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Organised Labour, Labour Market Imperfections, and Employer Wage Premia

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Organised Labour, Labour Market Imperfections, and Employer Wage Premia*

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Abstract

This paper examines how collective bargaining through unions and workplace co-determination through works councils relate to labour market imperfections and how labour market imperfections relate to employer wage premia. Based on representative German plant data for the years 1999–2016, we document that 70% of employers pay wages below the marginal revenue product of labour and 30% pay wages above. We further find that the prevalence of wage mark-downs is significantly smaller when organised labour is present and that the ratio of wages to the marginal revenue product of labour is significantly bigger. Finally, we document a close link between labour market imperfections and mean employer wage premia, that is wage differences between employers corrected for worker sorting.

Keywords: collective wage agreements, employer monopsony, employer wage premia, labour market power, wage mark-downs, wage mark-ups, worker monopoly, works councils

JEL classification: D22, J31, J42, J50

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1 Introduction

It has not been long since most labour economists abandoned the textbook model of perfect competition and embraced the idea that workers and employers possess some market power in the wage formation process. In the broadest sense, imperfect competition in the labour market can be seen as a situation where substantial employment rents accrue to workers and employers (Manning, 2011). This vision immediately raises the question of how these rents are split among workers and employers.

Booth (2014) approaches this question by considering two polar cases of wage formation under imperfect competition: employer wage setting, where employers possess monopsony power, and union wage setting, where workers exercise monopoly power when negotiating wages. Compared to a competitive labour market, labour market imperfections may thus either result in a wage mark-down with employers' monopsony power allowing them to set wages below the marginal revenue product of labour, or in a wage mark-up with workers' monopoly power permitting them to push through wages above the marginal revenue product.

Against this backdrop, our contribution is to investigate for Germany the extent of labour market imperfections and how they relate to industrial relations and employer wage premia. To that end, we rely on the production-function approach to measure price-cost mark-ups from the industrial organisation literature (e.g. De Loecker and Warzynski, 2012; De Loecker *et al.*, 2016) and its extension to imperfect labour markets by Dobbelaere and Mairesse (2013) that encompasses both wage mark-downs and wage mark-ups.

To measure labour market imperfections at the individual employer level, we exploit Dobbelaere and Mairesse's (2013) result that labour market imperfections drive a wedge between the output elasticities of labour and intermediate inputs and their revenue shares. As shown in recent work by Caselli *et al.* (2021) and Yeh *et al.* (2022), this wedge directly translates into the ratio of wages to the marginal revenue product of labour when considering the market for intermediate inputs as competitive benchmark. The ratio, in turn, provides us with a direct reduced-form employer-level measure of labour market imperfections that allows the researcher to keep agnostic about market structure and is directly tied to employers' wage bill. So it is rooted in individual employers' exercise of rather than their potential for labour market power. What is more, using the production-function approach permits us to control for price-cost mark-ups and thus to account for a possible interdependency between labour and product market imperfections that would otherwise contaminate estimates of labour market imperfections (for a discussion in the case of price-cost mark-ups, see De Loecker *et al.*, 2016).

In this paper, we implement the production-function approach using a representative sample of about 9,000 German plants from the manufacturing and services industries for the years 1999–2016. At the heart of implementation lie sector-specific production-function estimates and employer-specific information on input use that allow us to measure the ratio of wages to the marginal revenue product of labour, where we follow recent contributions in the literature such as De Loecker and Warzynski (2012), De Loecker *et al.* (2016), and Yeh *et al.* (2022) and estimate production functions using Ackerberg *et al.*'s (2015) control function estimator.

This paper contributes to the literature in several ways. First of all, we will document the prevalence and size of wage mark-downs and wage mark-ups among German plants. We will then move on to investigate how collective bargaining by unions and workplace co-determination through works councils relate to their prevalence and size controlling for a rich set of plant characteristics. We expect to find such partial correlations because we expect organised labour to benefit workers in shifting market power from employers to workers. Finally, we will examine how the measures of labour market imperfections from the production-function approach relate to employer wage premia, that is to employers' wage levels after accounting for the sorting of workers of different quality into plants, holding constant plant surplus and a rich set of further plant characteristics. To measure employer wage premia, we will follow Card *et al.* (2018) and Hirsch and Mueller (2020) and rely on the employer wage effect from an AKM decomposition of individual workers' log wages (Abowd *et al.*, 1999).

2 Literature, hypotheses, and institutional backdrop

Whereas wage mark-ups and their theoretical foundation in union wage-bargaining models form the starting point of the broad empirical rent-sharing literature (surveyed by Card *et al.*, 2018, and Dobbelaere and Mairesse, 2018), wage mark-downs are at the heart of the recent literature on the prevalence and causes of monopsony in the labour market (for overviews, see Manning, 2011, 2021). Until recently, though, both strands of the literature evolved separately. What is more, in quantifying labour market imperfections they have largely neglected possible links between labour and product market imperfections that may contaminate findings.

