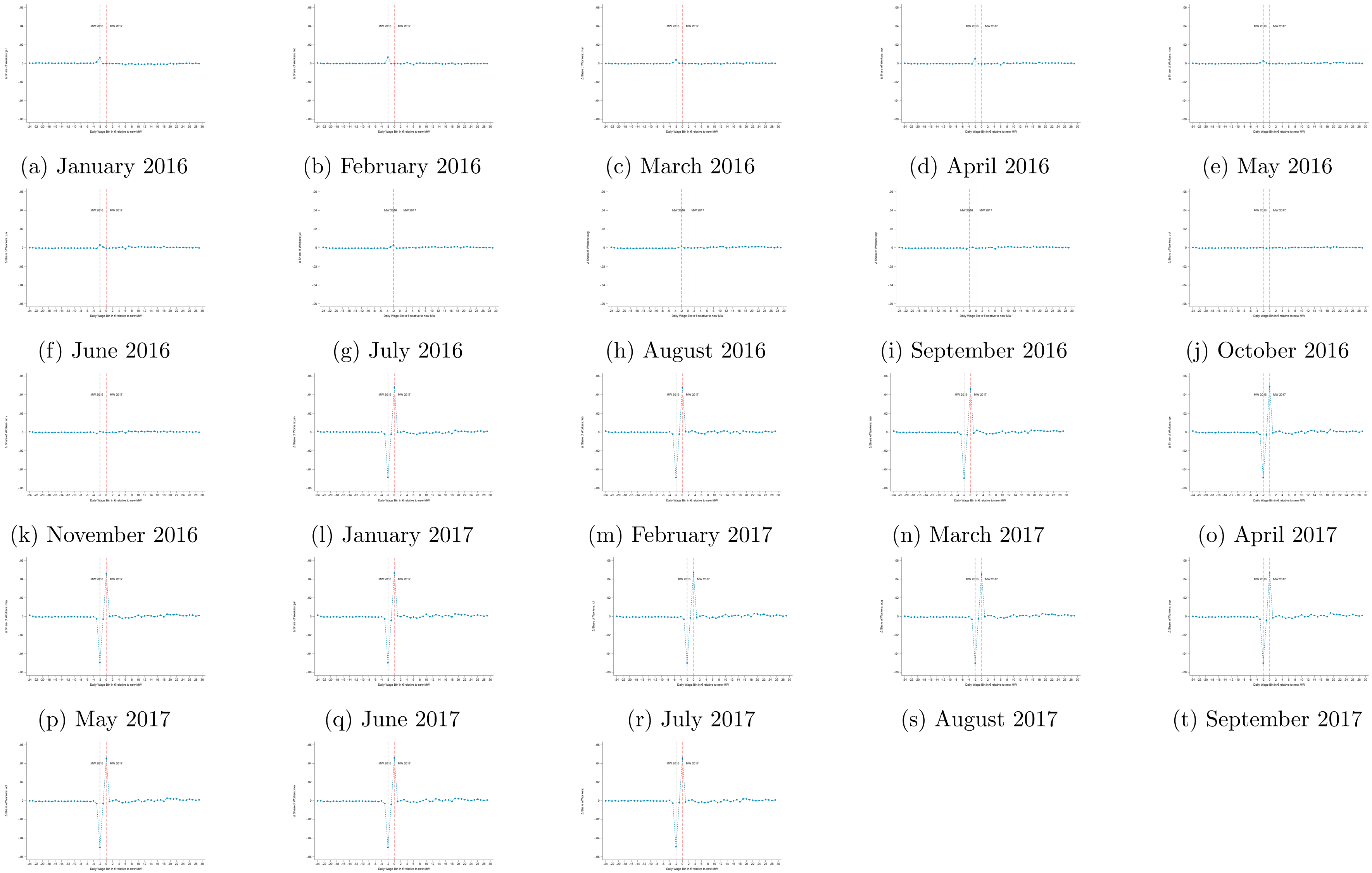
(v) November 2018



(w) December 2018

Note: This Figure shows the frequency distribution of all the months in 2017 and 2018 differentiated with respect to December of 2017 of the daily base pay of salaried workers.

Figure A4: Month by Month Daily Wage Distributions: Differentiated with respect to December 2016



