How is the Minimum Wage Shaping the Wage Distribution: Minimum Wage, Spillovers, and Wage Inequality in Portugal

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HOW IS THE MINIMUM WAGE SHAPING THE WAGE DISTRIBUTION: MINIMUM WAGE, SPILLOVERS, AND WAGE INEQUALITY IN PORTUGAL

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Abstract
Over the last three decades, wage inequality and the importance of the minimum wage presented a nearly symmetric behavior in Portugal. Applying a semiparametric approach, this paper presents significant visual and quantitative evidence of how the MW structurally reshaped the wage distribution. The remarkable rise in the real MW of 2006-2019 explained virtually all of the decline in wage inequality, and 40% of the average wage growth, mostly driven by spillovers, which cascaded way above the minimum. The MW was most important for women, although spillovers were greater for men. Exploring the total-base wage differential also uncovered important new insights.

Keywords: labour economics, minimum wage, spillovers, wage inequality, wage distribution, counterfactual decomposition, distribution regression, rank regression, kernel density, reweighting

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1 Introduction

Mounting wage inequality starting around the 1980s was a phenomenon experienced by most advanced economies (Piketty 2014; Hoffmann et al. 2020). It was primarily driven by labor supply and demand dynamics, like skill-biased technological change (Card and DiNardo 2002), globalization (Feenstra and Hanson 1996), and the general polarization of the labor market (Autor et al. 2008), but the decay of labor market institutions in several countries, like the minimum wage and unionization, has also been implicated (DiNardo et al. 1996; Koeniger et al. 2007).

Over a period where inequality in the upper half of the wage distribution follows a clear, positive trend across developed economies, the behavior of inequality in the lower half of the distribution was much more diverse. Over the same period, the minimum wage, a policy that specifically targets the lower end of the distribution, also exhibited large cross-country heterogeneity, frequently in negative correlation with lower tail wage inequality.[1] That is good reason to give it particular attention in research of inequality and the shaping of the wage distribution.

In Portugal, wage inequality was high and rising between the 1980s and the mid-2000s, and that increase was mostly due to a widening of the wage distribution at the top (Cardoso 1998; Alvaredo 2009; Centeno and Novo 2014). After that, inequality actually decreased through a compression of the lower half of the wage distribution. In fact, the behavior of wage inequality in Portugal since the mid-1980s can be well divided into three very distinct periods: between 1986 and 1994 inequality increased sharply, especially in the middle and upper-tail of the distribution; between 1994 and the mid-2000s changes in wage inequality were positive but small; and since the mid-2000s it decreased significantly, with an emphasis on the lower-half of the distribution. This is clearly illustrated in figure 1, and quantified in table A.1 of the appendix.

1. For instance, the real value of the federal minimum wage declined continuously in the United States, during the 1980s, and wage inequality rose dramatically (DiNardo et al. 1996; Lee 1999), while the UK (Stewart 2012) and Germany (Bossler and Schank 2020) both saw wage inequality declining at the bottom of the distribution following the introduction of national minimum wages in 1999 and 2015, respectively.

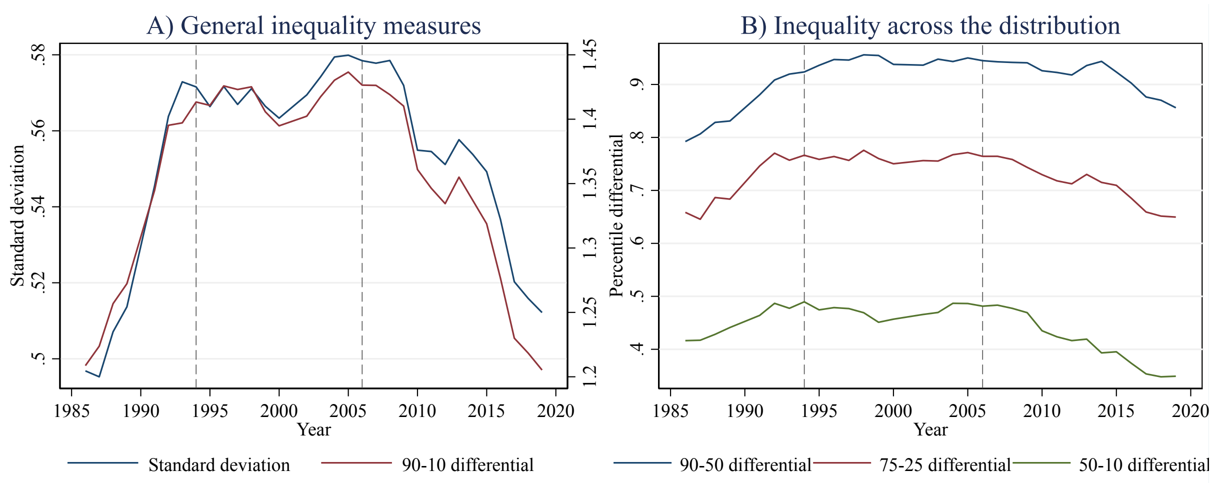

Figure 1: Measures of wage inequality. Panel A depicts wage inequality measures for the entire distribution. Panel B depicts measures of inequality at different parts of the distribution. Both standard deviation and the wage percentile differentials use the logarithm of total monthly wages. The two dashed vertical lines, in 1994 and 2006, divide the three periods of analysis.

The relatively short economic literature aiming to explain the changes in the Portuguese wage distribution over the last decades has naturally focused on the labor market dynamics side of the equation, which does explain a substantial part of those changes. Skill-biased technological changes and the overall modernization of the labor market had a major impact in the widening of the wage distribution since the 1980s (Cardoso 1997, 1998; Centeno and Novo 2014), especially in what regards the remarkable increase in the education levels of Portuguese workers (Machado and Mata 2005; Pereira 2021), a growing disparity in the returns to education across the wage distribution (Cardoso 1998; Martins and Pereira 2004; Machado and Mata 2005), and also the rising number of women in the workforce (Cardoso 1999; Pereira 2021).

Still, after 1994 the widening of the wage distribution moderated and literature is yet to fully explain that phenomenon, aside from a possible excess of supply of intermediate-skill workers relative to unskilled ones due to the increased education levels, that narrowed the lower tail of the distribution (Centeno and Novo 2014), and a fading association between high-paying firms and high-wage workers (Portugal et al. 2018). Furthermore, wage inequality plummeted since the mid-2000s, especially for lower-wage workers - over a period where the nominal minimum wage almost doubled and the share of workers on a base wage equal or lower than the minimum went from 8% up to 23% - and that remarkable phenomenon is yet to be studied.

With that in mind, this paper contributes to the literature by investigating a side of the story acknowledged in no more than a handful of articles: the role of the minimum wage. Applying a semiparametric approach that bridges the distribution regression (Chernozhukov et al. 2013) and the rank regression framework (Fortin and Lemieux 1998), explored in Fortin et al. (2021), and exploiting the very rich administrative data of the individual records of *Quadros de Pessoal*, this paper presents estimates of the Portuguese wage density over three different time periods - 1986-1994, 1994-2006 and 2006-2019 - as well as a series of counterfactual scenarios that allow us to decompose changes in the distribution into the underlying change and the change attributed to the variation in the minimum. The effect of the minimum wage can then itself be decomposed into minimum wage "bite" effects and spillover effects. More, these results are not only presented in a visually clear way, but they are also quantified in several statistics of interest.

The results unambiguously show that the minimum wage was a crucial factor in the shaping of the Portuguese wage distribution when its relative importance increased. That is to say, while in the first period of analysis the minimum wage barely changed and its impact on the distribution was negligible, in the last period, a hike of 30% in its real value over 13 years was enough to structurally reshape the wage distribution, which would be much wider today had the minimum not increased. For instance, the 90-10 percentile differential decreased by 22 log points between 2006 and 2019, and all of that declined can be attributed to the increase in the minimum wage, while the 50-10 differential would have actually increased by 9 points instead of decreasing by 13, had the minimum wage not been raised. Between 2006 and 2019 the average wage of Portuguese workers increased by 16 log points and the rise in the minimum was responsible for almost 40% of that increase. For workers at the lowest percentiles of the distribution, which were the ones who saw their wages increase the most out of everyone in the workforce in reality, wages were stagnant in the counterfactual. The results also suggest that, in many cases, the effect of spillovers can be even higher than the minimum wage “bite”, and that the increase in the minimum wage was most important in reducing female wage inequality. Finally, this paper uncovers a large discrepancy between the behavior of base and total wages over time, which reacted very differently to rises in the minimum wage - while the minimum wage pushes up the base wage when it binds, the spillover effects were almost entirely reflected in the total wage.

The remaining of this paper is organized as follows: section 2 presents a review of the literature and relevant information on the minimum wage and wage inequality, section 3 presents the methodology and details on data and estimation, section 4 presents the results of the paper along with an analysis of those results, and section 5 concludes the paper with some final remarks.

2 The minimum wage and the wage distribution

The minimum wage allows for a set of margins through which labor markets can adjust, like employment, hours worked, wages and prices, but its impact across the wage distribution stands out in the sense of how structural it can be, depending on its value and the latent distribution.

When analyzing the distributional effects of an increase in the real value of the minimum wage on wages – or the introduction of a minimum wage, for that matter – we must consider three main ideas. First, the minimum wage can destroy jobs, leading to reduced incomes for those who would have been able to find a job in the absence of it. Second, and most notably, it allows some people at the bottom of the wage distribution to receive a higher wage. Third, the rise in wages can spillover to workers higher up in the pay-scale who would not apparently benefit from the raise. There are many other mechanisms through which a minimum wage can affect wages, but their effects are either still unsettled in the literature or just not structural, by affecting only specific segments of the workforce and not the wage distribution *per se*.[2]

The first concept regards disemployment effects, which ought to raise *income* inequality since the minimum wage can be discarding the left tail of the wage distribution and cutting the incomes of all those workers that cannot find a job with the higher minimum (Stigler 1946; Mincer 1976; Neumark et al. 2004). The impact on *wage* inequality, however, will be the exact opposite, as the workers that are "discarded from the distribution" are those at its very end, ironically flattening the distribution (Machin et al. 2003; Teulings 2003). Still, the empirical literature on these disemployment effects is extensive, and has indicated that job losses attributed to the minimum wage are oftentimes negligible (Brown et al. 1982; Card 1992; Katz and Krueger 1992; Machin and Manning 1994; Card and Krueger 1994, 1995; Dube et al. 2010).[3]

While distributional outcomes of disemployment effects can almost be seen as unintended consequences, the two other mechanisms through which the minimum wage can shape the wage structure are distributional by nature. The minimum wage "bite" (Meyer and Wise 1983a, 1983b; Machin et al. 2003) is the most fundamental, and the most obvious: setting a minimum wage – or raising it – will increase the wages of those workers initially making less than the minimum to exactly the level of the minimum, pushing those workers' wages at the left-most part of the distribution to the right, closer to the median, and compressing the wage distribution as a whole. This bite is in many ways the primary motivation for a minimum wage (Freeman 1996), and it is regarded as the main mechanism though which the minimum wage can affect wage dispersion.

Then there are the less evident spillover effects. Gramlich (1976) first suggested that pay raises could be spilling over to workers earning above the new minimum (Brown 1999), but spillovers have been widely recognized in the literature since then (Grossman 1983; Katz and

2. For instance, Freeman (1996) suggests that increasing the lower wages in a firm increases production costs, likely reducing either firms' shareholder income or higher-wage workers' wages. Firms may also have to increase prices, making those workers' wages, if not nominally, at least in real terms decreasing with the minimum wage.

3. In fact, a suitably chosen minimum wage may even raise wages and employment simultaneously in a labor market with monopsony power (Rebitzer and Taylor 1995; Manning 2003; Portugal and Cardoso 2006).

Krueger 1992; Lee 1999; Cengiz et al. 2019; Fortin et al. 2021). The idea that a minimum wage can raise wages above that minimum came first from the notion of substitution effects, as the higher relative price of low-skilled workers would lead employers to substitute towards higher-skilled labor (Gramlich 1976), although it shifted with time to more of a relative wage concern, as firms mitigate the deterioration in workers' wages relative to the lower-skilled ones (Grossman 1983).[4] Spillover effects are also the hardest to detect, but we at least know that their impact varies greatly, and that it is much higher for wages closer to the minimum.

Minimum wage research gained a lot of traction during the credibility revolution in labor economics (Angrist and Pischke 2010; Belman and Wolfson 2014), resulting in a wealth of empirical literature estimating the distributional effects of the minimum wage. The most influential papers study the United States over the last two/three decades of the 20th century, exploiting "the longest sustained decline in the real value of the federal minimum wage" in the US along with a "dramatic rise in earnings and wage inequality" (Lee 1999). The large majority come to similar conclusions: the falling real minimum wage accounted for much of the rise in dispersion in the lower tail of the wage distribution, without a significant effect on the upper tail of the distribution, particularly for women (Katz and Krueger 1992; Card and Krueger 1994; DiNardo et al. 1996; Lee 1999). The higher wages of workers that would earn below the minimum are in all cases the most important driver of this compressing effect on the distribution, although spillovers often have an additional attenuating impact on inequality when they are considered (Lee 1999; Teulings 2003), while disemployment effects are rarely accounted for in distributional analyses, as their effect is assumed to be relatively unimportant (DiNardo et al. 1996).