This started to change with the extension of the production-function approach to measuring price-cost mark-ups from the industrial organisation literature to imperfect labour markets by Dobbelaere and Mairesse (2013). As shown in recent work by Caselli *et al.* (2021) and Yeh *et al.* (2022), this approach allows identifying the ratio of the wages paid by individual employers to the marginal revenue product of labour for a given price-cost mark-up on the product market.

What is lacking, though, is evidence on how labour market imperfections and industrial relations, such as collective bargaining through unions and workplace co-determination through works councils, relate. To be sure, there exists a large body of evidence that industrial relations affect the wages paid by employers including some recent papers identifying wage effects from quasi-experimental variation in industrial relations (e.g. Jäger *et al.*, 2021; 2022).[1] Yet, in analysing reduced-form effects of industrial relations on wages these contributions just consider end-points rather than the parameters we consider that permit direct measurement of how much wages deviate from the marginal revenue product of labour. What is more, evidence resting on quasi-experiments tends to look at specific instances rather than broad-based populations of employers and workers that we are able

[1] Interestingly, Jäger *et al.* (2021) find for Germany that co-determination at the firm level, which gives to worker representatives seats in the supervisory board of large companies, does not affect rent sharing. Note, however, that our paper is about co-determination at the workplace level through works councils, which is far more prevalent than board representation and also different in its scope. As a case in point, unlike labour representatives at the board works councils possess legal veto rights and thus cannot be overruled by management. We will provide details about works councils below.

to consider, though the recent papers by Farber *et al.* (2021) and Dodini *et al.* (2022) form notable exceptions. For these reasons, we see our contribution as complementary to this quasi-experimental evidence although, admittedly, we cannot rest identification on that kind of exogenous variation in industrial relations.

By examining how labour market imperfections relate to industrial relations, this paper not only contributes to the literature on the determinants of wage mark-downs and wage mark-ups, but it also adds to the literature on the falling labour share in income (e.g. Grossman and Oberfield, 2022). If organised labour matters for labour market imperfections in that it shifts market power from employers to workers, then the erosion of organised labour documented for Germany as for other countries may be one common source of the trend of a decreasing labour share in income.

Turning to the system of industrial relations in Germany, the principle of bargaining autonomy grants unions and employers the right to regulate wages and working conditions absent state interference. Collective agreements are legally binding, are predominantly concluded as multi-employer agreements between a union and an employers' association at the sectoral level, and almost always apply to all of the covered employers' workers irrespectively of workers' union status. Individual employers are usually bound by a collective agreement as soon as they decide to join an employer association. Motivations for opting in include saving on transaction costs in wage setting and other benefits offered by employer associations to member firms such as legal services, seminars, and lobbying. Although sectoral negotiations mostly take place in regional bargaining units, officials of the two bargaining parties closely coordinate the regional negotiations within one sector, so that variations between them are small. There even exists some cross-sectoral coordination by both parties, giving rise to some uniformity in collective bargaining policy across sectors (for details, see Hirsch and Schnabel, 2014).

Collective bargaining in Germany predominantly concerns wages, but also determines job classifications, working time, and working conditions. Norms stipulated in the collective agreement are generally minimum terms, so that employers bound by the agreement cannot undercut, but only improve upon these terms and conditions.

Exceptions to this general rule are in some cases laid down in so-called opening clauses that allow re-negotiating collective bargaining issues, mostly wages and working time, at the plant level, typically under conditions of economic hardship.

Whereas many employers pay higher wages than stipulated in the collective agreements (Jung and Schnabel, 2011) and opening clauses have gained ground, for most workers the wages set in the agreements are crucial for the level and development of their actual wages. At the end of our observational window in 2016, 58% (47%) of workers in West (East) Germany held jobs in the 32% (21%) of plants covered by a collective agreement (Ellguth and Kohaut, 2017). Compared to the start of our observation period, we see a marked fall in collective bargaining coverage. In 2000, 70% (55%) of workers in West (East) Germany were employed by the 48% (28%) of covered plants (Kohaut and Schnabel, 2003).

On average, plants covered by a collective agreement pay higher wages than uncovered plants (Guertzgen, 2009; Fitzenberger *et al.*, 2013). In a recent study, Hirsch and Mueller (2020) further show that higher average wages in covered plants reflect higher employer wage premia, holding constant plant surplus. They interpret their finding as evidence that collective bargaining increases workers' bargaining power. This interpretation is in line with evidence from the empirical rent-sharing literature and with a host of theoretical contributions arguing that collective bargaining enables workers to push through wage mark-ups. Hence, we expect a lower prevalence of wage mark-downs and, in general, a higher ratio of wages to the marginal revenue product of labour in covered than in uncovered plants.

On top of collective bargaining typically conducted at the sectoral level, the second backbone of Germany's dual system of industrial relations is given by workplace co-determination through works councils, the German counterpart of the workplace union in other countries. Works councils are mandatory but not automatic in all plants with at least five permanent workers, for setting up a works council requires three workers or a union representative to initiate an election procedure in the plant.