(a) January 2016 (b) February 2016 (c) March 2016 (d) April 2016 (e) May 2016

(f) June 2016 (g) July 2016 (h) August 2016 (i) September 2016 (j) October 2016

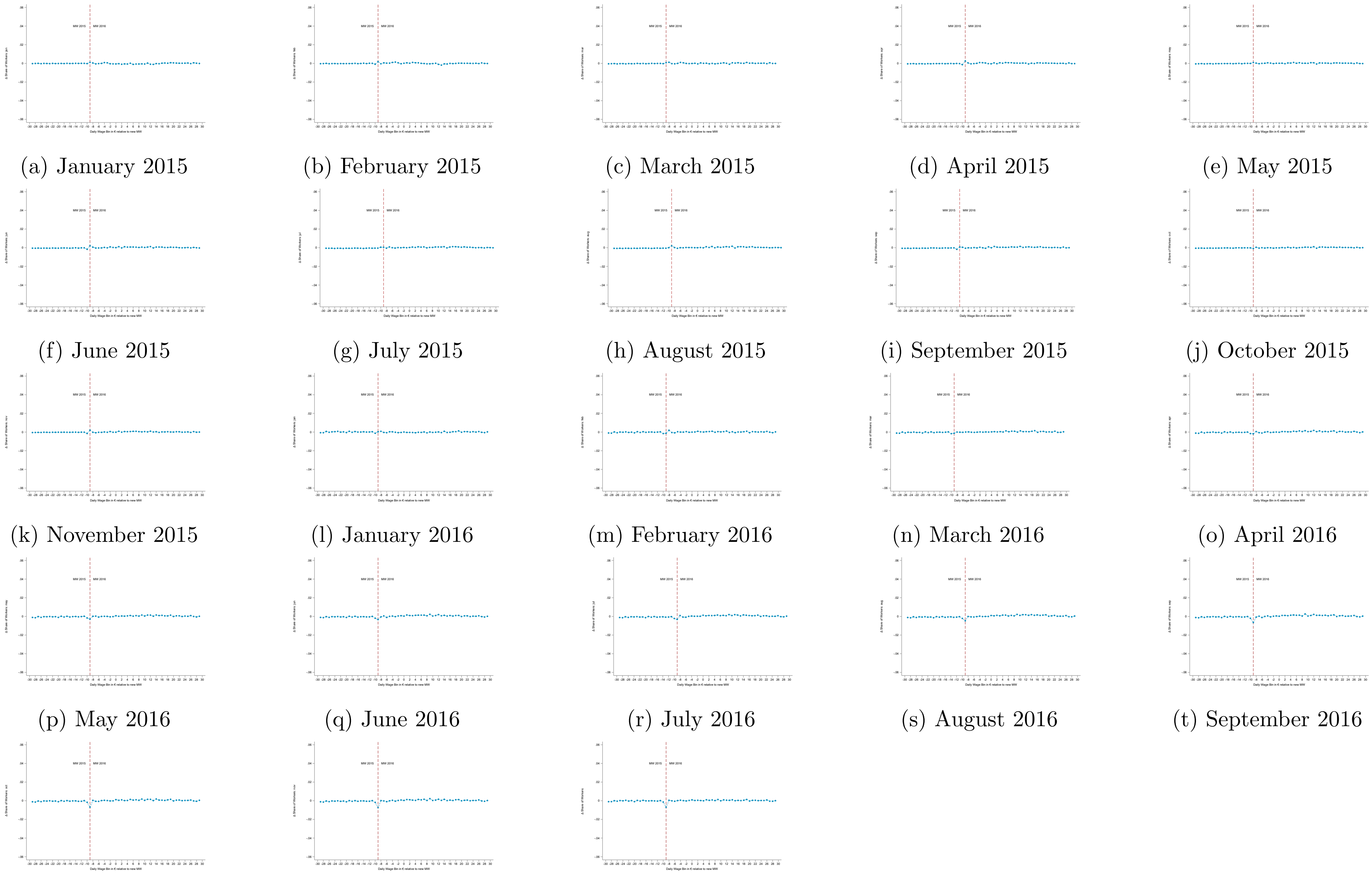
(k) November 2016 (l) January 2017 (m) February 2017 (n) March 2017 (o) April 2017

(p) May 2017 (q) June 2017 (r) July 2017 (s) August 2017 (t) September 2017

(u) October 2017 (v) November 2017 (w) December 2017

Note: This Figure shows the frequency distribution of all the months in 2016 and 2017 differentiated with respect to December of 2016 of the daily base pay of salaried workers.

Figure A5: Month by Month Daily Wage Distributions: Differentiated with respect to December 2015



