Employment-maximizing minimum wages[*]

Gabriel M. Ahlfeldt   Duncan Roth   Tobias Seidel

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PRELIMINARY VERSION

Abstract

Motivated by a reduced-form evaluation of the impacts of the German nationally uniform minimum wage on labour, goods and housing markets, we develop a simple model that nests a monopsonistic labour market with heterogeneous firms. The model predicts that the employment effect of a minimum wage is a bell-shaped function of the minimum wage level. Consistent with the model prediction, we find the largest positive employment effects in regions where the minimum wage corresponds to 48% of the pre-policy median wage and negative employment effects in regions where the minimum exceeds 80% of the pre-policy median wage. Our estimates provide first bounds for an evidence-based minimum wages that avoid detrimental employment effects.

Key words: General equilibrium, minimum wage, monopsony, employment, Germany, inequality
JEL: J31, J58, R12

1 Introduction

There is a plethora of evidence on the employment effects of minimum wages, but the literature is far from reaching a consensus. About thirty years ago, consistent with the standard competitive labour market model, economists were in agreement that minimum wages caused job loss (Brown, 1988). Starting in the early 1990s, a new wave of minimum wage research, with Card and Krueger (1994) being the perhaps most prominent example, challenged conventional wisdom by showing non-negative or even positive employment effects that are consistent with monopsonistic labour markets (Manning, 2003). More recently, there has been a focus on methodological refinements with implicit claims that estimated minimum wage effects tend to decrease as the credibility of the counterfactual increases (Dube et al., 2010). Today, there is some recognition that estimated minimum wage effects likely depend on the econometric setup as well as the degree of competitiveness of the studied labour market. Neumark (2017), emphasizing the former, calls for evidence that links the monopsony model's prediction for a minimum wage effect to observable patterns in the data. Manning (2016), emphasizing the latter, argues that it is time to move beyond the question whether a minimum wage decreases employment or not, and instead search for the minimum wage level at which its employment effects turn negative.

We address both research questions and add the identification of employment and welfare-maximizing minimum wage schedules to the agenda. To this end, we develop a simple model nesting a monopsonistic labour market with heterogeneous firms. Motivated by reduced-form evidence on minimum wage effects on a battery of outcomes, our model integrates labour, goods, and housing markets. Heterogeneous firms, for which labour is the only factor of production, produce varieties under monopolistic competition which are nationally traded at zero trade costs. The introduction of a uniform minimum wage can have negative, positive, or neutral effects on labour demand, depending on a firm's productivity. Workers consume the tradable differentiated good and housing, which is supplied inelastically. We use this model to show how the regional employment effects of a minimum wage is a bell-shaped function of the regional productivity. For a given national minimum wage, low-productivity regions experience reductions in employment levels whereas employment increases in higher productivity regions. Employment effects are marginal in the highest-productivity regions where the minimum wage is hardly binding. Our empirial results substantiate the emerging notions in the literature that labour markets tend to be monopsonistic and there is no such thing as *one* minimum wage

effect (Neumark, 2017; Manning, 2016). We find that the employment-maximizing national minimum wage within our model corresponds to 46% of the national median wage, which is close to the actual minimum wage (48%). Beyond a minimum wage level of 80% () of the national median wage, the aggregate employment effect would turn negative.

Following the labour economics monoposony model (Manning, 2003), firms set employment levels by equating the marginal revenue product of labour (MRPL) to marginal costs of labour that strictly exceed average costs, resulting in equilibrium employment levels that are lower than on competitive markets. The introduction of a minimum wage has no effect on the most productive firms, which we term *unconstrained* because they voluntarily pay wages above the minimum wage. In addition, there are two types of constrained firms. *Supply-constrained* firms choose employment levels at which the MRPL exceeds the minimum wage, but worker compensation is below. The effect of the minimum wage is to eliminate the monopsony power and to incentivize firms to hire more workers. For *demand-constrained* firms, the effect is the opposite. At the profit-maximizing employment level, the minimum wage exceeds the MRPL, so the minimum wage forces a firm to employ fewer workers. For a given firm productivity distribution, our model predicts net employment effect within a region to be a bell-shaped function of the minimum wage level. The effect is positive and increasing for low minimum wage levels. Beyond a critical level, the marginal effect is negative and, eventually, the aggregate effect becomes negative. Intuitively, the employment effect of the minimum wage depends on how policy makers set the level relative to average productivity in a region. Mechanically, the minimum wage increases average productivity by shifting workers from the least productive demand-constrained firms to the more productive supply-constrained firms.

Empirically, we make use of a matched employer-employee data set covering approximately the universe of German workers (about 30M) and establishments (about 3M) from 2011 to 2016. Since we track workers over time at their residence and workplace, we directly monitor their commuting patterns. To this data set, we merge micro-data of about 10M property transactions from which we construct a municipality-level house price index. Further, we collect data on regional consumer prices and firm profits. We use this remarkable data set for four purposes. First, we evaluate the effects of the minimum wage on various outcomes using a regional-level difference-in-differences model where shares of workers in a region with pre-policy wages below the minimum wage provides variation in treatment intensity. The results motivate the choice of a monopsony model in the context of the German labour

market. Second, we estimate the within-region employment effects comparing workers which in their last pre-policy employment were paid below the minimum wage to those higher further up in the wage distribution, using an individual-level difference-in-differences analysis, executed separately for 4460 regions. From the region-specific treatment effects, we infer the critical levels for the (nationally uniform) minimum wage relative to the (regionally varying) median wages at which the employment effects are maximized (48%) and become negative (80%).

We connect to a large literature summarized by Manning (2016) and Neumark (2017) that has evaluated the employment effects of minimum wages finding positive (Card and Krueger, 1994), negative (Clemens and Wither, 2019; Harasztosi and Lindner, 2019), or economically marginal (Cengiz et al., 2019; Dube et al., 2010) effects. Our contribution is to reconcile the evidence by showing theoretically and empirically how in a monopsonistic labour market the aggregate employment effect can be positive or negative, depending on where the level is set relative to local productivity.

In doing so, we build on a history of thought on how monopsony (Stigler, 1946) and search models (Brown et al., 2014; Blömer et al., 2018) can rationalize positive and negative employment effects of minimum wages. To substantiate the theoretical argument, Neumark (2017) calls for explicit evidence linking predictions of the monopsony model to minimum wage effects in the data. Our contribution to the debate is to show that the monopsony model generates an bell-shaped employment effect of a national minimum wage across regions of distinct productivity levels that is supported by evidence.

Also approaching minimum wage effects from the angle of a monopsonistic labour market, Manning (2003) argues that the appropriate research question is not *if* a minimum wage has negative employment effects, but *at what level*. Our contribution is to provide a first point of reference in that the employment effect is predicted to turn negative in regions where the national minimum wage corresponded to more than 80% of the regional median wage.

While the positive literature on minimum wage effects is extensive, the normative literature on minimum wages is much smaller. Allen (1987) and Guesnerie and Roberts (1987) find that minimum wages are in conflict with the optimal non-linear tax system whereas Lee and Saez (2012) argue that minimum wages can be optimal even in perfectly competitive labour markets since the distributional effects outweigh the unemployment effects. Our contribution to this literature is to show how in an imperfect labour market an employment-maximizing minimum wage can be desirable from an efficiency *and* equity perspective.

The remainder of the paper is structured as follows. Section 2 introduces into the institutional and empirical context. Section 3 provides reduced-form evidence that motivate our modelling choices. Section 4 develops our quantitative model and derives key predictions on minimum wage effects. Section 5 provides model predictions and reduced-form evidence on the bell-shaped relationship between the regional employment effect of the minimum wage and the regional productivity. Section 6 concludes.

2 Empirical context

2.1 The German minimum wage

The first uniformly binding federal minimum wage was introduced in Germany in 2015. Since then, German employers have to pay at least 8.50 euros per hour corresponding to 48 percent of the median salary of full-time workers. This level is high compared to the US (36 percent) and because no similar regulation preceded the statutory wage floor, it represented a potentially significant shock to regions in the left tail of the regional wage distribution. Subsequently, the minimum wage has been raised to 8.84 in 2017, 9.19 in 2019. It is set to increase to 9.35 in 2020.