At the end of our observation period in 2016, 43% (34%) of workers in West (East) Germany were employed by the 9% (9%) of plants with a works council (Ellguth and

Kohaut, 2017). Like collective bargaining coverage, workplace co-determination dropped compared to the start of our observational window. In 2000, 50% (41%) of workers in West (East) Germany held jobs in the 12% (12%) of plants with a works council (Ellguth and Kohaut, 2018).[2] Together, shrinking collective bargaining coverage and works council prevalence point at an erosion of the traditional model of industrial relations in Germany.

Works councils have far-reaching co-determination rights, in particular on what are termed 'social matters', which comprise remuneration arrangements, the commencement and termination of working hours, the regulation of overtime and reduced working hours, as well as health and safety measures (for details, see Addison, 2009). Unlike unions, though, works councils may not call a strike and they are excluded from reaching agreement with the employer on wages and working conditions that are settled or normally settled by collective agreements between unions and employers' associations at the sectoral level. One exception to this general rule is that collective agreements contain opening clauses (mentioned before) that explicitly authorise works councils to do so.

However, even if opening clauses are absent, works councils' extensive co-determination rights on many other issues mean that works council existence is likely to improve workers' bargaining power and thus to spur rent-seeking activities (Freeman and Lazear, 1995). In line with this conjecture, extant studies have documented that works council presence is accompanied by higher average wages (Addison *et al.*, 2001, 2010). Furthermore, Hirsch and Mueller (2020) show that the higher average wages in plants with a works council mirror higher employer wage premia, holding constant plant surplus, and interpret their finding as evidence that workplace co-determination increases workers' bargaining power. Although we lack direct empirical evidence on how works council presence relates to labour market imperfections, we follow the received wisdom that it shifts market power from employers to workers and thus expect a lower prevalence of wage mark-downs and,

[2] Since employers are not allowed to interfere with works council introduction and since elected works councillors enjoy strict employment protection, the low prevalence of works councils implies that running a council imposes some costs on workers. First, as many employers have reservations against works councils (Mueller and Stegmaier, 2020), becoming exposed as a works councillor itself can be costly. Second, works councillors have to actively represent their colleagues' interests and will be made personally responsible for the negotiation outcomes. Time spent on work as a works councillor, however, counts as regular working time and thus not necessarily imposes extra cost on workers.

in general, a higher ratio of wages to the marginal revenue product of labour when works councils are present.

3 The production-function approach

To measure labour and product market imperfections at the level of the individual plant, we follow the production-function approach introduced by Dobbelaere and Mairesse (2013) and its modification by Yeh *et al.* (2022).[3] It allows to quantify by how much wages deviate from the marginal revenue product of labour based on production-function estimates and information on plants' input use. So it provides us with a reduced-form plant-level measure on the direction (i.e. wage mark-down vs. wage mark-up) and size of labour market imperfections. In this section, we will summarise the assumptions and outcomes of this approach, along with underlying intuitions, whereas we relegate derivations to Appendix A.

Consider plant i at time t with productivity level Ω_{it} that produces a good Q_{it} from its labour input N_{it}, its intermediate inputs M_{it}, and its capital input K_{it}, subject to the strictly increasing (in all its arguments) and concave production function:

$$Q_{it} = \Omega_{it} Q(N_{it}, M_{it}, K_{it}) \tag{1}$$

In terms of the plant's input choices, we assume (i) that labour and intermediate inputs are free of adjustments costs and are thus choice variables in the short run, (ii) that capital is predetermined and thus no choice variable in the short run, and (iii) that the plant takes the price of its intermediate inputs as given.[4] We further assume that all plants in the market maximise short-run profits. Then, the plant's optimisation problem involves

[3] In our data, we observe plants rather than firms and will thus refer to plants throughout the paper.

[4] Given recent evidence on imperfections in intermediate inputs markets by Morlacco (2020) and Dhyne *et al.* (2022), this latter assumption of price taking for intermediate inputs might be perceived as being restrictive. This evidence notwithstanding, we stick to the assumption for two reasons. The first is a data reason. Like Morlacco (2020), we could easily model imperfections in intermediate inputs markets as an additional unit cost that drives a wedge between the marginal cost of production and the marginal product of plants' inputs. Data constraints, however, prevent us from putting this approach to work. The second reason is that we want to focus our empirical analysis on the relationship between industrial relations and labour market imperfections faced by plants, abstaining from non-competitive buyer behaviour in the market for intermediate inputs.

maximising short-run profits with respect to output Q_{it}, labour N_{it}, and intermediate inputs M_{it}, and the corresponding first-order conditions allow us to infer the existing product and labour market imperfections.

