SUPPLEMENTARY MATERIAL FOR THE PAPER:

"OPTIMAL MINIMUM WAGES IN SPATIAL ECONOMIES"

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This document contains additional material that is not included in the main appendix.

A Literature

This section complements Section 1 by providing a more complete discussion of the vast literature on the impact of the German statutory minimum wage (an overview of the extant literature can also be found in Caliendo et al. (2019), while Möller (2012) and Fitzenberger and Doerr (2016) discuss research on earlier sector-specific minimum wages in Germany).

The national minimum wage in Germany came into effect on 1 January 2015 (see Section B.1) and its introduction has been followed by a large amount of research on the effects that this policy has had on a variety of outcomes. A specificity of the German minimum wage is that it—with only a few exceptions—applies to all workers who earn less than the specified threshold. In contrast to the US literature in which the effects of the minimum wage are often identified from state-specific changes in minimum wage levels and where comparable workers from unaffected states can serve as a control group (e.g. Dube et al., 2010), such an approach is not feasible in Germany. Moreover, the possibility of spill-over effects makes it difficult to infer the effects of the minimum wage from a comparison of worker below and above the minimum wage threshold. Many empirical studies have therefore used a difference-in-differences approach in which the effects of the minimum wage are identified from the variation in the extent to which workers in given entities are directly affected by the introduction of the minimum wage—the regional minimum wage bite defined in Machin et al. (2003) being an example. Before turning to the evidence on the effects of the German statutory minimum wage, we provide a short description of the data sets that have been used in the empirical research will discuss.

Data sets. The evaluation of the effects of the German minimum wage is not restricted to a single data source. Most studies have, however, used one of the following data sets (a more detailed description can be found in Mindestlohnkommission (2020):

- The **German Socioeconomic Panel (SOEP)** is an annual survey currently consisting of a representative sample of about 15,000 households and 30,000 individuals, which was first conducted in 1984. Relevant for minimum wage research, participants provide information about their weekly working hours (actual and contractual) and monthly labour income which can be used to construct an estimate of hourly wages.

Due to its comparatively small sample size, the potential for a regionally differentiated analysis are limited. Further information on SOEP can be found in Goebel et al. (2019).

- The **Structure of Earnings Survey (SES)** is mandatory establishment survey that is carried out by the German Statistical Offices. First carried out in 1951, it has been conducted every four years since 2006. The most recent survey refers to the year 2018 and contains information on approximately 60,000 establishments and 1,000,000 employees. As in the case of SOEP, the SES contains information about working hours and monthly earnings which can be used to estimate hourly wage rates and to determine whether a person earns more or less than a given minimum wage level. Evaluation of the effects of the minimum wage is facilitated by the availability of additional earnings surveys that have been conducted in years in which the SES was not carried out. Compared to the SES, these data sets are considerably smaller (between 6,000 and 8,000 establishments) and participation is not mandatory.

- The **Integrated Employment Biographies (IEB)** is prepared by the Institute for Employment Research (IAB) and covers episodes of employment, unemployment and participation in measures of active labour market policies for the majority of labour market participants in Germany (certain groups are, however, not covered: e.g. employment records do not contain information about civil servants or the self-employed). Employment records are based on mandatory notifications made by employers for the social security systems and, as such, are highly reliable. One advantage of the IEB is its size, which makes it possible to conduct analyses for specific groups or at a regionally differentiated level. A disadvantage in terms of minimum wage research is the fact, that the data set does not contain working hours which makes it necessary for this information to be provided by other data sources (see Section B.2.1).

- The **IAB Establishment Panel** is an annual establishment survey that is carried out by IAB. It covers a representative sample of about 15,000 establishments. The survey contains a unique establishment ID which can be used to link the survey with administrative data on the employees of the sampled establishments. Further information on the IAB Establishment Panel can be found in Ellguth et al. (2014).

- The **Federal Employment Agency** provides administrative statistics on various labour-market outcomes, such as employment levels (e.g. by year, region, sector for various demographic groups).

Hourly wage outcomes. The extant literature has provided ample evidence that the introduction of the minimum wage has led to an increase in *hourly* wages at the lower end of the wage distribution. Burauel et al. (2020b) use SOEP data to estimate wage effect of the minimum wage introduction in a differential trend-adjusted difference-in-differences (DTADD) framework. Their results show that—conditional on their respective wage growth trends—workers, who initially earned less than the minimum wage, experienced an increase in hourly wage of 6.5% between 2014 and 2016 compared to workers above the minimum wage level. Evaluated at the mean hourly wage of workers in the treatment group, this suggests an increase of about €0.45 per hour. Qualitatively similar results are obtained by Caliendo et al. (2023) who also use SOEP data, but identify the effect of the minimum wage wage from the variation in the regional minimum wage bite, i.e. the share of workers who initially earned below the minimum wage threshold. Their findings show that a higher minimum wage bite is associated with faster hourly wage growth in the year 2015 (i.e. following the introduction of the minimum wage) for workers in the lowest quintile of the hourly wage distribution, while no significant effects are found for workers in higher quintiles. Dustmann et al. (2022) and Ahlfeldt et al. (2018) also use variation in the regional exposure to the minimum wage (in form of the Kaitz index and the minimum wage bite, respectively) to evaluate the impact on hourly wages in a difference-in-differences framework. Based on data from the IEB, their results suggest that regions with a higher degree of exposure experienced faster hourly wage growth at the lower end of the hourly wage distribution. Evidence by Fedorets and Shupe (2021) suggests that the introduction of the minimum wage not only affected realised hourly wages, but also led to an adjustment of reservation wages. Using SOEP data, the authors find that reservation wages increased considerably among non-employed job seekers. This adjustment, however, appears to have been temporary as reservation wages are found to return to their initial level. Even if only temporary, an increase in reservation wages represents a possible reason for why minimum wages may not lead to higher labour market participation.

Hours worked and monthly wage outcomes. While evidence from different studies, using different data sources and identification strategies, have provided comparable evidence of a positive effect on hourly wages, it is ex ante unclear whether this finding also carries over to monthly labour earnings. The reason for this is that, faced with a higher cost per working hour, employers might choose to reduce the number of hours offered to minimum wage workers. In such a case, the impact of the minimum wage on monthly outcomes would be ambiguous and depend on whether the positive effect on hourly wages outweighed the potentially negative effect on the number of hours worked. An analysis by Burauel et al. (2020a) concludes that the number of contractual hours decreased by 5% in the year 2015 among workers who initially earned below the minimum wage level. No significant reduction is found, however, for the year 2016. This pattern corresponds with findings provided by Burauel et al. (2020b). According their these results, worker who initially earned below the minimum wage, did not experience a significant increase in monthly earnings (relative to workers from the control group) in 2015, but realised a 6.6% increase in the year 2016. Similar results are provided by Caliendo et al. (2023) for the year 2015. Slightly different results are provided by Bossler and Schank (2022). Based on IEB data and adopting a difference-in-differences framework based on the regional minimum wage bite, they find a statistically significant increase in monthly wage earnings in regions with a higher minimum wage bite from the year 2015 onward.

Wage spillovers. While minimum wages directly affect the wages of workers earning less than the specified threshold, there can also be effects on workers higher up the wage distribution. One reason for such spillover effects is that employers want to retain initial pay differences and therefore decide to also raise wages of workers above the threshold. Bossler and Gerner (2019) provide direct evidence on the extent of wage spillovers using information from the IAB Establishment Panel in which employers were asked whether they adjusted the remuneration of workers earning above the minimum wage threshold in response to the policy. Less than 5% of establishments in their sample report to have made such an adjustment. The analysis by Burauel et al. (2020b) relies on the assumption that the control group of workers above the minimum wage threshold is not affected by wage spillovers. To validate this assumption, they estimate the wage effects using a control group of workers further up the wage distribution, which yields comparable results. Based on the assumption that spillovers are likely to affect workers close to the minimum wage threshold, they conclude that spillover effects are limited. Dustmann et al. (2022) assess the existence of wage spillovers by comparing the change in two-year wage growth for the years following the introduction of the minimum wage between workers in different wage bins. As expected, excess wage growth (relative to the reference period 2011-13) is particularly pronounced for workers who initially earned less than the minimum wage. However, an increase in wage growth—though smaller—is also found up to the 12.50 € per hour bin, which suggests that the minimum wage also had an effect on workers above the threshold. Bossler and Schank (2022) find that the introduction of the minimum wage had an effect on monthly labour income up to the 50^{th} percentile.

Wage inequality, welfare receipt and in-work poverty. As described above, the introduction of the minimum wage led to an increase in wages at the lower end of the wage distribution. As such, it has been hypothesised that the minimum wage also contributed to a reduction in lower-tail wage inequality. It is, however, difficult to evaluate ex ante to what extent this is the case, as non-compliance or spillover effects might reduce the impact of the minimum wage. According to Bossler and Schank (2022) the minimum wage contributed considerably to the reduction in wage inequality. Based on counterfactual analyses, the authors conclude that between 40% and 60% of the observed decrease in wage inequality, as measured by the variance of log monthly wage earnings, can be ascribed to the introduction of the minimum wage. While wage income represents a worker-level outcome, poverty status and the eligibility of welfare benefits are determined on the basis of household-level income. In contrast to its effect on wages and wage inequality, existing evidence suggests that the minimum wage introduction only had a limited impact on welfare receipt and (in-work) poverty. According to results by Bruckmeier and Bruttel (2021), the minimum wage neither exerted downward pressure on the number of employees receiving top-up benefits nor did it alleviate poverty rates. Among other factors, the authors explain the absence of any sizeable effect by the fact that low household income is more often due to a low number of hours worked rather than a low hourly wage. Moreover, they argue that low-wage workers are not restricted to low-income households, but can rather be found throughout the household income distribution, so that a policy that increase the wages of low-wage workers does not necessarily improve the situation of low-income households.

Employment and unemployment. In a perfectly competitive labour market, a binding minimum wage will unambiguously lead to a lower equilibrium level of employment. As outlined in Section 3.1.2, this need not be the case in a monopsonistic labour market. From a theoretical perspective, the extent and sign of the employment effect of a minimum wage are, therefore, ex-ante unclear. A considerable amount of research has evaluated the impact that the introduction of the German minimum wage had on employment and unemployment. In contrast to the analysis presented in this paper, these studies are, however, based on partial equilibrium analysis. Caliendo et al. (2018) provide one of the earliest evaluations of the employment effects of the German minimum wage. Combining data from the SES and administrative statistics, their identification strategy rests on the regional variation in the extent to which the minimum wage "bites" into the wage distribution (measured by the minimum wage bite or the Kaitz index). Their findings suggest that the effect of the minimum wage differed substantially between regular and marginal employment. Specifically, they estimate that the introduction of the minimum wage reduced the number of marginal employment jobs by 180,000 in 2015, while the effect on regular employment is smaller and not statistically significant in all specifications. Similar results are obtained by two other studies: Schmitz (2019), who uses administrative statistics from the Federal Employment Agency, and Bonin et al. (2020), who combine SES data with administrative statistics, also find that there was a small negative effect on overall employment, which was driven mainly by a reduction in the number of marginal employment jobs. Schmitz (2019) estimates that the minimum wage led to a decrease of about 200,000 marginal employment jobs in 2015). Moreover, Bonin et al. (2020) do not find any evidence for a corresponding increase in unemployment. A possible explanation for the absence of such an effect is that workers, who were negatively affected by the introduction of the minimum wage, withdrew from the labour market. Slightly different results are reported by Holtemöller and Pohle (2020), who use variation in the exposure to the minimum wage across federal state-sector cells. Based on administrative statistics from the Federal Employment Agency, their results confirm previous findings that the introduction of the minimum wage led to a decrease in marginal employment (between 67,000 and 129,000 jobs, depending on the chosen specification). However, they also find a positive effect on regular employment in the range of 47,000 to 74,000 jobs. Interestingly, they do not find any evidence for a substitution of marginal for regular employment. Garloff (2019) also uses data from the Federal Employment Agency and exploits the variation in the minimum wage bite across regions and demographic groups or sectors.

As in Holtemöller and Pohle (2020), his results show a negative relationship between the minimum wage bite and the development of marginal employment as well as a positive relationship with regular employment. With respect to overall employment, he finds a small positive association between the bite and the growth of total employment which amounts to approximately 11,000 additional jobs in the first year after the introduction of the minimum wage. Small positive effects of an increase in the minimum wage bite on total employment are also reported by Ahlfeldt et al. (2018) who use IEB data for their analysis. In contrast to the studies discussed above, which use the regional variation in the exposure to the minimum wage, Bossler and Gerner (2019) estimate the employment effects of the introduction of the minimum wage from the variation in establishment-level exposure. The authors use the IAB Establishment Panel to identify whether an establishment has at least one employee whose wage is directly affected by the policy. Comparing the development of employment among the treated establishments with a control group of unaffected establishments within a difference-in-differences framework, the authors find a reduction in employment in the post-treatment years among treated establishments of 1.7% as opposed to the control group. This result suggests that employment was lower by between 45,000 and 68,000 jobs at treated establishments as a result of the minimum wage introduction. The authors also provide evidence on the underlying mechanisms: according to their results, the negative employment effect is driven by a reduction in hires rather than by an increase in layoffs. Friedrich (2020) evaluates the impact that the minimum wage had on employment using the differential exposure to the policy between occupations. Consistent with the results from other contributions to the literature, he estimates that by the year 2017 the minimum wage (including its increase to a level of 8.84 € in 2017) led to a loss of approximately 50,000 jobs. This reduction is primarily driven by a decrease in marginal employment. Moreover, his findings suggest that there are considerable regional differences in the employment effects. Whereas, at least initially, the loss of marginal jobs was accompanied by an increase in regular employment in West Germany, such a compensating effect is not found for East Germany. While the employment effects that have been estimated by the extant literature differ in terms of size and sign, estimates of potential employment losses appear to be modest and considerably smaller than the large-scale job loss that was discussed before the introduction of the policy (e.g. Knabe et al., 2014).