2.2 Data

In our empirical analysis we make use of a variety of data sets from different sources. We provide a brief summary here and more detail in the appendix. Our primary data source are the Employment Histories (BeH) and the Integrated Employment Biographies (IEB) provided by the Institute of Employment Research (IAB) which contain individual-level data on the universe of labour market participants in Germany. Despite their comprehensiveness, the data do not include information about the number of hours worked. We follow Ahlfeldt et al. (2018) and impute average working hours separately for full-time and part-time workers from an auxiliary regression that accounts for sector of employment, federal state of employment, and various socio-demographic attributes and uses a 1% sample from the 2012 census (for details see appendix). We find that full-time employees work approximately 40 hours per week while the number is lower for regularly employed (21 hours) and for marginally employed part-time workers (10 hours). Combining working hours with average daily earnings delivers hourly wages. We also make use of property micro data from Immoscout24 covering more than 16.5 million sales proposals for apart-

ments and houses between 2007-2017.[1] Moreover, we utilize regionally disaggregated data on consumer prices and local business tax revenues from the federal statistical office. The spatial unit of analysis are 4,460 municipalities (*Verbandsgemeinden*).

2.3 Stylized facts

In this section we provide descriptive evidence on how the minimum wage affected the spatial structure of the economy in Germany. In panel (a) of Figure 1, we illustrate a measure of the regionally differentiated "bite" of the national minimum wage, very much in the tradition of Machin et al. (2003). Concretely, we compute the average of the shares of below-minimum-wage workers across municipalities, weighted by the bilateral commuting flows from the year 2014 according to

$$T_i = \sum_j \frac{L_{i,j}}{\sum_j L_{i,j}} S_j^{MW}, \qquad (1)$$

where $L_{i,j}$ is the number of commuters from municipality i into j and S_j^{MW} is the share of workers compensated below the minimum wage in j. This way, we incorporate the bite the policy might have in j, which could transmit to i through commuting linkages. Evidently, the minimum wage had a greater bite in the east, in line with the generally lower productivity. In panel (b) of Figure 1, we show that changes in low wages from 2014 to 2016, defined as the 10th percentile in the wage distribution, seem to be related to the distribution of the bite, suggesting a significant degree of compliance.

Figure 2 substantiates that the introduction of the minimum wage is associated with a decrease in spatial inequalities in low wages. The east-west gap in the 10th-percentile wage declines relatively sharply in 2015 (panel (a)). The dispersion in low wages across municipalities summarized by the coefficient of variation also decreases sharply in 2015, revealing spatial convergence (panel (c)). In contrast, there is little evidence for minimum wage effects on employment at the aggregate level. Employment in the east and in the west continues to grow (panel (b)). If anything, employment grows even faster in the east where the minimum wage had a stronger bite. Dispersion in employment across municipalities, if anything, increases (panel (d)).

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[1]See appendix for details. The data were accessed via the FDZ-Ruhr, see (**?**).

Figure 1: Minimum wage bite and change in 10th pct. regional wages

(a) Minimum wage bite
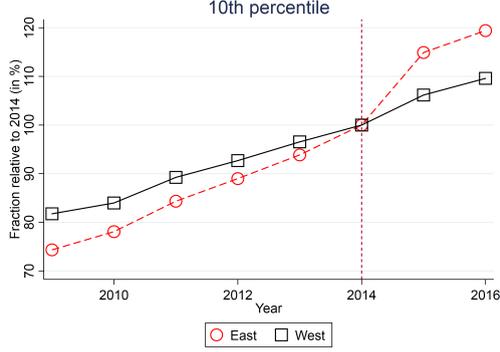
(b) Low-wage changes
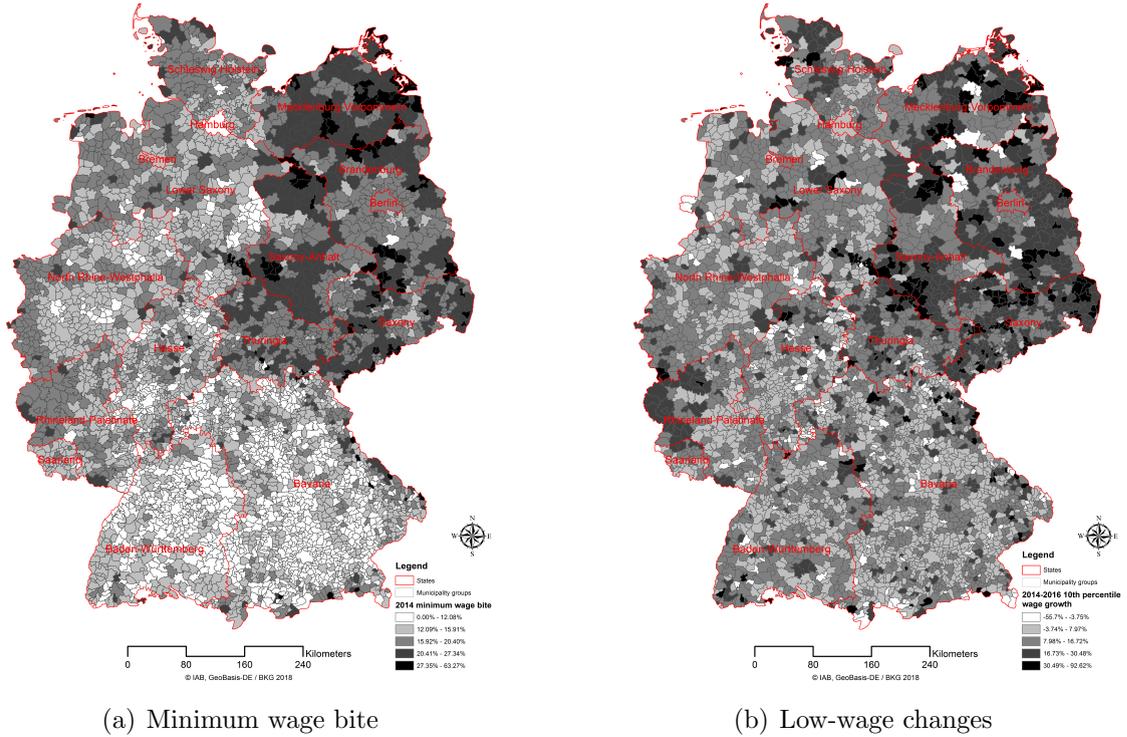
Note: Unit of observation is 4,460 municipalities. The 10th percentile wage refers to the 10th percentile in the distribution of individuals within a workplace municipality, re/weighted to the residence municipality using commuting flows. Wage and employment data based on the universe of full-time workers from the IAB.

3   Programme evaluation

3.1   Empirical strategy

Reduced-form programme evaluation methodologies represent a widely applied tool in the evaluation of minimum wage effects (Harasztosi and Lindner, 2019; Card and Krueger, 1994). In our implementation of this technique, we exploit that the German nationally uniform minimum wage had a different bite across regions, as illustrated in Figure 1. Specifically, we identify the minimum-wage-policy effect from a comparison of municipalities experiencing different intensities of treatment (bite) before and after the minimum wage introduction in a canonical difference-in-difference setting. We expand on the analysis by Ahlfeldt et al. (2018) and evaluate the regional effects of the minimum wage on a battery of outcomes using the following
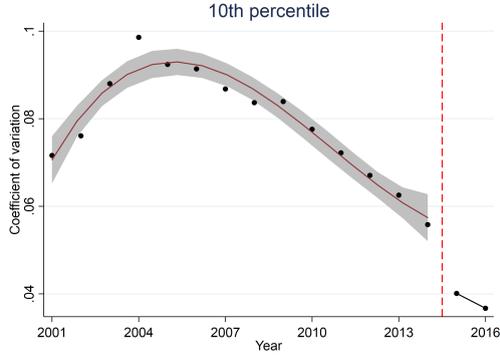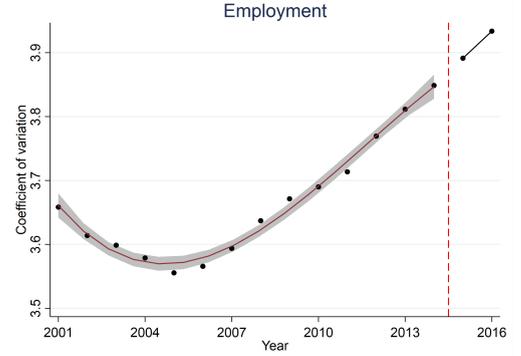
Figure 2: Convergence