Turning to the plant's product market first, we obtain the standard result that the plant's price is a mark-up over its marginal cost of production, where we denote the price-cost mark-up in the following by μ_{it}. Turning to the plant's choice of intermediate inputs next, we find that the price-cost mark-up is given as

$$\mu_{it} = \frac{(\varepsilon_M^Q)_{it}}{\alpha_{Mit}} \tag{2}$$

where $(\varepsilon_M^Q)_{it} = (\partial Q_{it}/\partial M_{it})(M_{it}/Q_{it})$ denotes the output elasticity of intermediate inputs, $\alpha_{Mit} = J_{it}M_{it}/R_{it}$ their revenue share, J_{it} their price, and $R_{it} = P_{it}Q_{it}$ the plant's revenues (see equation (A.4) in Appendix A.1). The intuition behind this result is that the plant will make economic profits when the output elasticity of intermediate inputs exceeds their revenue share and that these profits must stem from product market imperfections because the plant takes the price of intermediate inputs as given. Consequently, the gap between the output elasticity of intermediate inputs and their revenue share is informative on the price-cost mark-up.

Turning to the plant's labour market, the existence and size of possible wage mark-downs and wage mark-ups can be seen from the gap between the output elasticities of intermediate inputs and labour and their respective revenue shares

$$\psi_{it} = \frac{(\varepsilon_M^Q)_{it}/\alpha_{Mit}}{(\varepsilon_N^Q)_{it}/\alpha_{Nit}} = \frac{W_{it}}{(R_N)_{it}} \tag{3}$$

that gives the ratio of the plant's wage to the marginal revenue product of labour (see equation (A.7) in Appendix A.2 and Yeh *et al.*, 2022). In equation (3), $(\varepsilon_N^Q)_{it} = (\partial Q_{it}/\partial N_{it})(N_{it}/Q_{it})$ denotes the output elasticity of labour, $\alpha_{Nit} = W_{it}N_{it}/R_{it}$ its revenue share, W_{it} the wage, and $(R_N)_{it} = \partial R_{it}/\partial N_{it}$ the marginal revenue product of labour. We will, as a shorthand, often refer to ψ_{it} as the 'ratio' in the following. The intuition behind equation (3) is that in case of a wage mark-down the economic profits originating from the plant's labour input, which result in a gap between the output elasticity of labour and its revenue share, dominate those from its intermediate inputs, and thus a below-unity ratio ψ_{it} indicates a wage mark-down. Along the same lines, an above-unity ratio ψ_{it} indicates a wage mark-up.

The ratio ψ_{it} differs in several respects from other standard measures of employers' labour market power in the literature. In the monopsony literature, numerous studies measure employers' monopsony power by estimating the wage elasticity of the labour supply curve to the individual employer (see the survey by Manning, 2021, and the meta-analysis by Sokolova and Sorensen, 2021). As pointed out by Manning (2021), though, the labour supply elasticity is only a measure of potential monopsony power and its pass-through to wages may be constrained by other factors, such as the presence of organised labour. This contrasts with the ratio from the production-function approach that is rooted in employers' exercise of rather than their potential for labour market power. What is more, due to high data requirements most studies in the monopsony literature only provide estimates at a more aggregate level rather than at the level of the individual employer as does the production-function approach.

An alternative employer-level measure of labour market power that has recently been advocated in the literature is employer concentration in occupational labour markets (e.g. Azar *et al.*, 2022; Benmelech *et al.*, 2022; Rinz, 2022), which is found to negatively affect wages. There are, however, some downsides with this concentration approach. Other than the reduced-form measure from the production-function approach, it forces the researcher to take a stance on the relevant labour market of employers (say in terms of occupations, skills, and local labour markets) to measure concentration correctly.[5] Moreover, it is well known from the structure-conduct-performance paradigm of the industrial organisation literature (e.g. Syverson, 2019) that it is questionable to lend a causal interpretation to any reduced-form relationship between market shares and prices because these are simultaneously determined. Hence, an effect running from concentration to wages is unlikely to be informative on the underlying labour market power unless one is willing to

[5] The many problems involved when defining the relevant labour market are discussed in detail, e.g., by Schubert *et al.* (2022).

impose assumptions on the market structure, such as Cournot competition. Both these aspects contrast with the production-function approach that allows us to keep agnostic about market structure.

That being said, we also demonstrate in Appendices A.3 and A.4 that the ratio ψ_{it} has a one-to-one relationship to structural measures of employers' monopsony power when there is a wage mark-down and workers' monopoly power when there is a wage mark-up. So we can translate the reduced-form ratio ψ_{it} from the production-function approach into the implied labour supply elasticity or rent-sharing elasticity that rationalise the observed wage outcomes in a monopsony or efficient bargaining framework. Specifically, in case of a wage mark-down or $\psi_{it} < 1$ the wage elasticity of the labour supply curve to the plant in a simple monopsony model is given by (see equation (A.10) in Appendix A.3):

$$(\varepsilon_W^N)_{it} = \frac{\psi_{it}}{1 - \psi_{it}} \tag{4}$$

And in case of a wage mark-up or $\psi_{it} > 1$ the rent-sharing elasticity, that is the elasticity of wages with respect to the quasi-rent per worker, in an efficient bargaining model is given by (see equation (A.15) in Appendix A.4):

$$(\varepsilon_{QR/N}^W)_{it} = \frac{\psi_{it} - 1}{\psi_{it}} \tag{5}$$

4 Econometric implementation

Measuring labour and product market imperfections based on the ratio of wages to the marginal revenue product of labour ψ_{it} and the price-cost mark-up μ_{it} requires consistent estimates of the output elasticities of intermediate inputs $(\varepsilon_M^Q)_{it}$ and labour $(\varepsilon_N^Q)_{it}$ as well as their revenue shares α_{Mit} and α_{Nit}.