Worker reallocation. Despite an absence of large-scale disemployment effects, the minimum wage introduction led to considerable changes in the structure of employment. Dustmann et al. (2022) provide evidence for a systematic reallocation of low-wage workers from lower-quality to higher-quality establishments. While the authors do not find that the minimum wage increased the share of workers who changed their employer, those workers who did so between 2014 and 2016 moved to establishments whose average daily wage was approximately 1.8% higher (relative to the corresponding change in establishment-level pay between 2011 and 2013). Evaluated for all workers who initially earned less than the minimum wage and who switched to a higher-paying establishment, this upgrade accounts for approximately 17% of the minimum wage-induced increase in daily wages. Receiving establishments are found to be significantly larger and to employ a higher share of full-time as well as university-educated workers. Moreover, the upgrade in establishment-level average daily wages can be almost exclusively ascribed to changes between establishments within in the same region, while about two thirds of the upgrade is associated with changes within the same three-digit industry, suggesting that worker reallocation is not driven by either regional or sectoral mobility.

Price pass-through and other establishment-level outcomes. Evidence on whether and to what extent firms in Germany adjusted their prices in response to the introduction of the minimum wage is limited. An exception is the study by Link (2019) whose results suggest that a substantial share of the increased costs induced by the minimum wage were passed on to consumers in the form of higher prices. Based on data from the ifo Business Survey–a monthly survey consisting of approximately 5,000 establishments from the manufacturing as well as the service sector in Germany—, he analyses how the extent of the sector-location-specific minimum wage bite is related to the probability of a firm planning to adjust prices. According to his results, there is a positive association around the time of the introduction of the minimum wage. Moreover, the results suggest that a minimum wage-induced increase in costs of 1% is associated with an increase in prices by 0.82%. No substantial difference is found between firms in the manufacturing and the service sector. However, the extent of price pass-through is estimated to be more pronounced when firms face less competition. Bossler et al. (2020) provide evidence on further channels through which establishments might have adjusted to the introduction of the minimum wage. Using data from the IAB Establishment Panel, they show that treated establishments, i.e. those employing at least one worker in the year 2014 earning less than 8.50 € per hour, experience an increase in labour costs in the years 2015 and 2016. In terms of investments, the results show a small and statistically insignificant reduction in the volume of investment in physical capital per employee following the introduction of the minimum wage. Likewise, the authors find no evidence that treated establishments adjusted investment in apprenticeship training — measured either as the share of apprentices per establishment or the number of apprenticeship offers per employee. However, the results point towards a small, but statistically significant reduction in the intensity of further training in the year 2015, measured by the share of employees receiving further training per establishment. This result is consistent with evidence by Bellmann et al. (2017) who also report a decrease in training intensity among treated establishments.

B Empirical context

This section complements Section 2 in the main paper by providing additional detail on the German minimum wage, the data used, and stylized facts on the impact of the minimum wage.

B.1 The German minimum wage

This section complements Section 2.1 in the main paper. A statutory minimum wage, initially set at a level of €8.50 per hour, came into effect in Germany on 1 January 2015, having been ratified by Parliament on 3 July 2014. While the minimum wage, in principle, applies to all employees aged 18 years or older, certain groups are exempted: apprentices conducting vocational training, volunteers and internships as well as the long-term unemployed during the first six months of employment. Moreover, exemptions were made for existing sector-specific minimum wages that fell short of the level of the statutory minimum wage until 1 January 2017, when the value of €8.50 also applied in these cases. The number of employees covered by sector-specific minimum wages that were temporarily exempted from the new statutory minimum wage is comparatively small and has been estimated at approximately 115,000 by the Federal Statistical Office (Mindestlohnkommission, 2016).

The level of the statutory minimum wage is determined by the Minimum Wage Commission which consists of a chair person, three representatives each of employers and employees as well as two academic representatives (though, the latter two are not eligible to cast a vote). Following its introduction, the minimum wage has since been raised several times: to a level of €8.84 per hour from 1 January 2017 onward, €9.19 from 1 January 2018, €9.35 from 1 January 2021 and €9.60 from 1 July 2021. Further increases are scheduled for 1 January 2022 (€9.82) and 1 July 2022 (€10.45), while several political parties have campaigned for an increase of the minimum wage to a level of €12 per hour in the run-up to the 2021 Parliamentary elections. In deciding on adjustments to the level of the minimum wage, the Commission takes the development of collectively bargained wages into consideration. Further information on the statutory minimum wage in Germany can be found in Mindestlohnkommission (2016).

Table S1 shows the Kaitz index, the ratio of the minimum wage to the median wage, for the years 2015 to 2018. For full-time workers, the Kaitz index is fairly stable for the first three years, before rising slightly in 2018.

Table S1: Kaitz index

	2015	2016	2017	2018
All workers	52.85%	51.67%	52.14%	55.55%
Full-time workers	48.19%	47.35%	48.05%	51.59%

Notes: The Kaitz index is defined as the ratio of the minimum wage and the median hourly wage. See Section 2.2 for a description of how hourly wages are estimated.

B.2 Data

This section complements Section 2.2 by providing additional detail on some data.

B.2.1 Hours worked

The wage information in the *BeH* dataset is defined as the average daily wage: the total wage earnings of an employment spell divided by the length of that spell. Since the German minimum wage is set at the hourly level, it is necessary to supplement the wage data in the *BeH* with an estimate of the number of hours worked per day. For this purpose, we use data from the 2021 version of the German *Mikrozensus*, which is a representative annual survey comprising 1% of households in Germany. Specifically, we use the information on the number of hours that an employed individual ω usually works per week and regress it on two sets of explanatory variables. In doing so, we differentiate between two worker groups g and estimate separate models for workers who are employed subject to social security contributions and marginally employed workers. The first set of control variables accounts for the fact that there are considerable differences in the working hours by gender, part-time status, sector and regions. The model therefore includes indicator variables for females (fem_ω), part-time workers ($part_\omega$) and the interaction of both variables as well as for 21 sector categories s (*Abschnitte* according to the 2008 version of the *Klassifikation der Wirtschaftszweige*) and the 16 federal states f (referring to a person's place of employment). Crucially, these variables are also available in the *BeH* dataset, so that we can compute predicted values for every combination and merge them into the *BeH*. The second set of control variables contains various worker- and household-level characteristics (age, German nationality, tertiary education, marital status, personal income, household size, number of children and household income). We mean-adjusted these variables (separately by sector s and worker group g), so that the predicted working hours refer to a worker with average characteristics in the corresponding sector.

$$
\begin{aligned}
\ln(hours^g_\omega) = {} & \alpha^g_0 + \alpha^g_1 fem^g_\omega + \alpha^g_2 part^g_\omega + \alpha^g_3 fem^g_\omega part^g_\omega \\
& + \sum_{s=1}^{21} \beta^g_s D^g_s(sector^g_\omega = s) + \sum_{f=1}^{16} \gamma^g_f D^g_f(state^g_\omega = f) \\
& + \boldsymbol{\delta}^{\boldsymbol{g}\prime} \boldsymbol{x}^{\boldsymbol{g}}_{\boldsymbol{\omega}} + u^g_\omega,
\end{aligned}
\tag{38}
$$

Table S2 provides an overview of the predicted weekly working hours. For compatibility with the average daily wage contained in the *BeH* dataset, we finally divide the predicted number of weekly hours by 7.

B.2.2 Trade

Throughout the paper, spatial variables are based on the delineation from 31 December 2018. The trade flow data, however, uses the delineation from the year 2010 which makes

Table S2: Predicted weekly working hours

Gender	Part-time status	Hours (regular)	Hours (marginal)
Female	Full-time	39.43	-
Female	Part-time	21.24	9.98
Male	Full-time	41.22	-
Male	Part-time	20.71	10.43

Notes: Mean values are averaged across sectors and federal states of employment.

it necessary to apply a number of modifications to make it compatible with the 2018 delineation. Specifically, we merge counties *Göttingen (3152)* and *Osterode am Harz (3156)* into *Göttingen (3159)* and re-code the counties in Mecklenburg-Western Pomerania according to the 2011 reform. In doing so, we assign the former county *Demmin (13052)* completely to the new county *Mecklenburgische Seenplatte (13071)*.

B.2.3 Spatial unit

The spatial units that are used in this paper are based on the delineation from 31 December 2018. The unit of analysis in the empirical analysis are municipality groups (*Verbandsgemeinden*), which contain one or more municipalities (*Gemeinden*). To arrive at the final set of 4,421 municipality groups, we perform the following steps. First, we remove 29 island municipalities that are not connected to the main land by either road or rail. Second, we merge all municipalities which are classified as being *gemeindefrei* and which typically do not contain any employees with the closest municipality in the same county (*Kreise und kreisfreie Städte*). This procedure leaves us with 10,987 municipalities which are then aggregated to the level of municipality groups. Third, for reasons of data anonymity six municipality groups cannot be included in the analysis. One such area is dropped (because it is an island) and the remaining five are merged with the closest municipality group in the same county.

B.2.4 Average establishment productivity by year-region

This section complements Section 2.2 in the main paper. To estimate average establishment productivity within regions we perform an AKM-style wage decomposition (Abowd et al., 1999):

$$\ln(w_{\nu\omega jzt}) = \xi_\nu + \psi_\omega + \chi_{zt} + u_{\nu\omega jzt} \tag{39}$$

For this purpose, we regress the hourly wage of worker ν, who is employed at establishment ω in region j and zone z (East or West Germany) in year t, on worker (ξ_ν) and establishment (ψ_ω) fixed effects as well as on separate year fixed effects for East and West Germany. Restricting the sample to 2006-2014 ensures that the estimates are not contaminated by any effects that the introduction of the minimum wage in the year 2015 might have had on worker and establishment outcomes.

ψ_ω provides an estimate of the wage premium that establishment ω pays its workers. We interpret this quantity as a measure of establishment productivity. We then compute annual average regional productivity as the average of all establishment productivity estimates in a given region weighted by the number of workers in the corresponding establishment and year.[24]

B.3 Stylized evidence

In this section, we provide descriptive and reduced-from evidence on the effects of the German minimum wage introduced in 2015 that substantiates the discussion in Section 2.3.

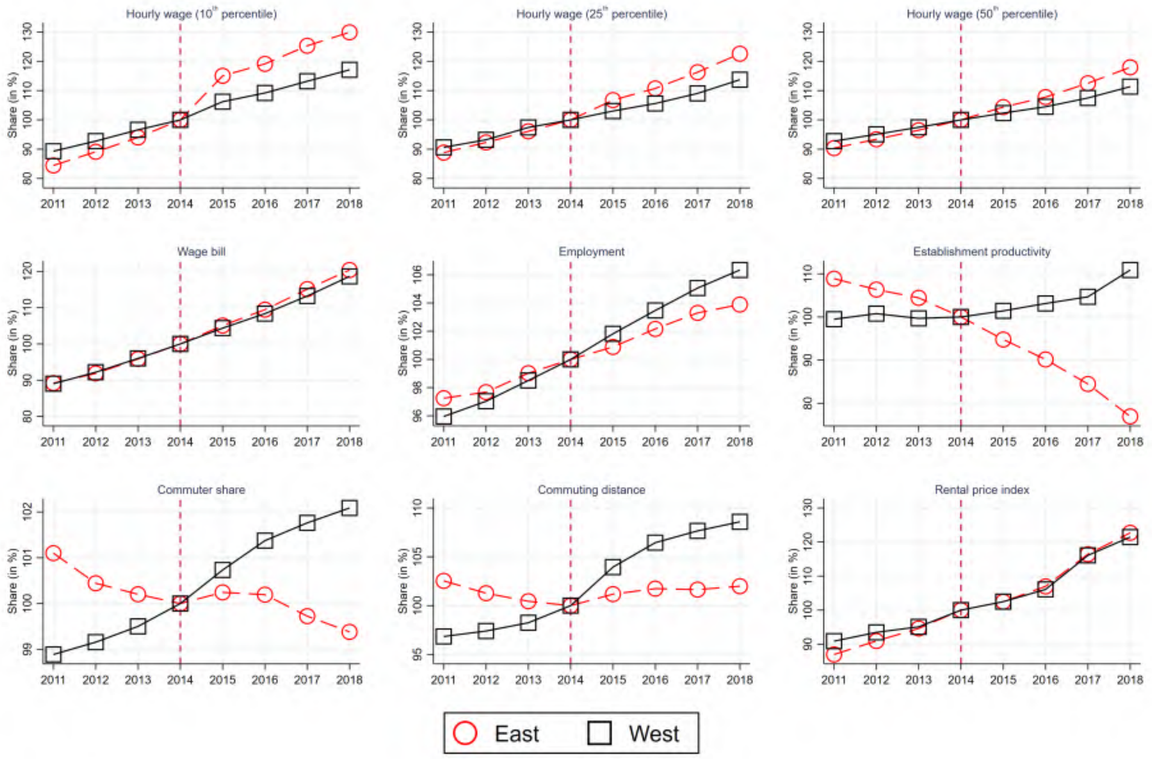
B.3.1 Outcome trends by eastern and western states

One legacy of the cold war era is a persistent gap in productivity between the western and eastern states. Therefore, it is no surprise that Figure S2 reveals a much greater bite in the eastern states. The shares of workers paid less than the minimum wage in 2014 are generally higher and, as a result, the impact on the left tail of the wage distribution was larger. Another insight from Figure S2 is that the spatial distribution of the minimum wage bite is much smoother when measured at the residence. This is reflective of significant cross-municipality commuting.