Modern studies, with updated methodologies, keep confirming the inequality-reducing effects of the minimum wage (Card and Krueger 2015; Autor et al. 2016; Brochu et al. 2018;

4. Spillovers can also arise in the presence of monopsony power, as unproductive firms close down when the minimum wage rises and their employees move to more productive, better-paying firms (Dickens et al. 2012).

Cengiz et al. 2019; Fortin et al. 2021), although some stress that spillovers seem to have lost importance over time, and studies outside the US have reached analogous conclusions.[5]

2.1 The Portuguese minimum wage

In Portugal, unlike many countries, the minimum wage rate is legislated at the national level. That monthly rate has been set by the government each January 1st almost every year since it was first legislated in 1974, and it covers nearly all workers in the country.[6] The few exceptions - like the youth and the agricultural minimum wages - tended to disappear over time.

The real value of the minimum wage grew steadily, but at a slow pace between the 1980s and the mid-2000s – only 10% in 20 years, between 1986 and 2006. After that, it grew at a much faster pace – 30% between 2006 and 2019 – with a slight slump between 2011 and 2014, when its nominal rate was frozen by the government in response to the financial crisis. The minimum wage relative to the average wage saw a severe drop between 1986 and 1994, decreased even more until 2006, although at a much lower pace, but started to increase dramatically since then. The share of workers earning the minimum wage or less decreased consistently but slowly until the mid-2000s but also increased rapidly since then, if we look at the base wage - strikingly, this sudden rise is not reflected in the aggregate of total wages. To some extent, the importance of the minimum wage over time in the Portuguese labor market can be summarized in the same three periods that characterize wage inequality: it was decreasing until 1994, somewhat stable until 2006, and increased significantly since then. This is illustrated in figure 2.

So, if we contrast this behavior with the behavior of wage inequality over the years, especially in the lower tail, there is a noticeable symmetry that presents clear potential for research

5. See Machin (1997) and Machin et al. (2003) for the UK, Bossler and Schank (2020) for Germany, Aeberhardt et al. (2016) for France, and Koeniger et al. (2007) and Joe and Moon (2020) for OECD cross-country analyses.

6. Although sector-specific wage floors, through extended collective bargaining agreements, are very widespread in the Portuguese context (Cardoso and Portugal 2005; Addison et al. 2017; Martins 2021).

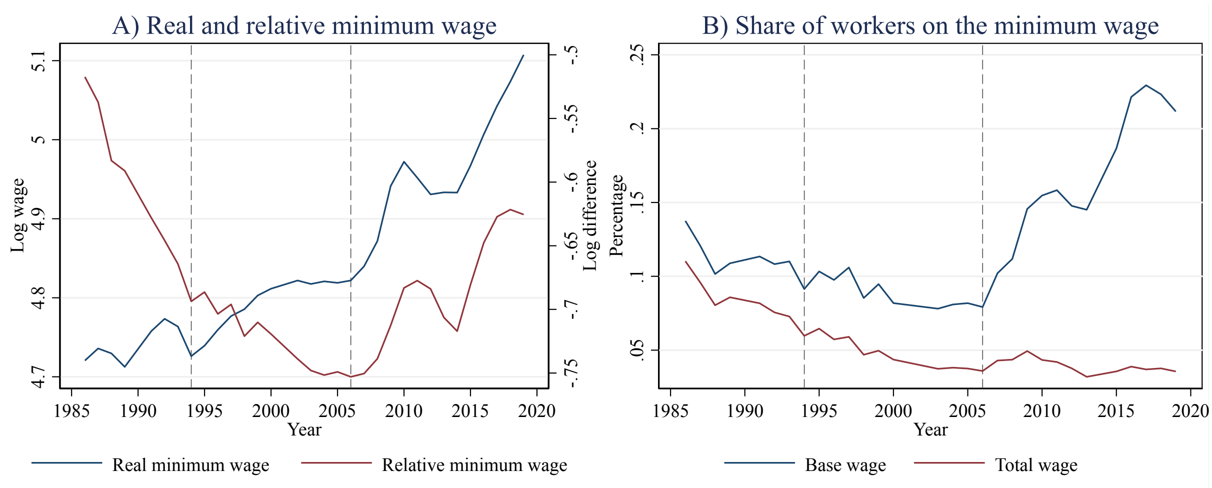

Figure 2: Importance of the minimum wage. Panel A depicts the logarithms of the real value of the minimum wage and the minimum wage relative to the average wage. Panel B depicts the share of workers with wages equal or lower than the minimum, using base and total wages (in 2002 and 2014 wage rounding near the minimum created noisy behavior in the graph, so those years were omitted). The two dashed vertical lines, in 1994 and 2006, divide the three periods of analysis.

of minimum wage's distributional effects. However, the amount of research assessing the role of the minimum wage on wage inequality in Portugal is very limited, mostly concluding that it has had some narrowing effect on the wage distribution (Centeno and Novo 2014; Campos Lima et al. 2021) - only Pereira and Galego (2019) find no significant contribution of the minimum wage in attenuating wage inequality. There is also little literature on the disemployment effect in Portugal, with unsettled, but generally slim results (Pereira 2003; Portugal and Cardoso 2006).

3 Methodology and data

To assess the effects of the minimum wage on wage inequality, the whole wage distribution is modelled by employing a framework that bridges distribution regressions and rank regressions introduced by Fortin et al. (2021).[7] This methodology allows for the detailed estimation of the distributional effects of the minimum wage and its spillovers assuming no disemployment effects, which is a relatively reasonable assumption in this context, according to recent literature.

7. Fortin et al. (2021) examine the role of minimum wages spillover effects and unionization threat effects in changes in the US wage distribution between 1979 and 2017, finding that spillovers magnify the explanatory power of decreasing minimum wages to two-thirds of the increase in inequality at the bottom of the female distribution.

3.1 Bridging distribution regressions and rank regressions

The distribution regression framework (Chernozhukov et al. 2013) can be used to estimate the probability of an outcome variable being below or above a given cutoff point in a distribution. For instance, we can estimate the probability of the outcome variable Y being above the cutoff y_k as a flexible function of covariates X using a probit model as $\text{Prob}(Y \geq y_k) = \Phi(X\beta_k)$.

Then we can model the whole distribution by dividing it in $K-1$ bins, delimited by the cutoff points y_k and y_{k+1} - which may be chosen as percentiles of the unconditional distribution or using a fine grid - and computing the probability of the outcome variable lying in each bin:

$$\begin{aligned}\text{Prob}(y_k \leq Y < y_{k+1}) &= \text{Prob}(Y \geq y_k) - \text{Prob}(Y \geq y_{k+1}) \\ &= \Phi(X\beta_k) - \Phi(X\beta_{k+1}) \qquad \text{for } k = 1, 2, \cdots, K.\end{aligned} \tag{1}$$

From these regressions, we can construct the conditional distribution from which all kinds of counterfactuals can be estimated, by changing the distributions of covariates or the regression coefficients themselves, allowing for the decomposition of changes in the wage distribution.

The general distribution regression framework as presented in Chernozhukov et al. (2013) is highly flexible, with no restrictions on how β_k coefficients vary across cutoffs, and that flexibility may be counterproductive when constructing the distribution, as we may get negative counterfactual probabilities and face identification problems in allowing for different β_k at different points for all covariates, without restrictions.[8] For that reason Fortin et al. (2021) propose a less flexible framework, closer to the rank regressions of Fortin and Lemieux (1998), where the effects of explanatory variables can be fixed or evolve smoothly across the distribution.

In Fortin and Lemieux (1998)'s rank regression framework the coefficients are fixed across the distribution. We can view it as a latent variable model where the latent variable index is given by $Y^* = X\beta + \varepsilon$, with $\varepsilon \sim N(0, 1)$, and the observed variable is the monotonic transformation

8. For instance, the final model will include a set of year dummies to capture macroeconomic conditions, which could absorb the whole effect of the minimum wage if we allowed for full flexibility of the β_k coefficients.

$Y = g(X\beta + \varepsilon)$, with each observation's latent and observed variable rank being the same. Then we can divide the observed variable range by the cutoffs y_k and compute the probability of it being above a given cutoff as $\text{Prob}(Y \geq y_k) = \Phi(X\beta - c_k)$, where $c_k = g^{-1}(y_k)$ are the corresponding cutoffs in the latent distribution. This way, we can model the distribution through an ordered probit where each category is a bin delimited by y_k and y_{k+1} with probability:

$$\text{Prob}(y_k \leq Y < y_{k+1}) = \Phi(X\beta - c_k) - \Phi(X\beta - c_{k+1}) \qquad \text{for } k = 1, 2, \cdots, K. \tag{2}$$

Here β coefficients are fixed across the distribution, as opposed to the β_k coefficients in equation 1. But the flexibility can also be advantageous. That is why we will employ a framework that bridges both methods, by introducing heteroscedasticity. Incorporating the interaction between X and y_k in the model allows for the effect of explanatory variables to evolve linearly across the wage distribution, such that $\text{Prob}(Y \geq y_k) = \Phi(X\beta + y_k X\gamma - c_k)$, and therefore:

$$\text{Prob}(y_k \leq Y < y_{k+1}) = \Phi(X\beta + y_k X\gamma - c_k) - \Phi(X\beta + y_{k+1} X\gamma - c_{k+1}) \tag{3}$$

3.2 Minimum wage effects

From this kind of framework, minimum wage effects can be estimated straightforwardly, by simply adding a set of dummy variables that indicate the distance to the minimum. We know that the effect of a minimum wage on the cumulative wage distribution would be the generation of a spike over that point. For instance, if in the latent wage distribution without the minimum wage we had $\text{Prob}(Y \geq y_k) = \Phi(X\beta - c_k)$ (using the rank regression model for simplification), if y_k is the cutoff point just above the minimum wage ($y_{k-1} \geq MW < y_k$), the probability of Y being above that cutoff point in the observed distribution can be characterized as $\text{Prob}(Y \geq y_k) = \Phi(X\beta - c_k + \delta_0)$, where δ_0 is a parameter that captures the effect of the minimum wage. In fact, $\text{Prob}(Y \geq y_k) = \Phi(X\beta - c_k + \delta_0)$ for all y_k above the minimum wage.

Furthermore, in the presence of spillover effects, they can also be accounted for with a similar strategy. For example, if the effect of the minimum wage spills over to only one wage bin above the minimum wage, we have $\text{Prob}(Y \geq y_k) = \Phi(X\beta - c_k + \delta_0 + \delta_1)$ for all $y_{k-1} > MW$.

With this in mind, we can estimate the effect of the minimum wage, above and below, by adding a set of dummy variables $D^m_{kt} = 1[y_{k-m} \leq MW_t]$ indicating the distance to that year's minimum wage, such that $\text{Prob}(Y \geq y_k) = \Phi(X\beta + \sum_m D^m_{kt}\,\delta_m - c_k)$, or in our framework:

$$\text{Prob}(Y \geq y_k) = \Phi\left(X\beta + y_k X\gamma + \sum_m D^m_{kt}\,\delta_m - c_k\right) \tag{4}$$

3.3 Empirical model and estimation

To model the entire wage distribution, the log wage range is divided into 60 wage bins between 4.5 and 7.5 (a range that comprises more than 99% of all observations), where each bin has a length of 5 log points, plus the first and the last bin, for a total of 62 bins (see the corresponding histograms in figure A.1 of the appendix). Then we estimate one stacked probit model, by stacking 62 copies of the original dataset, and adding the outcome variable, equal to 1 if $y_{it} > y_k$ and zero otherwise, for $k = 1, \cdots, 61$ (this stacking is illustrated in table A.2). This way we can allow the coefficients to evolve linearly throughout the distribution. The full model is:

$$\text{Prob}(Y_{it} \geq y_k) = \Phi\left(X_{it}\beta + y_k X_{it}\gamma + \sum_{m=b}^{a} D^m_{kt}\,\delta_m - c_k\right) \qquad \text{for } k = 1, 2, \cdots, 61. \tag{5}$$

The covariates X_{it} include the set of individual characteristics - gender, age and squared age, tenure and squared tenure and years of education - as well as 18 age-education interaction dummies in order to capture supply and demand dynamics (Bound and Johnson 1992), year and region fixed effects. Some specifications also include a "heaping variable".[9] Then we have the

9. Autor et al. (2016), in their critique of some minimum wage empirical research methods, suggest that the heaping of hourly wages at integer values in the US could be creating spurious spillovers when the minimum wage is slightly below an integer. Fortin et al. (2021) correct for that by including this type of variable which aims to capture the effect of heaping. Here an analogous strategy is used to capture heaping at multiples of 50€.

interaction term $y_k X_{it}$, although not all covariates are interacted with the cutoff points for computational convenience - only age-education interactions and year dummies are included here, capturing both supply and demand and education changes at different points of the distribution - which are the two main explanatory factors of changes in wage inequality according to the literature - as well as macroeconomic conditions. Minimum wage effects are captured in the δ_m coefficients, through the dummies D_{kt}^m, where $m \in \{b, a\}$ and ($b < 0 < a$). δ_0 measures the jump in probability at the minimum, $\delta_{m>0}$ measure the spillovers and $\delta_{m<0}$ measure any decrease in probability below the minimum. The number of bins above and below the minimum wage at which the effect is measured is different for different specifications, as these effects are not always the same. We will go further into this in section 4, but these dummies were allowed for up to 3 bins below and 8 bins above the minimum wage bin. Finally, c_k are wage bin dummies.