(a) 10th pct. wage level
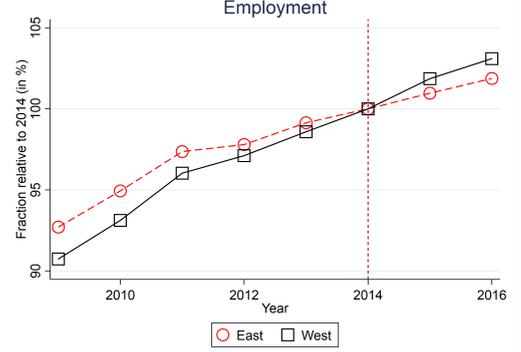
(b) Employment level

(c) 10th pct. wage variation

(d) Employment variation

Note: Coefficient of variation in (c) and (d) computed across 4460 municipalities. The 10th percentile wage refers to the 10th percentile in the distribution of individuals within a municipality. Wage and employment data based on the universe of full-time workers from the IAB.

specification:

$$Y_{i,r,t} = \sum_{z \neq 2014} a_z (T_i \times I(t=z)_t) + b_{r,t}^R + b_i^M + e_{i,r,t}, \tag{2}$$

where $Y_{i,r,t}$ denotes an outcome measured in municipality i in region $r = \{$east,west$\}$ in year t, T_j is the regional minimum wage bite measure defined in (1) and $I(.)$ is an indicator function returning one if a condition is fulfilled and zero otherwise. We measure worker outcomes at the residence and firm-level outcomes at the workplace. $b_{r,t}^R$ are region-year fixed effects, controlling for the legacy of the country's division owing to sluggish spatial arbitrage. b_i^M are municipality fixed effects controlling for unobserved time-invariant characteristics. a_z are the parameters of interest, which give the non-parametric trend in the marginal effect of the minimum wage bite normalized by the value in the base year 2014, i.e. $\alpha_z = \partial Y_{t=z}/\partial T - \partial Y_{t=2014}/\partial T$.

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We follow Monras (2019) and pre-process the data by removing county-specific trends fitted into the pre-period (2011-2014), before estimating equation (2). Thus, we present causal effects of the minimum wage bite under the identifying assumption that arbitrary linear trends observed during the pre-period extrapolate to plausible counterfactual trends during the post period. This approach has the advantage of delivering post-period effects that can be interpreted as treatment effects and pre-period effects that can be interpreted as placebo tests. In the appendix, we present the results of an alternative approach that delivers treatment effects in the spirit of Ahlfeldt et al. (2018) and Dustmann et al. (2019) in one estimation step at the expense of not delivering the pre-period placebo tests.

3.2 Results

Figure 3 summarizes the key findings of our reduced-form analysis of regional minimum wage effects on a variety of outcomes using conventional event-study graphs. In each panel, we report a 2016 treatment effect which, under the assumptions made, can be interpreted as the causal effect of an increase in the 2014 share of workers below the minimum wage by one percentage point (pp) on the (log) level of an outcome in 2016. For an intuitive interpretation, it is helpful to recognize that the inter-decile range in the minimum wage bite is about 10 pp. Note that in the remainder of this sub-section we touch upon results that, in the interest of a compact presentation, are relegated to the appendix.

From panel (a), we conclude that the minimum wage led to a relative increase in the aggregate wage bill in high-bite regions, i.e. the presumably positive effect on wages must have been greater than the potentially negative effect on labour demand. The effect is sizable in that a 10-pp increase in the bite leads to an increase in the wage bill of about 2%. Breaking down the effect into price and quantity effects in panels (b) and (c) reveals that, indeed, there is a positive impact on wages in the left-tail of the within-municipality wage distributions. A 10-pp increase in the bite leads to 7% increase in the 10th-percentile wage, once more confirming that many employers complied with the policy. There are spillover effects at higher percentiles in the within-municipality wage distribution, but these tend to be economically marginal and statistically insignificant beyond the 30th percentile (see appendix). Perhaps more surprisingly, the effect on employment is positive. At 0.7% for a 10-pp increase in the bite, the employment effect accounts for about one third of the effect of the wage bill. Further, the labour force (the working-aged population, irrespective of the employment status) grows in relative terms in high-bite regions, although at a smaller rate (4%), implying a positive effect on net-in-migration and
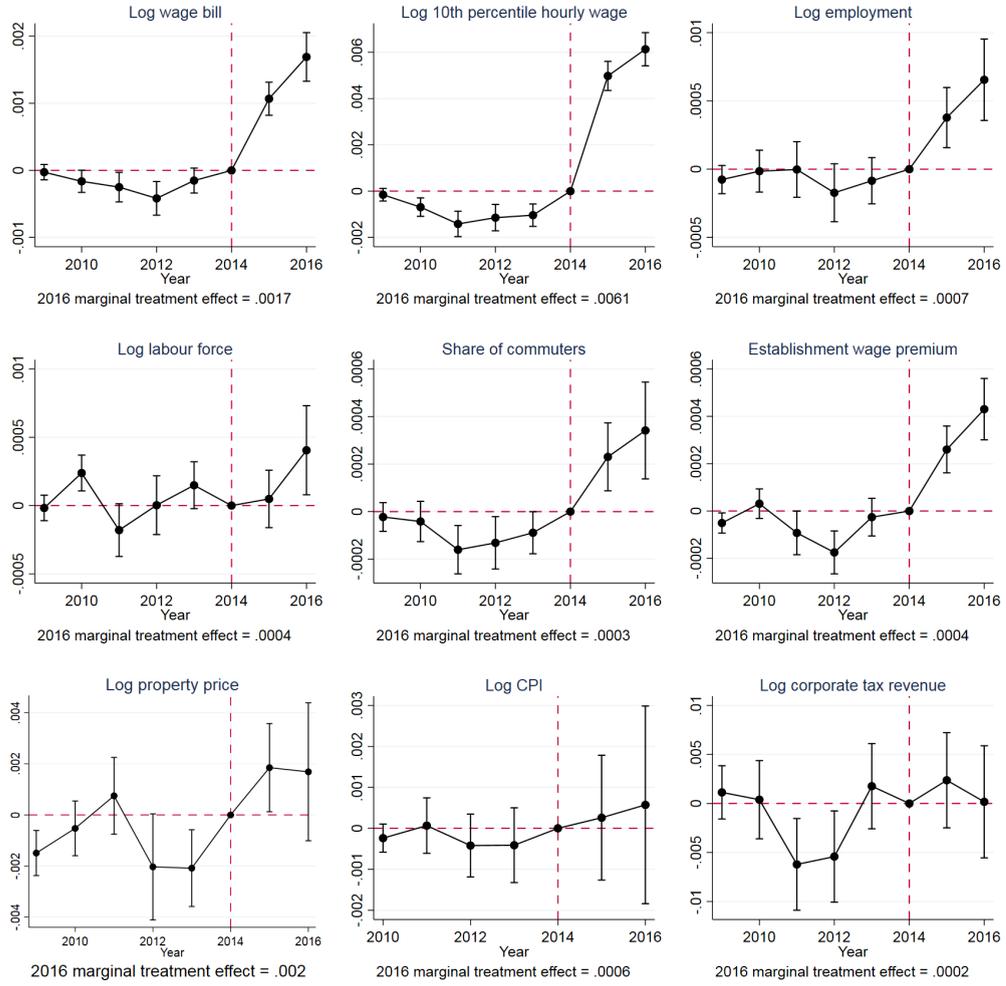
the employment rate (see appendix for additional evidence).

The effects on the workplace location choice seem to be even more pronounced as there is a relatively sharp increase in the share of cross-municipality commuters in high-bite regions (panel e). This effect is similarly strong when commuting is measured in terms of driving times or the share of cross-municipality commuters (see appendix). Panel (f) rationalizes the, on average, longer commutes by sorting into more productive establishments. To measure this sorting effect, we aggregate time-invariant establishment productivity using time-varying employment weights and use the results as an outcome measure. To obtain establishment productivity, we employ the conventional wage decomposition into worker and establishment fixed effect following Abowd et al. (1999) (see appendix for details). For a detailed analysis of the minimum wage effects on cross-establishment worker sorting, we recommend Dustmann et al. (2019). In this context, it is worth noting that we do not find convincing evidence for effects on transition rates from employment to unemployment or vice versa.