The spatial heterogeneity in the impact of the minimum wage bite makes it instructive to compare how employment and other outcomes evolved in the two formerly separated parts of the country over time. We offer this purely descriptive comparison in Figure S1. Confirming Figure S2, a jump at the 10^{th} percentile of the wage distribution in the east is immediately apparent. A more moderate increase is also visible for the west. For higher percentiles, it is possible to eyeball some increase in the east, but not in the west. A first-order question from a policy-perspective is whether the policy-induced wage increase came at the cost of job loss as predicted by the competitive labour market model. While we argue that—without a general equilibrium model—it is difficult to establish a counterfactual for aggregate employment trends, the absence of an immediately apparent employment effect in these time series is still informative. It is worth noticing that, while employment continues to grow in both parts of the country after the minimum wage introduction, the rate of growth appears to slow down in the east compared to the west. However, even if one is willing to interpret this as suggestive evidence of a negative employment effect, it will be difficult to argue that negative employment effects turned out to be as severe as in some pessimistic scenarios circulated ahead of the implementation (Ragnitz

[24] The parameter ψ_ω cannot necessarily be estimated for every establishment in the sample. This is the case when an establishment is only observed in a single year. Another possible reason is that an establishment's workers never move to another establishment so that worker and establishment fixed effects cannot be identified separately. Whenever the parameter ψ_ω cannot be identified, we replace the missing value by the average establishment productivity in the corresponding 3-digit sector-year combination. We use the same procedure in the case of establishments that first appear after 2014.

Figure S1: Outcome trends in western and eastern states



Note: All time series are normalized to 100% in 2014, the year before the minimum wage introduction. The establishment wage premium is the employment-weighted average across firm-year fixed effects from a decomposition of wages into worker and firm fixed effects following Abowd et al. (1999) (see Appendix B.2.4 for details).

and Thum, 2008). Since, following the minimum-wage introduction, the aggregate wage bill increases in the east, relative to the west, it seems fair to conclude that a positive wage effect has dominated a possibly negative employment effect, pointing to positive welfare effects. Figure S1 also illustrates the reallocation of workers to more productive establishments at greater commuting distance documented by Dustmann et al. (2022). Indeed, it appears that the effect has gained momentum subsequent to 2016, when their analysis ends. Finally, there appears to be a slight increase in the rate of property price appreciation after the minimum wage which could be reflective of increased demand.

B.3.2 Minimum wage bite

Figure S2 illustrates a measure of the regionally differentiated "bite" of the national minimum wage, very much in the tradition of Machin et al. (2003). Specifically, we compute a bite exposure measure for the year 2014 at the place of residence by taking the weighted average over the shares of workers earning less than the minimum wage across all workplace municipalities, weighted by the bilateral commuting flows in 2014. [25] This way,

[25] Formally, we define the bite as $\mathcal{B}_i = \sum_j \frac{L_{i,j}}{\sum_j L_{i,j}} S_j^{MW}$, where $L_{i,j}$ is the number of employees who live in municipality i and commute into municipality j for work and S_j^{MW} is the share of workers compensated

we capture the bite within the actual commuting zone of a municipality. Evidently, the minimum wage had a greater bite in the east, in line with the generally lower productivity. Changes in low wages, defined as the 10^{th} percentile in the within-area wage distribution, from 2014 to 2016 closely follow the distribution of the bite, suggesting a significant degree of compliance. Together, the two maps suggest that the minimum wage contributed to the reduction of spatial wage disparities in Germany.

For a formal test of whether the minimum wage bite determined the fortunes of regions, we aggregate an outcome Y to decile bins indexed by $d \in \{1, 2, 3, ..., 10\}$ defined in terms of the 2014 minimum-wage-bite distribution. Next, we detrend outcome $Y_{d,t}$ using the Monras (2019) procedure to address the concern that outcome trends are correlated with the minimum wage bite. For each decile, we regress the outcome against a linear time trend using years $t < 2015$ before the minimum-wage introduction. Based on the estimated regional trend, we detrend the entire time series, including years $t \geq 2015$. We then estimate a difference-in-differences specification with treatment heterogeneity along the minimum wage bite:

$$\ln Y_{d,t} = \sum_{s=2}^{10} b^s \left[\mathbb{1}(d = s) \times \mathbb{1}(t > 2015)\right] + b_d^I + b_t^T + e_{it}^d,$$

where $\mathbb{1}(.)$ is the indicator function returning one if a condition is met and zero otherwise. b_d^I are bin fixed effects, b_j^T are year fixed effects, and $e_{d,t}$ is an error term. The parameters of interest are b_s, each of which provides difference-in-difference comparison of the before-after change for bin $b = s$ relative to bin $b = 1$. To obtain time-varying treatment effects, we aggregate the estimated parameters to obtain a cardinal measure of treatment intensity

$$\mathcal{T}_d = \sum_{s=2}^{10} \hat{b}^s \mathbb{1}(d = s)$$

which we then use in a dynamic difference-in-difference specification:

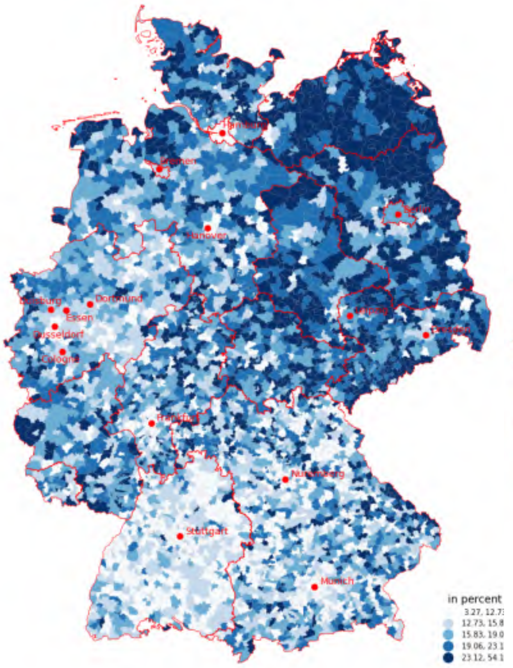
$$\ln Y_{d,t} = \sum_{z \neq 2014} \tilde{b}^z \left[\mathcal{T}_d \times \mathbb{1}\left(z = t\right)\right] + \tilde{b}_d^I + \tilde{b}_t^T + \tilde{e}_{d,t},$$

where, $\tilde{b}_j^I$ are region fixed effects, $\tilde{b}_d^T$ are year fixed effects, and $\tilde{e}_{d,t}$ is an error term (standard errors are bootstrapped). The parameters of interest are $\tilde{b}^z$ which provide an intensive-margin difference-in-difference comparison between year $t = z$ and the base year $t = 2014$. We present the estimated parameters of interest in Figures S3 and S4.

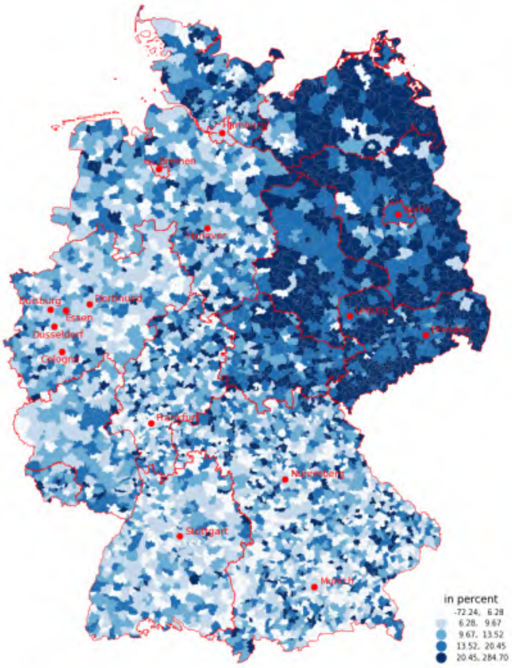
In keeping with expectations, low wages grew faster where the minimum wage bit harder, which echoes extant evidence (Ahlfeldt et al., 2018). Average establishment productivity (see Section B.2.4 for measurement details) also increased more where the bite was larger, suggesting that the minimum wage reallocated workers to more productive es-

below the minimum wage in j.

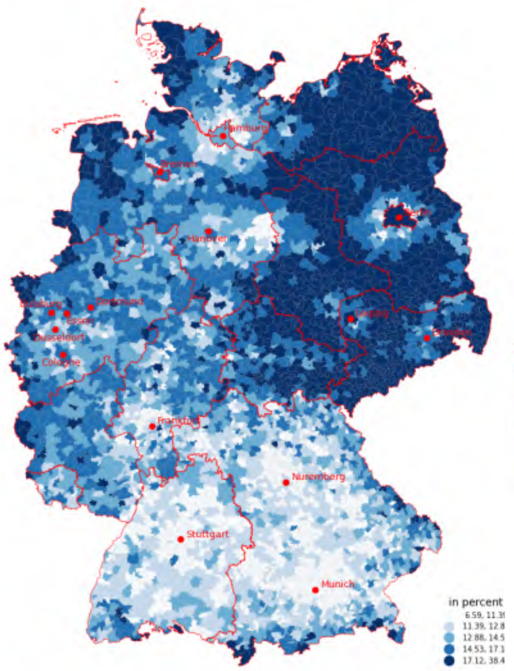
Figure S2: Minimum wage bite and change in 10th pct. regional wages



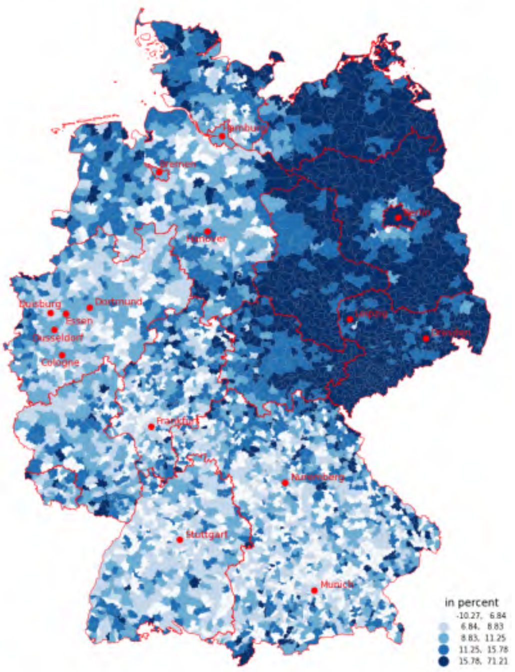
(a) Minimum wage bite in 2014, at workplace



(b) 2014-2016 wage growth at 10th pct., at workplace



(c) Minimum wage bite in 2014, at residence



(d) 2014-2016 wage growth at 10th pct., at residence

Note: Unit of observation is 4,421 municipality groups. The 10^{th} percentile wage refers to the 10^{th} percentile in the distribution of individuals within a workplace municipality. We re-weighted Wallace outcomes to the residence using commuting flows. Wage and employment data based on the universe of full-time workers from the *BeH*.

tablishments in more productive sectors (Dustmann et al., 2022). The total wage bill also increased faster in higher-bite places, suggesting that the positive wage effect dominates a potentially negative employment effect. The perhaps most interesting insight is that the employment effect is non-monotonic, a feature of the data that has not been stressed in the extant literature. Consistent with the standard competitive model, workplace employment in the highest-bite places decreases relative to lowest-bite places. However, there is positive relative employment growth within the third and fourth decile in the bite distribution, relative to highest *and* lowest-bite regions. This is inconsistent with the competitive model, but in line with a monopsonistic labour market in which firms increase labour input following a minimum-wage induced loss of monopsony power. The employment effect measured at the residence is also non-monotonic. The most and least affected places experience similar employment effects, whereas places with more moderate bites experienced relatively larger employment growth. Across deciles, the employment changes are generally smoother when measured at the place of residence, possibly because workers re-optimize workplace choices via commuting, which becomes a more widespread phenomenon in places where the minimum wage bit harder.

C Partial equilibrium

C.1 Reduced-form evidence

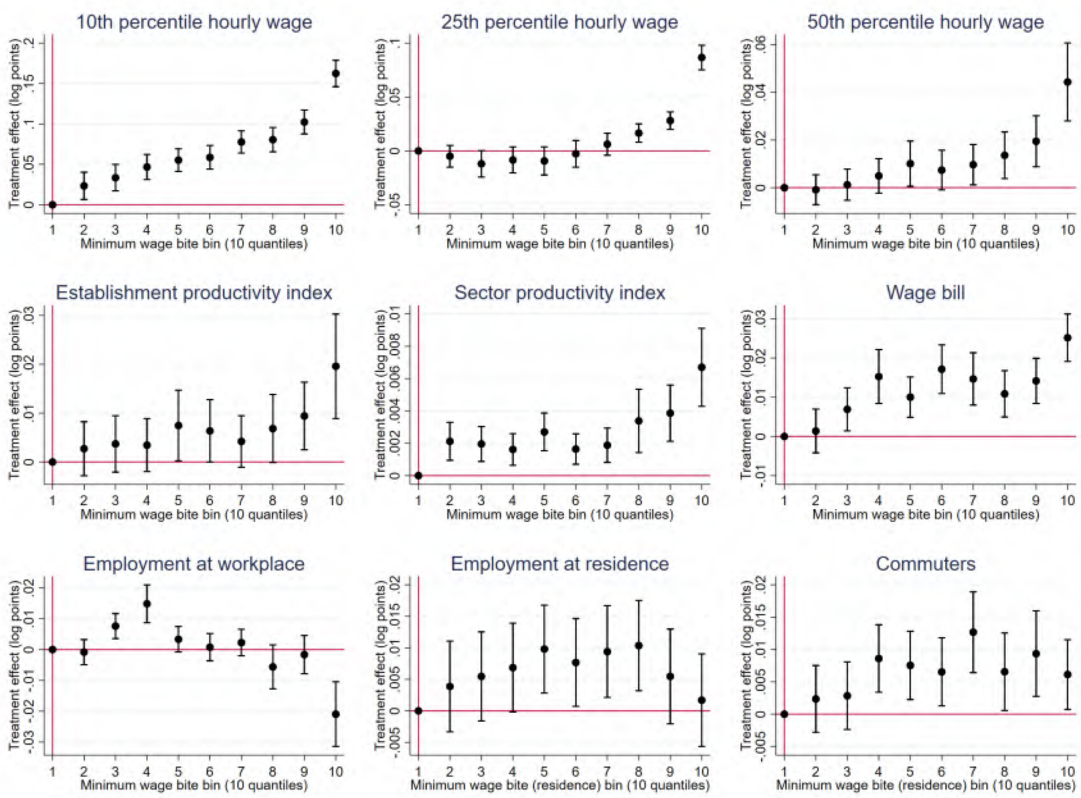
This appendix complements Section 3.2 in the main paper. We provide additional background on the critical points estimated in Figure 3. We also provide the results from robustness tests in which we select alternative temporal windows.