3.4 Details on data

The analysis in this paper makes use of the incredibly rich longitudinal matched employer-employee dataset of *Quadros de Pessoal* (QP), an annual mandatory survey of all establishments in Portugal with at least one wage earner, collected by the Portuguese Ministry of Employment. Among a remarkably extensive list of variables on both firms and workers, the QP dataset provides demographic information such as age, gender and education, and employment information like base and total monthly wages, hours worked, tenure at the firm and occupation, for all employees in Portugal since 1985 (except for 1990 and 2001, when it was not collected).[10]

All estimation exploits a random sample of 10% of all full-time workers between the ages of 18 and 64, from 1986 to 2019 - between $111,987$ observations in 1986 and $226,191$ in 2019.[11]

10. Few matched employer-employee datasets are as detailed and precise as QP since employers must provide their full roster of employees, *and* ensure that workers are also provided, to monitor compliance with labour law.

11. A random 10% sample is drawn for computational convenience, in order to handle a stacked dataset of $62 \times N$ observations. There is no reason to believe that any problem would arise from the use of a random sample given the large size of the original dataset and the nature of the estimations.

The variable of interest in most cases is the total monthly wage (deflated to 1986 CPI), which is most relevant in measuring wage inequality, and other variables utilised include age, gender, tenure, region and level of education (transformed into years of education). Still, base wages will also be utilized in order to study the different behavior of base and total wages over time.[12]

4 Results and analysis

As discussed in section 2.1, the joint behavior of wage inequality and the minimum wage between 1986 and 2019 can be organized into three distinct periods: 1986-1994, where inequality grew and the importance of the minimum wage was stagnant at best, 1994-2006, where inequality was stable and the minimum wage rose modestly, and 2006-2019, where inequality significantly decreased and the importance of the minimum wage increased unprecedentedly.

For a most complete analysis, the model laid out in section 3.3 was estimated separately for the three time-periods. The coefficients of interest resulting from that estimation - the coefficients measuring minimum wage effects, δ_m - are reported in table 1, specifications (1-3). Discussion in section 3.4 suggested that base wages could be reacting to changes in the minimum wage in a different way than total wages, so a model was also estimated for the period 2006-2019 using base wages instead of total wages, reported in table 1, specification (4).

The range of m, the maximum distance to the minimum at which minimum wage effects are allowed, above and below, was differently determined for each specification by excluding statistically insignificant coefficients, in order to best fit the model to each case. For instance, while minimum wage effects are identified up to 40% above the minimum in the period 2006-2019, no spillovers are found in 1986-1994. As such, the adopted ranges of m were $\{-3, 0\}$,

12. The wage distribution has had a very different behavior over time if we look at base wages or total wages - see the behavior of both distributions in figure A.1, but especially notice how the total-base wage differential has evolved differently at different points of the distribution in figure A.2. Unfortunately, discriminated data of the components that make up the total wage is not available. This phenomenon will be further discussed in section 4.1.

δ_m coefficients	Total wages			Base wages
	1) 1986-1994	2) 1994-2006	3) 2006-2019	4) 2006-2019
10%-15% below MW (δ_{-3})	0.096 (0.008)	0.459 (0.010)		
5%-10% below MW (δ_{-2})	0.127 (0.007)	0.370 (0.007)		
0%-5% below MW (δ_{-1})	0.045 (0.006)	0.336 (0.006)		
At the minimum wage (δ_0)	0.302 (0.005)	1.092 (0.005)	1.097 (0.005)	1.649 (0.004)
0%-5% above MW (δ_1)		0.068 (0.002)	0.117 (0.001)	0.166 (0.001)
5%-10% above MW (δ_2)		0.052 (0.002)	0.145 (0.001)	0.067 (0.001)
10%-15% above MW (δ_3)		0.067 (0.002)	0.172 (0.001)	
15%-20% above MW (δ_4)		0.057 (0.002)	0.121 (0.001)	
20%-25% above MW (δ_5)		0.042 (0.002)	0.086 (0.001)	
25%-30% above MW (δ_6)			0.055 (0.001)	
30%-35% above MW (δ_7)			0.033 (0.001)	
35%-40% above MW (δ_8)			0.021 (0.001)	
Number of observations	34724200	71344988	99422358	70180488

Table 1: Estimated coefficients of minimum wage effects. This table reports the probit regression estimates for the δ_m coefficients in equation 5. The range of m is tailored to each specification. All specifications include the explanatory variables mentioned in section 3.3, although the heaping variable is only present in specifications (3) and (4). Standard errors (in parentheses) are clustered by individual.

$\{-3, 5\}$, $\{0, 10\}$ and $\{0, 2\}$ for specifications (1), (2), (3) and (4), respectively.

These are probit regression coefficients so their direct interpretation can be problematic, but we already see that they are all positive, which is expected since they refer to the cumulative distribution. We can also clearly identify the spike created by the minimum wage in the δ_0 coefficients, which are much higher than other δ_m, and see that spillover effects tend to decrease as they draw away from the minimum, as coefficients are generally decreasing for $m > 0$.

4.1 Counterfactual wage densities

The beauty of this kind of methodology is its ability to let us play with all kinds of counterfactual scenarios in order to extract, from specific statistics, or from the entire distribution, the effect associated to certain explanatory factors. In this paper a series of counterfactuals scenarios are constructed in order to assess the effects of the minimum wage at different points of the distribution, which is straightforward after the estimation of the conditional wage distribution.

We will first look at a series of actual and counterfactual density estimates of the wage distribution, which are obtained using an adaptive kernel density estimator (Abramson 1982; Jann 2007). The construction of counterfactual densities is done through the reweighting approach of DiNardo et al. (1996) whereby samples are appropriately weighted in a similar way to common propensity score reweighting methods (Fortin et al. 2011).[13] Then, we will quantify the effect of the minimum wage in several statistics of interest, decomposing changes in those statistics into the underlying change, minimum wage bite effects and minimum wage spillover effects.

In short, counterfactual densities and statistics are obtained by changing the distribution of certain covariates - in this case, what changes is the distribution of the D^m_{kt} minimum wage effect dummy variables - and then reweighting the sample in accordance to the new distribution of covariates. For instance, to compute the wage the distribution that would have prevailed in 2019, had the minimum wage stayed at its 2006 level, we simply compute the above-mentioned probabilities, using the parameters that we estimated, but switching the distribution of the minimum wage effect dummies with their 2006 level, $D^m_{kt=2006}$. If the objective is to estimate the 2019 counterfactual wage distribution in the absence of spillovers, then we simply set the minimum wage effect dummies above the minimum - the spillovers - to zero: $D^m_{kt=2019} = 0$ for $m > 0$.

All in all, the wage distributions that would have prevailed in 1994, 2006 and 2019, had the minimum wage remained at its 1986, 1994 and 2006 level, respectively, are presented in figure 3. In figure 4 we can see the corresponding changes in density across the wage distribution that can be attributed to changes in the minimum wage. Figure A.3 of the appendix portrays the counterfactual densities of the last year in the absence of spillover effects for those three periods, and figures A.4, and A.5 present these density estimates by gender, and using base wages instead

13. The reweighted adaptive kernel density estimator is very briefly laid out in section A.1 of the appendix.

of total wages for the most recent period, 2006-2019.[14]

As we can see, while the wage distribution visibly widened to the right between 1986 and 1994, the real value of the minimum wage in 1986 was nearly the same eight years later. Unsurprisingly, the mere 1% increase in the minimum wage over this period had nearly zero impact on the 1994 wage density, which is almost identical to the actual wage density, except for a slight smoothing around the minimum which can be attributed to lack of common support.[15] The absence of spillovers, reflected in specification (1), makes the counterfactual in figure A.3 indistinguishable from the actual 1994 density, so we conclude that the unchanged minimum wage had no discernible effect on the wage density between 1986 and 1994.

In the second period of analysis we start to notice some minimum wage effects. Over twelve years, the minimum wage increased 9%, which is not much, but certainly enough to reshape the wage distribution to some extent. In figure 3 we can see that the mass of workers earning wages below the 2006 minimum would be much more representative had the minimum wage not risen by those 9%, and that a visible portion of the workers that earned wages up to 25% above the 2006 minimum would be earning lower-wages, many of them earning less than that new minimum. Figures 4 and A.3 confirm that the rise in the minimum wage was not only responsible for a rise in wages for those who are now earning the new minimum, but it also spilled over to workers that would not be affected by a higher minimum at first sight.

However, it is between 2006 and 2019 that we can observe the true potential of a minimum wage. Looking at the actual wage densities of 2006 and 2019 in figure 3 we can see that the distribution shifted to the right over 13 years, but that mainly happens through a significant compression of the distribution at the bottom. And watching the wage histograms move throughout

14. While results for different time periods and for base wages were all estimated separately, the results by gender were obtained using the estimates from specification (3), as the gains of estimating two additional models are trivial.

15. This type of weighting method can always be subject to problems of common support (Frölich 2004; Fortin et al. 2011), especially taking into account the binding nature of the minimum wage in the Portuguese context.

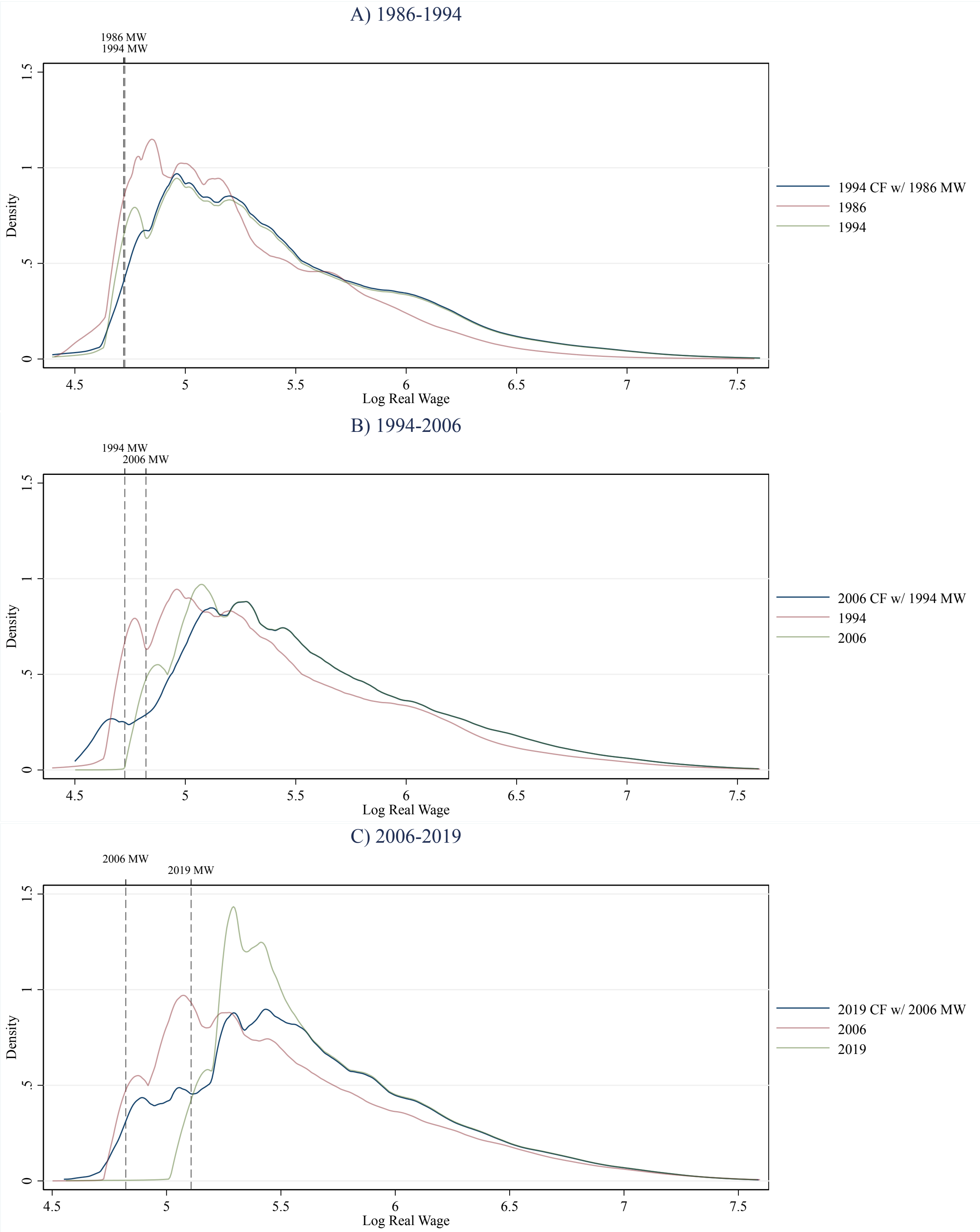

Figure 3: Counterfactual densities for the periods 1986-1994, 1994-2006, and 2006-2019. Each panel of this figure depicts the counterfactual density estimate for the last year, had the minimum wage stayed at its first year level, as well as the actual density estimates for the first and the last year of each period of analysis. The dashed vertical lines indicate the first and last years' minimum wages.

