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The Impact of the German Minimum Wage on Individual Wages and Monthly Earnings

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Abstract: This paper evaluates the short-run impact of the introduction of a statutory minimum wage in Germany on the hourly wages and monthly earnings of workers targeted by the reform. We first provide detailed descriptive evidence of changes to the wage structure in particular at the bottom of the distribution and distinguish between trends for regularly employed and marginally employed workers. In the causal analysis, we then employ a differential trend adjusted difference-in-differences (DTADD) strategy to identify the extent to which these changes in wages and earnings can be attributed to the minimum wage introduction. We find that the minimum wage introduction can account for hourly wage growth in the order of roughly 6.5 % or €0.45/hour and an increase in monthly earnings of 6.6 % or €53/month. Despite finding wage growth at the bottom of the distribution, the paper documents widespread non-compliance with the mandated wage floor of €8.50/hour.

Keywords: minimum wage, wage and earnings structure, inequality
JEL Classification: J31, J38, J22

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1 Introduction

On January 1st, 2015, a coalition government in Germany introduced the country's first national statutory minimum wage in history. In contrast to most evaluation studies that exploit marginal changes in the existing minimum wage laws in the United States or other countries, the German case study proves particularly interesting because it represents a high-impact, binding minimum-wage introduction with a large share of the population affected. With incremental changes, identification of effects has found mixed results, thus, yielding substantial uncertainty for the derivation of out-of-sample predictions with regard to this highly topical policy tool. This challenge is particularly problematic in light of the fact that substantial increases or new introductions of minimum wages have found their way into current debates in several countries (e.g. the US). Against this background, the German reform offers a unique opportunity to more clearly establish causality and contribute to the broader debate in Germany and around the world. The primary goal of the reform, which set a wage floor of €8.50 in all regions and economic sectors with few exceptions, was to increase gross hourly wages for low-wage workers. Against this background, this paper investigates the following two questions. Firstly, *how did the introduction of the German minimum wage impact the distribution of hourly wages in the economy?* Secondly, *how do these effects differ across pay groups and worker types?* Our causal analysis focuses on the short-run effects of the reform: the available data allow for the identification of changes to the wage distribution through mid-2016.

Due to the recency of its introduction, very few studies have investigated the impact of the statutory minimum wage reform in Germany on the wage and earnings distribution in a causal fashion using data from the post-reform period. Such studies include Bellmann et al. (2017), Caliendo et al. (2017) and Pusch and Seifert (2017). Using data from the IAB Establishment Panel for the state of Saxony, Bellmann et al. (2017) find a strong, positive effect of the reform on gross monthly earnings, not only for workers earning below €8.50 prior to the reform, but also for workers previously earning slightly above this threshold, an indication of "spillover effects". Caliendo et al. (2017) identify the impact of the reform on different segments of the wage and earnings distribution by exploiting the variation in the intensity, or 'bite' across German regions (*Raumordnungsregionen*). On the basis of data from the Socio-Economic Panel (SOEP) through 2015, they document above-average growth rates for wages in the bottom tail of the distribution as well as higher growth rates in the bottom segments in regions with a larger minimum wage bite. Moreover, these results as well as recent work by Burauel et al. (2017), Mindestlohnkommission (2016) and Pusch and Seifert (2017) demonstrate that a meaningful share of workers still receive

pay below the mandated wage floor also after the reform, constituting evidence of non-compliance.[1]

The present paper belongs to the first wave of evaluations using post-reform data and builds on these studies mentioned above by providing descriptive as well as causal evidence of wage changes around the time of, or on account of, the minimum wage. Our results also offer evidence regarding the distributional effects of the minimum wage which, with the exception of ex-ante evaluation studies, has been scarce.

Beyond the German context, a large literature has grappled with the distributional effects of minimum wages. In one of the earliest papers to address this question, DiNardo et al. (1996) study the importance of several institutional factors such as the decline in union coverage and the real minimum wage for explaining hourly wage inequalities in the United States. Using CPS data, they attribute 25 % of inequality growth among men and 30 % of inequality growth among women to the decreasing real value of the minimum wage over time. Lee (1999) likewise investigates the relationship between the real minimum wage and wage inequality using CPS data and corroborates this result. More recent papers by Autor et al. (2008) and Autor et al. (2016), however, attribute a much larger role to market factors such as skill-biased technological change rather than minimum wages in explaining wage inequality. Nevertheless, Autor et al. (2008) find that, in particular for women in the lower tail of the distribution, the intertemporal decline in the real minimum wage contributed meaningfully to wage inequality. Going beyond effects on the hourly price of labor (wages) and using the same data as these above mentioned studies, Neumark et al. (2004) explore several channels of minimum wage effects, including monthly earnings, employment probability and hours worked in addition to hourly wages. The authors find the largest increases to hourly wages in the bottom tail of the distribution, but they show that subsequent reductions in the hours worked and employment opportunities counteract the positive wage effect. Allowing for lagged responses to the minimum wage, they moreover find that the overall effect on monthly earnings becomes negative for low-wage workers. With the exception of some of the very recent substantial state hikes in minimum wages, minimum wage adjustments in the long history of the US minimum wage have predominantly been small and incremental in comparison to the bite of the German statutory minimum wage.

In Great Britain, where a national statutory minimum wage was introduced in 1998, several studies assess its impact on the wage and earnings distribution. Manning (2013), Low Pay Commission (2015, 2016) provide overviews of this work.

1 See Caliendo et al. (2019) for a general overview of the causal effects of the minimum wage introduction on a large set of outcome variables.

Using several different data sources,[2] these studies predominantly conclude that the British minimum wage decreased wage inequality at the lower tail of the distribution (see for example Dickens/Manning 2004; Dolton et al. 2012; Butcher et al. 2012).

The institutional setting, design and bite of minimum wage reforms as well as the pre-reform wage distribution differ greatly from country to country and are likely to influence the effect of reforms in the United States, Great Britain and Germany. Moreover, the spectrum of measured compliance – the degree to which a wage floor is actually enforced – varies substantially across countries and groups of workers as well as over time. Furthermore, measured compliance rates differ depending on whether the data employed in the analysis is based on statements from employees or employers. Ashenfelter and Smith (1979) calculate differences as large as 13 percentage points. Metcalf (2008) arrives at similar results. Previous literature has established different non-compliance rates across groups of workers, with larger rates among workers in low-wage sectors and those with immigrant backgrounds (Cortes, 2004; Weil, 2005). Using rich survey data from the Socio-Economic Panel Survey (SOEP), we are able to quantify the degree of non-compliance with the German minimum wage on average as well as across different types of workers.

The remainder of the paper is structured as follows. Section 2 provides a brief background to the timeline and eligibility rules of the reform. Section 3 describes the data used in the analysis and introduces the econometric method applied to identify causal effects of the reform. Section 4 offers a detailed analysis of trends in wages and salary earnings at the mean as well as separately for the bottom wage segments. Section 5.1 presents the results for the entire sample while Section 5.2 examines heterogeneous treatment effects for individuals in socially insured regular employment and the marginally employed separately. Section 5.3 tests the robustness of our results and Section 6 concludes.

2 Institutional background

Following years of debating the introduction of a minimum wage in Germany, the debate became more concrete during the Federal elections in September 2013 and even more so by the end of November of that same year when an emerging Grand Coalition government announced the intention to implement a national, statutory minimum wage of €8.50 per hour effective January 1,

2 These include the Labor Force Survey, the New Earnings Survey, General Household Survey, British Household Panel Survey and the Annual Survey of Hours and Earnings.

2015. The German parliament passed the proposal into law by July 2014. Prior to this implementation, minimum wages existed only at the sectoral level and differed fundamentally from the statutory wage floor in that previous minimum wages were negotiated by employers' associations and unions.[3] The new €8.50 minimum wage applied almost universally across all regions and sectors, with few exclusions. Exempted groups include: trainees, most interns, the long-term unemployed during the first 6 months of employment, and minors prior to completing vocational training. Moreover, sectors with their own bargained minimum wages received a temporary exemption until the end of 2017, at which time all sectors were to be integrated into the national minimum wage regime. Nevertheless, very few sectoral minimum wages fell below the national minimum.