Objective functions for α_0. To identify α_0 introduced in Eq. (12), we estimate Eq. (11) using OLS for set values of α_0 over the parameter space $[\underline{\alpha}_o, \bar{\alpha}_o] = [10, 10.1, ..., 22]$. For each set value α_0 and corresponding estimates of α_1, α_2, we predict $f(\underline{\varphi}_j)$ and compute the sum of squared residuals $RSS = \sum_j^J \tilde{\epsilon}_j$. We pick the parameter combination that minimizes the value of this objective function. Figure S5 shows that the objective function is well-behaved in the parameter space around the global minimum for any of the spatial windows in the outcome trends we consider.

Mapping to critical productivity values. The following mapping from the reduced-form parameters $\{\alpha_0, \alpha_1, \alpha_2\}$ to the mean wage levels $\{w^{\text{mean}'}, w^{\text{mean}''}, w^{\text{mean}'''}\}$, which in turn correspond to the productivity levels $\{\underline{\varphi}', \underline{\varphi}'', \underline{\varphi}'''\}$, follows directly from the second-order polynomial function in Eq. (12).

$$w^{\text{mean}'} == \alpha_0 - \frac{\alpha_1}{\alpha_2}$$
$$w^{\text{mean}''} = \alpha_0 - \frac{\alpha_1}{2\alpha_2}$$
$$w^{\text{mean}'''} = \alpha_0$$

Figure S3: Difference-in-difference estimates by minimum wage bite



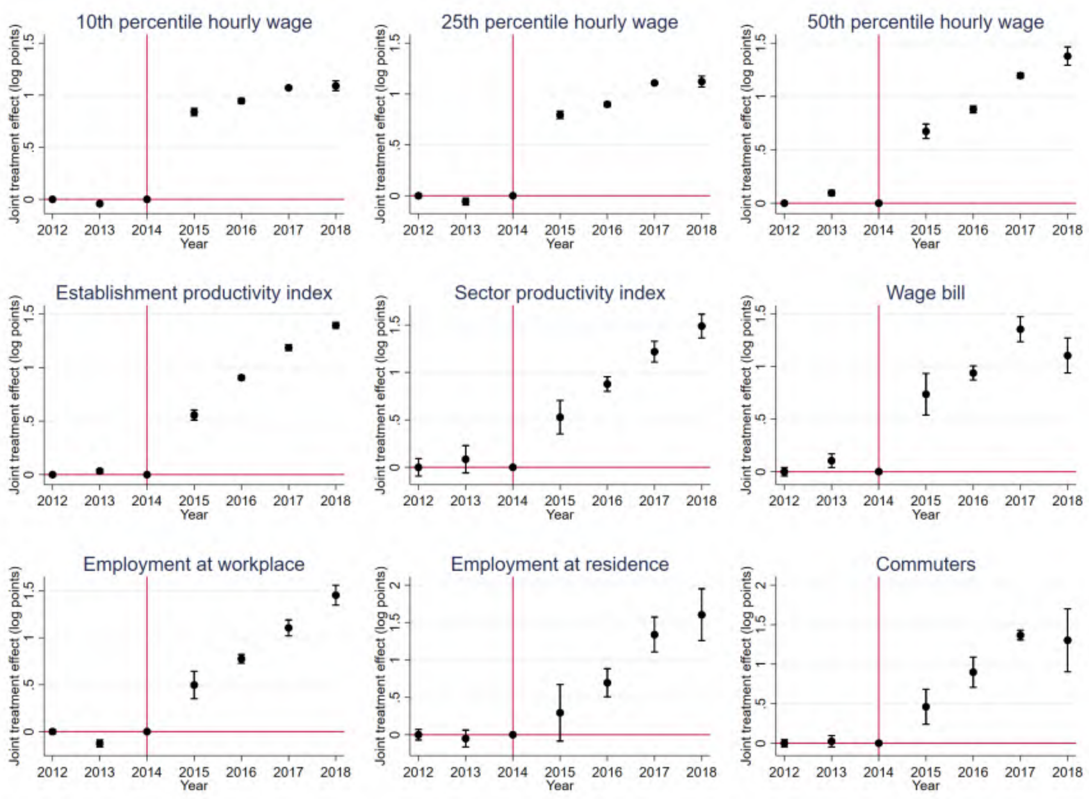
Note: Regions are grouped into decile bins according to the minimum wage bite shown in Figure S2. Each point estimate compares the change in an outcome from 2014 to 2016 using the first decile bin as a control. All time-series are adjusted for pre-trends in municipality-specific regressions of outcomes against a time trend using the period up to 2014 (Monras, 2019). Time-varying treatment effects are reported in Figure S4. The establishment wage premium is the employment-weighted average across firm fixed effects where the latter are recovered from a decomposition from a decomposition of wages into worker and firm fixed effects following Abowd et al. (1999) (see Appendix B.2.4 for details).

Alternative temporal windows. To control for unobserved trends at the area level, we take second-differences in Eq. (11). In Figure 3, we have set $\{t = 2016, m = 4, n = 2\}$, which implies that we take differences over the two two-year periods 2012-2014 and 2014-2016, i.e. we have used a two-year spatial window. As robustness tests, we replicate the procedure using a one-year and a three-year window in Figures S6 and S7. Reassuringly, the critical values for the relative minimum wages remain in the same ballpark.

A one-year spatial window implies that we take second differences over two one year periods centered on 2014, the year of the minimum wage introduction, i.e. we difference periods 2015-2014 and 2014-2013 when computing the outcome trend in Figures S6 and S7.

Time-varying treatment effects. In estimating Eq. (11), we have controlled for pre-trends that could potentially be correlated with regional productivity by means of a double-differencing approach. To substantiate the validity of this approach, we use the estimated hump-shaped employment effect as a treatment measure in a dynamic difference-

Figure S4: Time-varying minimum-wage-bite effects



Note: We report intensive-margin time-varying difference-in-difference estimates where the treatment variable is the bin-specific treatment effect reported in Figure S3. All time-series are adjusted for pre-trends in municipality-specific regressions of outcomes against a time trend using the period up to 2014 (Monras, 2019). The establishment wage premium is the employment-weighted average across firmfixed effects where the latter are recovered from a decomposition of wages into worker and firm fixed effects following Abowd et al. (1999) (see Appendix B.2.4 for details).

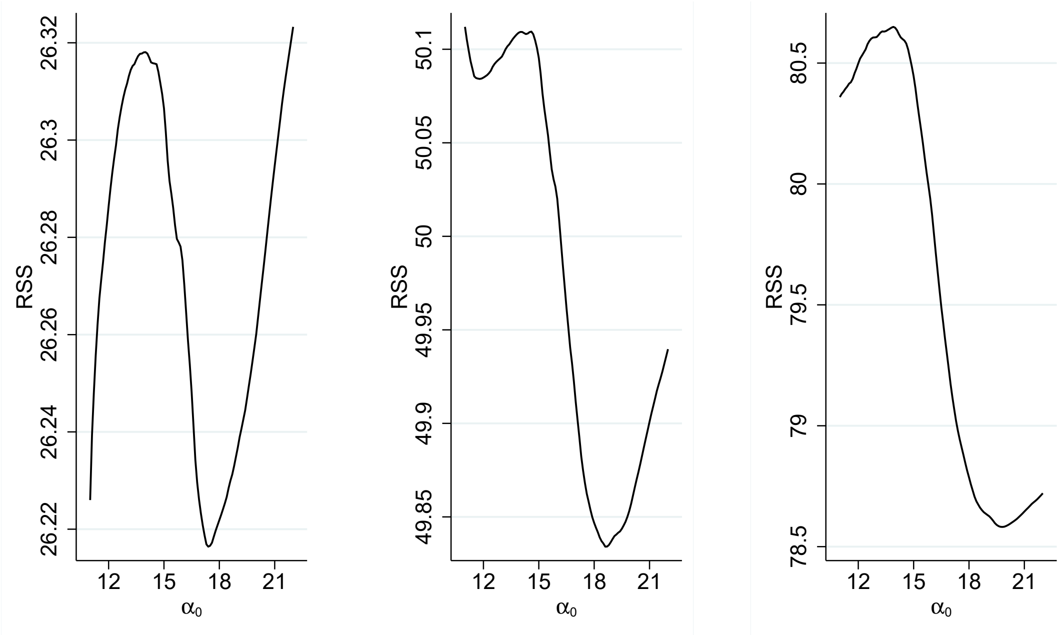
in-difference design. To this end, we compute a treatment measure, $\hat{f}$, based on the estimated parameters $\{\hat{\alpha}_0, \hat{\alpha}_1, \hat{\alpha}_2\}$:

$$\hat{f}_j = \mathbb{1}\left(w_j^{\text{mean}} \leq \hat{\alpha}_0\right) \times \left[\sum_{g=1}^{2} \hat{\alpha}_g \left(w_j^{\text{mean}} - \hat{\alpha}_0\right)^g\right]$$

Next, we detrend the outcome of interest, log employment $\ln L_{j,t}$, following Monras (2019). For each region, we regress the outcome against a linear time trend using years $t < 2015$ before the minimum-wage introduction. Based on the estimated regional trend, we detrend the entire time series, including years $t \geq 2015$. We then use our treatment measure and the detrended outcome in the following regression specification:

$$\ln L_{j,t} = \sum_{z \neq 2014} b_z^f \left[\hat{f}_j \times \mathbb{1}\left(z = t\right)\right] + b_j^I + b_t^T + e_{it}^f,$$

Figure S5: Value in objective function of identification of α_0



(a) One-year window (b) Two-year window (c) Three-year window

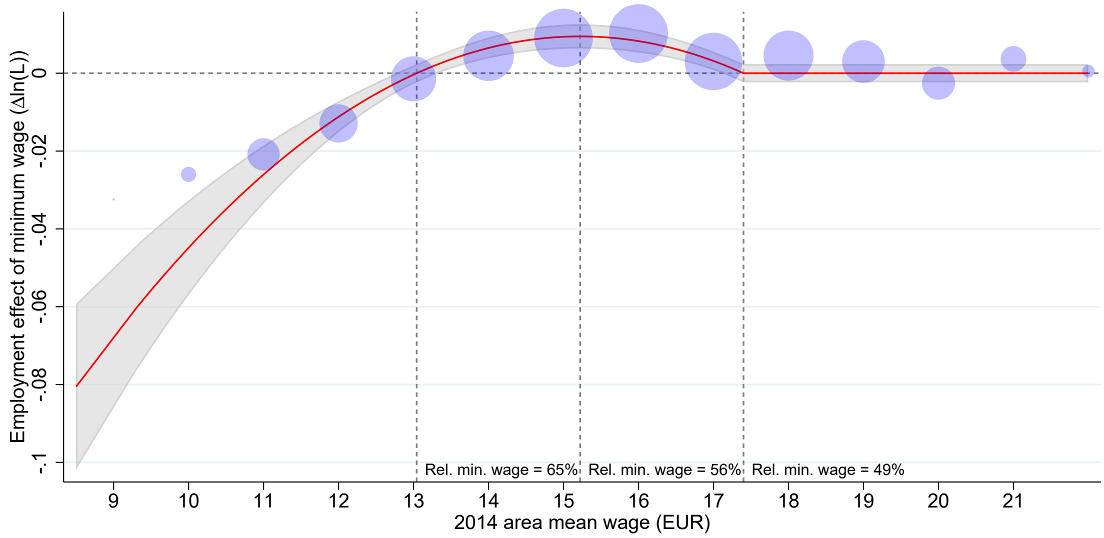
Note: Each panel shows the sum of squared residuals resulting from the estimation of Eq (11) for varying values of α_0 (introduced in Eq. (12). A one-year spatial window implies that we take second differences over two one-year periods centered on 2014, the year of the minimum wage introduction, i.e. we difference periods 2015-2014 and 2014-2013 when computing the outcome trend in Eq. (11).

where $\mathbb{1}$ is the indicator function that returns one if the condition is true and zero otherwise, b_j^I are region fixed effects, b_j^T are year fixed effects, and e_{it}^f is an error term. The parameters of interest are b_z^f which provide an intensive-margin difference-in-difference comparison between year $t = z$ and the base year $t = 2014$.

$$b_z^f = \frac{\partial \ln L_{j,t=z}}{\partial \ln \hat{f}_j} - \frac{\partial \ln \ln L_{j,t=2014}}{\partial \ln \hat{f}_j}$$

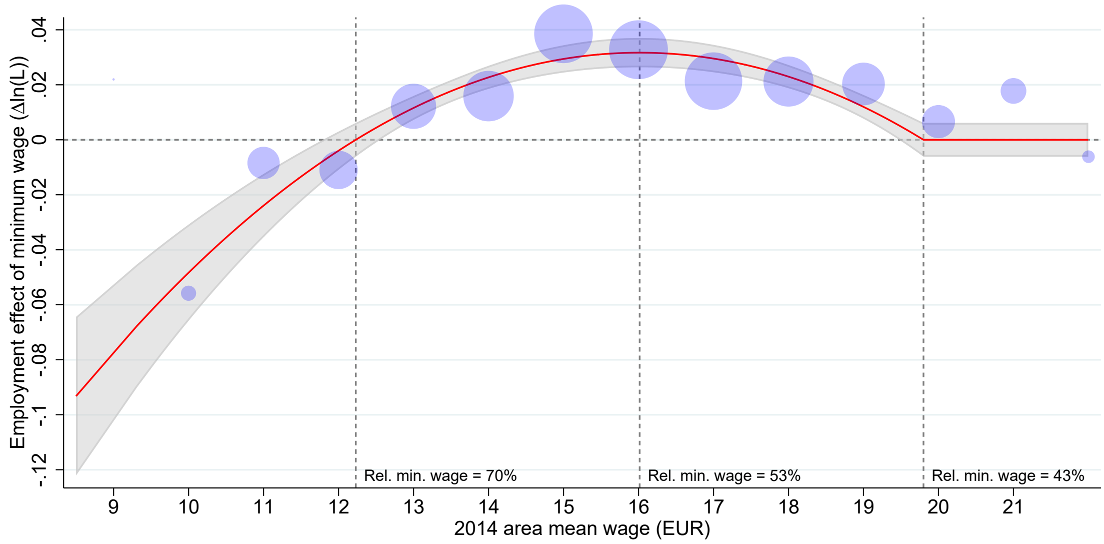
Notice that the employment effects illustrated in Figure 3 are estimated over a two-year period (2016 vs. 2014). Therefore, we expect the estimate of b_{2016}^f to be close to one. Indeed, the results summarized in Figure S8 reveal that this estimate is close to and not statistically significantly different from one. The time-varying treatment effects for all years before the minimum wage are close to and not significantly different from zero, mitigating concerns about a non-parallel-trends problem. Finally, the time-varying treatment effects are increasing over time, which is consistent with the three-year window estimates in Figure S7 being larger than the two-year window estimates in Figure 3 and the one-year window estimates in Figure S6.