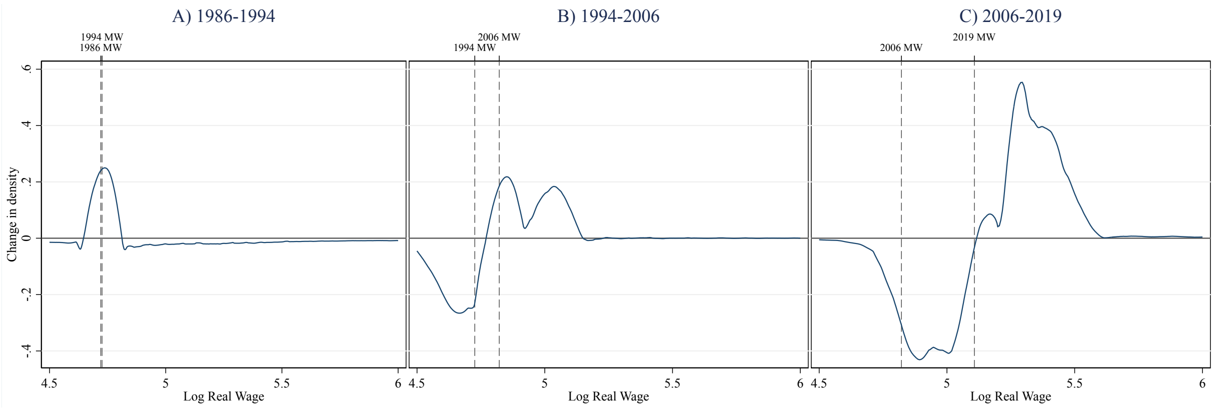

Figure 4: Changes in density attributed to the change in the minimum wage. This figure depicts the difference in densities between the actual last year distribution and the counterfactual distribution with first year's minimum wage for the three time periods. Dashed vertical lines indicate the minimum wages.

the years in the interactive figure A.1 does hint that it is the minimum wage that is pushing that left-tail more and more to the right. But it is by looking at the 2019 counterfactual density with the 2006 minimum wage, in figure 3, that we can truly grasp the effect of the minimum wage on the shape of the distribution. Had the real minimum wage not risen by the impressive 29% that it did, the shape of the distribution would be incredibly different in 2019, with the very high mass of workers earning up to 40% above the minimum, that we see in the actual distribution, significantly diluting, with a very large portion of workers shifting back in the pay-scale to wages much lower than the 2019 minimum, and many remaining at the 2006 minimum. And if the effect of spillovers is not clear enough, figures 4 and A.3 make it even more evident that a very large share of lower-wage workers saw their wages increase significantly, and that portion did not "accumulate" at the new minimum wage, but it actually spilled-over quite above that.

Furthermore, this impact was similar in shape for both women and men although, as we can see in figure A.4, as the female distribution was already much more compressed at the minimum in 2006 - while the male distribution was wider and further to the right - women seem to have benefited more from the minimum wage hike overall, consistent with the literature.

Finally, figure A.5 discloses even more surprising insights on Portuguese wages. We saw in figure 2 that base and total wages were not reacting to changes in the minimum wage in the same manner since 2006, as the share of workers on the minimum wage has been rapidly increasing if we look at base wages, but if we look at total wages it actually decreased. Comparing the previous results with figure A.5, we can see what is going on. Apparently, the total wages of middle- and low-wage workers have been increasing at a pace that is not reflected in their base wages - this phenomenon has increased the total-base wage differential that we see in figure A.2 over the years. However, since the 2000s, that differential ceased to increase at the very bottom of the distribution, where the minimum wage binds, because the minimum wage started catching up and pushing the base wage of more and more workers.[16] From this, and from the comparison of our results for total wages (figures 3, 4 and A.3) and base wages (figure A.5), we arrive at the conclusion that, while minimum wage bite effects are widely reflected in the base wage, spillover effects predominantly manifest themselves in the other components that make up the total wage. Since 2006, a very significant number of workers saw their base wages increase to the new minimum but spillovers were minimal when compared to total wages.

4.2 Quantifying minimum wage effects

After recognizing the clear visual impact that the minimum wage has had on the wage distribution, it is important to quantify that impact. The main effects of changes in the minimum wage are laid out in table 2, while table A.3 reports those effects by gender and for base wages.

The tables present several statistics of interest to evaluate the effect of the minimum wage in the scenarios that have already been presented. Each panel contains those statistics for the first year, the last year, a counterfactual last year where the minimum did not change, and a counterfactual last year without spillovers. These four scenarios allow us to then decompose the changes in the statistics into the underlying change - change that would have happened if the

16. The reasons for this are a mystery to the author and open up a new path for research - it could be happening as employers shield themselves from extreme nominal wage rigidity in the base wage (Carneiro et al. 2014; Guimarães et al. 2017) that may not reflect in the other components of wages, or simply due to tax optimization by firms.

	Sd	90-10	90-50	50-10	Workers on 1st year MW	Workers on last year MW	Mean wage
			A) 1986-1994 $(\Delta MW = 0.01)$				
1986	0.5	1.21	0.79	0.42	0.11	0.11	5.24
1994	0.57	1.41	0.92	0.49	0.02	0.06	5.42
1994 w/ 1986 MW	0.58	1.4	0.92	0.48	0.03	0.05	5.43
1994 w/o spillovers	0.57	1.41	0.92	0.49	0.02	0.06	5.42
Total change	0.07	0.2	0.13	0.07	-0.09	-0.05	0.18
Underlying change	0.08	0.19	0.13	0.06	-0.08	-0.06	0.19
Change due to MW	-0.01	0.01	0	0.01	-0.01	0.01	-0.01
Change due to bite	-0.01	0.01	0	0.01	-0.01	0.01	-0.01
Change due to spillovers	0	0	0	0	0	0	0
			B) 1994-2006 $(\Delta MW = 0.09)$				
1994	0.57	1.41	0.92	0.49	0.06	0.11	5.42
2006	0.58	1.43	0.95	0.48	0	0.04	5.57
2006 w/ 1994 MW	0.6	1.47	0.95	0.52	0.05	0.07	5.56
2006 w/o spillovers	0.58	1.47	0.94	0.52	0	0.06	5.57
Total change	0.01	0.02	0.03	-0.01	-0.06	-0.07	0.15
Underlying change	0.03	0.06	0.03	0.03	-0.01	-0.04	0.14
Change due to MW	-0.02	-0.04	0	-0.04	-0.05	-0.03	0.01
Change due to bite	-0.02	0	-0.01	0	-0.05	-0.01	0.01
Change due to spillovers	0	-0.04	0.01	-0.04	0	-0.02	0
			C) 2006-2019 $(\Delta MW = 0.29)$				
2006	0.58	1.43	0.95	0.48	0.04	0.23	5.57
2019	0.51	1.21	0.86	0.35	0	0.04	5.73
2019 w/ 2006 MW	0.57	1.43	0.86	0.57	0.03	0.16	5.67
2019 w/o spillovers	0.53	1.34	0.85	0.49	0	0.1	5.71
Total change	-0.07	-0.22	-0.09	-0.13	-0.04	-0.19	0.16
Underlying change	-0.01	0	-0.09	0.09	-0.01	-0.07	0.1
Change due to MW	-0.06	-0.22	0	-0.22	-0.03	-0.12	0.06
Change due to bite	-0.04	-0.09	-0.01	-0.08	-0.03	-0.06	0.04
Change due to spillovers	-0.02	-0.13	0.01	-0.14	0	-0.06	0.02

Table 2: Decomposition of changes in statistics of interest for the three periods. Each panel depicts statistics of interest for the first year, the last year, and the counterfactuals of the last year with the first year minimum wage and with no spillovers. They also contain the change in these statistics between the first and the last year, decomposed into the underlying change and the change attributed to the shift in the minimum wage, which is then itself decomposed into minimum wage bite effects and spillover effects. The table and the decomposition are explained in detail in section A.2 of the appendix.

minimum wage had not shifted - and the change that can be attributed to the shift in minimum wage. The effect of the minimum wage can itself be decomposed into minimum wage bite effects and spillover effects. The tables are explained in detail in section A.2 of the appendix.

The minimum wage practically stagnated during the first 8 years of the sample, so the deviation across the different 1994 scenarios for all statistics is negligible. Inequality increased rapidly, especially at the upper tail, the average wage increased too, but virtually all of it is explained by the underlying changes in the economy and not by any minimum wage changes.

Between 1994 and 2006 there was a 9% increase in the minimum wage and the growth in inequality slowed. The underlying increase in the standard deviation of log wages of 3 log points over 12 years was much lower than the 8 points in the previous 8 years anyway, so there clearly were other more important factors mitigating wage inequality. However, the minimum wage was still able to cut the increase in the standard deviation and the 90-10 percentile differential by two thirds, and was actually responsible for the 1 point decrease in the 50-10, which increased by 3 points in the counterfactual. Notably, if the minimum wage had not gone up, 5 of the 6% of workers that were on the minimum wage in 1994 would still be earning that value in 2006.

Nonetheless, it is again in the third period that we see the full impact of the minimum wage. As discussed before, wage inequality decreased greatly between 2006 and 2019 - the standard deviation of log wages decreased by 7 points, the 90-50 differential decreased by 9 points and the 50-10 by 13, for a total decline of 22 points in the 90-10 differential. And looking at figure 5, we see that wage growth between those years was almost inversely proportional to workers' wage percentiles, with wages at the very bottom of the distribution increasing by 30%, while wages at the very top almost stagnated. When we decompose those changes we find that, as the wage density estimates suggested, the minimum wage had a crucial role in those developments.

Had the minimum wage not increased, the standard deviation would have decreased by only

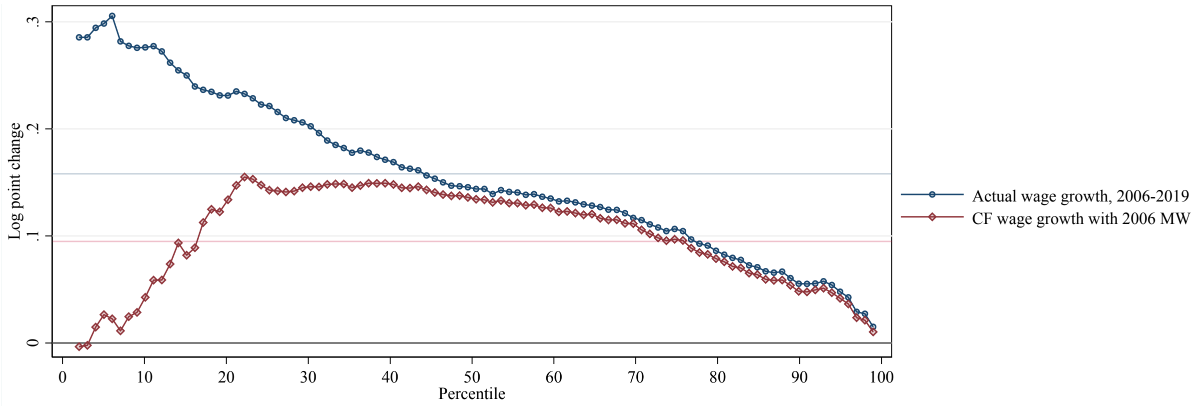

Figure 5: Wage growth incidence curves, 2006-2019. This graph depicts the actual and counterfactual growth rate of wages by wage percentile from 2006 to 2019. Shaded horizontal lines indicate the mean wage growth. Figure A.6 presents this for the three periods, as well as the full description of the graph.

one log point - the minimum wage bite was able to reduce the standard deviation by 4 extra log points and its spillovers managed to reduce it another 2 points. More striking, the 90-10 differential would not have changed at all - while upper-tail inequality decreased by 9 log points due to other factors, lower-tail inequality would have increased by 9 points, offsetting any changes in the 90-10 differential. Instead, it decreased by 22 points, 13 of those in the 50-10, and most of that was due to spillovers, which alone reduced the differential by 14 points. Figure 5 perfectly illustrates this - while the 2006-2019 wage growth incidence curve was straightly decreasing in actuality, if the minimum wage had not gone up we would be seeing an inverse-U-shaped curve, whereby the wages of workers in the lowest percentiles, the ones who saw their wages increase the most in reality, would have actually been the ones with the smallest growth.