Production function. Taking the logarithm of the production function (equation (1)) results in:

$$q_{it} = f(n_{it}, m_{it}, k_{it}; \boldsymbol{\beta}) + \omega_{it} \tag{6}$$

with lower-case letters denoting logs of variables, e.g. $q_{it} = \ln Q_{it}$, $\boldsymbol{\beta}$ a vector of technology parameters that need to be identified, and ω_{it} a Hicks-neutral productivity shock observed by the plant, but unobserved by us. Enriching our empirical model by an idiosyncratic error term ϵ_{it} that comprises unpredictable output shocks as well as potential measurement error in output and inputs gives:

$$y_{it} = f(n_{it}, m_{it}, k_{it}; \boldsymbol{\beta}) + \omega_{it} + \epsilon_{it} \tag{7}$$

with $y_{it} = q_{it} + \epsilon_{it} = f_{it} + \omega_{it} + \epsilon_{it}$, where we assume ϵ_{it} to be mean independent of current and past input choices.

We approximate the unknown regression function $f(\cdot)$ by means of a second-order Taylor polynomial (including a full set of region dummies and a linear time trend, which we will omit in the following for notational ease):

$$\begin{aligned} y_{it} = {} & \beta_0 + \beta_n n_{it} + \beta_m m_{it} + \beta_k k_{it} + \beta_{nn} n_{it}^2 + \beta_{mm} m_{it}^2 + \beta_{kk} k_{it}^2 \\ & + \beta_{nm} n_{it} m_{it} + \beta_{nk} n_{it} k_{it} + \beta_{mk} m_{it} k_{it} + \omega_{it} + \epsilon_{it} \end{aligned} \tag{8}$$

where the regression constant β_0 measures the mean efficiency level across plants.

Identification. Identifying $\boldsymbol{\beta}$ relies crucially on the timing assumptions of the plant's input choices in combination with a functional form assumption on the productivity transition process to avoid bias from the endogeneity of input decisions to unobservable productivity ω_{it} (Marschak and Andrews, 1944). With respect to unobservable productivity, we assume that ω_{it} evolves according to an endogenous first-order Markov process. Following De Loecker and Warzynski (2012) and De Loecker (2013), we assume that the plant's decision to engage in exporting activity might endogenously affect future productivity, which is at the heart of the Melitz (2003) model and amply supported by existing evidence (e.g. Helpman, 2006; Bernard *et al.*, 2007, 2012).[6] Consequently, we can decompose ω_{it} into its expectation conditional on the information I_{it-1} available to the plant in $t-1$ and a

[6] By allowing a plant-level decision (i.e. export participation) to directly affect the plant's future productivity, we address the potential problem of restricting the productivity process to be exogenous (see fn. 8).

random innovation to productivity denoted by ξ_{it}:

$$\omega_{it} = \mathrm{E}[\omega_{it}|I_{it-1}] + \xi_{it} = \mathrm{E}[\omega_{it}|\omega_{it-1}, EXP_{it-1}] + \xi_{it} = g(\omega_{it-1}, EXP_{it-1}) + \xi_{it} \quad (9)$$

In equation (9), EXP_{it-1} denotes plant i's export status in $t-1$, $g(\cdot)$ denotes some function, and ξ_{it} is assumed to be mean independent of the plant's information set I_{it-1} in $t-1$.

As elaborated in Section 3, labour and intermediate inputs are assumed to be variable inputs whereas capital is predetermined. We assume that plants decide on their capital input k_{it} one period ahead at time $t-1$, that is before the productivity shock ξ_{it} is observed by the plant, which reflects planning and installation lags and causes capital to be predetermined. Among the variable factors of production, we assume that labour n_{it} is less variable than intermediate inputs m_{it} in that it is determined by plants at time $t-b$ with $0 < b < 1$. Hence, plants choose labour after capital but prior to intermediate inputs being chosen at time t, where the latter is in line with plants requiring time to train new workers, with significant firing or hiring costs, or with long-lasting labour contracts in internal labour markets or unionised plants.