Figure S6: Reduced-form evidence with one-year window



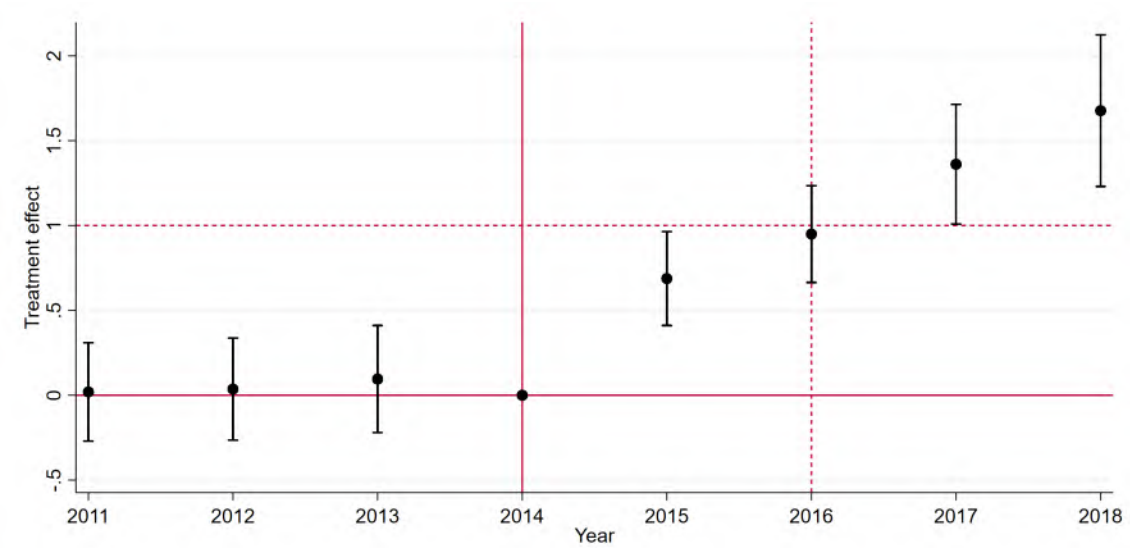
Note: Dependent variable is the second difference in log employment over the 2013-14 and 2014-15 periods. Markers give averages within one-euro bins, with the marker size representing the number of municipalities within a bin. The last bin (22.5) includes all municipalities with higher wages because observation are sparse. The red solid line is the quadratic fit, weighted by bin size. Two outlier bin effects are excluded to improve readability, but they are included in the estimation of the quadratic fit. Confidence bands (gray-shaded area) are at the 95% level. The relative minimum wage is the ratio of the 2015 minimum wage level $\underline{w} = 8.50$ over the 2014 mean wage (when there was no minimum wage).

Figure S7: Reduced-form evidence with three-year window



Note: Dependent variable is the second difference in log employment over the 2011-14 and 2014-17 periods. Markers give averages within one-euro bins, with the marker size representing the number of municipalities within a bin. The last bin (22.5) includes all municipalities with higher wages because observation are sparse. Red solid line is the quadratic fit, weighted by bin size. Two outliers bin effects are are excluded to improve readability, but they included in the estimation of the quadratic fit. Confidence bands (gray-shaded area) are at the 95% level. The relative minimum wage is the ratio of the 2015 minimum wage level $\underline{w} = 8.50$ over the 2014 mean wage (when there was no minimum wage).

Figure S8: Dynamic difference-in-difference effect of "hump treatment"



Note: This figure reports time-varying treatment effects from a dynamic difference-in-difference specification where the dependent variable is the log of employment at the municipality-year level. For each municipality, the outcome is adjusted for pre-trends following Monras (2019). The treatment variable is the predicted employment effect displayed in Figure 3. Confidence bands are at the 95% level and based on bootstrapped standard errors.

D General equilibrium

D.1 The German minimum wage

D.1.1 Margins of spatial adjustment

This section complements Section 4.4.1 in the main paper. The upper-left panel of Figure 4 reveals that the model generates the hump-shaped relationship between the regional employment response to the German minimum wage regional productivity that we observe in the data as per Figure 3. From Figure 4 it is also clear that the model generates the hump-shaped relationship even if workers are immobile across residences, i.e. commuting represents a sufficient margin of adjustment in labour supply.

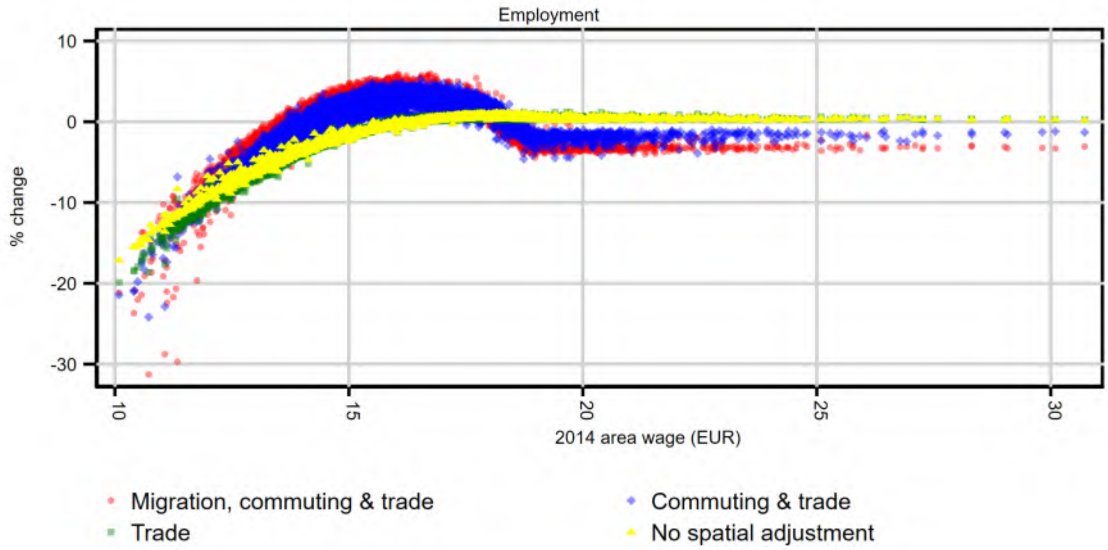
Figure S9 reveals that commuting also is a necessary margin of adjustment. If we hold commuting probabilities λ_{ij} constant at pre-minimum wage levels and, hence, there is no spatial adjustment via migration or commuting, the hump shape disappears. Switching off, in addition, spatial adjustments via domestic trade (by holding trade shares θ_{ij} constant) has minor effects only. The implication is that local increases in labour force participation cannot rationalize the sizable hump shape that we find in the data. Some form of labour mobility is necessary to rationalize the relative increase in employment in regions of intermediate productivity that we see in the data.

D.1.2 The reallocation effect

This section adds to Sections 3.1.2 and 4.4.1 in the main paper by illustrating how the German minimum wage has reallocated workers between firms of different productivities. To this end, we first generate municipality-specific firm productivity distributions based on the lower-bound productivities $\underline{\varphi}_j$ and the shape parameter k (see Section 4.2). Next, we compute the employment distribution by firm productivity for municipality for the scenario without the minimum wage and with minimum wage, distinguishing between the long-run and the short run. To this end, we compute the cut-off points that mark the least productive unconstrained ($\underline{\varphi}_j^u(\underline{w})$) and supply-constrained ($\underline{\varphi}_j^u(\underline{w})$) firm for each municipality using Eqs. (5) and (6) then compute employment at each percentile of the productivity distribution using the mapping from productivity to employment in Table A1. Notice that the general-equilibrium terms $\{S_j^h, S_j^r\}$ affect the cut-off points and the relative employment levels within firm types. Since these vary between the short short-run (no labour mobility across residence locations) and the long run (full mobility), the reallocation effect can differ between the short run and the long run.

In Figure S11, we illustrate the distribution of the relative changes in the shares at municipality employment by productivity bin for two municipalities. *Amt Büsum-Wesselburen* is a rural municipality in the federal state *Schleswig-Holstein* in the north of Germany. Productivity is relatively low and, as a result, the majority of firms are demand-constrained (lying to the left of the short-dashed vertical line). Within these demand-constrained firms,

Figure S9: Employment effects by productivity with different spatial adjustments



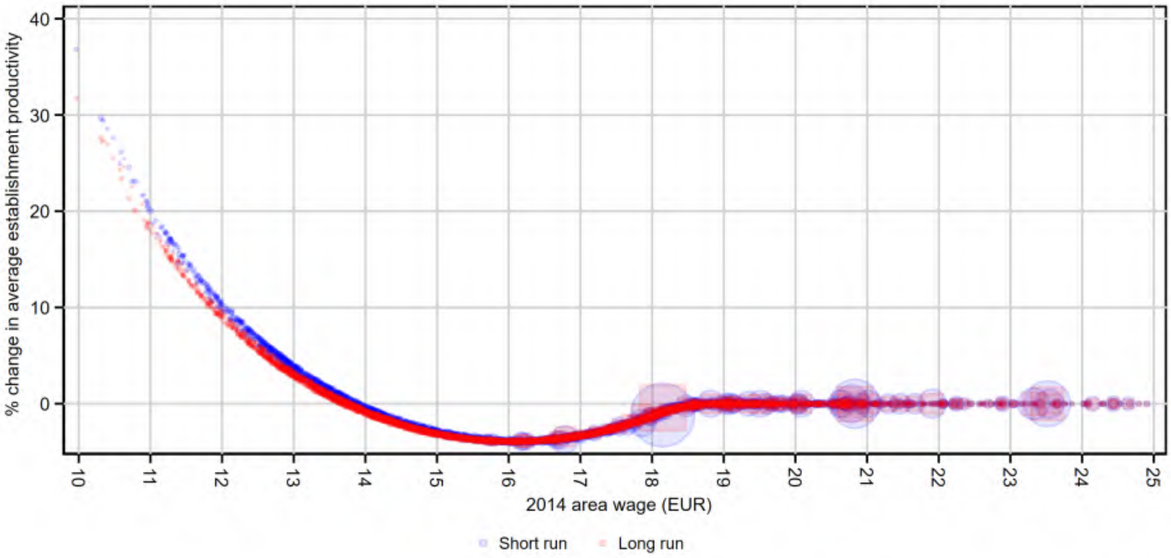
Note: Each icon represents one outcome for one area (*Verbandsgemeinde*). Results of model-based counterfactuals comparing the equilibrium under a federal minimum of 48% (the value observed in data) of national mean wage to the equilibrium with a zero minimum wage. *Red squares* show outcomes when workers are mobile across residence (spatial adjustments via migration, commuting, and trade). *Blue circles* show outcomes when workers are immobile across residences (spatial adjustments via commuting and trade). *Green squares* show outcomes when workers are fully immobile across workers are immobile across residences and workplaces (spatial adjustments via trade). *Yellow triangles* show outcomes when workers are fully immobile and domestic trade does not adjust (no spatial adjustments). For a more intuitive interpretation, we multiply the normalized regional mean wage on the x-axes by the 2014 national mean wage. To improve the presentation, we crop the right tail of the regional productivity distribution (about one percent).

the minimum wage, reallocates labour from low-productivity firms that must reduce employment to raise their MRPL towards higher-productivity firms that lose monopsony power. Supply-constrained firms (between the vertical dashed lines) also gain employment, in relative terms. Unconstrained firms (to the right of the long-dashed vertical line) more or less keep the same share at municipality employment. The difference between the short-run and long-run reallocation effect is marginal. Evidently, the reallocation of workers from low-productivity demand-constrained firms to higher-productivity demand-constrained firms and supply-constrained firms results in an increase in average productivity. This is the reallocation effect as emphasized by Dustmann et al. (2022).

The reallocation effect, however, can also work in the opposite direction as highlighted by the case of *Berlin*. Firms in Berlin, the capital city of Germany, are generally more productive than in *Amt Büsum-Wesselburen* and, as a result, there are few demand-constrained firms. In contrast, there are more (also in relative terms) supply-constrained firms which expand employment and increase their share at municipality employment as they lose monopsony power. As a direct consequence, the share of unconstrained firms at municipality employment decreases (even if they do not reduce employment) and average productivity falls.