3 Methodology

3.1 Data and sample restrictions

Nationally representative data from the 2010 to 2016 waves of the Socio-economic Panel (SOEP) form the basis for our analysis. The SOEP is a panel survey conducted annually in Germany since 1984 and contains about 15,000 households (Goebel et al., 2018). It surveys households regarding their composition, income and relevant employment information, including gross monthly earnings and working hours. Individual hourly wages and gross monthly earnings form the central outcome variables of interest in the present analysis. Although the SOEP does not ask respondents their hourly wage directly, it can be calculated as the quotient of two variables ascertained in the survey, namely monthly earnings and usual weekly hours worked, with the denominator multiplied by 4.33 weeks/month.[4]

Because the field interviews predominantly end in the first half of the year, this time frame enables us to study pre-reform trends, anticipation effects and two years of post-reform effects. Furthermore, the survey asks respondents about their contractual as well as actual hours worked by asking them to report paid

3 Fitzenberger and Doerr (2016) provide an overview of these sectoral minimum wages. Due to their nature as negotiated wage floors, the sectoral minimum wages are not comparable to the mandated, statutory minimum.

4 Respondents are asked to disregard additional payments and fringe benefits such as vacation or Christmas money or a 13th/14th salary in the calculation of their monthly earnings. While legal precedence has determined that employers may include these payments in the basis for the minimum wage, these payments play only a minor role in the low wage sector, which is of primary concern in this paper.

and unpaid hours usually worked in their *main* job.[5] This information allows us to investigate the possible adjustment channel of increased unpaid overtime work. In the following, we refer to the sum of paid and unpaid hours as 'actual hours worked' and the number of paid hours as 'contractual hours worked', the latter of which presents the primary measure for analysis, as it is less prone to measurement error.[6]

The SOEP consists of several subsamples that together (weighted) represent the entire population. In this paper, we utilize both the cross-sectional and longitudinal samples, as they possess different, complementary advantages. Central parameters representative of the entire population are constructed using the cross-sectional sample and weights. The measurement of individual changes in hourly wages and monthly earnings, however, requires that individuals were present and employed in at least two consecutive SOEP waves. Thus, for this latter analysis, we employ the panel sample and weights. Together, these two samples enable us to paint a full picture of the minimum wage effects. The following Table 1 summarizes the sample restrictions applied throughout the paper.

Table 1: Sample size by survey year.

	2012	2013	2014	2015	2016	Total
Employed	16,155	18,199	16,066	15,822	14,895	81,137
Hourly wage undefined	−3,734	−4,236	−3,392	−3,553	−3,445	−18,360
Exempt from minimum wage or has sector-specific minimum wage	−2,522	−2,904	−2,458	−2,727	−2,447	−13,058
Cross-Sectional Sample	9,899	11,059	10,216	9,542	9,003	49,719
Not observed in $t + 2$	−3,341	−4,026	−3,336	-/-	-/-	−29,248
Job loss	−62	−51	−75	-/-	-/-	−188
Missing information	−363	−279	−330	-/-	-/-	−972
2-Year Panel Sample	6,133	6,703	6,475	-/-	-/-	19,311

Source: SOEP v33 2012-2016, own calculations.

5 Hours worked in secondary jobs are not included.

6 The ability to work fewer hours at a later time in the year in order to compensate for accumulated overtime renders a clear determination of the number of unpaid overtime hours difficult for some respondents. Moreover, previous research has found that, when asked about their hours worked, employees tend to overestimate them (see for example Bound et al. 2001). Any measurement error would persist both before and after the reform and should therefore not drive our results. Nevertheless, unpaid hours are likely more susceptible to any measurement error than contractual hours because contractual hours are made explicit in all employment contracts.

On average, the SOEP contains about 16,000 annual observations of employed individuals above the age of 18. This number includes both full-time and part-time workers as well as the marginally employed and self-employed. We exclude roughly 16 percent of these observations from the sample due to their exemption status from the minimum wage, discussed in detail above. Making these exclusions ensures that treatment and control groups defined in the causal analysis remain comparable. The following analysis applies exclusively to this sample of the population.[7] The remaining 49,719 individuals form the sample population for the cross-sectional analysis.

Building upon the cross-sectional sample, we construct the sample for the longitudinal analysis, referred to subsequently as the panel sample. With a reference year in time t, the panel sample draws upon individual information from the wave two periods later, in time $t + 2$. Therefore, the panel setting imposes additional restrictions on the sample. Individuals must participate in at least two SOEP waves that lie two years apart and make all necessary information available for the determination of hourly wages. Due to item non response and panel attrition, only part of the cross-sectional sample fulfills these requirements.[8] The panel focus permits the evaluation of *individual* changes in hourly wages or monthly earnings. In the following, we designate this sample the 'two-year panel'. Analogously, we create a 'one-year panel' consisting of individuals who make available the necessary information in periods t and $t+1$. For the analysis of wage changes due to the minimum wage reform, the two year panel is preferred because it can better capture the effects of lagged implementation. Nevertheless, for completeness we also provide estimates for the one-year panel.

3.2 Econometric specification

In order to distinguish a causal effect of the minimum wage introduction from secular wage trends that would have developed even absent the reform, we employ a differential trend adjusted difference-in-differences strategy (DTADD) (Blundell/Dias 2009). A difference-in-differences (DD) strategy would not suffice because hourly wages of low-wage workers do not exhibit a parallel trend[9] with any control group and, thus, such estimates would prove biased. For the DTADD strategy, average individual wage growth of the treatment and control

7 Individuals with sector-specific minimum wages are excluded from the analysis.

8 At the time of writing this study, the period of observation ends in 2016. Therefore, there are no observations in $t + 2$ for the years 2015 and 2016.

9 The dynamic of individual wages generally decreases with the hourly wage percentile.

group forms the foundation for the analysis. We define the treatment group as individuals earning below €8.50/hour and the control group as individuals with an hourly wage just above the wage floor, between €8.50 and less than €10.00 per hour. As we focus on low-wage earners, we truncate the control group at €10.00 to ensure comparability between the treatment and control group. $\overline{w^i_{t+2} - w^i_t}$ represents the average individual wage growth of group i between two years, $t \in \{2012, 2014\}$, where i refers to either the treatment group ($i = T$) or the control group ($i = C$). Then the DTADD estimator of the minimum wage effects can be expressed as follows:

$$\underbrace{[\overline{(w^T_{2016} - w^T_{2014})} - \overline{(w^T_{2014} - w^T_{2012})}]}_{Observed} - \underbrace{[\overline{(w^C_{2016} - w^C_{2014})} - \overline{(w^C_{2014} - w^C_{2012})}]}_{Counterfactual} \quad (1)$$

The first difference of the DTADD estimator is defined through the four terms of the group-specific average individual wage growth between time t and $t+2$ in the parentheses: $\overline{(w^T_{2016} - w^T_{2014})}$, $\overline{(w^T_{2014} - w^T_{2012})}$, $\overline{(w^C_{2016} - w^C_{2014})}$, and $\overline{(w^C_{2014} - w^C_{2012})}$. The second difference is then calculated within each group, such that it depicts the difference between the time period of the minimum wage implementation and the previous period for the observed scenario and the counterfactual scenario: $\overline{(w^T_{2016} - w^T_{2014})} - \overline{(w^T_{2014} - w^T_{2012})}$ and $\overline{(w^C_{2016} - w^C_{2014})} - \overline{(w^C_{2014} - w^C_{2012})}$. The third difference is the difference between the "observed" scenario and the "counterfactual" scenario. The observed (counterfactual) scenario summarizes the change in average two-year wage growth in the treatment group (control group) between 2012–2014 and 2014–2016.