In panel (g), we turn out attention to house prices. It appears that house prices increased in high-bite regions, which is consistent with an increase in demand owing to a greater wage bill that interacts with short-run inelastic housing supply. In fact, the treatment effects on the wage bill and on house prices are within close range. For consumer prices, the point estimates suggest a positive effect on regional price trends, which would be consistent with producers passing on some of the additional labour cost onto consumers (panel h). The estimates, however, are quite imprecise, likely because we measure consumer prices at the level of federal states (the highest spatial detail available in federal statistics). For further evidence on positive, sizable, and significant effects of the minimum wage on consumer prices, we, thus, refer to Link (2019) who uses firm-level data from the ifo Business Survey. For housing prices, we find positive and significant effects (panel i), consistent with a positive demand shock that interacts with inelastic housing supply. Concretely, a 10-pp increase in the minimum wage bite leads to a 3% increase in housing costs. Finally, we note that, unfortunately, we can measure the minimum wage effects on firm profits indirectly and imperfectly through local business taxes. Possibly due to the limitation of the data, we do not find significant effects on firm profits (see appendix).

One naturally wonders whether the minimum wage effects summarized in Figure 3 are driven by selected industries. To address this question, we replicate most of the above analyses using sector-specific outcome and bite measures. The interested reader will find a battery of results in the appendix. In Figure 4, we focus on some of the arguably more interesting outcomes. In panel (a), we report the 2016

Figure 3: Time-varying treatment effects

treatment effects on employment, separately estimated for 20 sectors (on the y-axis). Correlating these with the 2016 treatment effects on the 10th percentile wage (on the x-axis), we ask whether a minimum wage policy has a more detrimental employment effect in sectors where the minimum wage is more binding. Perhaps surprisingly, the answer is not a definitive yes. Wage and employment effects are at best weakly correlated across sectors. More generally, we cannot reject a zero-employment effect at conventional significance levels for 12 out of 20 sectors. In panel (b), we similarly ask the question if the commuting effect is driven by selected sectors. Not surprisingly, the commuting effect tends to be positive and significant in those sectors where we find a negative and significant effect on employment (A,L,O).

However, significant commuting effects also arise in a range of other sectors and there is, again, little correlation with the strength of the wage impact.

Figure 4: Treatment effects by sectors
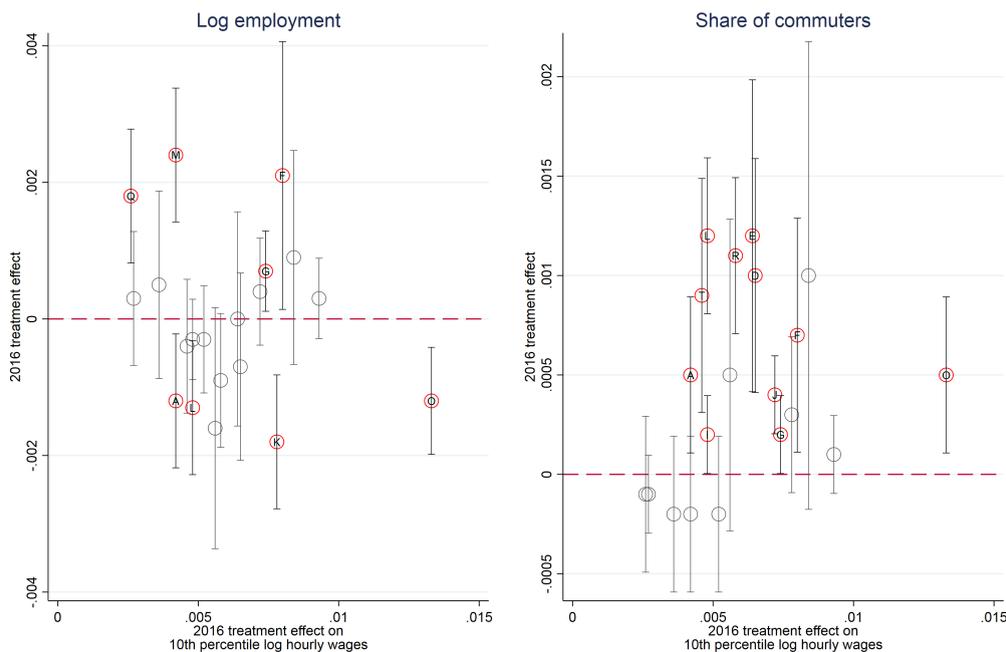
Note: If the 2016 treatment effect of the outcome variable is statistically significant at the 0.05 level, the corresponding marker is labelled. If in addition, the 2016 treatment effect on the log 10th percentile hourly wage is significant, the marker is a red circle. We provide a mapping sector codes (capital letters) to sector descriptions in appendix .2.1. Unit of observation in the underlying analyses is 4460 municipalities. The 10th percentile wage refers to the 10th percentile in the distribution of individuals within a municipality. Time-varying treatment effects are estimated according to (2) and then stripped off by a linear trend estimated in an auxiliary regression of the α_z treatment effects against a time trend using the pre-period (until 2014). Wage and employment data based on the universe of full-time workers from the IAB.

3.3   Theoretical implications

The perhaps most important insight that emerges from the reduced-form evidence presented so far is that the exogenous increase in the cost of labour in the left tail of the wage distribution owing to the minimum wage is not associated with a decrease in employment. This echoes existing evidence on minimum wage effects in Germany (Ahlfeldt et al., 2018; Caliendo et al., 2018; Dustmann et al., 2019), and beyond (Neumark, 2017; Manning, 2016) and is of crucial importance for our modeling assumptions. This finding is inconsistent with a competitive labour market model in which workers are compensated according to the marginal productivity. We conclude that a monopsony model is better suited for a quantitative evaluation of the effects of the German minimum wage effects. As we discuss in detail in the next section, the sorting effect of workers into more productive establishment is consistent with the monopsony model if there is heterogeneity in firm productivity.

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In contrast, the minimum wage effects on unemployment appear to be marginal and, if anything, the unemployment rate decreases slightly in high-bite regions. Thus, we abstract from unemployment in our model. Finally, we find little systematic variation in employment effects across sectors, which is consistent with a relatively homogeneous labour supply elasticity across sectors in Germany (Bachmann and Frings, 2017).

4 Model

We model an economy with $i, j \in J$ regions endowed with workers L and land/ housing stock H. The economy has one sector producing a differentiated good under monopolistic competition where firms differ with regard to total factor productivity and, importantly, exert monopsony power in their hiring and wage offer behavior.

4.1 Preferences and demand

The utility of a worker ω living in region i and working in region j is given by

$$U_{ij\omega} = \frac{b_{ij\omega}}{\kappa_{ij}} \left(\frac{Q_{i\omega}}{\alpha} \right)^{\alpha} \left(\frac{H_{i\omega}}{1-\alpha} \right)^{1-\alpha}, \tag{3}$$

where $Q_{i\omega}$ denotes the quantity of a freely-tradable differentiated good, $H_{i\omega}$ represents consumption of housing, κ_{ij} captures bilateral commuting costs and $b_{ij\omega}$ is a location-worker-specific amenity parameter. The differentiated good is aggregated according to

$$Q_{i\omega} = \left[\sum_{j \in J} \int_0^{M_j} q_{ji}(\nu)^{\frac{\sigma-1}{\sigma}} d\nu \right]^{\frac{\sigma}{\sigma-1}}.$$

The elasticity of substitution between varieties, $\sigma > 1$, is assumed to be constant and $q_{ji}(\nu)$ denotes the quantity of variety ν that is produced in region j and consumed by a worker living in region i. M_j is the measure of firms located in region j.

Utility maximization implies that households dedicate fixed income shares α and $1 - \alpha$ to tradable varieties and housing. Denoting by $w_{ij\omega}$ wage income of resident ω in i, we have

$$Q_{i\omega}^* = \frac{\alpha w_{ij\omega}}{P_{Q,i}}; \qquad H_{i\omega}^* = \frac{(1-\alpha)w_{ij\omega}}{P_{H,i}}, \tag{4}$$

where $P_{Q,i}$ is the price index of the composite good and $P_{H,i}$ denotes the price per unit of housing in region i. In the case of the tradable good, the demand of worker

ω in region i for a variety ν imported from j is given by

$$q_{ji}(\nu) = \frac{p_{ji}(\nu)^{-\sigma}}{P_{Q,i}^{1-\sigma}} \alpha w_{ij\omega}, \qquad (5)$$

with $p_{ji}(\nu)$ denoting the corresponding consumer price. Notice that landowners and firm owners spend their entire income on consumption goods such that total expenditure on Q_i equals $P_{Q,i}Q_i = (\alpha \tilde{w}_i^R + (1-\alpha)\tilde{w}_i^R)R_i + \Pi_i = \tilde{w}_i^R R_i + \Pi_i$ with $\tilde{w}_i^R$ representing average wage income of residents and Π_i summarizes aggregate firm profits in i. This formulation implies that aggregate income equals expenditure on the differentiated good in every region, so $P_{Q,i}Q_i \equiv E_i$.