Furthermore, the share of workers earning the 2006 minimum wage in 2019 would still be 3% - the shift in the minimum ensured that no worker was earning that value in 2019 - but what is more striking is the share of workers earning the the 2019 minimum in both years. In 2019 the minimum wage was 600€, and only 4% of the workforce had a total wage equal or less than that, but the share of workers earning that value in 2006, in real terms, was a staggering 23%. This 19 point decrease over 13 years is due in part to other changes in the economy, but mostly due to the increase in the minimum wage. The minimum wage bite put 6% of the workforce above that threshold and the spillovers put another 6%. In the end, such a powerful impact of the minimum wage across the distribution could only translate itself in the average wage. And it did. The average wage increased by 16 points over 13 years. That is not much, but it would have been only 10 points if the minimum had not risen by those 29%. The rise in the minimum wage was responsible for about 40% of the growth in the average wage between 2006 and 2019.

Table A.3 provides results by gender, clearly reflecting what we had observed in the wage densities - the minimum wage was more important for women than for men. While male wage inequality would have declined over this period anyway, the standard deviation, the 90-10 and the 50-10 differentials of female wages would have actually increased by 2, 7 and 14 points respectively. In reality, they all decreased thanks to the higher minimum. Still, men's wages were originally higher, so spillovers were much more decisive in reducing male wage inequality.

Finally, that table also contains the results using base wages instead of total wages. Again, we see a great impact of the minimum wage in reducing inequality, although in this case it is almost all due to the minimum wage bite - spillovers are minor, and only reach up to 10% above the minimum. For instance, the bite single handedly cut the 50-10 differential by 23 points, while spillover effects actually increased that differential by 2 points (which shows how close the minimum is to the median in the base wage distribution). The bite also raised the wages of the 8% of workers for whom the minimum wage bound in 2006, as predicted in the previous section, and was responsible for two-thirds of the 12 point increase in the mean wage. Still, the influence of the minimum on the distribution is visibly smaller for base wages, especially due to the lack of spillovers: while the share of workers earning more than the real value of the 2019 minimum wage grew between 2006 and 2019, for both base (58% to 79%) and total wages (77% to 96%), the share of that increase that can be attributed to the minimum is only one-third in the case of base wages, much less than the two-thirds we found for total wages.

5 Conclusion

Over the last three-and-a-half decades, wage inequality in Portugal increased, then it stagnated, and then it fell. And the importance of the minimum wage in the labor market presented a nearly symmetric behavior. This paper explored this significant *negative* correlation to try and understand the impact of the minimum wage on the whole shape of the wage distribution.

The results clearly show how much the minimum wage can structurally reshape the distribution. Between 2006 and 2019, the remarkable rise in the real minimum wage was responsible for virtually all of the decrease in wage inequality in Portugal, especially by deterring an increase in inequality at the bottom half of the distribution. And most of that impact was driven by spillover effects, since workers' wages did not simply *accumulate* at the minimum - they cascaded up to 40% above the minimum wage. More, the minimum wage was not only able to structurally reshape the wage distribution, but it actually shifted it to the right, explaining 40% of the increase in the Portuguese average wage over that period. In accordance with the literature, the minimum wage was most important in reducing female wage inequality, since women's wages were already lower, although spillovers turned out to be much more relevant for men.

The analysis was mostly done using total wages, but looking at base wages uncovered a whole new phenomenon. Total wages have been growing faster than base wages for most workers in Portugal, but the rapid growth of the minimum wage since the mid-2000s pushed the base wage of more and more low-wage workers, stopping the rise of that differential when the minimum wage binds. Still, while minimum wage bite effects were widely reflected in the base wage, spillovers predominantly manifest themselves in the other components of the total wage.

Such a powerful reshaping, such high spillovers, or such a total-base wage difference are not common in the literature, but neither is a compression of the distribution and a minimum wage hike like these, so this paper certainly opens up many issues to be addressed in future research.

References

Abramson, Ian S. 1982. “On Bandwidth Variation in Kernel Estimates-A Square Root Law.” *The Annals of Statistics* 10 (4): 1217 – 1223.

Addison, John T, Pedro Portugal, and Hugo Vilares. 2017. “Unions and collective bargaining in the wake of the Great Recession: evidence from Portugal.” *British Journal of Industrial Relations* 55 (3): 551–576.

Aeberhardt, Romain, Pauline Givord, and Claire Marbot. 2016. *Spillover effect of the Minimum Wage in France: An Unconditional Quantile Regression.* Working Paper 2016-05. Center for Research in Economics and Statistics.

Alvaredo, Facundo. 2009. “Top incomes and earnings in Portugal 1936–2005.” *Explorations in Economic History* 46 (4): 404–417.

Angrist, Joshua D., and Jörn Steffen Pischke. 2010. “The credibility revolution in empirical economics: How better research design is taking the con out of econometrics.” *Journal of Economic Perspectives* 24 (2): 3–30.

Autor, David H., Lawrence F. Katz, and Melissa S. Kearney. 2008. “Trends in U.S. Wage Inequality: Revising the Revisionists.” *The Review of Economics and Statistics* 90 (2): 300–323.

Autor, David H., Alan Manning, and Christopher L. Smith. 2016. “The Contribution of the Minimum Wage to US Wage Inequality over Three Decades: A Reassessment.” *American Economic Journal: Applied Economics* 8 (1): 58–99.

Belman, Dale, and Paul J. Wolfson. 2014. *What does the minimum wage do?* WE Upjohn Institute.

Bossler, Mario, and Thorsten Schank. 2020. “Wage Inequality in Germany after the Minimum Wage Introduction.” IZA Discussion Paper.

Bound, J., and G. Johnson. 1992. “Changes in the structure of wages in the 1980’s: an evaluation of alternative explanations.” *American Economic Review* 82 (3): 371–392.

Brochu, Pierre, David A Green, Thomas Lemieux, and James Townsend. 2018. *The minimum wage, turnover, and the shape of the wage distribution.* Working Paper.

Brown, Charles. 1999. “Minimum wages, employment, and the distribution of income.” Chap. 32 in *Handbook of Labor Economics,* edited by Orley Ashenfelter and David Card, vol. 3B, 2101–2163. Elsevier.

Brown, Charles, Curtis Gilroy, and Andrew Kohen. 1982. “The effect of the minimum wage on employment and unemployment: a survey.” *Journal of Economic Literature* 20 (2): 487–528.

Campos Lima, Maria da Paz, Diogo Martins, Ana Cristina Costa, and Antonio Velez. 2021. "Internal devaluation and economic inequality in Portugal: challenges to industrial relations in times of crisis and recovery." *Transfer: European Review of Labour and Research* 27 (1): 47–73.

Card, David. 1992. "Using Regional Variation in Wages to Measure the Effects of the Federal Minimum Wage." *Industrial and Labor Relations Review* 46 (1): 22–37.

Card, David, and John E. DiNardo. 2002. "Skill-biased technological change and rising wage inequality: Some problems and puzzles." *Journal of Labor Economics* 20 (4): 733–783.

Card, David, and Alan B. Krueger. 1994. "Minimum wages and employment: a case study of the fast-food industry in New Jersey and Pennsylvania." *American Economic Review* 84 (4): 772–793.

———. 1995. "Time-Series Minimum-Wage Studies: A Meta-analysis." *American Economic Review* 85 (2): 238–243.

———. 2015. *Myth and Measurement: The New Economics of the Minimum Wage.* Princeton University Press.

Cardoso, Ana Rute. 1997. "Workers or Employers: Who is Shaping Wage Inequality?" *Oxford Bulletin of Economics and Statistics* 59 (4): 523–547.

———. 1998. "Earnings inequality in Portugal: High and rising?" *Review of Income and Wealth* 44 (3): 325–343.

———. 1999. "Firms' Wage Policies and the Rise in Labor Market Inequality: The Case of Portugal." *Industrial and Labor Relations Review* 53 (1): 87–102.

Cardoso, Ana Rute, and Pedro Portugal. 2005. "Contractual Wages and the Wage Cushion under Different Bargaining Settings." *Journal of Labor Economics* 23 (4): 875–902.

Carneiro, Anabela, Pedro Portugal, and José Varejão. 2014. "Catastrophic job destruction during the portuguese economic crisis." *Journal of Macroeconomics* 39 (B): 444–457.

Cengiz, Doruk, Arindrajit Dube, Attila Lindner, and Ben Zipperer. 2019. "The Effect of Minimum Wages on Low-Wage Jobs." *The Quarterly Journal of Economics* 134 (3): 1405–1454.

Centeno, Mário, and Alvaro A. Novo. 2014. "When supply meets demand: wage inequality in Portugal." *IZA Journal of European Labor Studies* 3 (1): 1–20.

Chernozhukov, Victor, Iván Fernández-Val, and Blaise Melly. 2013. "Inference on counterfactual distributions." *Econometrica* 81 (6): 2205–2268.

Dickens, Richard, Alan Manning, and Tim Butcher. 2012. *Minimum Wages and Wage Inequality: Some Theory and an Application to the UK.* CEP-LSE Working Paper Series 4512.

DiNardo, John, Nicole M. Fortin, and Thomas Lemieux. 1996. “Labor Market Institutions and the Distribution of Wages, 1973-1992: A Semiparametric Approach.” *Econometrica* 64 (5): 1001–1044.

Dube, Arindrajit, T. William Lester, and Michael Reich. 2010. “Minimum wage effects across state borders: Estimates using contiguous counties.” *Review of Economics and Statistics* 92 (4): 945–964.

Feenstra, Robert C., and Gordon H. Hanson. 1996. “Globalization, Outsourcing, and Wage Inequality.” *American Economic Review* 86 (2): 240–245.

Fortin, Nicole M., and Thomas Lemieux. 1998. “Rank regressions, wage distributions, and the gender gap.” *Journal of Human Resources* 33 (3): 610–643.

Fortin, Nicole M., Thomas Lemieux, and Sergio Firpo. 2011. “Decomposition Methods in Economics.” Chap. 1 in *Handbook of Labor Economics,* edited by Orley Ashenfelter and David Card, vol. 4A, 1–102. Elsevier.

Fortin, Nicole M., Thomas Lemieux, and Neil Lloyd. 2021. “Labor Market Institutions and the Distribution of Wages: The Role of Spillover Effects.” *Journal of Labor Economics* 39 (S2): S369–S412.

Freeman, Richard B. 1996. “The Minimum Wage as a Redistributive Tool.” *The Economic Journal* 106 (436): 639–649.

Frölich, Markus. 2004. “Finite-sample properties of propensity-score matching and weighting estimators.” *The Review of Economics and Statistics* 86 (1): 77–90.

Gramlich, Edward M. 1976. “Impact of Minimum Wages on Other Wages, Employment, and Family Incomes.” *Brookings Papers on Economic Activity* 1976 (2): 409–462.

Grossman, Jean Baldwin. 1983. “The Impact of the Minimum Wage on Other Wages.” *The Journal of Human Resources* 18 (3): 359–378.

Guimarães, Paulo, Fernando Martins, and Pedro Portugal. 2017. *Upward Nominal Wage Rigidity.* Working Papers 2017. Banco de Portugal Economics and Research Department.

Hoffmann, Florian, David S. Lee, and Thomas Lemieux. 2020. “Growing Income Inequality in the United States and Other Advanced Economies.” *Journal of Economic Perspectives* 34 (4): 52–78.

Jann, Ben. 2007. *KDENS: Stata module for univariate kernel density estimation.* Statistical Software Components, Boston College Department of Economics.

Joe, Dong-Hee, and Seongman Moon. 2020. “Minimum Wages and Wage Inequality in the OECD Countries.” *East Asian Economic Review* 24 (3): 253–273.

Katz, Lawrence F., and Alan B. Krueger. 1992. “The Effect of the Minimum Wage on the Fast-Food Industry.” *Industrial and Labor Relations Review* 46 (1): 6–21.

Koeniger, Winfried, Marco Leonardi, and Luca Nunziata. 2007. “Labor market institutions and wage inequality.” *Industrial and Labor Relations Review* 60 (3): 340–356.

Lee, David S. 1999. “Wage Inequality in the United States During the 1980s: Rising Dispersion or Falling Minimum Wage?” *The Quarterly Journal of Economics* 114 (3): 977–1023.