The case of *Berlin* also highlights that there can be a more notable difference between

Figure S10: Short-run and long-run reallocation effects by regional productivity



Note: Each icon represents one outcome for one municipality (*Verbandsgemeinde*). Results of model-based counterfactuals comparing the equilibrium under a federal minimum of 48% (the value observed in data) of national mean wage to the equilibrium with a zero minimum wage. *Blue circles* show outcomes when workers are immobile across residences (short run). *Red squares* show outcomes when workers are mobile across residence (long run). For a more intuitive interpretation, we multiply the normalized regional mean wage on the x-axes by the 2014 national mean wage. To improve the presentation, we crop the right tail of the regional productivity distribution (about one percent).

the short-run and the long-run effect. The long-run relocation of workers to the surrounding eastern states (see Figure 5) has a favorable market-access effect, which lowers the threshold for unconstrained firms. Consequentially, there are fewer supply-constrained firms that expand employment, resulting in a smaller effect on average productivity.

To generalize the insights from Figure S11, we use the distributions of firm-level employment φ_j and employment densities $l(\varphi_j)$ to compute the worker-weighted average productivity:

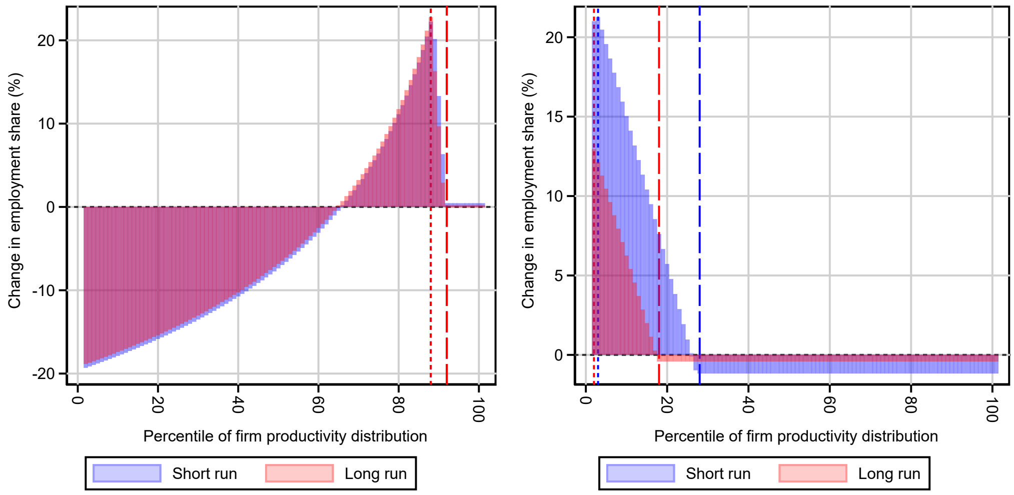
$$\tilde{\varphi}_j = \int_{\underline{\varphi}_j}^{\infty} l_j(\varphi_j)\varphi_j d\varphi_j$$

for all municipalities, in the long run and short run. Plotting the percentage differences between the scenario with and without the minimum wage against the initial (no minimum wage) municipality mean wage (a productivity proxy) confirms that the strength and the direction of the reallocation effect depends on the regional productivity level (see Figure S10).

D.1.3 Validation against data

This section complements Section 4.4.2 in the main paper. To investigate the model's out-of-sample predictive power, we use the minimum wage effect predicted by the model, $\hat{\mathbf{X}} = \frac{\mathbf{X}^{\mathbf{C}}}{\mathbf{X}^{\mathbf{0}}}$, as an input into a dynamic difference-in-difference model with time-varying

Figure S11: Employment reallocation effects within municipalities



(a) Amt Büsum-Wesselburen (b) Berlin

Note: Changes in within-municipality employment shares are from model-based simulations comparing the scenario with the German federal minimum wage to the scenario without the minimum wage. The short-dashed vertical line marks the cut-off point $\underline{\varphi}_j^s(\underline{w})$ (the productivity of the least-productive supply-constrained firm). The long-dashed vertical line marks the cut-off point $\underline{\varphi}_j^u(\underline{w})$ (the productivity of the least-productive unonstrained firm).

treatment effects:

$$\ln \mathbf{X^D_{i,t}} = \sum_{z \neq 2014} a_z \left[\ln \hat{\mathbf{X}}_\mathbf{i} \times \mathbb{1}\left(z = t\right)\right] + a^T_{z(i),t} + a^I_i + e^D_{it}, \tag{40}$$

where $\mathbb{1}$ is the indicator function returning one if the condition is true and zero otherwise, $\mathbf{X^D_{i,t}}$ is an outcome observed for region i in year t, $z(i), t$ is a year-by-zone (former East and West Germany) fixed effect, a^I_i denotes a region fixed effect and e^D_{it} is an error term. This specification generates the following intensive-margin difference-in-difference treatment effects:

$$\begin{aligned} \alpha^z &= \frac{\partial \ln \mathbf{X^D_{i,t=z}}}{\partial \ln \hat{\mathbf{X}}_\mathbf{i}} - \frac{\partial \ln \mathbf{X^D_{i,t=2014}}}{\partial \ln \hat{\mathbf{X}}_\mathbf{i}} \\ &= \frac{\partial \left(\ln \mathbf{X^D_{i,t=z}} - \ln \mathbf{X^D_{i,t=2014}}\right)}{\partial \left(\ln \mathbf{X^C_i} - \ln \mathbf{X^0_i}\right)} \end{aligned} \tag{41}$$

Thus, if changes in the data scale proportionately in changes predicted by the model, we will observe treatment effects $\alpha^z \geq 2015$ close to one. In practice, it is unrealistic to expect a coefficient of close to one since, unlike in the model, fundamentals in the real world change for reasons unrelated to the minimum wage, resulting in attenuation bias. Hence, positive coefficients are all the more reassuring of the model's ability to forecast minimum wage effects. $\alpha^z < 2015$ can be interpreted as placebo effects, which we expect to be near zero as the minimum wage should not have had any effects before its introduction.

D.2 Equity

To capture how the minimum wage affects the distribution of income across workers, we compute an *equity* measure that captures how evenly income is distributed across workers. We measure equity as $1-\mathcal{G}$ where G is the Gini coefficient of the distribution of nominal wages across all workers in all regions.

D.2.1 The Gini coefficient in the model

We derive the Gini-coefficient according to the following steps.

1. We derive the CDF of aggregate employment for each location.
2. We aggregate the CDFs to the national level by taking the sum over the employment-weighted location-specific CDFs.
3. We define wage bins and compute PDFs from differentiating CDFs across adjacent bins.
4. Multiplying the employment densities with the wage level in each bin and computing the cumulative sum delivers the CDF of labor income.
5. Plotting the CDF for employment and labor income against each other delivers the Lorenz curve. The Gini coefficient is defined as $\mathcal{G} = 1 - 2B$, where B is the area under the Lorenz curve.

Cumulative distribution function of aggregate employment. First, we derive the number of workers in location j who are employed at firms with productivities between $\underline{\varphi}_j$ and φ^b:

$$\begin{aligned}
L_j(\varphi_j^b) = M_j \Bigg\{ & l_j^d(\underline{\varphi}_j) \int_{\underline{\varphi}_j}^{\min\{\varphi_j^b, \max\{\underline{\varphi}_j^s, \underline{\varphi}_j\}\}} \frac{l_j^d(\varphi_j)}{l_j^d(\underline{\varphi}_j)} \frac{dG(\varphi_j)}{1-G(\underline{\varphi}_j)} \\
& + l_j^s(\min\{\varphi_j^b, \max\{\underline{\varphi}_j^s, \underline{\varphi}_j\}\}) \frac{1-G(\min\{\varphi_j^b, \max\{\underline{\varphi}_j^s, \underline{\varphi}_j\}\})}{1-G(\underline{\varphi}_j)} \\
& \times \int_{\min\{\varphi_j^b, \max\{\underline{\varphi}_j^s, \underline{\varphi}_j\}\}}^{\min\{\varphi_j^b, \max\{\underline{\varphi}_j^u, \underline{\varphi}_j\}\}} \frac{l_j^s(\varphi_j)}{l_j^s(\min\{\varphi_j^b, \max\{\underline{\varphi}_j^s, \underline{\varphi}_j\}\})} \frac{dG(\varphi_j)}{1-G(\min\{\varphi_j^b, \max\{\underline{\varphi}_j^s, \underline{\varphi}_j\}\})} \\
& + l_j^u(\min\{\varphi_j^b, \max\{\underline{\varphi}_j^u, \underline{\varphi}_j\}\}) \frac{1-G(\min\{\varphi_j^b, \max\{\underline{\varphi}_j^s, \underline{\varphi}_j\}\})}{1-G(\underline{\varphi}_j)} \\
& \times \int_{\min\{\varphi_j^b, \max\{\underline{\varphi}_j^u, \underline{\varphi}_j\}\}}^{\varphi_j^b} \frac{l_j^u(\varphi_j)}{l_j^u(\min\{\varphi_j^b, \max\{\underline{\varphi}_j^u, \underline{\varphi}_j\}\})} \frac{dG(\varphi_j)}{1-G(\min\{\varphi_j^b, \max\{\underline{\varphi}_j^u, \underline{\varphi}_j\}\})} \Bigg\}.
\end{aligned}$$

We now substitute productivity thresholds with critical minimum wage levels according to Eq. (A.6) and use

$$\frac{\underline{\varphi}_j}{\varphi^b} = \left(\frac{\underline{w}_j^u}{w^b}\right)^{\frac{\sigma+\varepsilon}{\sigma-1}}.$$

To compute the share of workers that earn less than w^b, we use the facts that all constrained firms pay the minimum wage and that $w^b \geq w_j^s(\underline{\varphi}_j) > w_j^u(\underline{\varphi}_j)$. Following the same procedure as in Appendix A.3, we get

$$L_j(\underline{w}, w^b) = \chi_L \Phi_j^L(\underline{w}, w^b) M_j l_j^u(\underline{\varphi}_j)$$

where $\chi_L \equiv k/\{k - [\varepsilon/(\varepsilon+1)]\gamma\}$ and

$$\begin{aligned}
\Phi_j^L(\underline{w}, w^b) \equiv\; & \frac{l_j^d(\underline{\varphi}_j)}{l_j^u(\underline{\varphi}_j)} \frac{k - [\varepsilon/(\varepsilon+1)]\gamma}{k-(\sigma-1)} \left[1 - \left(\frac{\underline{w}_j^s}{\min\{w^b, \max\{\underline{w}_j^s, \underline{w}\}\}}\right)^{\frac{[k-(\sigma-1)](\sigma+\varepsilon)}{\sigma-1}}\right] \\
& + \frac{l_j^s}{l_j^u(\underline{\varphi}_j)} \frac{k - [\varepsilon/(\varepsilon+1)]\gamma}{k} \left[\left(\frac{\underline{w}_j^s}{\min\{w^b, \max\{\underline{w}_j^s, \underline{w}\}\}}\right)^{\frac{k(\sigma+\varepsilon)}{\sigma-1}}\right. \\
& \left. - \left(\frac{\underline{w}_j^u}{\min\{w^b, \max\{\underline{w}_j^u, \underline{w}\}\}}\right)^{\frac{k(\sigma+\varepsilon)}{\sigma-1}}\right] \\
& + \left[\left(\frac{\underline{w}_j^u}{\min\{w^b, \max\{\underline{w}_j^u, \underline{w}\}\}}\right)^{\frac{\{k-[\varepsilon/(\varepsilon+1)]\gamma\}(\sigma+\varepsilon)}{\sigma-1}} - \left(\frac{\underline{w}_j^u}{w^b}\right)^{\frac{\{k-[\varepsilon/(\varepsilon+1)]\gamma\}(\sigma+\varepsilon)}{\sigma-1}}\right] \\
=\; & \left(\frac{\rho}{\eta}\frac{\underline{w}_j^u}{\underline{w}}\right)^{\sigma} \frac{k - [\varepsilon/(\varepsilon+1)]\gamma}{k-(\sigma-1)} \left[1 - \left(\frac{\underline{w}_j^s}{\min\{w^b, \max\{\underline{w}_j^s, \underline{w}\}\}}\right)^{\frac{[k-(\sigma-1)](\sigma+\varepsilon)}{\sigma-1}}\right] \\
& + \left(\frac{\underline{w}_j^u}{\underline{w}}\right)^{-\varepsilon} \frac{k - [\varepsilon/(\varepsilon+1)]\gamma}{k} \left[\left(\frac{\underline{w}_j^s}{\min\{w^b, \max\{\underline{w}_j^s, \underline{w}\}\}}\right)^{\frac{k(\sigma+\varepsilon)}{\sigma-1}}\right. \\
& \left. - \left(\frac{\underline{w}_j^u}{\min\{w^b, \max\{\underline{w}_j^u, \underline{w}\}\}}\right)^{\frac{k(\sigma+\varepsilon)}{\sigma-1}}\right] \\
& + \left[\left(\frac{\underline{w}_j^u}{\min\{w^b, \max\{\underline{w}_j^u, \underline{w}\}\}}\right)^{\frac{\{k-[\varepsilon/(\varepsilon+1)]\gamma\}(\sigma+\varepsilon)}{\sigma-1}} - \left(\frac{\underline{w}_j^u}{w^b}\right)^{\frac{\{k-[\varepsilon/(\varepsilon+1)]\gamma\}(\sigma+\varepsilon)}{\sigma-1}}\right].
\end{aligned}$$

Notice that for a given wage level w^b the density for any of the three firm types must not be negative. We ensure this in the code by manually assigning appropriate values to w^b for the respective firm types. To give an example, for demand-constrained firms, if $\underline{w} > \underline{w}_j^s$ and $w^b < \underline{w}_j^s$, we set $w^b = \underline{w}_j^s$. This ensures that the density of demand-constrained firms for wage bins smaller than the mandatory minimum wage is zero. We apply this logic to all cases and firm types.