Housing market clearing determines the housing price as a function of the exogenous supply H_i:

$$P_{H,i} = \frac{(1-\alpha)\tilde{w}_i^R R_i}{H_i}. \qquad (6)$$

4.2 Production and labor market

Technology. Firms in the tradable goods sector are heterogeneous with regard to their productivity φ. They operate under increasing returns to scale and monopolistic competition so every firm produces a unique variety ν of the differentiated good Q. We abstract from trade costs to treat the economy as a fully-integrated market with aggregate expenditure $E = \sum_i E_i$. Further, firms charge the same price in all regions, $p_{ij} = p_i$, implying the same price index everywhere, $P_{Q,i} = P_Q$.

Although there is generally free entry in the economy and firms need to pay fixed costs to enter the market and start production, we regard them as sunk and focus on the short run with a fixed number of firms M_i in each location. We make this assumption to study the implications of the national minimum wage for firm profits and hence the distribution of income between firm owners, workers and land owners. Labor is required as the only variable input of production. Denoting by A_i a location-specific productivity shifter, a firm needs to hire

$$l_i(\varphi) = \frac{q_i(\varphi)}{A_i \varphi} \qquad (7)$$

workers to produce $q_i(\varphi)$ units of output.

Monopsonistic labor market. Firms have monopsony power when hiring workers. The labor supply curve that a firm is facing therefore slopes upwards implying that a higher level of firm employment can only be maintained if the firm pays higher wages (see, e.g., Manning 2003). One popular rationale for this

relationship has been offered by Burdett and Mortensen (1998). Employees search for more attractive wage offers from other firms on the job so that quit rates decline in the wage rate while hiring rates increase in labor remuneration. Therefore, a firm can only expand production and maintain a higher level of employment by paying higher wages. As an alternative, Egger et al. (2019) introduce worker-specific amenities for being employed at a specific firm which, in turn, allows the employer to offer wages less than the marginal value product. To keep the model simple in terms of notation, we are agnostic about the specific underlying mechanism and simply impose that a firm in location i has to pay a wage rate per worker

$$w_i(\varphi) = \delta_i l_i(\varphi)^\eta \tag{8}$$

to maintain an employment level $l_i(\varphi)$ with firm-specific labor-supply elasticity $\eta > 0$ and δ_i denoting the region-specific slope parameter.

Profit maximization under minimum wages. Taking technology and labor market characteristics together, the marginal cost of hiring one worker $MCL = (1 + \eta)\delta_i l_i(\varphi)^\eta$ depends on the employment level and falls short of average labor costs $ACL = \delta_i l_i(\varphi)^\eta$. When maximizing profits, firms choose the employment level that equates MCL with the marginal revenue product of labor $MRPL$. This can be obtained from partially differentiating revenues with respect to l_i. Expressing firm revenues as

$$r_i(\varphi) = p_i(\varphi)q_i(\varphi) = [l_i(\varphi)A_i\varphi]^{\frac{\sigma-1}{\sigma}} \left(\alpha E P_Q^{\sigma-1}\right)^{-\frac{1}{\sigma}}, \tag{9}$$

the marginal change of revenues when hiring one additional worker reads

$$MRPL_i(\varphi) = \frac{\sigma-1}{\sigma}l_i(\varphi)^{-\frac{1}{\sigma}} \left(A_i\varphi\right)^{\frac{\sigma-1}{\sigma}} \left(\alpha E P_Q^{\sigma-1}\right)^{-\frac{1}{\sigma}}. \tag{10}$$

Figure 5 summarizes these functional forms graphically. ACL and MCL are upwards sloping and linear while $MRPL$ is convex due to the CES-assumption in demand for varieties of the differentiated good. Notice that $MRPL$ shifts outwards for higher productivity levels φ while the cost curves stay put. It will be helpful to define $\varphi^u > \varphi^s$ as productivity thresholds for unconstrained and supply-constrained firms, respectively. If $\varphi \geq \varphi^u$, a firm is unconstrained by the minimum wage in its hiring of workers. For all $\varphi^s \leq \varphi \leq \varphi^u$, firms are restricted by the firm-specific labor supply curve when hiring workers. All firms with $\varphi < \varphi^s$ are constrained by the firm-specific labor demand schedule ($MRPL$). In the sequel, we will derive these thresholds explicitly and provide more explanation using Figure 5.

Unconstrained firms. A firm is unconstrained if its voluntary wage offer is larger or equal to the mandatory minimum wage that we denote by $\bar{w}$. Hence, we search

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Figure 5: Profit-maximizing firm employment
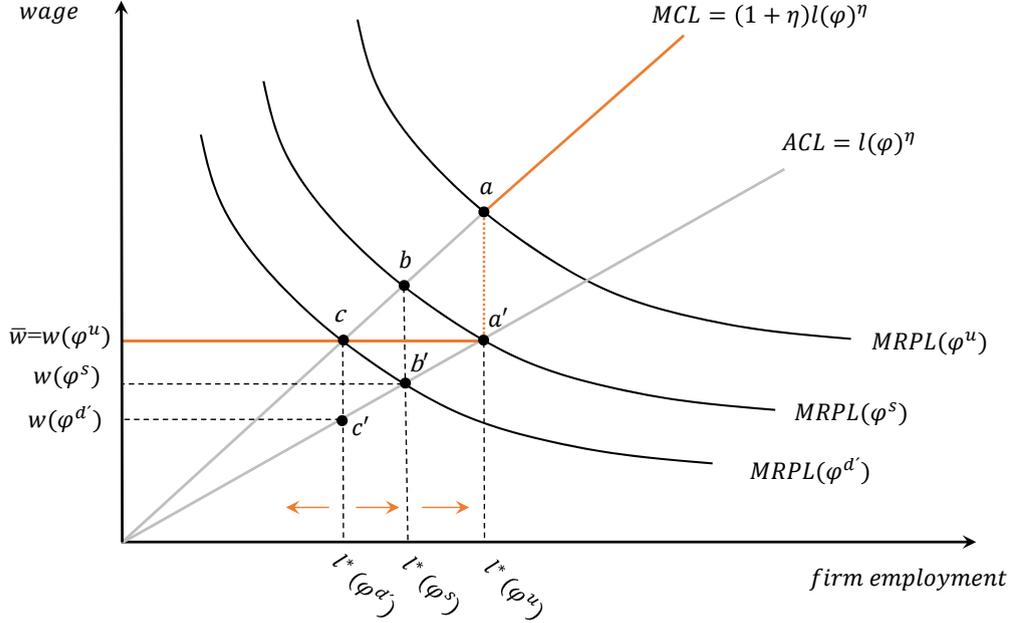
for the employment level that equalizes $MRPL$ and MCL to maximize profits. This condition reads

$$\frac{\sigma-1}{\sigma}l_i(\varphi)^{-\frac{1}{\sigma}}\left(A_i\varphi\right)^{\frac{\sigma-1}{\sigma}}\left(\alpha E P_Q^{\sigma-1}\right)^{-\frac{1}{\sigma}}=\delta_i l_i(\varphi)^{1+\eta}$$

and delivers

$$l_i^u(\varphi)=\left[\frac{\frac{\sigma-1}{\sigma}(A_i\varphi)^{\frac{\sigma-1}{\sigma}}\left(\alpha E P_Q^{\sigma-1}\right)^{\frac{1}{\sigma}}}{\delta_i(1+\eta)}\right]^{\frac{\sigma}{\eta\sigma+1}}. \tag{11}$$

To obtain the threshold φ^u that identifies the least productive unconstrained firm, we need to impose the condition that the minimum wage $\bar{w}$ equals average costs, so $\bar{w}=\delta_i[l_i^u(\varphi_i^u)]^\eta=ACL(\varphi_i^u)$. Plugging optimal employment of an unconstrained firm (11) into ACL and solving for φ_i^u yields

$$\varphi_i^u=\left[\frac{\bar{w}^{\frac{\eta\sigma+1}{\eta\sigma}}(1+\eta)\delta_i^{-\frac{1}{\eta\sigma}}}{\frac{\sigma-1}{\sigma}A_i^{\frac{\sigma-1}{\sigma}}\left(\alpha E P_Q^{\sigma-1}\right)^{\frac{1}{\sigma}}}\right]^{\frac{\sigma}{\sigma-1}}. \tag{12}$$

All firms in region i with $\varphi\geq\varphi_i^u$ are unconstrained by the minimum wage. Referring back to Figure 5, firm φ^u maximizes profits when choosing employment $l^*(\varphi^u)$ that is determined by the intersection of the MCL and the $MRPL(\varphi^u)$ schedule in point a. Due to monopsony power, however, the firm only needs to offer a wage according

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to average costs ACL determined in a'.