To control for unobserved productivity, we use the control-function approach (Levinsohn and Petrin, 2003; Ackerberg *et al.*, 2015) that builds on the insight that plants' optimal input choices hold information about unobserved productivity and that is common in the literature using the production-function approach (e.g. De Loecker and Warzynski, 2012; De Loecker, 2013; De Loecker *et al.*, 2016; Yeh *et al.*, 2022). In particular, we invert the intermediate input demand function to recover the latent productivity level ω_{it}, which can be used to construct the productivity shock ξ_{it} using the productivity law of motion.[7]

Given the timing assumptions, plant i's demand for intermediate inputs in t directly

[7] An alternative identification strategy is to combine the timing assumptions with the dynamic panel approach of Blundell and Bond (2000). The latter assumes that productivity follows an $AR(1)$ process and relies on differencing out the persistent part of productivity. Imposing such $AR(1)$ rules out a richer productivity function $g(\cdot)$, though, and is far less used in empirical applications than the control-function approach.

depends on n_{it} as well as on the other state variables k_{it}, EXP_{it}, and ω_{it}:[8]

$$m_{it} = m_t(n_{it}, k_{it}, EXP_{it}, \omega_{it}) \tag{10}$$

Crucially, productivity ω_{it} is the only unobservable entering the demand function $m_t(\cdot)$. Provided strict monotonicity of the demand function with respect to ω_{it}, we can invert $m_t(\cdot)$ to infer ω_{it} from observables as:

$$\omega_{it} = m_t^{-1}(m_{it}, n_{it}, k_{it}, EXP_{it}) \tag{11}$$

Estimation. Using the timing assumptions of the plant's input choices in combination with the law of motion of productivity, we estimate the coefficients of a translog production function $\boldsymbol{\beta}$ for each two-digit sector using a two-stage procedure.

The first stage produces an estimate of the plant's log output net of idiosyncratic factors $q_{it} = y_{it} - \epsilon_{it}$. Plugging equation (11) into equation (7) results in a first-stage regression equation:

$$\begin{aligned} y_{it} &= f(n_{it}, m_{it}, k_{it}; \boldsymbol{\beta}) + m_t^{-1}(m_{it}, n_{it}, k_{it}, EXP_{it}) + \epsilon_{it} \\ &= \varphi_t(n_{it}, m_{it}, k_{it}, EXP_{it}) + \epsilon_{it} \end{aligned} \tag{12}$$

that we exploit to separate the productivity shock ω_{it} from the idiosyncratic ϵ_{it}. This first stage uses the regression equation (12) together with the moment condition $\mathrm{E}[\epsilon_{it}|I_{it}] = 0$ to obtain an estimate $\widehat{\varphi}_{it}$ of the composite term $\varphi_t(n_{it}, m_{it}, k_{it}, EXP_{it}) = f_{it} + \omega_{it}$. After the first stage we get an estimate of ω_{it} (up to a constant) for a given coefficient vector

[8] Adding the plant's export status EXP_{it} as an observed shifter to the plant's demand for intermediate inputs m_{it} while excluding it from the production function addresses a fundamental identification problem for the output elasticity of intermediate inputs and thus permits us to use Ackerberg *et al.*'s (2015) control function approach in the estimation of a gross output production function. To provide intuition for this problem, note that absent such a shifter the plant's demand for intermediate inputs would be $m_{it} = m_t(n_{it}, k_{it}, \omega_{it})$. In this case, unobserved productivity ω_{it} would be the only demand shifter except for the other inputs in the production function n_{it} and k_{it}. Since the output elasticity of intermediate inputs is identified from the co-movement of output and intermediate inputs holding constant the other inputs n_{it} and k_{it}, the only source of variation in the demand for intermediate inputs left would be unobserved productivity ω_{it}. Unobserved productivity ω_{it}, though, shifts both output and the demand of intermediate inputs, rendering the output elasticity of intermediate inputs unidentified in this case.

$\boldsymbol{\beta}$:

$$\begin{aligned}\widehat{\omega}_{it}(\boldsymbol{\beta}) &= \widehat{m}_t^{-1}(m_{it}, n_{it}, k_{it}, EXP_{it}) \\ &= \widehat{\varphi}_{it} - \beta_n n_{it} - \beta_m m_{it} - \beta_k k_{it} - \beta_{nn} n_{it}^2 - \beta_{mm} m_{it}^2 - \beta_{kk} k_{it}^2 \\ &\quad - \beta_{nm} n_{it} m_{it} - \beta_{nk} n_{it} k_{it} - \beta_{mk} m_{it} k_{it}\end{aligned} \tag{13}$$

We use the law of motion of productivity (equation (9)) in combination with equation (13) to recover the innovation to plant productivity (ξ_{it}) given $\boldsymbol{\beta}$. Specifically, we arrive at a consistent non-parametric estimate of the conditional expectation $\mathrm{E}[\omega_{it}|\omega_{it-1}, EXP_{it-1}]$ by taking the predicted value of a non-parametric (second-order polynomial) regression of $\widehat{\omega}_{it}(\boldsymbol{\beta})$ on $\widehat{\omega}_{it-1}(\boldsymbol{\beta})$ and EXP_{it-1}. The residual from this regression, in turn, provide us with a consistent estimate of $\xi_{it}(\boldsymbol{\beta})$.