(a) January 2015 (b) February 2015 (c) March 2015 (d) April 2015 (e) May 2015

(f) June 2015 (g) July 2015 (h) August 2015 (i) September 2015 (j) October 2015

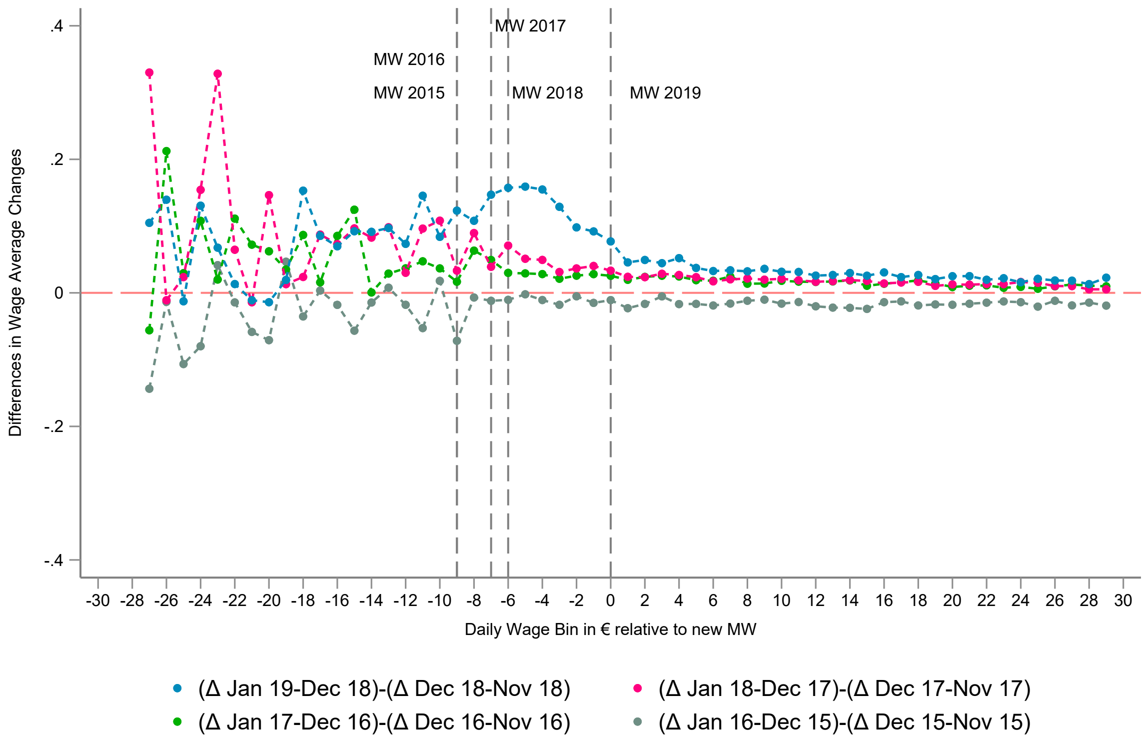
(k) November 2015 (l) January 2016 (m) February 2016 (n) March 2016 (o) April 2016

(p) May 2016 (q) June 2016 (r) July 2016 (s) August 2016 (t) September 2016

(u) October 2016 (v) November 2016 (w) December 2016

Note: This Figure shows the frequency distribution of all the months in 2015 and 2016 differentiated with respect to December of 2015 of the daily base pay of salaried workers.

Figure A6: Caption



Note: This Figure shows the differences of the distributions between the base pay change of salaried workers that there is between November and December of a certain year , t, and December year t and January year $t+1$. The blue line represents the difference between 2018 and 2019, the pink line between 2017 and 2018, the green line between 2016 and 2017 and finally, the gray line the difference between 2015 and 2016. The vertical gray lines represent the daily minimum wage level of each year. The bins have a width of 1€and daily wage is calculated in relation to the MW level of 2019.

B Robustness Checks

Let $n_{k,m,t}$ be the number of workers employed in bin k during month m of year t. We follow Quach (2021) and model the number of employees within each bin in January of year t as follows:

$$n_{k,Jan,t} = n_{k,Dec,t-1} + \alpha_{kt} + \beta_k D_{t=2019} + \epsilon_{kt} \tag{11}$$

where α_{kt} is the average change in the number of workers in bin k between January of year t and December of year $t-1$, absent the policy. $D_{t=2019}$ is an indicator variable for the year 2019 and the coefficient β_k is the causal effect of increasing the minimum wage on the number of workers in bin k.

Two assumptions are necessary to identify the β_k's from the α_{kt}'s:

$$\beta_k = 0 \quad \forall\, k \geq k^*$$

$$\alpha_{kt} = \gamma_1 \alpha_{k,t-1} + \gamma_0$$

The first assumption means that the increase in the minimum wage has no effect on the number of workers earning above a threshold bin k^*. Figure XX provides evidence to support this claim: the upper tail of the difference-distribution between December 2018 and January 2019 fluctuates around zero The second claim asserts that the distribution of changes in employment between January of year t and December of year $t-1$ follows a linear transformation. This assumption is supported by the observation in figures YY and ZZ

Therefore, the stability of the change in distribution each year suggests that the difference distribution in year is a good approximation for how the 2019 distribution would have evolved if the minimum wage had been increased by 22%.

Following the two assumptions we are able to estimate β_k. The logic is as follows: for every $k \geq k^*$,

$$n_{k,Jan,t} = n_{k,Dec,t-1} + \alpha_{kt}$$

$$\Delta n_{kt} = +\alpha_{kt}$$

$$\Delta n_{kt} = \gamma_1 \alpha_{k,t-1} + \gamma_0$$

$$\Delta n_{kt} = \gamma_1 \Delta n_{k,t-1} + \gamma_0$$

which implies we can estimate γ_1 and γ_0 by regressing Δn_{kt} on $\Delta n_{k,t-1}$ using all bins $k \geq k^*$. Then, we can predict the α_{kt}'s with bins $k < k^*$:

$$\hat{\alpha}_{kt} = \hat{\gamma}_1 \Delta n_{k,t-1} + \hat{\gamma}_0$$

and estimate the following equation to obtain the $\hat{\beta}_k$:

$$n_{k,Jan,t} = n_{k,Dec,t-1} + \hat{\alpha}_{kt} + \beta_k D_{t=2019} + \epsilon_{kt} \quad (12)$$