Supply-constrained firms. If we reduce firm productivity below φ^u, the hiring of workers becomes constrained via the upwards-sloping labor supply function because the firm would voluntarily make a wage offer to the worker which falls short of $\bar{w}$. To determine the least productive supply-constrained firms, we derive the threshold φ_i^s by imposing $\bar{w} = ACL(\varphi_i^s) = MRPL(\varphi_i^s)$. According to Figure 5, this firm would like to offer a wage $w(\varphi^s)$ in the absence of the minimum wage (determined by b and b' in the figure). The minimum wage, however, alters the labor supply curve to $\bar{w}$ such the profit-maximizing employment level for firm φ^s increases to $l^*(\varphi^u)$. Formally, we have

$$l_i(\varphi_i^s)^* = \left[\frac{\frac{\sigma-1}{\sigma}(A_i\varphi_i^s)^{\frac{\sigma-1}{\sigma}}\left(\alpha E P_Q^{\sigma-1}\right)^{\frac{1}{\sigma}}}{\delta_i} \right]^{\frac{\sigma}{\eta\sigma+1}}.$$

Setting $\bar{w} = \delta_i l_i^*(\varphi_i^s)^\eta$ then yields

$$\varphi_i^s = \left[\frac{\bar{w}^{\frac{\eta\sigma+1}{\eta\sigma}}\delta_i^{-\frac{1}{\eta\sigma}}}{\frac{\sigma-1}{\sigma}A_i^{\frac{\sigma-1}{\sigma}}\left(\alpha E P_Q^{\sigma-1}\right)^{\frac{1}{\sigma}}} \right]^{\frac{\sigma}{\sigma-1}}.$$

Both thresholds are increasing in the minimum wage. As profit-maximizing firm-level employment is given by $\bar{w} = ACL(\varphi)$ for $\varphi_i^u > \varphi \geq \varphi_i^s$, we have

$$l_i(\varphi) = \left(\frac{\bar{w}}{\delta_i}\right)^{\frac{1}{\eta}}.$$

Demand-constrained firms. Finally, firms with productivity $\varphi_i < \varphi_i^s$ are demand constrained. Reducing φ below φ^s shifts $MRPL$ towards the origin in Figure 5 such that profit-maximizing employment is determined by the intersection of $\bar{w}$ and $MRPL$. While firms with a marginally lower productivity level than φ^s find it optimal in increase employment in response to the introduction of the minimum wage $\bar{w}$, the least productive firms will *reduce* employment. We are able to determine this threshold, referred to as $\varphi_i^{d'}$, by imposing $\bar{w} = MCL(\varphi_i^d) = MRPL(\varphi_i^d)$. We use (11) together with MCL to get

$$\varphi_i^d = \left[\frac{\bar{w}^{\frac{\eta\sigma+1}{\eta\sigma}}[(1+\eta)\delta_i]^{-\frac{1}{\eta\sigma}}}{\frac{\sigma-1}{\sigma}A_i^{\frac{\sigma-1}{\sigma}}\left(\alpha E P_Q^{\sigma-1}\right)^{\frac{1}{\sigma}}} \right]^{\frac{\sigma}{\sigma-1}}.$$

All firms with $\varphi < \varphi^d$ reduce employment when the minimum wage $\bar{w}$ is introduced. Notice that this threshold increases in the minimum wage, too. The optimal

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Figure 6: Minimum wage effect on firm-level employment
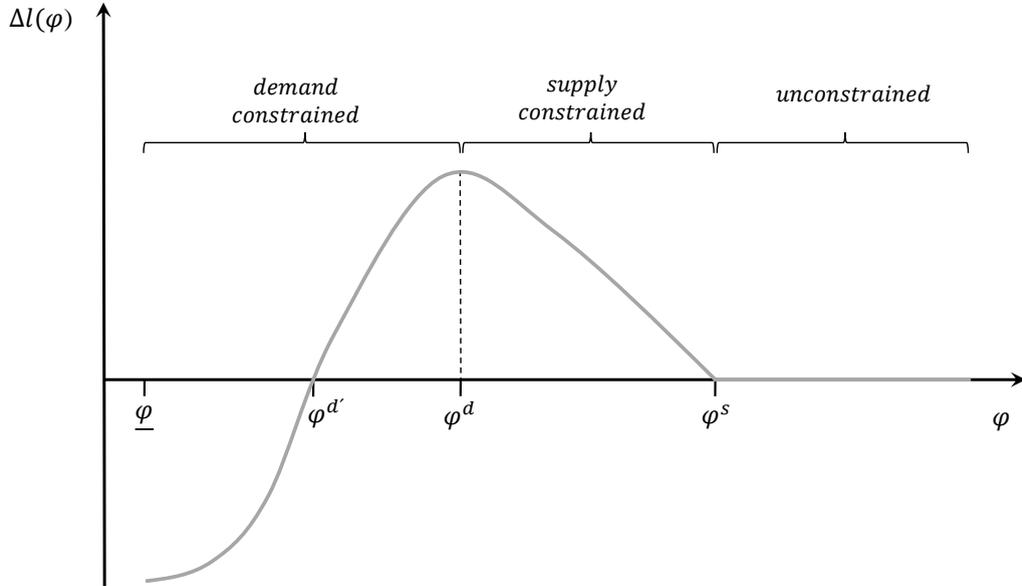
Note: Stylized illustration.

employment level for demand-constrained firms results as

$$l_i(\varphi) = \left(\frac{\sigma - 1}{\sigma \bar{w}}\right)^{\sigma} \frac{(\varphi A_i)^{\sigma - 1}}{\alpha E P_Q^{\sigma - 1}}.$$

Summing up, our model implies that the minimum wage alters the firm size distribution. Firms with $\varphi^{d'} < \varphi < \varphi^s$ expand their employment both in absolute and in relative terms while low-productivity firms shrink and high-productivity firms do not change their hiring strategy. This logic is graphically summarized in Figure 6.
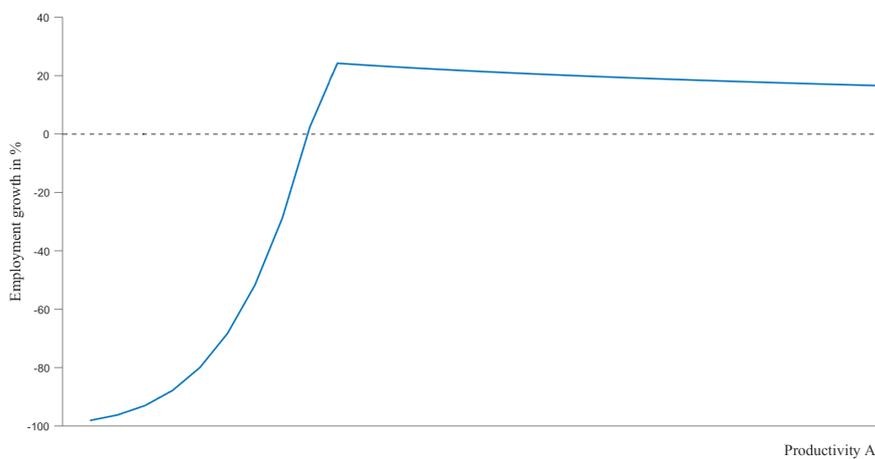
5 Employment effects by region

The model allows us to single out one prediction for the effect of a nationally uniform minimum wage that is of immediate policy relevance: We use the model to predict how the effect of a national minimum wage depends on a region's productivity. We then test whether the model predictions are consistent with evidence within a reduced-form estimation framework. This way, we provide a theory-guided and yet transparent and intuitive approach to evaluating the critical levels where the employment effect of a minimum wage reaches a maximum and turns negative. Since we fit the model using pre-minimum-wage data exclusively, the evidence provided in this section can be viewed as an over-identification test for the predictive power of the model.