The second stage produces estimates of the production function coefficients $\boldsymbol{\beta}$ through standard GMM using the moment conditions formed by the timing assumptions of our framework:

$$\mathrm{E}[\xi_{it}(\boldsymbol{\beta})(n_{it-1}, m_{it-1}, k_{it}, n_{it-1}^2, m_{it-1}^2, k_{it}^2, n_{it-1}m_{it-1}, n_{it-1}k_{it}, m_{it-1}k_{it})'] = \mathbf{0} \tag{14}$$

We arrive at estimates of the output elasticities $(\varepsilon_M^Q)_{it}$ and $(\varepsilon_N^Q)_{it}$ by combining the estimated $\widehat{\boldsymbol{\beta}}$ with data on plants' input choices:

$$(\widehat{\varepsilon}_M^Q)_{it} = \widehat{\beta}_m + 2\widehat{\beta}_{mm} m_{it} + \widehat{\beta}_{mn} n_{it} + \widehat{\beta}_{mk} k_{it} \tag{15}$$

$$(\widehat{\varepsilon}_N^Q)_{it} = \widehat{\beta}_n + 2\widehat{\beta}_{nn} n_{it} + \widehat{\beta}_{nm} m_{it} + \widehat{\beta}_{nk} k_{it} \tag{16}$$

Hence, both output elasticities vary across plants and over time.[9] Since the observed output $Y_{it} = Q_{it} \exp \epsilon_{it}$ includes idiosyncratic factors that are orthogonal to input use and productivity, we cannot take revenue shares from our data without correcting for these factors. Following De Loecker and Warzynski (2012) we do so by recovering an estimate

[9] Note that with a Cobb-Douglas production technology, output elasticities would simplify to $(\widehat{\varepsilon}_M^Q)_{it} = \widehat{\beta}_m$ and $(\widehat{\varepsilon}_N^Q)_{it} = \widehat{\beta}_n$ and thus vary neither across plants (within two-digit sectors) nor over time.

of ϵ_{it} from the production-function estimation and calculate adjusted revenue shares as:[10]

$$\widehat{\alpha}_{Mit} = \frac{J_{it}M_{it}}{P_{it}Y_{it}/\exp\widehat{\epsilon}_{it}} \tag{17}$$

$$\widehat{\alpha}_{Nit} = \frac{W_{it}N_{it}}{P_{it}Y_{it}/\exp\widehat{\epsilon}_{it}} \tag{18}$$

Combining the estimated output elasticities (15) and (16) and the adjusted revenue shares (17) and (18), we arrive at estimates of the price-cost mark-up and the ratio of wages to the marginal revenue product of labour:

$$\widehat{\mu}_{it} = \frac{(\widehat{\varepsilon}^{Q}_{M})_{it}}{\widehat{\alpha}_{Mit}} \tag{19}$$

$$\widehat{\psi}_{it} = \frac{(\widehat{\varepsilon}^{Q}_{M})_{it}/\widehat{\alpha}_{Mit}}{(\widehat{\varepsilon}^{Q}_{N})_{it}/\widehat{\alpha}_{Nit}} \tag{20}$$

We can further transform the ratio ψ_{it} into the implied labour supply elasticity in case of wage mark-downs or the implied rent-sharing elasticity in case of wage mark-ups that rationalise the observed wage outcomes in a monopsony or efficient bargaining framework:

$$(\widehat{\varepsilon}^{N}_{W})_{it} = \frac{\widehat{\psi}_{it}}{1-\widehat{\psi}_{it}} \tag{21}$$

$$(\widehat{\varepsilon}^{W}_{QR/N})_{it} = \frac{\widehat{\psi}_{it}-1}{\widehat{\psi}_{it}} \tag{22}$$

5 Data

Our data come from the IAB Establishment Panel described by Ellguth *et al.* (2014). Starting in 1993 (1996), the IAB Establishment Panel has surveyed West (East) German

[10] Such a correction is important since output prices are not available at the plant level, so that output levels are obtained by deflating revenues using a two-digit sector output price deflator (see Section 5), inducing bias when measuring real output. Note, however, that this correction cancels out when computing the ratio ψ_{it}, so it is only relevant for the estimation of the price-cost mark-up μ_{it} and here it improves the plausibility of our estimates substantially. Specifically, applying the correction reduces the number of plant-year observations with a below-unity price-cost mark-up markedly from 15,768 or 37.4% of the sample to 9,730 or 23.1% of the sample. As pointed out by a reviewer, below-unity mark-ups are only plausible in the short run or may reflect measurement error and the mark-up $\mu_{it} = (\varepsilon^{Q}_{M})_{it}/\alpha_{Mit}$ shows up in the numerator of the ratio ψ_{it}, so observations with below-unity mark-ups may arouse concerns that we overstate the prevalence and the size of wage mark-downs. That said, we will show in later checks of robustness that this is unlikely to affect any of our conclusions (see fn. 17).

plants (not firms) that employ at least one worker covered by the social security system on 30th June of the survey year, and is representative of the population of these plants.