If, for instance, hourly wages in the treatment group increased on average by €0.2 between 2012 and 2014, but by €0.5 between 2014 and 2016, wage growth in the treatment group would then lie €0.3 higher in the period between 2014 and 2016 than in the period before. However, one could not exclude the possibility that business cycle effects stemming from Germany's economic growth during that time positively influenced wage growth between 2014 and 2016. For this reason, it is essential to employ a counterfactual situation that captures how wage growth would have evolved absent the reform. For this purpose, we include the change in wage growth of the control group. Our method relies on the assumption that any changes observed for wage growth in the control group also would have occurred in the treatment group had the reform not taken place. If, for example, average wage growth in this group between 2014 and 2016 surpassed that in the previous period (2012 to 2014) by €0.1, only €0.2 and not €0.3 could be ascribed to the introduction of the minimum wage. The difference between changes in growth in the treatment group and the changes observed in the control group present the treatment effect of interest.

In contrast to the DD analysis, this identification strategy does not require the common trend assumption to hold. Rather, it modifies this assumption to stating that existing differences between the treatment and control group would have remained unchanged on average over time. The assumption requires that business cycle effects equally impact the treatment and control group between 2012–2014 and 2014–2016. Given the consistently strong business cycle during these years, this assumption likely holds.[10] A further threat to identification could arise if the control group is affected by the minimum wage. Previous studies have established the existence of such "spillover" effects in the United States and Germany for earlier reforms, at least in the long run (Lee 1999; Neumark et al. 2004; Dickens/Manning 2004; Aretz/Gregory 2013, Autor et al. 2016). Data from the IAB Establishment Panel suggest that also for the statutory minimum wage reform, effects on wages may have also spilled over to higher segments of the wage distribution already in the short run (Mindestlohnkommission, 2016). For this reason, Section 5.3 tests the validity of this assumption and does not find evidence of any significant spillover effects.

To illustrate the identification strategy applied in this paper, Table 2 provides descriptive statistics of wage growth for the treatment and control groups. The sample includes only observations present and employed in both t and $t+2$. Panel A summarizes the available number of observations used in the later analysis. Panel B displays the average absolute change in hourly wages. Panel C supplements this information with the relative change in wage dynamics, defined as $ln(\frac{w_{it+2}}{w_{it}}) * 100$. This last panel allows for an evaluation of wage effects relative to the initial value (w_{it}) at the individual level. Columns (1)–(3) present these values for the period used for the identification of treatment effects of the minimum wage introduction. Columns (4)–(6) demonstrate the critical identification assumption of time-constant differences between the treatment and control group by providing the same values for earlier periods.

Table 2 shows an average increase in hourly wages of €2.70 among individuals who earned below €8.50 in 2014 and remained employed in 2016 (see Column (1) of panel B). In the same period, average hourly wages of the control group rose by approximately €1.40. Such differences, however, also existed in the previous period from 2012 to 2014: the treatment group experienced wage growth in the order of €0.60 higher than that of the control group (€2.10–€1.50). Due to this systematic difference in wage growth trends, a simple DD estimator would yield biased results. The DTADD approach accounts for the above-described differences in wage dynamics of individuals earning above and below €8.50 prior

10 According to the German Statistical Office, GDP per capita increased by 5.8 % between 2012 and 2014 and by 5.7 % between 2014 and 2016.

Table 2: Average growth in contractual hourly wages.

	DTADD			Placebo		
	(1)	(2)	(3)	(4)	(5)	(6)
	2014/16	2012/14	Difference (1)–(2)	2012/14	2010/12	Difference (4)–(5)
Panel A: Observations						
Wage<8.50	545	549		549	533	
8.50 ≤ Wage < 10	438	412		412	397	
Panel B: Absolute Change (in Euro)						
Wage<8.50	2.7	2.1	0.6	2.1	2.0	0.1
	(3.8)	(3.9)		(3.9)	(3.3)	
8.50 ≤ Wage < 10	1.4	1.5	−0.1	1.5	1.1	0.4
	(3.5)	(3.2)		(3.2)	(2.4)	
DTADD			0.7*			−0.3
Panel C: Log Change (× 100)						
Wage<8.50	28.8	22.5	6.3	22.5	22.0	0.5
	(33.8)	(35.8)		(35.8)	(32.8)	
8.50 ≤ Wage < 10	10.5	11.6	−1.1	11.6	8.6	3.0
	(26.0)	(23.7)		(23.7)	(22.5)	
DTADD			7.4***			−2.5

Source: SOEP v33 2010-2016, own calculations. Results are based on contractual hourly wages and are Unweighted. Standard errors in parentheses. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

to the reform. Controlling for the counterfactual scenario, the true difference becomes:

$$\underbrace{(2.70 - 2.10)}_{Observed} - \underbrace{(1.40 - 1.50)}_{Counterfactual} \approx 0.70 \tag{2}$$

To place this effect in relation to the individual, pre-reform wage level, we consider the logged change in panel C, which indicates a relative change of 7.4 percentage points additional wage growth between 2014 and 2016 due to the minimum wage introduction. With a mean hourly wage of €6.90 in the treatment group during the initial period, this difference equates to €0.50 extra per hour (6.90 × 0.074) in comparison to the control group.

To complete the analysis of the causal effect of the minimum wage reform on hourly wages, we use regression analysis to additionally control for differential characteristics of the treatment and control group that likewise influence hourly

wages, independently of the minimum wage reform. The regression equation can be stated as follows:

$$\Delta w_{it} = \beta_0 + \beta_1 T_{it} + \beta_2' Y_{it} + \beta_3' T_{it} \times Y_{it} + \beta_4' X_{it} + \beta_5' Change_{it} + \varepsilon_{i,t} \quad (3)$$

Δw_{it} captures the individual hourly wage change from time t to $t + 2$. T_{it} represents the treatment indicator that takes the value of one if the individual earned less than €8.50 per hour in period t and zero otherwise. β_1, therefore, represents the average wage growth of individuals who earned less than €8.50 in time t. Interacting this term with the time vector Y_{it} demonstrates whether significant deviations from the average growth, β_1, occurred in any specific year. As such, the coefficient of interest, β_3, identifies for $Y_{it} = 2014$ wage changes attributable to the minimum wage. Individual characteristics captured by X_{it} include: age, sex, marital status, citizenship status, highest educational attainment level, place of residence and the number of children under the age of 16 living in the household. Additionally, the following employment characteristics enter into the regression in the form of dummy variables: part-time employment, time-limited contract, firm size and economic sector. $Change_{it}$ further contains information regarding whether the individual changed employment characteristics between periods t and $t + 2$, including: eligibility for the minimum wage, job change, receiving a permanent contract, firm size and sector. ε_{it} is an idiosyncratic error term. We estimate the regression equation with OLS. Results are presented in Section 5.

4 Trends in wages and salary earnings

4.1 Wage growth throughout the distribution

Before turning our attention to the causal analysis, this section describes trends in gross hourly wages before and after the minimum wage reform. Table 3 presents descriptive statistics for the central variables of the cross-sectional analysis in each year between 2012 and 2016. Among the population of employees eligible for the minimum wage, mean gross monthly earnings amount to €2,620 in 2012 and €2,850 in 2016 in unadjusted nominal terms. Dividing the monthly income by usual (contractual) monthly hours worked, we arrive at our working concept of hourly wages, which increase between 2012 and 2016 from approximately €17.2 to €18.7. Because actual hours worked surpass contractual hours, the use of contractual hours yields a significantly higher hourly wage. However, this observation is valid also for the pre-reform period.

A look at the evolution of contractual wages in Germany during the past decades helps to understand the role of the minimum wage introduction for the

Table 3: Earnings, working hours and hourly wage – by year.