5.1 Model prediction

Collecting firm-level employment and the cutoff productivities from Section 4.2, we derive aggregate employment per region based on the assumption of Pareto distributed productivities φ. In Figure 7, we illustrate the relative change in regional employment $\hat{L}_j = L_i^{MW}/L_i$ - defined as the ratio of the counterfactual employment in the minimum-wage scenario L_i^{MW} over the observed pre-minimum wage employment level L_i - as a function of regional productivity A_i. The model reveals a non-monotonic relationship. While low-productivity locations experience aggregate employment losses, employment increases in high-productivity regions. An increase in the minimum wage would shift the curve towards the right meaning that aggregate employment declines in a larger number of regions.

Figure 7: Regional minimum wage effects: Theoretical prediction

Note: Model-based simulation of general equilibrium effects of the introduction of the minimum wage for 4,460 municipalities. Changes are percentage changes from the observed regional employment in 2014 to counterfactual employment levels following the introduction of a €8.50 allowing for general equilibrium adjustments in all endogenous variables. Regional productivity is inverted using the structure of the model and a municipality-level wage index that is adjusted for individual fixed effects.

The main takeaway from Figure 7 is that in a monopsonistic labour market, a national minimum wage can have positive or negative regional (and, hence, national) effects, depending on a region's productivity. This is intuitive since in a low-productivity region the minimum wage effect is driven by demand-constrained firms, which are forced to reduce employment. At higher productivity levels, supply-constrained firms that expand employment become relatively more important. At very high productivity levels, the employment effect is dominated by unconstrained firms, which are not affected by the minimum wage.

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5.2 Empirical strategy

To evaluate the employment effect of the minimum wage within each of the 4,460 municipalities, we employ the following difference-in-differences specification:

$$Y_{w,j,r,t} = \sum_{z=2015,2016} a_z^j (T_{wj} \times I(t=z)_t) + b^T (T_{wj} \times t) \tag{13}$$
$$+ b_{r,t}^R + b_j^M + b_w^I + e_{w,j,r,t},$$

where $Y_{w,j,r,t}$ denotes the employment status of worker w, measured on a zero (unemployed)-one (employed) scale in year t at the workplace municipality j. T_{wj} is the worker-level minimum wage bite. This measure takes the value of one for workers in the treatment group exposed to the minimum wage and zero for a control group. We control for worker fixed effects b_w^I and, since workers can switch between municipalities, for municipality fixed effects b_j^M and region-year effects $b_{r,t}^R$. We estimate specification (13) in J municipality-specific separate regressions, so that focusing on z = 2016, we obtain J estimates of the municipality-j-specific treatment effects:

$$\hat{a}_j^{z=2016} = [E(Y_{wt})|(T_w=1) - E(Y_{wt})|(T_w=0)]^{j,t=2016} -$$
$$[E(Y_{wt})|(T_w=1) - E(Y_{wt})|(T_w=0)]^{j,t\leq 2014}$$

We define the treatment group to consist of workers who either earned an hourly wage in 2014 in municipality j below €8.50 or were unemployed. We assign unemployed workers to workplace municipalities based on their last workplace before 2014. The identifying assumption we make is that workers in the control group provide a credible counterfactual for the employment trend of treated workers. In selecting a plausible control group we face a trade-off in that workers earning just above €8.50 in the same municipality j in 2014 may be exposed to spillovers from the treatment group whereas higher-wage workers are likely exposed to different shocks than the treated since they likely work in occupations and sectors that differ from minimum wage workers. Facing this trade-off we select workers whose hourly wage in 2014 ranges between €12.50 and €17. We control for heterogeneity in outcome trends between workers in the treatment and control group, via the term $b^T (T_{wj} \times t)$ and, naturally, experiment with alternative specification of the control group. We note that specification (13) corresponds to the one-step alternative to the two-step approach used in 3, which produces identical point estimates (see appendix). We opt for the straightforward one-step approach here since the presentation of $J = 4,460$ event-study graph would be overwhelming.

We subject the estimated treatment effects $\hat{a}_j^{z=2016}$ to a second-stage analysis of

the following form:

$$\hat{a}_j^{z=2016} = c^R + \sum_{o=1,2} a_o^R (A_j)^o + X_j \rfloor + e_j, \tag{14}$$

where A_j is a measure of regional productivity, X_j is a vector of covariates that control for composition effects with respect to worker demographics and skills as well as occupations and industry sectors. Given the theoretical predictions depicted in Figure 7, we expect $a_1^R > 0$ and $a_2^R < 0$ from which it is straightforward to compute the critical points in the regional productivity distribution at which the employment effect of the minimum wage turns positive (first critical point) and when it reaches its maximum (second critical point).

5.3 Results

In Figure 8 we use a second-order polynomial to approximate the relationship between the estimated 2016 treatment effects $\hat{\alpha}_j^{z=2016}$ and different measures of regional productivity. To allow for an intuitive evaluation of how well the the second-order polynomial approximates the non-linear functional form in the data, we overlay the fitted lines with the averages of the estimated treatment effects within one-euro-per-hour bins. These bin averages are represented by circles whose size we make proportionate to the number of municipalities in a bin to reflect the distribution of regional productivity. Weather we use the worker-fixed-effects-adjusted regional mean wage A_j (left), the median wage (middle) or the 25th percentile wage (right) to approximate regional productivity, we find an inverse-u-shape relationship that is consistent with the theoretical predictions. The majority of municipalities have a regional productivity between the critical points. This suggest that the minimum wage had, indeed, positive employment effects in most municipalities. However, there is also a sizable number of municipalities in the left tail of the productivity distribution which experience negative employment effects. While there are fewer municipalities in the downward-sloping part of the distribution, it is still quite evident that beyond the second critical point, the effect of the minimum wage on employment no longer increases in productivity. For further evidence substantiating the prediction of a bell-shaped employment effect, we refer to Christl et al. (2018) who find a similar pattern in cross-country analysis of minimum wages and youth employment rates.

To inform policy, it is useful to express the regional productivity levels at the critical points relative to the minimum wage level. Focusing on the middle panel, the positive employment effect of the minimum wage is estimated to be largest (in 2016) in a region where the national minimum wage corresponds to 45% of the re-

Figure 8: Regional minimum wage effects: Reduced-form evidence
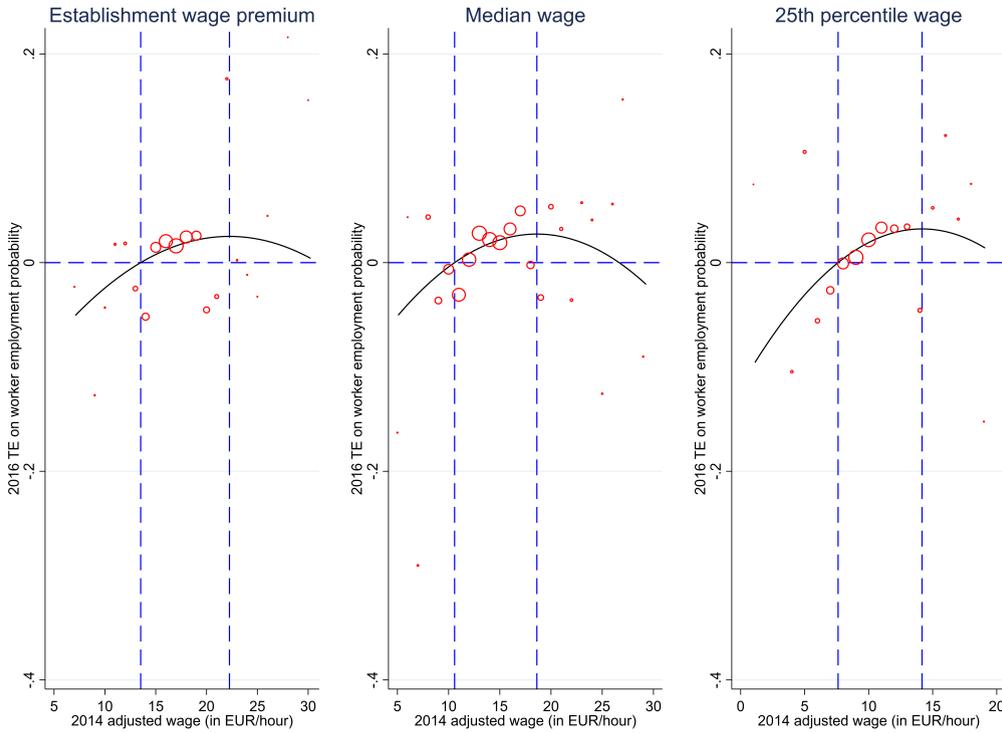
Note: Second-order polynomial fits of the unconditional relationship between 4,460 regional (municipality) minimum wage effects $\hat{\alpha}_j^{z=2016}$ estimated according to (13) (on the y-axis) and varying measures of regional productivity (on the x-axis). Each $\hat{\alpha}_j^{z=2016}$ estimate is derived from a within-municipality difference-in-difference analysis at the worker level, where the treatment group consists of workers who in 2014 in a given municipality where either unemployed or earned a wage below the €8.50 minimum wage and the control group consists of those who earned between €12.50 and €17. Circles represent the averages across all treatment effects within one-euro-per-hour bins. The size is proportionate to the number of municipalities within a bin. Vertical lines project the first (where the employment effect turns positive) and second (where the employment effect is maximized) critical points onto the x-axis. Municipality wage premium is the average 2014 wage, adjusted for individual effects following the standard AKM decomposition.