Relating $L_j(\underline{w}, w^b)$ to L_j delivers the cumulative density of workers as a function of wages:

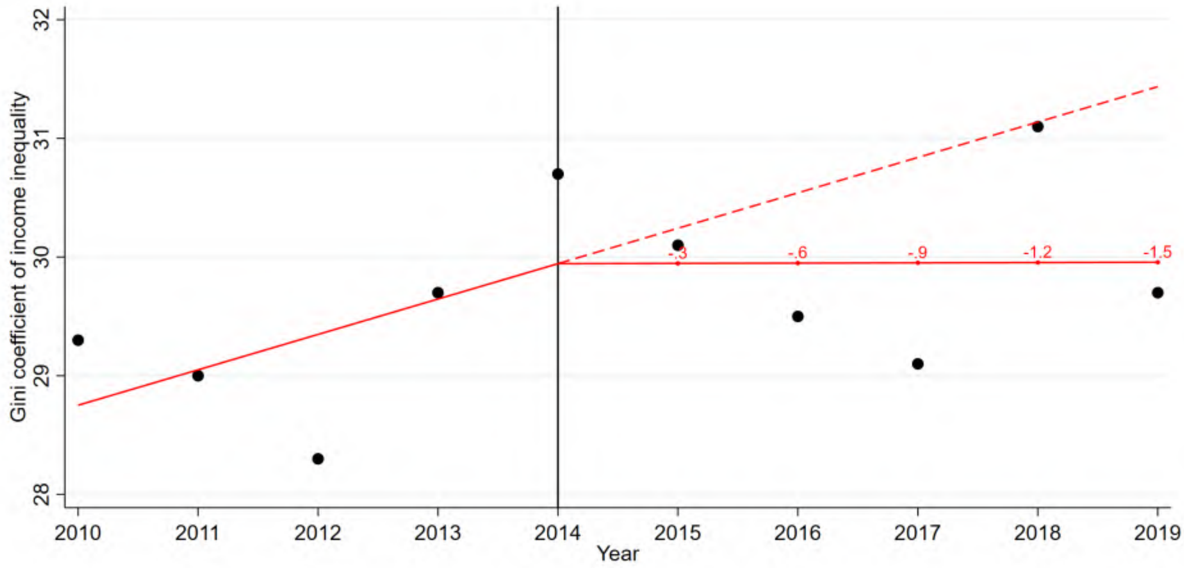
$$Z_j(w \leq w^b) = \Phi_j^L(\underline{w}, w^b)/\Phi_j^L,$$

where we take Φ_j^L from Appendix A.3.

The remaining steps as introduced above can be executed straightforwardly.

D.2.2 The Gini coefficient in data

Figure S12: Gini coefficient in data



Note: Own illustration using Gini coefficients from the German Statistical Office. Each dot represents a Gini coefficient of the income distribution across all workers in all regions measured in data. The red solid line is the fit of a linear spline function with a knot in 2014. The dashed red line is the linear extrapolation of the pre-policy trend.

In Figure S12, we plot Gini coefficients of wage inequality across German workers by year. They are generally around 30% in Germany, which is a typical value for a European country and within close range of the wage inequality we generate within our model. While there is some volatility across years, there are clear trends within the three years preceding and succeeding the minimum wage inequality: Inequality increased before the introduction and decreased afterwards, consistent with the intended policy objective. If we expand the temporal window, there is more noise, but the perception of a reduction in wage inequality persists. 2018—a suspicious outlier—aside, Gini coefficients are lower during the post-policy period than in 2014 and certainly lower than predicted by an extrapolation of previously observed trends. Comparing a linear trend interpolation within the post-policy period to a linear trend extrapolation from the pre-policy period, we estimate a reduction in the Gini coefficient of 1.5 percentage points which is close to the 2-percentage reduction predicted by our model.

D.3 Dispersion

To capture how the minimum wage affects the spatial distribution of economic activity, we compute a *dispersion* measure that captures how evenly economic activity is distributed across regions. We measure dispersion as $1 - \mathcal{S}$ where S is the Gini coefficient of the distribution of employment across regions.

D.3.1 The spatial Gini coefficient in the model

To compute the spatial Gini coefficient S, we order regions by their employment and calculate the cumulative shares. This immediately leads to the Lorenz curve and the Gini coefficient (see also Appendix D.2). We then apply this measure to various contexts and compare it to the baseline value in 2014, prior to the introduction of the minimum wage, to obtain percentage changes.

D.3.2 The spatial Gini coefficient in data

Figure S13 illustrates the Gini coefficient of the distribution of employment across regions by year. Gini coefficients are generally high, revealing that economic activity is highly spatially concentrated in Germany. There is a trend towards greater spatial concentration prior to the minimum wage, which accelerates after the introduction of the minimum wage. However, the effect is quantitatively marginal. Based on the small magnitude of the departure from the pre-trend, it seems fair to conclude that the minimum wage had a small, if any, impact on the spatial distribution of economic activity. This is consistent with our model-based simulations which suggest that the German minimum wage (48% of the national mean) is too high to reduce spatial concentration, but too low significantly increase it (see Figure 7).

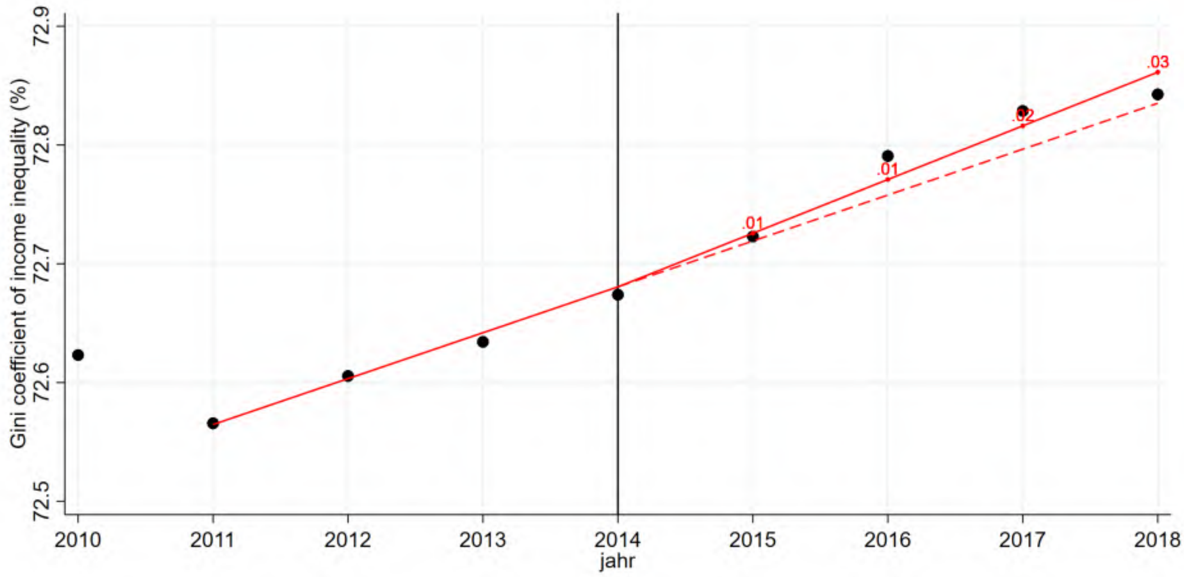
D.4 Optimal minimum wages

This section complements Section 4.5 by providing additional detail on the causes, effects, and the regional distribution of the effects of the optimal minimum wages discussed in Table 2.

We begin by showing the short-run analog to Figure 7 in Figure S14. Confirming Table 2, the long-run effects are remarkably similar to the short-run effects, once more revealing that commuting is a sufficient spatial margin of adjustment of labour supply.

Next, we provide descriptive statistics on the four outcomes illustrated in Figure 5 derived under alternative minimum wages in Table S3. We present the results for employment-maximizing and welfare-maximizing federal and regional minimum wages introduced in Table 2. We further distinguish between short-run and long-run effects. The, perhaps, most striking insight from Table 2 is that *regional* minimum wages—because they "bite" similarly in all regions—have effects that hardly vary by region. In contrast, *federal* minimum wages lead to great spatial heterogeneity in the welfare incidence in the short-

Figure S13: Spatial Gini coefficient in data



Note: Gini coefficients summarize the distribution of employment across municipalities by year. Each dot represents a Gini coefficient. The red solid line is the fit of a linear spline function with a knot in 2014. The dashed red line is the linear extrapolation of the pre-policy trend.

run. The long-run, spatial arbitrage results in large reallocation of the labour force towards those regions experiencing short-run welfare gains. Because the welfare-maximizing federal minimum wage is more ambitious than the employment-maximizing minimum wage, the spatial heterogeneity in the effects is particularly striking. A comparison of Figure S15 to Figure 5 reveals that the way this heterogeneity plays out depends on the level of the minimum wage.

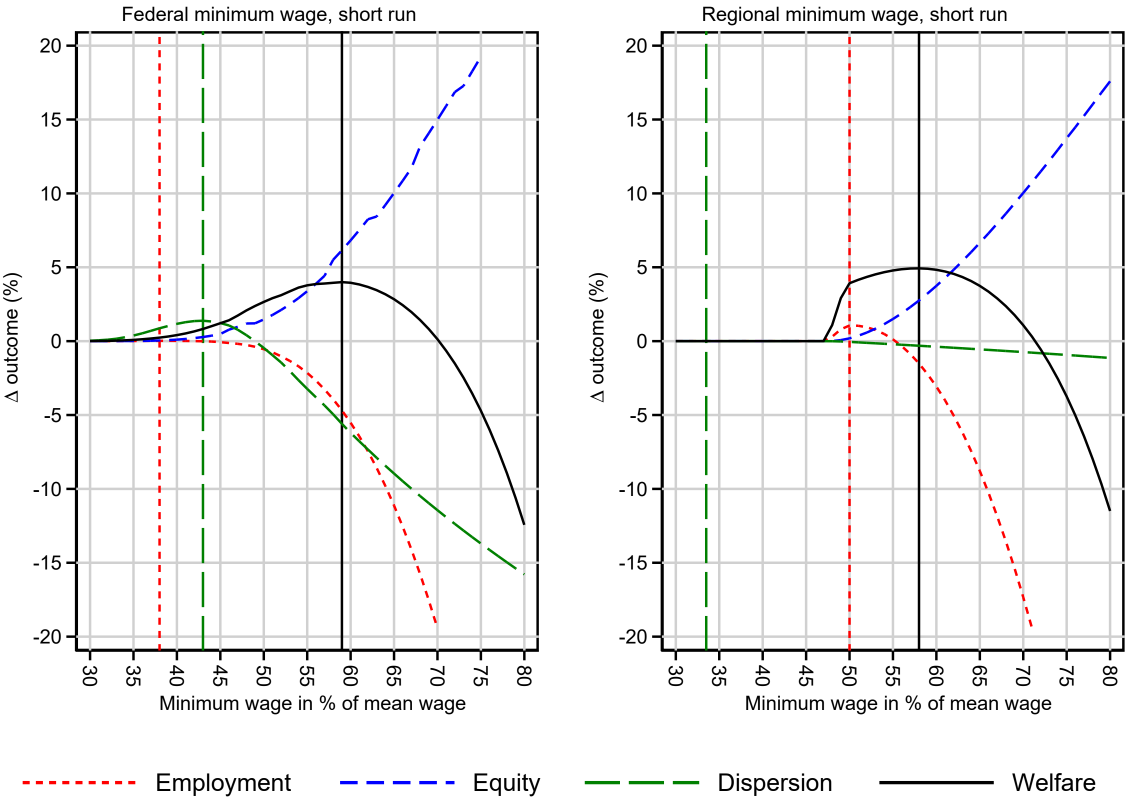
As the welfare-maximizing minimum wage is higher than the implemented German minimum wage (58% vs 48%), we observe more pronounced increases in real wages from panel (a) of Figure S15. These wage increases that are particularly prevalent in East Germany are associated with reductions in employment probabilities that can be quite substantial in certain municipalities (up to -25%). While the former effect dominates the latter, it is remarkable that the net effect is now larger in West Germany. This is almost exactly the opposite of the actual German minimum wage that is about 20% lower. As an immediate consequence, the higher welfare gains in the west cause a different migration responses. In contrast to Figure 5, we now observe emigration from East Germany. Increasing the minimum wage from moderate levels therefore affects different regions at different stages. For medium to high minimum wages (relative to the mean wage), it is the medium to high productivity locations that experience short-run welfare gains and long-run immigration.