Machado, José A. F., and José Mata. 2005. “Counterfactual decomposition of changes in wage distributions using quantile regression.” *Journal of Applied Econometrics* 20 (4): 445–465.

Machin, Stephen. 1997. “The decline of labour market institutions and the rise in wage inequality in Britain.” *European Economic Review* 41 (3-5): 647–657.

Machin, Stephen, and Alan Manning. 1994. “The Effects of Minimum Wages on Wage Dispersion and Employment: Evidence from the U.K. Wages Councils.” *ILR Review* 47 (2): 319–329.

Machin, Stephen, Alan Manning, and Lupin Rahman. 2003. “Where the minimum wage bites hard: Introduction of minimum wages to a low wage sector.” *Journal of the European Economic Association* 1 (1): 154–180.

Manning, Alan. 2003. *Monopsony in motion: Imperfect competition in labor markets.* Princeton University Press.

Martins, Pedro S. 2021. “30,000 minimum wages: The economic effects of collective bargaining extensions.” *British Journal of Industrial Relations* 59 (2): 335–369.

Martins, Pedro S, and Pedro T Pereira. 2004. “Does education reduce wage inequality? Quantile regression evidence from 16 countries.” *Labour Economics* 11 (3): 355–371.

Meyer, Robert H, and David A Wise. 1983a. “Discontinuous Distributions and Missing Persons: The Minimum Wage and Unemployed Youth.” *Econometrica* 11 (6): 1677–1698.

———. 1983b. “The effects of the minimum wage on the employment and earnings of youth.” *Journal of Labor economics* 1 (1): 66–100.

Mincer, Jacob. 1976. “Unemployment effects of minimum wages.” *Journal of Political Economy* 84 (4, Part 2): S87–S104.

Neumark, David, Mark Schweitzer, and William Wascher. 2004. “Minimum wage effects throughout the wage distribution.” *Journal of Human Resources* 39 (2): 425–450.

Pereira, João Manuel. 2021. “Did wage inequality increase in Portugal? Yes, and for good reasons.” *Applied Economics Letters* 28 (12): 973–977.

Pereira, João Manuel, and Aurora Galego. 2019. “Diverging trends of wage inequality in Europe.” *Oxford Economic Papers* 71 (4): 799–823.

Pereira, Sonia C. 2003. “The impact of minimum wages on youth employment in Portugal.” *European Economic Review* 47 (2): 229–244.

Piketty, Thomas. 2014. *Capital in the Twenty-First Century.* Harvard University Press.

Portugal, Pedro, and Ana Rute Cardoso. 2006. “Disentangling the minimum wage puzzle: An analysis of worker accessions and separations.” *Journal of the European Economic Association* 4 (5): 988–1013.

Portugal, Pedro, Pedro S Raposo, and Hugo Reis. 2018. *The distribution of wages and wage inequality,* Economic Bulletin and Financial Stability. Banco de Portugal Economics and Research Department.

Rebitzer, James B., and Lowell J. Taylor. 1995. “The consequences of minimum wage laws Some new theoretical ideas.” *Journal of Public Economics* 56 (2): 245–255.

Silverman, Bernard W. 1986. *Density estimation for statistics and data analysis.* Chapman Hall.

Stewart, Mark B. 2012. “Wage inequality, minimum wage effects, and spillovers.” *Oxford Economic Papers* 64 (4): 616–634.

Stigler, George J. 1946. “The Economics of Minimum Wage Legislation.” *American Economic Review* 36 (3): 358–365.

Teulings, Coen N. 2003. “The contribution of minimum wages to increasing wage inequality.” *Economic Journal* 113 (490): 801–833.

A Appendix

A.1 The reweighted adaptive kernel density estimator

The applied reweighted adaptive kernel density estimator is defined as

$$\hat{f}_h(y) = \frac{1}{hN\lambda_i} \sum_{i=1}^{n} \psi(X_k) \cdot K\left(\frac{y - Y_i}{h\lambda_i}\right) \tag{6}$$

where $K(.)$ is an alternative Epanechnikov kernel function, h is the Silverman (1986) bandwidth, and λ_i are the local bandwidth factors (Abramson 1982; Jann 2007), based on a preliminary fixed bandwidth density estimate, and estimated as

$$\hat{\lambda}_i = \sqrt{\frac{G(\hat{f}_h(Y))}{\hat{f}_h(Y)}}, \quad i = 1, \cdots, n. \tag{7}$$

where $G(.)$ stands for the geometric mean over all i. Note that $G(\lambda) = 1$, and thus $G(h\lambda) = h$.

Then, $\psi(X_k)$ is the reweighting factor proposed in DiNardo et al. (1996) and generalized in Fortin et al. (2011), estimated as

$$\hat{\psi}(X_k) = \frac{\bar{Y}_k^C(X)}{\bar{Y}_k(X)}, \quad k = 1, \cdots, K. \tag{8}$$

where $\bar{Y}_k$ are the averages of the outcome variable per wage bin in the actual scenario, and $\bar{Y}_k^C$ are the averages outcome in the counterfactual.

A.2 Interpreting the decomposition tables and results

Tables 2 and A.3 present the main quantitative results of this paper. Table 2 presents the results for the three periods of analysis, while table A.3 presents the results of 2006-2019 by gender, and using base wages instead of total wages.

The columns of the tables present several statistics of interest (referring to the logarithm of real wages): the *standard deviation* and the *90-10* percentile differential to measure inequality across the distribution, the *90-50* and the *50-10* differentials to measure upper-half and lower-half inequality, the *share of workers that is earning the real value of the first year's minimum wage or less* and the *share of workers that is earning the real value of the last year's minimum wage or less*[17], and the *average wage*.

The first four rows of each panel present these statistics of interest for the different scenarios that were estimated. Using panel A of table 2 as reference: *1986*, the actual statistics of the first year; *1994*, the actual statistics of the last year; *1994 w/ 1986 MW*, the counterfactual statistics of the last year, had the minimum wage stayed at its first year level; *1994 w/o spillovers*, the counterfactual statistics of the last year, had there been no minimum wage spillover effects.

The three rows after that present the decomposed change in those statistics. *Total change* is the actual change that occurred between 1986 and 1994, *underlying change* is the change that would have occurred between those years if the real value of the minimum wage had stayed at its 1986 level, and the *change due to the minimum wage* is the change driven by the shift in the

17. For example, in the first row of table 2 we see the share of workers that was earning the real value of the 1986 minimum wage or less in 1986, and then the share of workers that was earning the real value of the 1994 minimum wage or less in 1986.

minimum wage between those years:

$$\begin{aligned} \textit{Total change} &= \textit{Underlying change} + \textit{Change due to MW} \\ \textit{Underlying change} &= \textit{1994 w/ 1986 MW} - \textit{1986} \\ \textit{Change due to MW} &= \textit{1994} - \textit{1994 w/ 1986 MW} \end{aligned} \tag{9}$$

The two final rows of each panel present the *Change due to MW* decomposed into the *change due to the minimum wage bite*, the change driven by the workers whose wages would be below the new minimum but the minimum wage managed to push to that new minimum, and the *change due to the spillovers*, driven by the workers who would be earning the new minimum wage or more but, due to the minimum wage raise, still benefited from a wage boost:

$$\begin{aligned} \textit{Change due to MW} &= \textit{Change due to bite} + \textit{Change due to spillovers} \\ \textit{Change due to bite} &= \textit{1994 w/o spillovers} - \textit{1994 w/ 1986 MW} \\ \textit{Change due to spillovers} &= \textit{1994} - \textit{1994 w/o spillovers} \end{aligned} \tag{10}$$

A.3 Figures

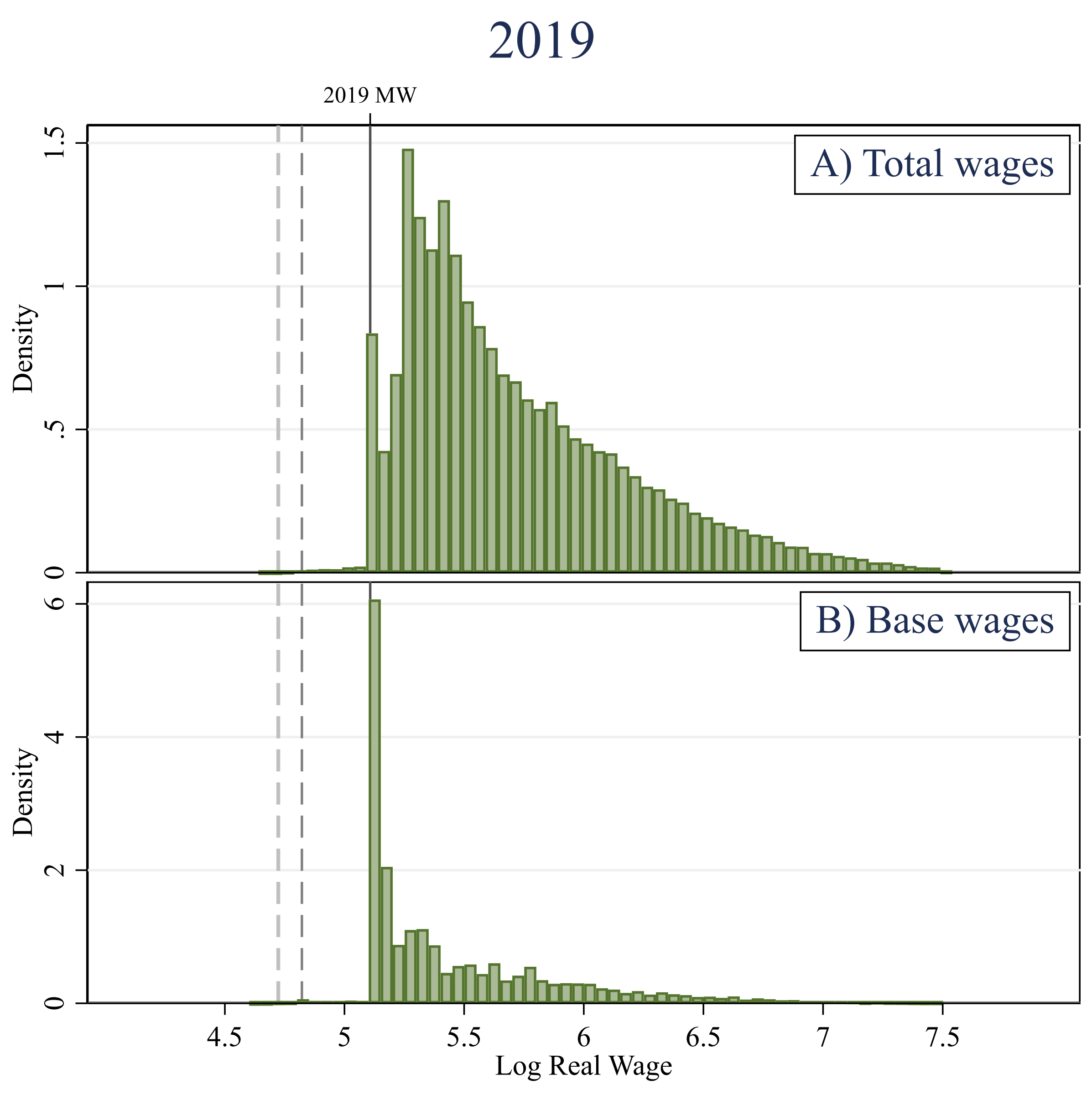

Figure A.1: Distribution of wages from 1986 to 2019. This figure depicts the distribution of the logarithm of real wages across the years using total wages and base wages. Histograms have the same wage bins that are used in the estimation of the model (0.05 log bins, between 4.5 and 7.5). The black vertical line indicates each year's minimum wage, while the dashed lines indicate the reference years' minimum wages as they appear. This is an interactive figure. Click play to see the distribution moving over the years or use the controls to move across the years (Acrobat Reader recommended).