	2012	2013	2014	2015	2016
Monthly Gross Earnings	2,622.77	2,649.42	2,703.05	2,818.06	2,846.49
in Euros	(1,534.92)	(1,577.11)	(1,639.14)	(1,684.00)	(1,685.27)
Weekly Hours Worked	34.18	34,10	33,75	34,03	33.98
Contractual	(9.81)	(9,64)	(9,96)	(9,78)	(9.77)
Actual	37.76	37.58	36.98	37.17	37.11
	(11.72)	(11.65)	(11.81)	(11.59)	(11.51)
Hourly Wage in Euros	17.22	17.41	17.88	18.54	18.74
Contractual	(8.51)	(8.72)	(9.06)	(9.25)	(9.24)
Actual	15.58	15.8	16.28	17.00	17.16
	(7.22)	(7.52)	(7.80)	(8.05)	(8.06)
Observations	9,899	11,059	10,216	9,542	9,003

Source: SOEP v33 2012–2016, own calculations. The table shows weighted averages based on the cross-sectional sample; standard deviations in parentheses.

evolution of wages immediately following the reform. Figure 1 exhibits growth rates in decile-specific average contractual hourly wages throughout the wage distribution for two-year changes between 1998 and 2016. We denote these growth rates 'anonymized growth rates' because this procedure measures growth not at

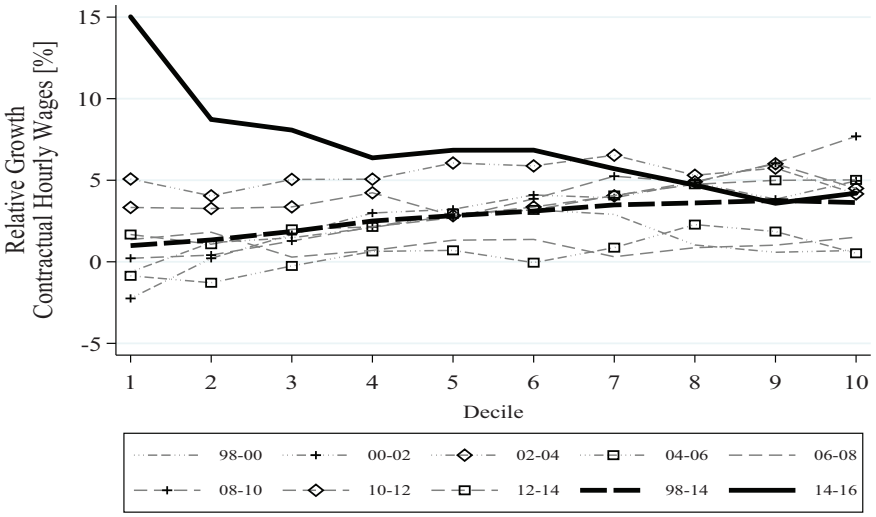

Figure 1: Relative changes in contractual hourly wage by wage decile - Various two-year time periods.
Source: SOEP v33, panel sample, own calculations.

the individual level, but rather based on decile-specific averages, which may be comprised of a different pool of people from one year to the next.

The light-grey, dashed lines show the growth rates based on the two years' difference during the pre-reform period. The black dashed line represents the average over these years before the minimum wage introduction. The black, solid line shows the two year difference between 2014 and 2016. As such, Figure 1 shows that the correlation between wage decile and wage growth systematically differs from the trend in the pre-reform period. The average pre-reform growth rate lies at around 2.5 %, with the upper wage deciles experiencing faster growth at about 3.5 % compared to the lower ones at below 2 %. Between 2014 and 2016 in contrast, wage growth in the lower deciles lay well above the decile-specific average of the past years, accelerating from a meager 1 % average growth to 15 %. At the same time, wage growth in the higher deciles continued at about the same rate after the reform compared to the average of the previous years.

4.2 Changes in wage inequality

Concerns regarding growing wage inequality in Germany motivated support for the minimum wage reform of 2015. For this reason, this section briefly discusses the evolution of wage inequality both prior to and after the minimum wage introduction. The mean log deviation (MLD) in wages serves as a standard measure of inequality, which we also utilize here. Two advantages of MLD make it particularly appropriate for our analysis: it is especially sensitive to changes at the bottom of the wage distribution where the minimum wage binds and it can be decomposed into wage difference between and within groups (see for example Cowell 2011). Table 4 displays the MLD for the entire cross-section. The first row shows the lower and the third row the upper limit of the 95 % confidence interval. The second row contains the point estimate.

Table 4: Inequality in contractual gross hourly wages (MLD Coefficient).

	2012	2013	2014	2015	2016
Lower Limit	0.111	0.112	0.116	0.113	0.106
Point Estimate	0.115	0.117	0.121	0.118	0.111
Upper Limit	0.120	0.121	0.125	0.122	0.116

Source: SOEP v33 2012–2016, cross-sectional sample, own calculations. Results are weighted and lower and upper limits refer to a 95% confidence interval using a bootstrapping procedure with 200 iterations.

While inequality in the entire cross-sectional sample increased during the period from 2012 to 2014, this trend reversed by 2015, in the year immediately following the introduction of the minimum wage. Table 4 shows a statistically significant reduction in inequality of average hourly wages in 2016 compared to 2014 before the introduction of the minimum wage. This result should not be interpreted as a causal effect of the minimum wage, as any number of factors could have contributed to this evolution. Instead, results place the minimum wage reform in the context of increasing wage inequality that began to decrease during the same period as the minimum wage introduction. Section 5 builds on this descriptive evidence by exploring a causal link between wage growth and the reform.

4.3 Developments in the bottom wage segments

The previous section showed trends in average wages throughout Germany. This section focuses on developments in the bottom 40 % of the gross hourly wage distribution between 2012 and 2016. Figure 2 highlights these developments using Pen's Parade. This graphical concept first sorts all workers in the given year according to their hourly wage, from lowest to highest. The next step entails plotting the average wage in each percentile against each consecutive percentile of

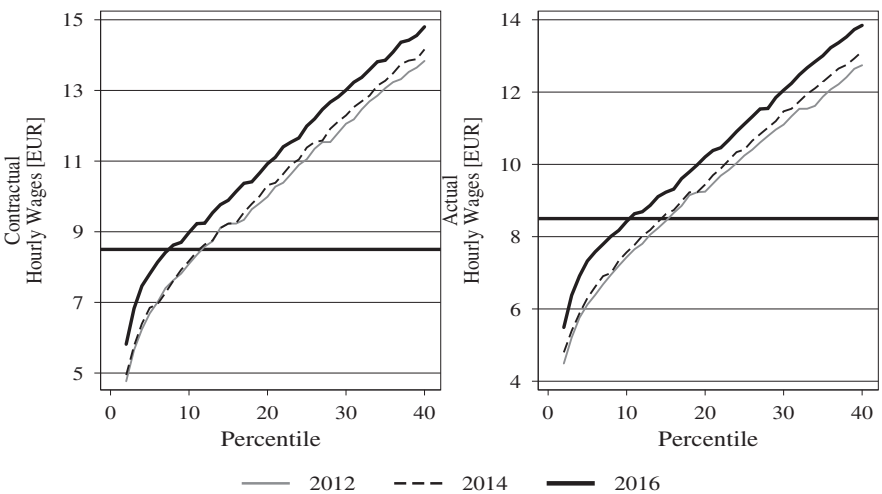

Figure 2: Pen's parade of contractual and actual gross hourly wages in the bottom 40 % of the wage distribution.
Source: SOEP v33, cross-sectional sample, own calculations.

workers. Plotting Pen's Parade for between 2012 and 2016 together allows for a comparison of wage growth over several years. Figure 2 shows Pen's Parade for workers earning in the bottom 40 % of the hourly wage distribution.

The left-hand panel of Figure 2 depicts Pen's Parade of average hourly wages calculated on the basis of contractual hours worked and the right-hand panel the corresponding rates on the basis of actual hours worked. The figure confirms and shows in more detail the wage growth in the low-wage segments targeted by the reform. In addition, the image quantifies the share of workers earning below the minimum wage level of €8.50/hour in gross terms before and after the reform. The horizontal line demarcates the wage floor. Whereas the share lying below the red line amounts to 12 % in both 2012 and 2014, it is reduced to 7 % by 2016. The nationally representative survey weights enable a conversion of this percentage into the number of employees – roughly 1.8 million – still earning below the minimum wage after the first quarter of 2016. In 2015 this number amounted to roughly 2.1 million, down from about 2.8 million prior to the reform. Measured in actual rather than contractual hours worked, as displayed in the right-hand panel, the share of non-compliance is higher, but the magnitude of the reduction from approximately 14.5 % in 2012 and 2014 to 10 % in 2016 shows a similar pattern. Note that the sample only includes individuals eligible for the minimum wage such that wages under €8.50 cannot be explained by exempted groups of employees.