Table S3: Optimal minimum wages

Objective	Scheme	Case	Outcome	Mean	S.D.	Min.	Max.
Employment	Federal	SR	Real wage	0.080	0.470	-1.250	4.500
Employment	Federal	SR	Employment prob.	-0.110	0.290	-4.600	0.000
Employment	Federal	SR	Welfare	0.280	0.380	-0.540	2.610
Employment	Federal	SR	Labour force	0.080	0.110	-0.150	0.720
Employment	Federal	LR	Real wage	0.030	0.430	-1.180	3.900
Employment	Federal	LR	Employment prob.	-0.120	0.310	-4.960	0.000
Employment	Federal	LR	Welfare	0.250	0.000	0.250	0.250
Employment	Federal	LR	Labour force	0.060	1.480	-4.320	8.520
Employment	Regional	SR	Real wage	4.610	0.010	4.590	4.640
Employment	Regional	SR	Employment prob.	-0.010	0.000	-0.010	-0.010
Employment	Regional	SR	Welfare	3.920	0.000	3.900	3.940
Employment	Regional	SR	Labour force	1.070	0.000	1.070	1.070
Employment	Regional	LR	Real wage	4.610	0.000	4.590	4.630
Employment	Regional	LR	Employment prob.	-0.010	0.000	-0.010	-0.010
Employment	Regional	LR	Welfare	3.920	0.000	3.920	3.920
Employment	Regional	LR	Labour force	1.060	0.020	0.990	1.120
Welfare	Federal	SR	Real wage	11.680	5.150	2.890	40.150
Welfare	Federal	SR	Employment prob.	-7.650	3.820	-24.310	-0.540
Welfare	Federal	SR	Welfare	4.320	0.550	2.190	6.210
Welfare	Federal	SR	Labour force	1.170	0.140	0.610	1.660
Welfare	Federal	LR	Real wage	11.670	5.140	3.840	40.260
Welfare	Federal	LR	Employment prob.	-7.650	3.800	-24.150	-0.510
Welfare	Federal	LR	Welfare	4.020	0.000	4.020	4.020
Welfare	Federal	LR	Labour force	2.200	2.480	-7.910	14.190
Welfare	Regional	SR	Real wage	6.610	0.030	6.540	6.800
Welfare	Regional	SR	Employment prob.	-2.800	0.000	-2.800	-2.800
Welfare	Regional	SR	Welfare	4.900	0.020	4.800	4.980
Welfare	Regional	SR	Labour force	1.330	0.010	1.300	1.350
Welfare	Regional	LR	Real wage	6.610	0.030	6.560	6.780
Welfare	Regional	LR	Employment prob.	-2.800	0.000	-2.800	-2.800
Welfare	Regional	LR	Welfare	4.920	0.000	4.920	4.920
Welfare	Regional	LR	Labour force	1.260	0.100	0.790	1.590

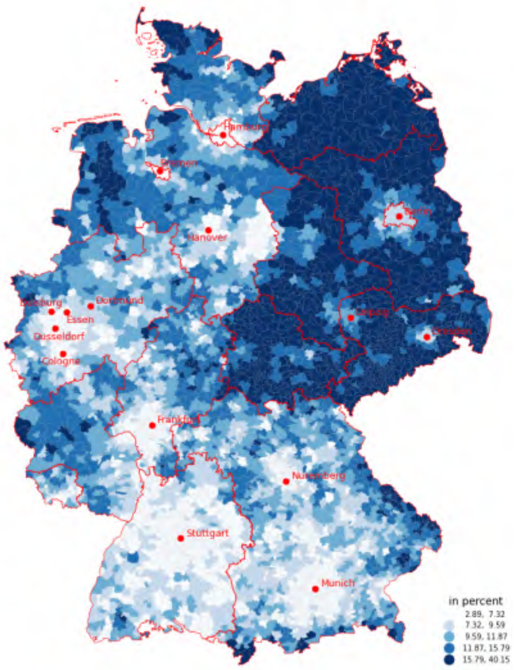
Notes: This table provides a additional outputs of the simulated minimum wage effects summarised in Table 2. *Objective* describes if the minimum wage is employment-maximizing or welfare-maximizing. SR = short run; LR = long run. *Mean* is the unweighted average across municipalities. It does not correspond to the national average.

Figure S14: Minimum wage effects in the short run

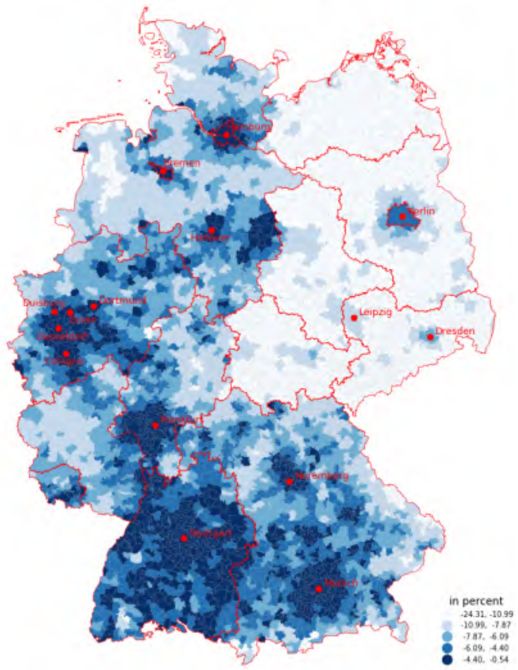


Note: Results of model-based counterfactuals. Employment is the total number of workers in employment. Equity is measured as 1-$\mathcal{G}$, where $\mathcal{G}$ is the Gini coefficient of real wage inequality across all workers in employment. Equity is measured as 1-$\mathcal{S}$, where $\mathcal{S}$ is the Gini coefficient of the distribution of employment across regions. Welfare is the expected utility of as defined by Eq. (37). It captures individual who are active on and absent from the labour market and accounts for minimum wage effects on employment probabilities, wages, tradable goods prices, housing rents, commuting costs, and worker-firm matching qualities. In the short run, workers are immobile across residence locations whereas workers re-optimize their residential location choice in the long run.

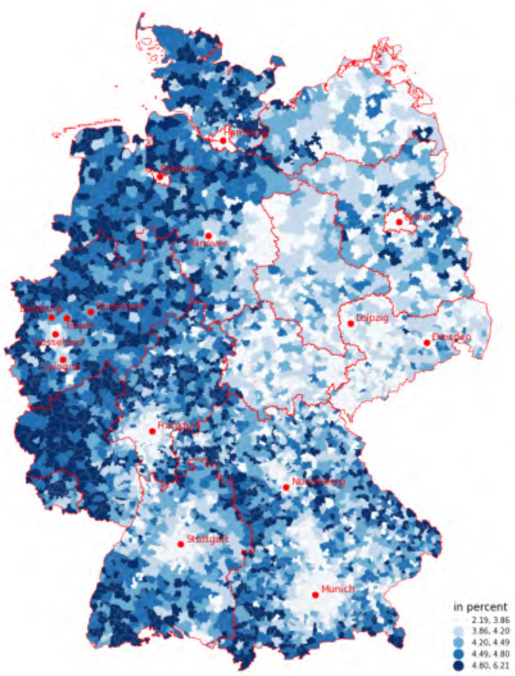
Figure S15: Effects of the welfare-maximizing federal minimum wage



(a) Real wage, short run



(b) Employment probability, short run



(c) Welfare, short run

(d) Labour force, long run

Note: Unit of observation are 4,421 municipality groups. The welfare-maximizing federal minimum wage is set at 60% of the national employment-weighted mean wage. Results from model-based counterfactuals are expressed as percentage changes. All outcomes are measured at the place of residence. To generate the data displayed in panels a) and b), we break down residential income from Eq. (33) into two components. The first is the residential wage conditional on working $\sum_j \lambda^N_{ij|i} \tilde{w}_j$, which we normalize by the consumer price index (the weighted combination of goods prices and housing rent) to obtain the real wage. The second is the residential employment probability $\sum_j \lambda^N_{ij|i} L_j / H_j$, which captures the probability that a worker finds a job within the area-specific commuting zone.

Table S4: Minimum wage schedules

Objective	Scheme	Level rel. to Mean	p50	Employment SR	LR	Equity SR	LR	Dispersion SR	LR	Welfare SR	LR
Employment	State	42.0	46.2	0.0	0.0	0.1	0.1	1.4	1.6	0.5	0.5
Dispersion	State	45.0	49.5	0.0	0.0	0.3	0.3	1.6	1.8	1.0	1.0
Welfare	State	58.0	63.8	-3.2	-3.2	4.2	4.2	-4.5	-4.6	4.3	4.4
Employment	County	50.0	55.0	0.4	0.4	0.6	0.6	0.1	0.1	3.1	3.2
Dispersion	County	47.0	51.7	0.0	0.0	0.2	0.2	1.6	1.8	0.8	0.8
Welfare	County	58.0	63.8	-2.2	-2.2	3.4	3.4	-2.7	-2.9	4.7	4.7

Notes: All values are given in %. *Objective* describes if the minimum wage is employment-maximizing or welfare-maximizing. *State* indicates a minimum wage that is set the respective *level* of the state (*Bundesland*) mean. *County* indicates a minimum wage that is set the respective *level* of the county (*Kreis*) mean. Results are from model-based counterfactuals. Employment is the total number of workers in employment. Equity is measured as 1-$\mathcal{G}$, where $\mathcal{G}$ is the Gini coefficient of real wage inequality across all workers in employment. Dispersion is measured as 1-$\mathcal{S}$, where $\mathcal{G}$ is the Gini coefficient of the distribution of employment across regions. Welfare is the expected utility of as defined by Eq. (37). It captures individual who are active on and absent from the labour market and accounts for minimum wage effects on employment probabilities, wages, tradable goods prices, housing rents, commuting costs, and worker-firm matching qualities. In the short run, workers are immobile across residence locations whereas workers re-optimize their residential location choice in the long run. We strictly select the long-run maximizing minimum wages.

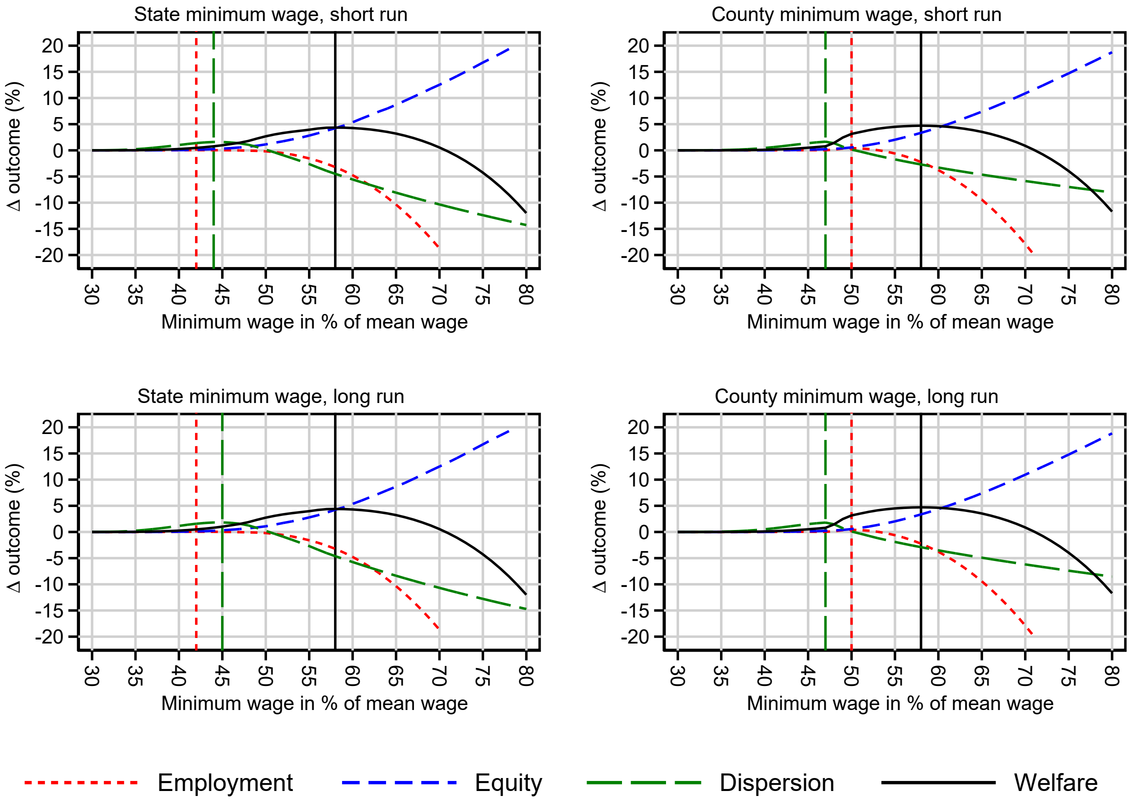
D.5 Regional minimum wages for alternative spatial units

This section complements Section 4.5 in which we quantitatively evaluate the effect of a regional minimum wage set at the municipality level. Here, we consider regional minimum wages set at the level of federal states (*Bundesländer*) and counties (*Kreise and Kreisfreie Städte*) as alternatives. To this end, we compute the worker-weighted wage across all municipalities in a region (county or state) and set the regional minimum wage such that it corresponds to a given fraction of the regional mean wage. Otherwise, the procedure is identical to the one used in Section 4.5.

The main insight from Figure S16, which is the analog to Figure 7 in the main paper, is that the state minimum wage resembles the federal minimum wage, whereas the county minimum wage resembles the municipality minimum wage. This impression is reinforced by Table S4, which is the analog to Table 2 in the main paper. The employment-maximizing and welfare-maximizing levels of the *state* minimum wage are close to those of the *federal* minimum wage, and so are the employment, equity and welfare effects. Similarly, the levels of employment-maximizing and welfare-maximizing *county* minimum wage are close to those of the *municipality* minimum wage, and so are the employment, equity and welfare effects.

We conclude that for regional minimum wages to play out their strengths—mitigating the trade-off of positive welfare and negative employment effects—they need to be set for relatively small spatial units, at least in countries where productivity varies strongly between cities and towns within broader regions.

Figure S16: Regional minimum wages at state and county levels



Note: Results of model-based counterfactuals. Employment is the total number of workers in employment. Equity is measured as 1-$\mathcal{G}$, where $\mathcal{G}$ is the Gini coefficient of real wage inequality across all workers in employment. Dispersion is measured as 1-$\mathcal{S}$, where $\mathcal{S}$ is the Gini coefficient of the distribution of employment across regions. Welfare is the expected utility of as defined by Eq. (37). It captures individual who are active on and absent from the labour market and accounts for minimum wage effects on employment probabilities, wages, tradable goods prices, housing rents, commuting costs, and worker-firm matching qualities. In the short run, workers are immobile across residence locations whereas workers re-optimize their residential location choice in the long run.

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