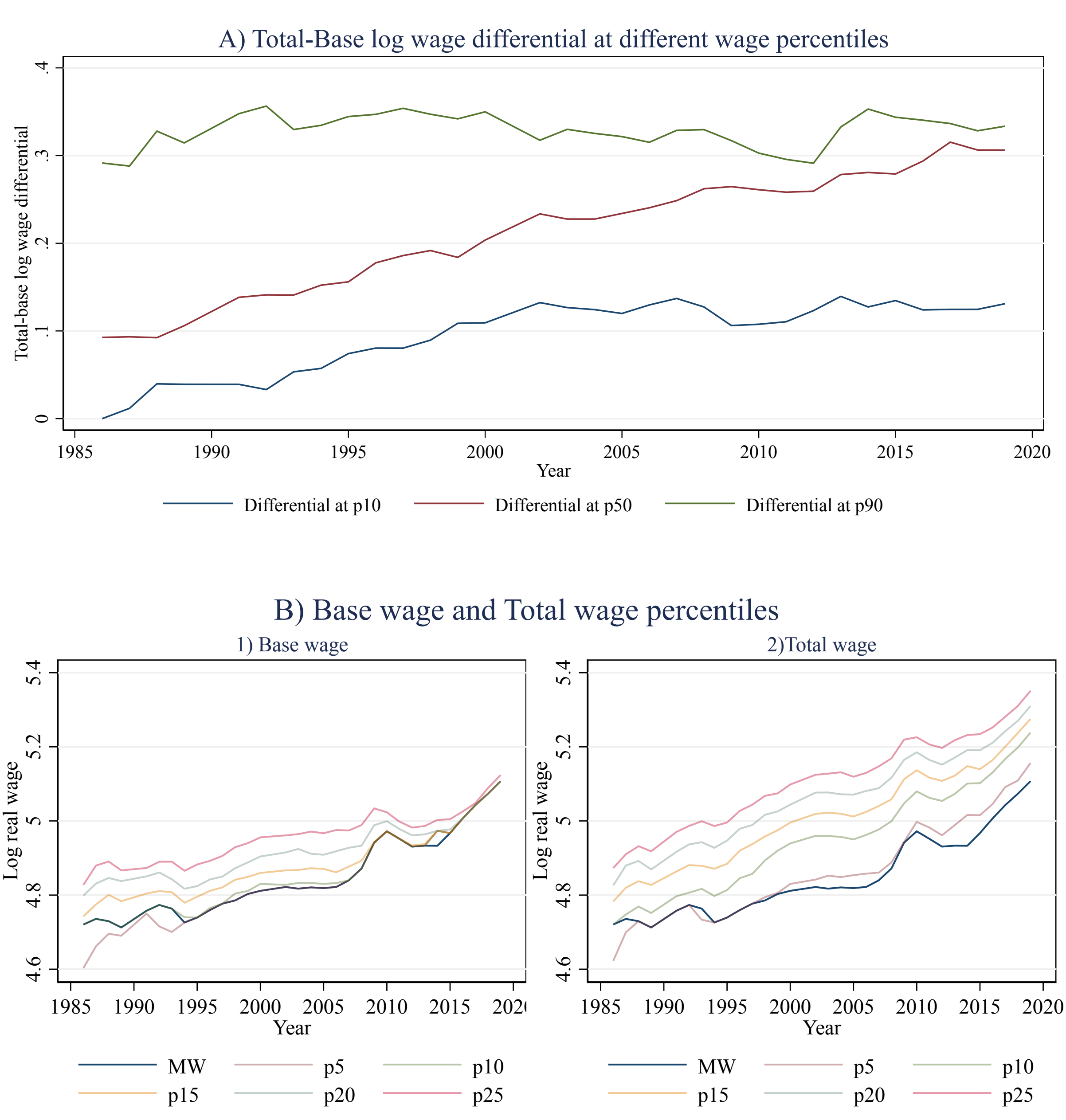

Figure A.2: Differences between Base wages and Total wages. This figure depicts some percentile-based measures to help us understand the different behavior of base and total wages across the distribution over time. Panel A depicts the Total wage-Base wage log differential for different wage percentiles - the average log difference between total and base wages for the 10th, 50th and 90th percentiles of the wage distribution. Panel B depicts the average wage at different percentiles at the lower-end of the distribution for base and total wages, as well as the minimum wage line.
The total-base differential - the share of total wages that is composed by extra hours, food allowance, shift allowance, and other regular and irregular payments - has grown at the middle of the distribution and below over the years, and remained stable at the top of the distribution. However, it ceased to increase at the very bottom of the wage distribution since the 2000s because, at that point, the minimum wage started catching up and pushing the slower-growing base wages of more and more workers at the bottom of the distribution, while total wages kept their pace.

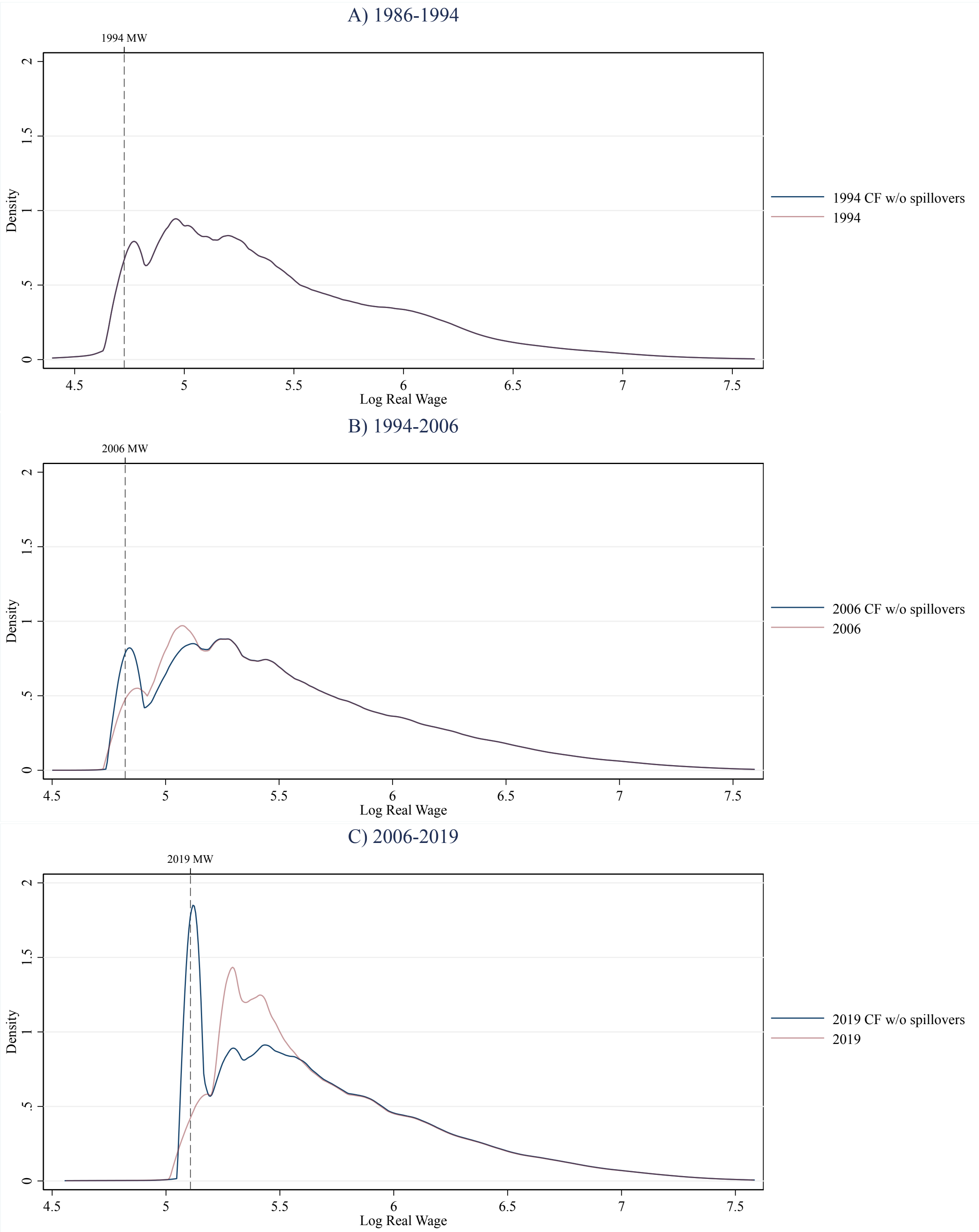

Figure A.3: Counterfactual densities in the absence of spillovers for 1986-1994, 1994-2006, and 2006-2019. Each panel of this figure depicts the counterfactual density estimate for the last year of each period of analysis, had there been no minimum wage spillover effects, as well as the actual density estimate for that year. The dashed vertical line indicates minimum wage.

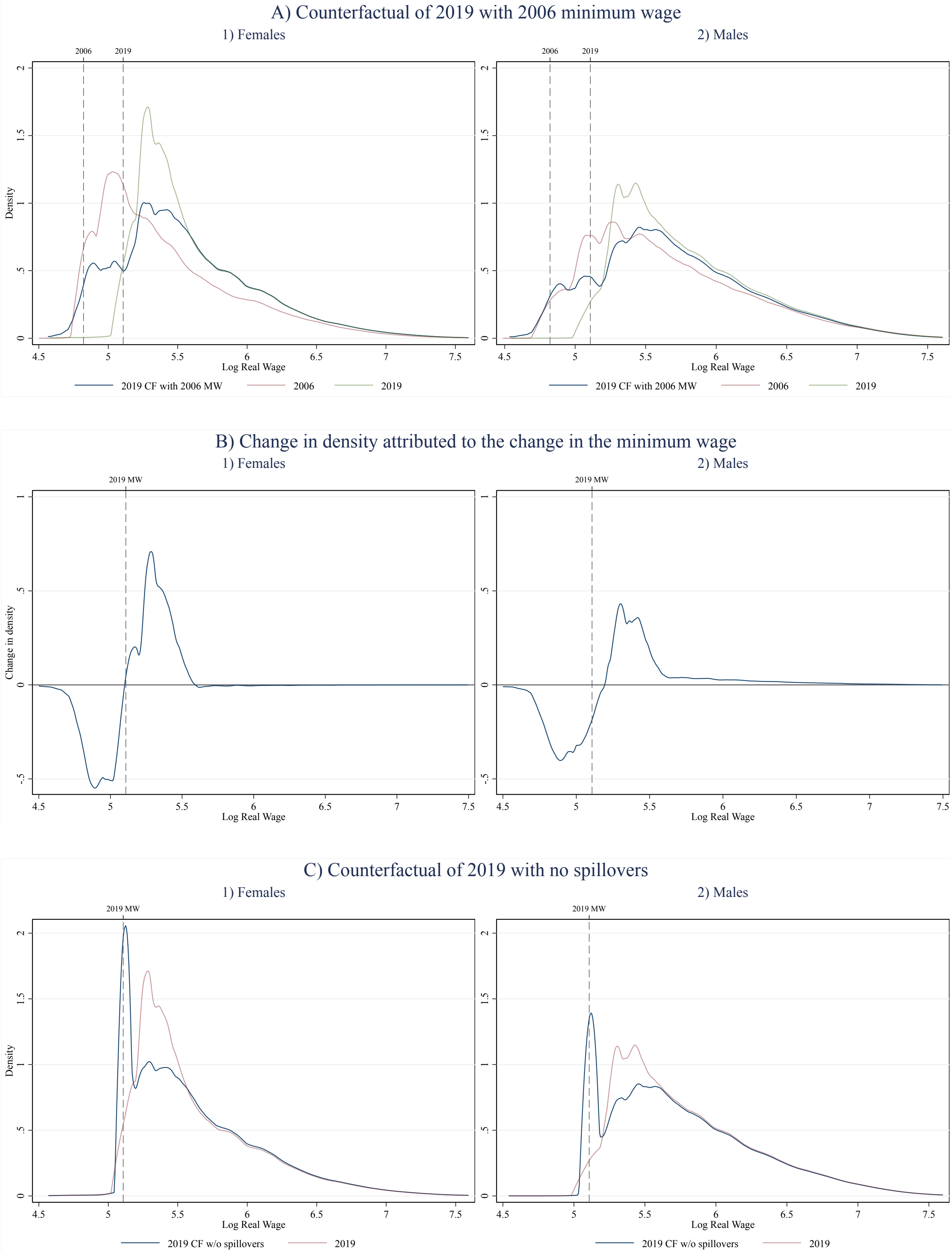

Figure A.4: Density estimates by gender. Each panel of this figure depicts the density estimate graphs already presented for females and males. Panel A depicts the equivalent to figure 3, Panel B depicts the equivalent to figure 4 and Panel C depicts the equivalent to figure A.3.