4.4 Individual wage growth

Following the cross-sectional analysis of changes in (anonymized) wages throughout the distribution, this section utilizes the panel sample in order to focus on changes to the wages of individuals who earned below the minimum wage prior to the reform and remained employed after its introduction. Figure 3 illustrates these changes with a personalized wage growth curve. The personalized wage growth curve describes the relationship between average individual wage growth and the *individual's* position in the wage distribution in the initial, pre-reform period. Whereas a Pen's Parade depicts how the wage, for example, in the 30th percentile of the wage distribution in 2016 changed in comparison to the wage at this percentile in 2014, the personalized curve describes the development over time of the average wage of individuals who earned at the 30th percentile of the wage distribution in 2014 (and in any percentile in 2016).

Like the anonymized (cross-sectional) wage growth curve in Figure 1, Figure 3 exhibits the change in wages from 2014 to 2016 as a solid, thick black line and juxtaposes this growth to historical two-year changes in wages between 1998 and

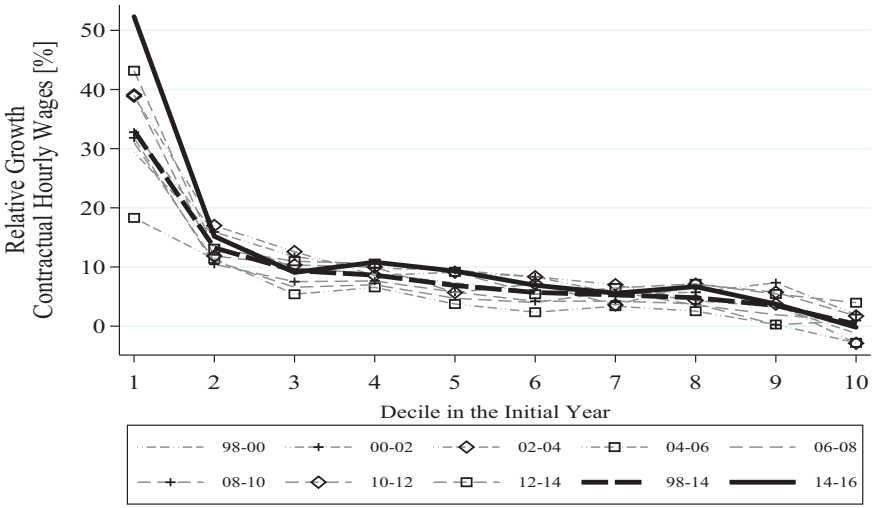

Figure 3: Personalized growth curves for gross hourly wages.
Source: SOEP v33, panel sample, own calculations.

2014. Light grey, dashed lines capture individual two-year changes and the thick black dashed line the average of these between 1998 and 2014.

In the bottom decile of the wage distribution for each initial period, wages grow by 30–40 % and then sink to a rate under 20 % by the second decile, indicating historically high growth rates of the average individual with the lowest wages in the initial period. High growth rates at the bottom demonstrate that, for many individuals, low wages represent a transitory phenomenon. Workers with wages in the lowest decile tend to be young with short work biographies who then gain human capital and work experience that subsequently promote them into higher wage categories. From 2014 to 2016, growth at the bottom increased even further, to about 50 %.

4.5 Mobility between wage segments

This section examines the transitions of individuals across wage segments of the distribution, as workers may occupy different positions throughout their working biography. For this exercise, we use transition matrices to illustrate mobility. The matrices describe the probability to transition from a wage segment in time t to another segment in time $t + 2$, for instance from below the minimum wage to the segment between the €8.50 wage floor and €10.50. In contrast to the wage curves in Figures 1 and 3, the transition matrix also accounts for individuals switching

Table 5: Transitions for contractual gross hourly wages (2012–2016).

	Not Employed	Below EUR 8.50	EUR 8.50 –10.50	EUR 10.50 –12.00	Above EUR 12.00
			Wage Group in 2014		
Wage Group in 2012					
Not Employed	0.922	0.021	0.015	0.007	0.035
	(0.004)	(0.002)	(0.002)	(0.001)	(0.003)
Below EUR 8.50	0.274	0.379	0.198	0.078	0.07
	(0.027)	(0.029)	(0.024)	(0.024)	(0.014)
EUR 8.50-10.50	0.137	0.073	0.369	0.185	0.236
	(0.020)	(0.015)	(0.028)	(0.025)	(0.027)
EUR 10.50-12.00	0.132	0.011	0.069	0.314	0.474
	(0.025)	(0.004)	(0.019)	(0.042)	(0.039)
Above EUR 12.00	0.093	0.006	0.01	0.013	0.879
	(0.007)	(0.001)	(0.003)	(0.002)	(0.008)
			Wage Group in 2016		
Wage Group in 2014					
Not Employed	0.930	0.011	0.015	0.005	0.039
	(0.004)	(0.002)	(0.002)	(0.001)	(0.003)
Below EUR 8.50	0.217	0.235	0.302	0.097	0.149
	(0.026)	(0.024)	(0.030)	(0.023)	(0.027)
EUR 8.50-10.50	0.162	0.073	0.377	0.21	0.177
	(0.025)	(0.013)	(0.029)	(0.023)	(0.023)
EUR 10.50-12.00	0.166	0.029	0.116	0.237	0.452
	(0.032)	(0.016)	(0.021)	(0.031)	(0.037)
Above EUR 12.00	0.094	0.004	0.008	0.016	0.878
	(0.006)	(0.002)	(0.002)	(0.003)	(0.007)

Source: SOEP v33 2012-2016, panel sample. N = 14,538 in the sample 2012-2014 and N = 14,398 in the sample 2014-2016. All probabilities stated in decimal value (0.285 = 28.5%). Standard deviations in parentheses.

from employment to not working. Table 5 presents a transition matrix for contractual hourly wages in 2012/2014 and 2014/2016. We distinguish between four wage segments as well as the transition out of employment and vice versa. We define the following groups as non-employed: trainees and apprentices, those participating in older worker part-time schemes (*Altersteilzeit*), but who report zero hours, those in military or the civil social service, working in an establishment for disabled people and those reporting non-employment.

Each row describes a certain wage group status in the initial period, 2012 for the upper panel and 2014 for the lower panel. The columns represent the share of each group that transitions from the given wage group to the wage group denoted in the column title (each row adds up to one). The shares in the main diagonal

correspond to the share of each wage segment that remained in that wage group two years later. The table shows that the share of individuals that remained in employment remunerated below the minimum wage level of €8.50 substantially decreased after the introduction of the minimum wage: in the period from 2012 to 2014, 38 % remained in this wage category, while from 2014 to 2016 the share dropped to 24 %. At the same time, a slightly smaller share of workers previously earning below the minimum wage transitioned out of employment from 2014 to 2016 compared to 2012 to 2014 and a much larger share (30 % compared to 20 %) experienced upward wage mobility into a higher wage segment between €8.50 and €10.50. It is also noteworthy that the share of workers paid below the minimum wage in the previous period and who transitioned into an even higher segment with an hourly wage above €12.00 doubled in 2014/2016 compared to 2012/2014. Finally, the share of non-workers who remained out of work slightly increased in 2014/2016 compared to 2012/2014. Moreover, transitions out of employment from the wage segment just above the minimum wage between €8.50-€10.50 as well as €10.50-€12.00 increased from 14 % to 16 % and from 13 % to 17 %, respectively.

The descriptive evidence provided in this section paints a clear picture: following many years of low wage growth at the bottom of the wage distribution, the introduction of the statutory minimum wage is associated with significant growth in wage dynamics in the bottom decile of the distribution.[11] and, consequently, a compression of the wage distribution. Nevertheless, compliance with the minimum wage remains imperfect and many eligible workers still earn an hourly wage below €8.50/hour. The following section addresses the question to what extent the observed changes in wage growth can be causally attributed to the minimum wage introduction.