gional median wage (in 2016). In contrast, where the minimum wage exceeds 80% of the median wage, the employment effect is negative. The implication is that relatively small differences in the real minimum wage can make the difference between a positive and a negative employment effect. Against this background, the seemingly non-negative employment effect of the minimum wage in Germany is in line with a sufficiently moderate level of 48% of the national median wage (in 2014). However, assuming that the critical points expressed as fractions of the median wage generalize from the regional to the national level, it appears that the national minimum wage has been set slightly higher than the employment-maximizing level. The marginal effect of an increase in the minimum wage level (at constant productivity) might well be negative, with the most detrimental effects in low-productivity regions.

Of course, the evidence provided in Figure 8 is specific to the introduction of the minimum wage in Germany. While it is impossible to claim external validity,

it is at least reassuring that the estimates of the second-order polynomial function remain virtually unchanged if we estimate the full version of equation (14), controlling for composition effects related to worker demographics, skills, occupations, and industry sectors (see appendix). We stress that with respect to policy advise, we prefer an evaluation of minimum-wage effects within the full structure of the general equilibrium model as outlined in the next section. Nevertheless, the 44%-80% band for a minimum wage expressed a percentage of the median wage may represent a first point of reference for those wishing to ground the minimum-wage setting in transparent reduced-form evidence.

6 Conclusion

We show theoretically and empirically how in a monopsonisitic labour market the employment effect first increases and then decreases in the level of a binding minimum wage. Hence, a nationally uniform minimum wage may have positive aggregate employment effects at the expense of the least productive regions. In the case of Germany, the employment effects were most positive for regions where the minimum wage corresponded to 46% of the median wage. It was negative for regions where the minimum wage exceeded 80% of the median wage. These estimates provide first bounds for an evidence-based minimum wage setting that seeks to avoid detrimental effects of minimum wages.

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Appendix I: Empirics

This appendix complements the main paper by providing additional detail on the data, stylized facts on the spatial distribution of economic activity in Germany, and ancillary evaluations of minimum wage effects

.1 Establishment wage index

To obtain a mix-adjusted establishment wage index (superscript p below indicates plant ???), we conduct the following wage decomposition in the spirit of (Abowd et al., 1999):

$$\ln \mathcal{W}_{a,\omega,t} = \mathcal{X}_{a,t} b^p + c_a^p + W_\omega^p + e_{a,\omega,t}^w,$$

where $\ln \mathcal{W}_{a,\omega,t}$ is the log wage of worker a in establishment ω at time t, $\mathcal{X}_{a,t}$ are observable worker characteristics, c_a^p are worker fixed effects, and W_ω^p are establishment fixed effects. We recover the latter as a mix-adjusted establishment wage index for homogeneous workers.

.2 Region-year wage index

To obtain a mix-adjusted region-year index (what does supercript w stand for?), we follow a similar approach:

$$\ln \mathcal{W}_{a,j,t} = \mathcal{X}_{a,t} b^w + c_a^w + W_{j,t}^w + e_{a,j,t}^w,$$

where $\ln \mathcal{W}_{a,j,t}$ is the log wage of worker a in region j at time t, $\mathcal{X}_{a,t}$ are observable worker characteristics, c_a^w are worker fixed effects, and $W_{j,t}^w$ are region-year effects. We recover the latter as a mix-adjusted region-year wage index for homogeneous workers.

.2.1 Region-year rent index

To generate a mix-adjusted municipality-year house price index, we start from a micro data set covering close to 20 million transactions over the 2007-2018 period provided by the FDZ at RWI Essen (**?**). We eliminate outliers with less than 30 square meters or 500 square meters of floor space and per-square-meter prices of less than 20% or more than 500% of the county-year average. This shrinks the sample by about 2.5%.

On the remaining sample we run a locally weighted regressions (LWR) approach for target municipality $n \in J = 4460$. In each LWR, we predict a mix-adjusted

property price index for the target municipality using the following specification:

$$\ln \mathcal{P}_{s,i,k,t} = a^n + \bar{X}_s b^n + d^n D_{i,n} + e^n I(i=n)_i + \theta_{k,t}^n + \epsilon_{s,i,k,t}^n,$$

where s indexes a transaction, i indexes the municipality in which a transaction takes place, k indexes the county in which the transaction takes place, and t indexes the year of the transaction. $\bar{X}_s$ is a vector of covariates rescaled to a have zero mean and b^n are the LWR-n-specific hedonic implicit prices. For all hedonic attributes, we generate attribute-specific dummy variables indicating missing values and set the missing values to zero. $D_{i,n}$ is the distance from the transaction municipality i to the target municipality n with d^n being the LWR-n-specific gradient. $e^n I(i=n)_i$ is a transaction-municipality-specific effect in regression n. $\theta_{k,t}^n$ are LWR-n-specific county-year effects. $\epsilon_{s,i,k,t}^n$ are the residuals. In each LWR n, observations in i are weighted using the following kernel:

$$W_{i,n} = \frac{w_{i,n}}{\sum_i w_{i,n}},$$

$$w_{i,n} = \begin{cases} I(D_{i,n} \leq 10km), & \text{if } N^{D_{i,n} \leq 10km} \geq 10k \\ I(D_{i,n} \leq 25km), & \text{if } N^{D_{i,n} \leq 10km} < 10k \ \& N^{D_{i,n} \leq 25km} \geq 10k \\ I(D_{i,n} \leq 50km), & \text{if } N^{D_{i,n} \leq 25km} < 10k \ \& N^{D_{i,n} \leq 50km} \geq 10k \\ I(D_{i,n} \leq 100km), & \text{if } N^{D_{i,n} \leq 50km} < 10k \end{cases}$$

After each LWR n, we predict the index for target municipality $i = n$

$$\ln \mathcal{P}_{i=n,t} = \hat{\alpha}^n + \hat{e}^n I(i=n)_i + \hat{\theta}_{k,t}^n$$

Note that if there are no observations in municipality m, we have $I(i=i)_i = 0$ so that the term $\hat{e}^n I(i=n)_i$ drops out of the equation. $\ln \mathcal{P}_{i=n,t}$ is then predicted using a combination of county-year effects and within-county variation in distance from the target municipality. Intuitively, we predict the index at a distance $D_{i,n} = 0$ assuming a locally linear distance gradient and allowing for arbitrary local shocks at the county level. Sparse data at the county-year level is not an issue owing to the sheer size of the data set. To ensure that the municipality effect is reasonably representative, we require a minimum of 25 observations per municipality. Else, we set observations to missing and rely on the distance-based prediction.

Summary statistics

Add a summary table here.

Sector defitions

Add a table with the sector descriptions here

Stylized facts

Additional material on the spatial distribution of economic activity in Germany

Programme evaluation

Event study graphs

- treatment effects by wage percentile

One-step estimation of treatment effects