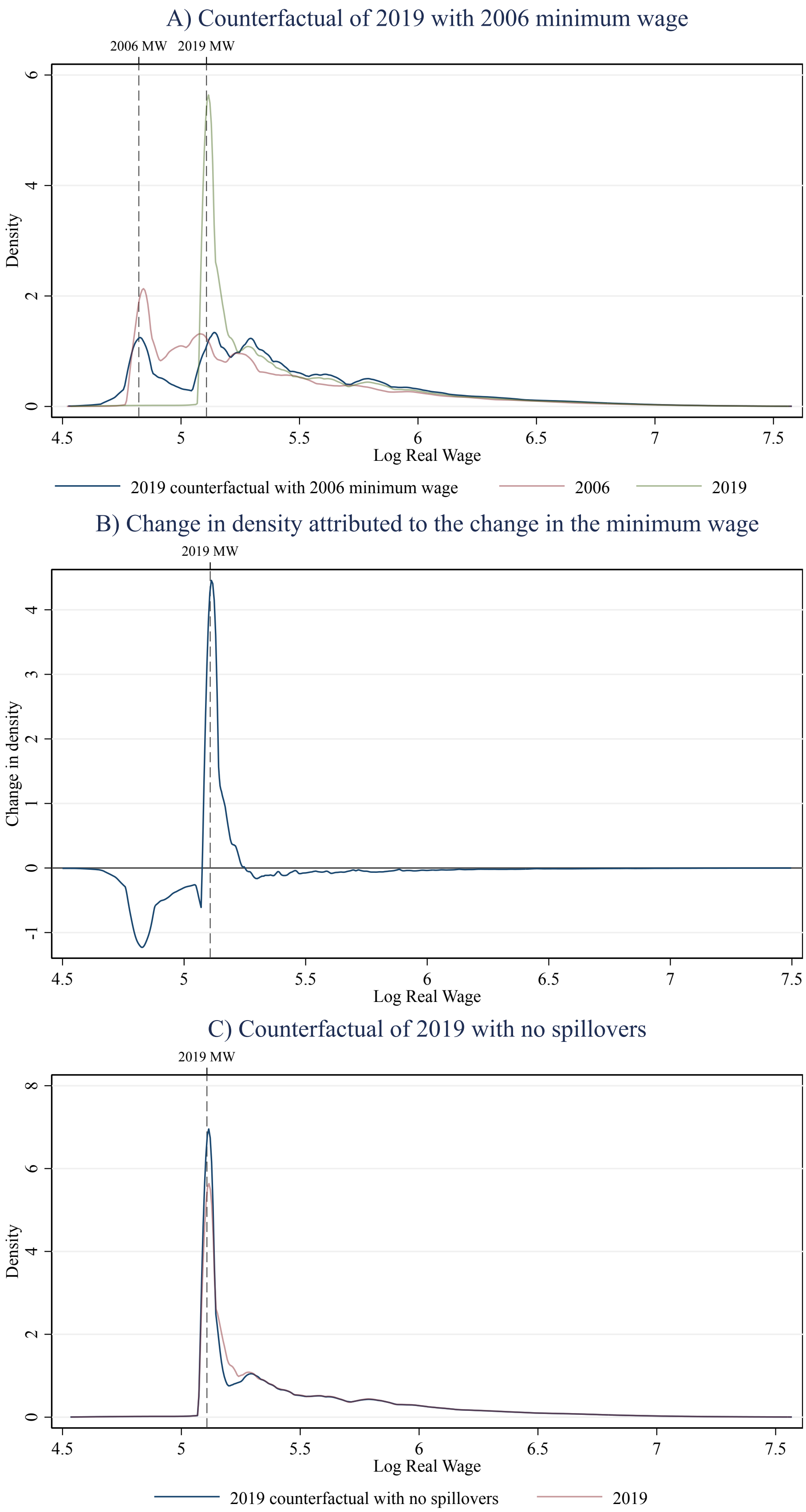

Figure A.5: Density estimates using base wages. Each panel of this figure depicts the density estimate graphs already presented, but using base wages instead of total wages. Panel A depicts the equivalent to figure 3, Panel B depicts the equivalent to figure 4 and Panel C depicts the equivalent to figure A.3.

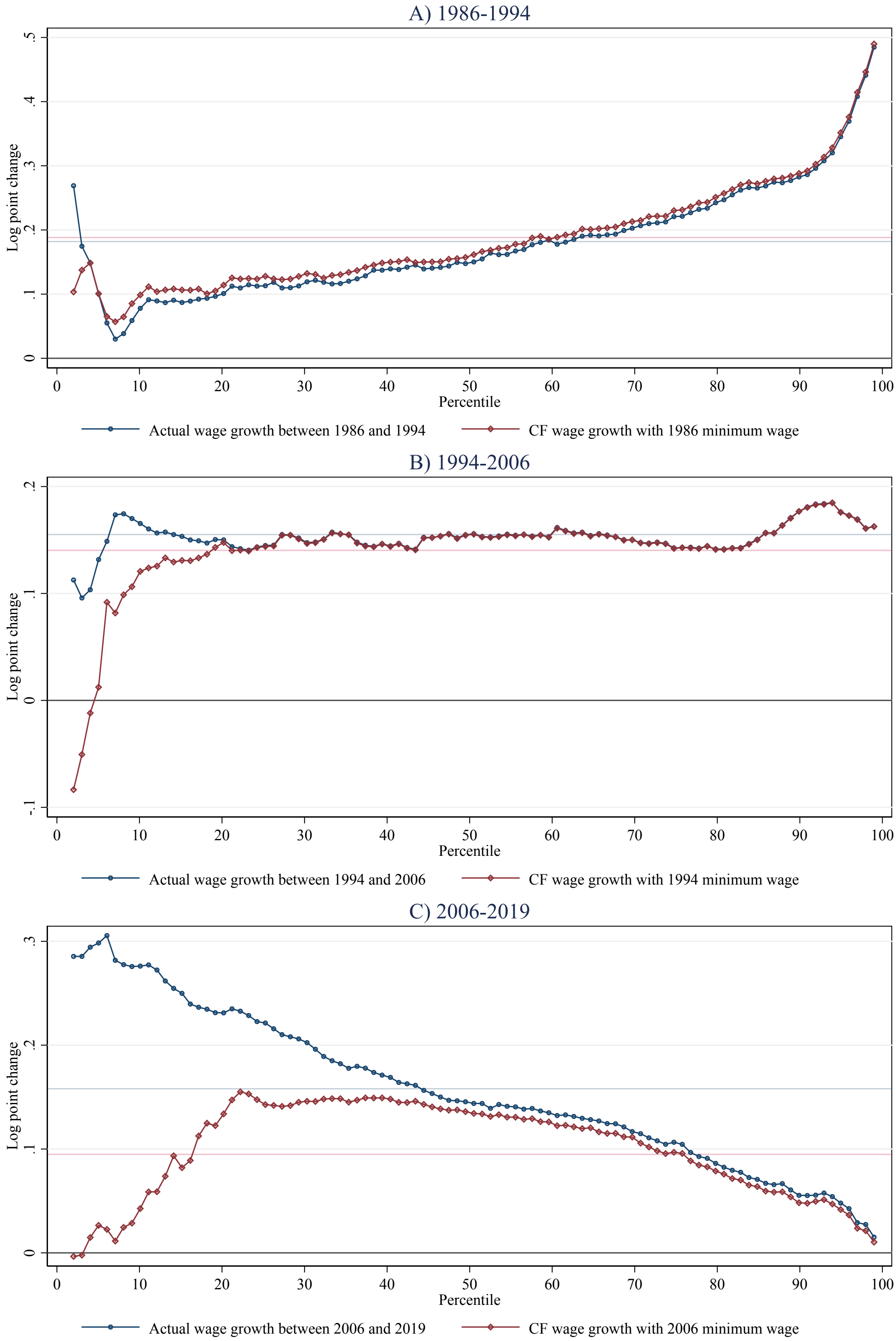

Figure A.6: Wage growth incidence curve over each of the three periods of analysis. This graph depicts the actual and counterfactual growth rate of wages for every percentile of the distribution between 1986-1994, 1994-2006, and 2006-2019. The shaded horizontal lines represent the mean wage growth. The slight difference between the actual and counterfactual curves above the 43rd percentile (the last percentile where spillovers are identified) is due to the reweighing, not representing actual lower wage growth. The first percentile was omitted in all three panels to avoid misbehavior related to the estimation in the graph.

A.4 Tables

Year	1986	1994	2006	2019
Mean log real wage	5.24	5.42	5.57	5.73
Mean log real wage (base wages)	5.10	5.24	5.35	5.47
(A) Inequality:				
Gini index	0.3	0.35	0.37	0.33
Standard deviation (of log wages)	0.5	0.57	0.58	0.51
90-10 log percentile differential	1.21	1.41	1.43	1.21
90-50 log percentile differential	0.79	0.92	0.95	0.86
75-25 log percentile differential	0.66	0.77	0.76	0.65
50-10 log percentile differential	0.42	0.49	0.48	0.35
(B) Minimum wage:				
Log real minimum wage	4.72	4.73	4.82	5.11
Relative minimum wage (log difference to the mean)	-0.52	-0.69	-0.75	-0.63
Share of workers on the MW or less	0.11	0.06	0.04	0.04
Share of workers on the MW or less (base wages)	0.14	0.09	0.08	0.21
(C) Composition of the workforce:				
Share of male workers	0.68	0.61	0.57	0.54
Average years of education	5.28	6.56	8.62	10.78

Table A.1: Descriptive statistics of interest. Panels A, B and C of this table provide descriptive measures of wage inequality, the importance minimum wage, and the composition of the workforce, respectively, for the four years that delimit the three periods of analysis. Wage-based statistics use total wages unless specified.

Year	Id	Log real wage
...	...	...
2010	3825	7.26
2010	3836	4.83
...	...	...

Year	Id	Log real wage	Wage bin	Outcome
...	...	...	...	...
2010	3825	7.26	54	1
2010	3825	7.26	55	1
2010	3825	7.26	56	1
2010	3825	7.26	57	0
2010	3825	7.26	58	0
2010	3825	7.26	59	0
2010	3825	7.26	60	0
2010	3825	7.26	61	0
2010	3825	7.26	62	0
2010	3836	4.83	1	1
2010	3836	4.83	2	1
2010	3836	4.83	3	1
2010	3836	4.83	4	1
2010	3836	4.83	5	1
2010	3836	4.83	6	1
2010	3836	4.83	7	1
2010	3836	4.83	8	0
2010	3836	4.83	9	0
...	...	...	...	...

Table A.2: Illustration of the stacked dataset. This table illustrates how the original dataset was stacked in order to perform the estimation. Each observation in the original data was multiplied by 62, the number of wage bins, and the outcome variable was determined for each wage bin, so as to "simultaneously estimate 62 probit regressions".

	Sd	90-10	90-50	50-10	Workers on 1st year MW	Workers on last year MW	Mean wage
A) Females ($\Delta MW = 0.29$)							
2006	0.52	1.26	0.88	0.38	0.05	0.32	5.44
2019	0.46	1.08	0.79	0.29	0	0.04	5.64
2019 w/ 2006 MW	0.54	1.33	0.81	0.52	0.05	0.24	5.52
2019 w/o spillovers	0.48	1.17	0.8	0.37	0	0.13	5.61
Total change	-0.06	-0.18	-0.09	-0.09	-0.05	-0.28	0.2
Underlying change	0.02	0.07	-0.07	0.14	0	-0.08	0.08
Change due to MW	-0.08	-0.25	-0.02	-0.23	-0.05	-0.2	0.12
Change due to bite	-0.06	-0.16	-0.01	-0.15	-0.05	-0.11	0.09
Change due to spillovers	-0.02	-0.09	-0.01	-0.08	0	-0.09	0.03
B) Males ($\Delta MW = 0.29$)							
2006	0.6	1.48	0.95	0.53	0.03	0.16	5.68
2019	0.54	1.29	0.88	0.41	0	0.03	5.82
2019 w/ 2006 MW	0.57	1.39	0.87	0.52	0.02	0.08	5.81
2019 w/o spillovers	0.56	1.44	0.87	0.56	0	0.09	5.8
Total change	-0.06	-0.19	-0.07	-0.12	-0.03	-0.13	0.14
Underlying change	-0.03	-0.09	-0.08	-0.01	-0.01	-0.08	0.13
Change due to MW	-0.03	-0.1	0.01	-0.09	-0.02	-0.05	0.01
Change due to bite	-0.01	0.05	0	0.04	-0.02	0.01	-0.01
Change due to spillovers	-0.02	-0.15	0.01	-0.15	0	-0.06	0.02
C) Base wage ($\Delta MW = 0.29$)							
2006	0.51	1.24	0.87	0.37	0.08	0.42	5.35
2019	0.46	1	0.83	0.17	0	0.21	5.47
2019 w/ 2006 MW	0.5	1.22	0.84	0.38	0.08	0.29	5.42
2019 w/o spillovers	0.46	1.01	0.86	0.15	0	0.25	5.46
Total change	-0.05	-0.24	-0.04	-0.2	-0.08	-0.21	0.12
Underlying change	-0.01	-0.02	-0.03	0.01	0	-0.13	0.07
Change due to MW	-0.04	-0.22	-0.01	-0.21	-0.08	-0.08	0.05
Change due to bite	-0.04	-0.21	0.02	-0.23	-0.08	-0.04	0.04
Change due to spillovers	0	-0.01	-0.03	0.02	0	-0.04	0.01

Table A.3: Decomposition of changes in statistics of interest by gender and for base wages, 2006-2019. Each panel depicts statistics of interest for 2019, 2006, and the counterfactuals of 2019 with 2006 minimum wage and with no spillovers. They also contain the change in these statistics between the first and the last year, decomposed into the underlying change and the change attributed to the shift in the minimum wage, which is then itself decomposed into minimum wage bite effects and spillover effects. The table is explained in detail in section A.2 of the appendix.