5 Results of the causal effects analysis

5.1 Main results

Table 6 summarizes the results from the regression analysis for changes in contractual hourly wages of all workers eligible for the minimum wage. In order to control for non-linear relationships, the dependent variable is defined in logarithmic rather than absolute terms. Therefore, coefficients should be interpreted

11 For the first wage decile, a t-test reveals a statistically significant difference ($p < 0.001$) in the relative growth rate of contractual hourly wages in 2014-2016 in comparison to all other periods (1998-2014). For the second decile, this difference is insignificant ($p \approx 0.12$).

Table 6: Minimum wage effect on relative wage growth.

	One-Year Analysis			Two-Year Analysis		
	(1)	(2)	(3)	(4)	(5)	(6)
One-Year Analysis						
Hourly wage < EUR 8.50	10.83***	12.57***	12.49***			
	(1.57)	(1.59)	(1.59)			
× DTADD 2014–2015	4.01*	4.13*	3.96*			
	(2.14)	(2.12)	(2.11)			
× Placebo 2012–2013	−2.21	−1.5	−1.42			
	(2.19)	(2.17)	(2.17)			
Two-Year Analysis						
Hourly wage < EUR 8.50				10.89***	12.59***	12.93***
				(1.92)	(1.95)	(1.94)
× DTADD 2014–2016				7.44***	6.75**	6.47**
				(2.71)	(2.68)	(2.68)
× Placebo 2010–2012				2.49	2.29	2.07
				(2.63)	(2.61)	(2.59)
Constant	6.62***	13.44***	7.31**	11.58***	20.04***	10.59***
	(0.92)	(2.77)	(3.45)	(1.17)	(3.55)	(4.09)
Control Variables						
Year fixed effects	yes	yes	yes	yes	yes	yes
Socio-demographic info.		yes	yes		yes	yes
Employment characteristics		yes	yes		yes	yes
Changes in Employment			yes			yes
Observations	3,523	3,523	3,523	2,874	2,874	2,874
Adj. R^2	0.043	0.081	0.085	0.056	0.087	0.098

Source: SOEP v33 2010-2016, own calculations. Robust standard errors in parentheses, clustered at the individual level. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

as percentage changes. In addition to showing results for the two-year changes, (Columns (4)–(6)), Table 6 also provides results for one-year changes (Columns (1)–(3)) in order to describe potential differences in the effects across the time period following the reform. Columns (1) and (4) present results for the baseline specification using only treatment indicators and year fixed effects as control variables. Columns (2) and (5) additionally include sociodemographic and employment characteristic controls. Columns (3) and (6) also include controls for changes in employment.

The first row of Table 6 quantifies the differential wage dynamics within the one-year panel sample between treatment and control groups. According to the one-year analysis, hourly wages of workers earning below €8.50 grew on average

by 10.83 % faster than the control group (workers earning €8.50-€10.00) between 2012 and 2015. The introduction of the minimum wage further increased this growth by about 4 percentage points, which is captured by the DTADD interaction term for 2014–2015 in Column (1). This treatment effect can be considered causal, is significant at the 90 % confidence level and proves robust to the inclusion of controls for sociodemographic and employment characteristics as well as for changes in employment status. With a mean wage of €6.90/hour for the treatment group in 2014, the economic magnitude of the treatment effect amounts to an additional €0.30/hour (€6.90 × 0.04) above and beyond the wage growth that would have been expected absent the minimum wage introduction. An alternative way to consider the effect offers insight into the issue of non-compliance with the minimum wage: without the reform, hourly wages in the treatment group would have been expected to grow by €0.90/hour (€6.9 × 0.125), reaching €7.80/hour (€6.90 + €0.90). Instead, the minimum wage caused average wages in the treatment group to rise to €8.10, which still falls, on average, below the legal wage floor, indicating substantial non-compliance.

The two-year analysis shows that hourly wages of employees earning below €8.50 continue to increase through the second quarter of 2016 and grow dynamically in comparison to the control group. According to the two-year perspective, the marginal treatment effect of the minimum wage introduction on hourly wage growth is 6.47 percentage points in the preferred specification with full controls, an even higher and statistically more significant impact than that found in the one-year analysis. From the mean of €6.90/hour, this effect amounts to €0.45/hour more than would have been the case absent the reform (€6.90 × 0.065 = €0.45). Even with this larger effect, however, the average hourly wage of the treatment group fell shy of the €8.50 legal wage threshold at €8.24/hour (€6.90 + €0.89 + €0.45).

Finally, the third row of results for the one-year and two-year analyses lend credence to the validity of the crucial identifying assumption for the DTADD approach, namely time-persistent differences between treatment and control groups. Specifically, the placebo test examines whether wages of the treatment and control groups grew at different speeds during the period of 2012–2013 than in 2013–2014. The observed differences prove statistically insignificant in all specifications.

To answer the question of whether the minimum wage not only increased hourly wages, but also the overall labor income position of the target group, it becomes necessary to consider the effect on monthly earnings. After all, the goal of the reform was not just to increase wages per hour, but rather to improve the economic situation of low-income individuals. Monthly earnings combine two possible dimensions of adjustment: hours worked and hourly wages. In a related

contribution Burauel et al. (2019) demonstrate that the minimum wage introduction not only increased wages, but also had a negative impact on average hours worked. Therefore, in the following, we investigate the net effect of these two opposing forces. Table 7 depicts the results of the DTADD estimation from eq. (3) where the change in gross monthly earnings replaces the change in wages as the dependent variable.

The one-year analysis of Table 7 reveals that the effect of the minimum wage on the gross monthly earnings of the treatment group could not be statistically distinguished from zero. Similar to the results for changes in (log) wages, gross monthly (log) earnings experienced a higher growth rate in the treatment group than in the control group during the period under investigation (2012–2015): the first row of the first two columns indicates that earnings grew by roughly 10.5% more in the treatment than in the control group. The minimum wage, however, did not affect this relationship. Although the minimum wage led to a rise in

Table 7: Minimum wage effect on relative gross monthly earnings.

	One-Year Analysis		Two-Year Analysis	
	(1)	(2)	(3)	(4)
Hourly wage < EUR 8,50	10.98***	10.54***	8.91***	8.24***
	(1.91)	(1.90)	(2.42)	(2.42)
× DTADD 2014–2015	1.39	1.09		
	(2.69)	(2.63)		
× DTADD 2014–2016			8.70**	6.58*
			(3.54)	(3.40)
× Placebo 2012–2013	−4.45	−3.63		
	(2.71)	(2.64)		
× Placebo 2010–2012			4.15	3.08
			(3.53)	(3.46)
Constant	7.79***	17.68***	12.69***	11.63**
	(1.25)	(4.24)	(1.57)	(5.23)
Control Variables				
Year fixed effects	yes	yes	yes	yes
Sociodemographic information		yes		yes
Employment characteristics		yes		yes
Changes in employment		yes		yes
Observations	3,523	3,523	2,874	2,874
Adj. R^2	0.022	0.071	0.027	0.122

Source: SOEP v33 2010–2016, own calculations. Robust standard errors in parentheses, clustered at the individual level. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

hourly wages, it also lowered hours worked for this same group. In sum, the net impact of the minimum wage on monthly earnings of the target group can not be distinguished from zero in the one-year horizon.

5.2 Heterogeneity of effects by employment type

As argued in Burauel et al. (2018), one would expect the introduction of the minimum wage to differentially impact employees with socially insured positions and the marginally employed. Marginally employed individuals have an incentive to reduce their hours worked in order to remain below the threshold of €450 monthly, beyond which workers become subject to social security contributions. Moreover, the wages of marginally employed workers lie well below those of the regularly employed and, due to a lower skill level on average, generally have a weaker position when negotiating wages with employers (see also Stegmaier et al. 2015). At the same time, the minimum wage is more likely to price these workers out of the market than the regularly employed when their marginal productivity of labor falls below the wage floor. Garloff (2016), Schmitz (2017) and Caliendo et al. (2018) show that, in fact, the minimum wage decreased the number of marginally employed workers. Therefore, for this group, we also examine the wage and earnings effects of the minimum wage for these two types of employment separately.

Figure 4 juxtaposes Pen's Parade for the regularly employed (including both part- and full-time) to that of the marginally employed. The upper panel considers

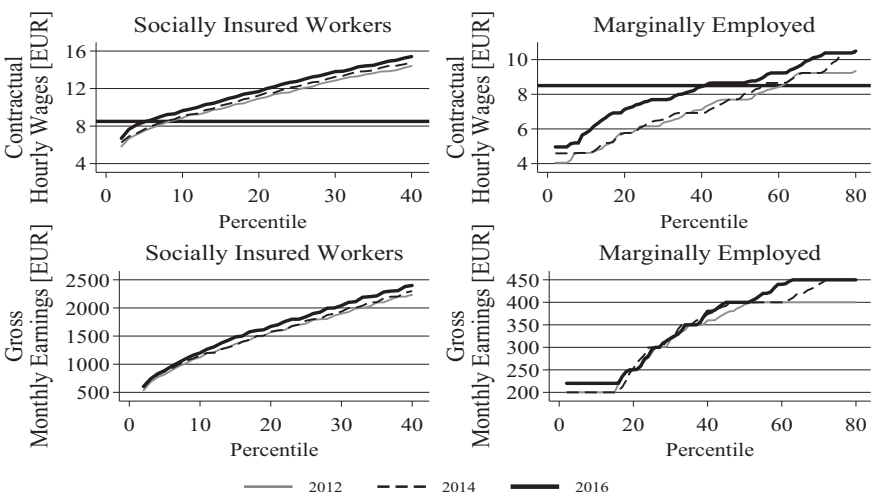

Figure 4: Evolution of hourly wages and monthly earnings by employment type.
Source: SOEP v33, cross-sectional sample, own calculations.

hourly wages and the lower panel describes gross monthly earnings. The horizontal line in the upper panel denotes the minimum wage level. The figure documents that remuneration below the minimum wage in 2016 is predominantly a phenomenon of the marginally employed. While one observes an increase in wages up to the 60th percentile of this group, roughly 40 percent of this population receives an hourly wage below the legal wage floor. The distribution of hourly wages for the socially insured workers remains noticeably above that for the marginally employed. As a consequence, the relative growth patterns from 2014 to 2016 compared to 2012–2014 shown in the upper panel of Figure 4 are more pronounced for the marginally employed.

The lower panel of Figure 4 shows the evolution of monthly gross earnings for the socially insured compared to the marginally employed workers between 2012 and 2016. The left panel reveals only a slight improvement for the socially insured in terms of gross monthly earnings. For the marginally employed, in contrast, the share of the group earning below the tax threshold of €450/month decreases by 10 percentage points: whereas in 2014, 70 % of the marginally employed earned within the limits of the tax preference, in 2016 only 60 % did so.

Turning to the causal effects for regularly employed and marginally employed workers separately, Table 8 shows results based on the two-year panel sample. The subgroup analysis further splits the sample of regularly employed individuals into full- and part-time categories to examine potential heterogeneous treatment effects.[12] This further partition reduces the sample size and, thus, the power of the separate regressions compared to using the full sample. Analogously to the results of the full sample, the column titled "Hourly Wage < 8.50" reflects the different wage dynamics between treatment and control groups. "DTADD 2014–2016" identifies the change in hourly wage attributable to the minimum wage introduction. "Placebo 2010–2012" tests the critical identification assumption for the DTADD, namely whether wage differences between treatment and control groups can be considered time-constant. All regressions consider the full set of controls.

The differential analysis according to regular employment status reveals substantial heterogeneity in the treatment effect. During the period under investigation, wage growth was the most dynamic for the marginally employed, followed by the part-time regularly employed, increasing 17.4 % and 14.5 %, respectively, more in the treatment compared to the control group. In contrast, wage growth for full-time employees in the treatment group surpassed that of the control group by 10.7 %. Despite the high growth rates of the part-time regularly employed, this growth cannot be attributed to the minimum wage. For this group, the effect of

12 Full-time is defined as working more than 30 hours per week.

Table 8: Minimum wage effect on gross hourly wage growth by employment type.

	Observations 2014							
	Treatment	Control Group	Hourly Wage <8.50		DTADD 2014-2016		Placebo 2010-2012	
Panel A: Hourly Wages								
Entire Sample	545	438	12.93***	(1.94)	6.47**	(2.68)	2.07	(2.59)
Socially Insured Workers	382	383	11.79***	(2.15)	4.57	(2.99)	2.36	(2.85)
Full-Time Regularly Employed	270	303	10.73***	(2.46)	7.79**	(3.44)	3.64	(3.19)
Part-Time Regularly Employed	112	80	14.53***	(4.52)	−5.01	(6.07)	−0.28	(6.65)
Marginally Employed	163	55	17.40***	(4.80)	15.51**	(6.90)	2.43	(6.66)
Panel B: Monthly Earnings								
Socially Insured Workers	382	383	9.60***	(2.56)	3.54	(3.51)	5.29	(3.56)
Marginally Employed	163	55	3.85	(6.37)	13.14	(9.21)	−11.96	(12.01)

Source: SOEP v33 2012–2016, own calculations. Robust standard errors in parentheses, clustered at the individual level. All regressions include the full set of controls, including demographic and employment characteristics as well as information regarding changes in employment. Individuals will only appear in the sample in those years for which the row-specific condition is fulfilled. To deal with changes in employment, e.g. from marginal employment to part-time employment, we control for changes in eligibility, job, contract term, company size and sector. Significance levels: * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

the reform is negative, but statistically insignificant. The reform did, however, positively impact hourly wages of full-time employees by 7.8 percentage points. According to the subgroup analysis, the minimum wage introduction had the largest, positive effect on the hourly wages of the marginally employed, who experienced a growth rate 15.5 percentage points higher in the treatment than in the control group. Finally, Panel B of Table 8 considers the net effect on gross earnings, which results from changes in hourly wages and in hours worked, for the socially insured and marginally employed separately. Despite positive treatment effects on hourly wages of the marginally employed, the reduction in hours worked counteracts the wage effect (compare Burauel et al., 2019). Neither for socially insured nor for the marginally employed can any positive impact of the minimum wage reform on gross monthly earnings be detected. At the same time, partitioning workers into these categories renders the sample sizes smaller than in the entire sample and the sample size may simply become too small to detect an effect.

5.3 Robustness analysis - Spillover effects

As discussed in Section 3.2, the causal identification of the DTADD treatment effect relies on the assumption that the introduction of the minimum wage did not affect the selected control group. A priori, the direction of potential spillover effects is unclear. On the one hand, rising wage costs in the lower segment of the distribution could cause employers to decrease wages of higher earners in order to pass along the additional costs of the reform. However, in reality, wages tend to be sticky and long-term contracts as well as social norms may prevent employers from doing so. Negative spillover effects in the form of wage compression tend to be associated with new hires rather than the current stock of employees, rendering this type of spillover a predominantly long-term phenomenon. On the other hand, wages may also rise for workers previously earning just above the minimum wage if employers wish to retain the wage structure within their establishment. Data from the IAB Establishment Panel Survey suggest this latter direction is more likely: 14 percent of all responding establishments report increasing wages not only for those previously earning below the minimum, but also for those earning above the mandated threshold (Mindestlohnkommission, 2016). The presence of positive spillover effects would bias the estimates of wage growth downward if the control group does not correctly reflect the counterfactual situation.

The existing literature finds that spillover effects appear mostly in groups earning close to the minimum wage cutoff. For this reason, we test the existence of possible spillover effects by comparing the results of our main specification from

Table 6 with a robustness estimation in which we employ an alternative control group consisting of workers earning between €10.00 and €11.50 (while the definition of the original treatment group remains unchanged). If wages of our preferred control group of employees earning between €8.50 and €10.00 were not affected by the reform, we should not observe changes in wage growth between the original control group and alternative control group. The validity of this approach rests on the assumption that any potential spillover effects shrink as one moves further away from the minimum wage cut-off toward higher segments of the wage distribution. This assumption likely holds, as other studies have found that the spillover effects in Germany were in fact small and decreasing in higher segments of the wage distribution (Mindestlohnkommission, 2018; Caliendo et al., 2019).

Table 9 summarizes results for the one-year and two-year comparison and demonstrates that results remain robust to this alternative control group. It shows a positive and statistically significant treatment effect for the original treatment group between 2014 and 2015 (Columns (1) and (2)). For the two-year analysis, the treatment effect has a similar magnitude, although it loses its significance (Columns (3) and (4)). Only a marginal difference exists in the general wage dynamics between workers earning between €8.50-€10.00 and those earning between €10.00-€11.50. These differences, however, did not change during the time period under investigation, neither for the one-year nor for the two-year analysis (see "Spillover DTADD" and "Spillover Placebo"). These results are furthermore robust to alternative definitions of the additional control group, including individuals earning up to €13.00/hour. In conclusion, the robustness test does not find any evidence of spillover effects in the short run for the German minimum wage reform (2015–2016).

6 Conclusion and discussion

In this paper, we descriptively examine the evolution of the wage and earnings structure of German workers around the time of the introduction of the minimum wage reform and causally identify the impact of the reform on the wage and income distribution. The descriptive analyses illustrate an acceleration of wage growth for workers earning below €8.50/hour after the introduction of the wage floor in January 2015. In the bottom 10th percentile of the wage distribution, wages increased by 15 % between 2014 and 2015 despite a consistently lower growth rate of below 2 % in previous periods (1998–2014). Between 2014 and 2016, contractual and actual hourly wages of low wage workers experienced above-average growth, not only with respect to previous periods, but also in comparison to high-wage earners. In line with this trend, the analysis further finds

Table 9: Robustness: Spillover effects on contractual gross hourly wages.

	Change in Contractual Hourly Wages			
	One-Year Analysis		Two-Year Analysis	
	(1)	(2)	(3)	(4)
One-Year Analysis				
Hourly wage < EUR 8,50	10.83***	12.56***		
	(1.57)	(1.58)		
× DTADD 2014–2015	4.01*	4.00*		
	(2.14)	(2.11)		
× Placebo 2012–2013	−2.21	−1.45		
	(2.19)	(2.17)		
EUR 10 ≤ Wage < EUR 11.50	−1.76	−2.93**		
	(1.43)	(1.42)		
× Spillover DTADD 2014–2015	−0.04	−0.02		
	(1.92)	(1.88)		
× Spillover Placebo 2012–2013	1.28	1.96		
	(1.95)	(1.94)		
Two-Year Analysis				
Hourly wage < EUR 8,50			18.67***	21.41***
			(3.11)	(3.10)
× DTADD 2014–2016			8.28*	6.48
			(4.53)	(4.44)
× Placebo 2010–2012			1.94	1.25
			(4.10)	(4.02)
EUR 10 ≤ Wage < EUR 11.50			− 3.04	−2.9
			(2.17)	(2.22)
× Spillover DTADD 2014–2016			0.56	−0.91
			(3.15)	(3.16)
× Spillover Placebo 2010–2012			3.71	3.05
			(2.88)	(2.88)
Constant	7.16***	6.94**	15.79***	21.59***
	(1.02)	(2.88)	(1.69)	(4.71)
Control Variables				
Year fixed effects	yes	yes	yes	yes
Sociodemographic information		yes		yes
Employment characteristics		yes		yes
Changes in employment		yes		yes
Observations	4,927	4,927	4,036	4,036
Adj. R^2	0.052	0.089	0.061	0.103

Source: SOEP v33 2010-2016, own calculations. DTADD regressions, robust standard errors in parentheses, clustered at the individual level with * p<0.1, ** p<0.05, *** p<0.01. Results are unweighted and based on the panel sample.

reduction in mean log deviations of wages throughout the distribution from 2014 to 2016, indicating a compression in the overall wage distribution. Notwithstanding above-average wage growth at the bottom of the distribution, however, hourly wages of approximately 1.8 million workers still remained below the legal wage floor at the end of the first quarter of 2016 compared to 2.8 million before the reform. As such, the cross-sectional analysis paints an ambivalent picture, with substantial wage gains for many in the low-income segments of the distribution, but also with a large number of workers for whom compliance remains an issue.

As a complement to the cross-sectional analysis, the panel allowed for an investigation of individual wage growth and mobility. Particularly high growth rates in the bottom decile of the distribution indicate that very low wages represent a transitory phenomenon for many workers. This group tends to consist of young workers with short employment biographies, who gain experience and quickly transition into higher wage segments. The panel analysis further finds that workers earning below the minimum wage before the introduction had a higher probability of transitioning into higher wage segments than had been the case in previous years: the probability of transitioning into the segment between €8.50 and €10.50 increased by 10 percentage points and the probability of transitioning into a job paying over €12.00 increased by 7.5 percentage points. Meanwhile, the probability of this group to leave employment decreased by 6 percentage points and the probability of the non-employed to take up a job decreased by 1 percentage point from 2014 to 2016 compared to 2012–2014.

Moving beyond the description of trends to the causal analysis, we employ a DTADD strategy to establish the extent to which increases in wages and earnings can be ascribed to the reform of 2015. We find that the minimum wage introduction can account for hourly wage growth in the order of 6.47 percentage points, or €0.50/hour more than would have otherwise been the case for the treatment group of individuals earning below €8.50/hour before the reform. Further, we examine whether the positive impact on hourly wages translated into an improvement of the earnings position of low-wage workers in terms of gross monthly earnings. The analysis yields a positive and marginally significant treatment effect on monthly earnings of 6.6 percentage points, or €54/month.

Subgroup analysis according to type of employment (socially insured vs. marginally employed) revealed that the minimum wage had the highest positive impact on the wages of marginal workers, who experienced a 15.5 percentage points higher growth rate on account of the reform, followed by the full-time regularly employed with an additional increase in hourly wages of 7.8 percentage points. Despite positive treatment effects for hourly wages in both of these groups, however, no impact of the minimum wage reform on monthly earnings could be detected when estimating the effect for these groups separately. The absence

of an effect may be attributed to a reduction in power (small sample size) after partitioning the sample into the socially insured and marginally employed.

The introduction of the statutory minimum wage in Germany presents a substantial intervention into the labor market. This paper investigated its short-term impacts on the wage and earnings distribution, accounting for detectable effects through the second quarter of 2016. Evaluations of minimum wages in other countries have established that the full implementation of national, statutory minimum wages tend to experience a delay due to lags in wage and salary policy responses or adjustments to production processes of employers and/or time needed to clarify legal details. Therefore, continued evaluation of the medium to long-run effects will prove indispensable for understanding the full impact of the reform. Going forward, it remains to be seen whether the positive treatment effect will persist or even grow over time and whether the compliance gap will close, for instance due to stronger sanctions for non-compliance or to social pressure. More compliance, on the other hand, could induce stronger negative employment effects, which would carry further repercussions for the wage distribution. Moreover, it is likely that the relatively favorable business cycle that accompanied the introduction prevented a larger negative employment reaction. This situation may change if faced with a future recession. Finally, substitution effects in the medium run cannot be ruled out. It is possible that firms begin to favor workers exempted from the minimum wage or that they alter their production processes to outsource work packages abroad or to the self-employed in order to cut costs. All of these adjustments could influence the long-run income distribution in Germany.

Future research could furthermore consider whether the increase in the initial minimum wage level to €8.84/hour on January 1, 2017 or the end of the transition period for exempted economic sectors on December 31, 2017 affected wages, earnings and employment. Both of these changes influence the number of people on the labor market with the legal right to a higher wage. Lastly, more research is needed to understand the adjustment mechanisms used by employers to cope with the additional costs of higher wages. Possible channels include, but are not limited to: higher production expectations toward workers, passing on the costs to consumers through higher prices, or decreasing extra payments and non-monetary fringe benefits of workers.

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