Crucial for our purpose, it contains information on plants' revenues and intermediate inputs, employment, wage bill, and industrial relations (i.e. collective bargaining coverage and works council existence). To arrive at plants' total labour costs, we use information from the Federal Statistical Office on the non-wage labour costs at the two-digit sector level and add it to the wage bill. We further deflate all nominal values using two-digit price deflators and apply the procedure by Eberle *et al.* (2011) to construct a time-consistent sector classification. Although the IAB Establishment Panel has no direct information on plants' capital stock, it can readily be computed from the included investment data using a modified perpetual inventory approach put forward by Mueller (2008). Since our estimation approach uses lagged information on plants and since the survey information on plants' revenues and intermediate inputs is for the previous year, plants only enter the sample if we observe them in at least three consecutive years. Using information from the survey waves for 1998–2017, we are thus able to build a panel for the years 1999–2016.[11]

In our analysis, we focus on the manufacturing and service sectors and discard the financial and insurance sectors, for which output measures are not comparable to the other sectors in our sample. We further exclude plants producing tobacco products (i.e. 89 plant-year observations belonging to this highly regulated industry) and disregard plants with less than five workers, which are not at risk of having a works council. Our final regression sample comprises 42,127 observations of 9,160 plants belonging to 38 two-digit sectors (for descriptive statistics, see Table 1; the included sectors are visible from Table 2).[12]

[11] We cannot use earlier waves because of a change in the questionnaire regarding plants' industrial relations and because we do not want to constrain our analysis to West Germany.

[12] Note that we have to drop 1,771 observations (or about 4% of observations) because they involve a negative ψ_{it} and such a negative ratio of wages to the marginal revenue product of labour, which is likely to reflect poorly estimated output elasticities, is not economically meaningful in equilibrium, though it may occur in transitory paths not captured by our framework (e.g. employers involving in labour hoarding yielding a negative marginal revenue product of labour).

6 Industrial relations and labour market imperfections

6.1 Descriptive analysis

Using our panel of German plants for 1999–2016, we now apply the estimation approach described in Section 4. In a first step, we estimate translog production functions for each two-digit sector based on the control function approach by Ackerberg *et al.* (2015) that allows us to control for unobserved productivity shocks. In a second step, we use the estimated coefficients together with information on plants' input use to compute the ratio of wages to the marginal revenue product of labour ψ_{it}.

Table 2 presents means (overall and by two-digit sector) of the estimated output elasticities of labour, intermediate inputs, and capital as well as the resulting returns to scale, i.e. the sum of the three output elasticities. For our whole sample, average output elasticities are 0.46 for labour, 0.54 for intermediate inputs, and 0.11 for capital, with returns to scale amounting to 1.11 and thus slightly above constant returns. We also see marked differences in production technologies across sectors.

We now use plants' estimated output elasticities and revenue shares to compute the ratio of wages to the marginal revenue product of labour ψ_{it}. Throughout, our descriptive evidence will come from population weighted samples, thereby allowing us to draw conclusions on the population of manufacturing and service plants in Germany. As is clear from Table 3, 70% of (plant-year) observations involve a wage mark-down with $\psi_{it} < 1$ and just 30% a wage mark-up with $\psi_{it} > 1$. We note in passing that we obtain an average price-cost mark-up of 1.22 that is much larger when there is a wage mark-up than in case of a wage mark-down (1.40 vs. 1.15), which is reassuring as a wage mark-up arguably presupposes substantial rents to be split between employers and workers and is thus only sustainable when product market imperfections shield employers from competition.[13]

[13] Note that the average price-cost mark-up across plants is rather modest in size compared to existing estimates in the literature. Yet, one has to bear in mind that previous studies typically ignore labour market imperfections in that they assume competitive wage formation and thus, given that wage mark-downs are much more prevalent than wage mark-ups in our data, are prone to overstating the gap between product prices and marginal costs (as discussed in detail by De Loecker *et al.*, 2016). Moreover, as pointed out by a reviewer, the bias from not having separate price and quantity information when estimating production functions, which is at the heart of the Bond *et al.* (2021) critique, is likely to be exacerbated when not accounting for imperfections in input markets. Reassuringly, our numbers are similar in size to recent estimates that allow for labour

Turning to plants' industrial relations, we observe big differences in the prevalence of wage mark-downs across plants with and without a works council and no differences across plants covered by collective agreements and uncovered plants. Wage mark-downs are 9pp less frequent where works councils exist but equally frequent among covered and uncovered plants. These findings make sense against the background that collective bargaining is typically conducted at the sectoral level and is, for this reason, less likely to limit the power imbalance between individual employers and workers than worker co-determination at the workplace. They further square up with the result of Hirsch and Mueller (2020) that works council existence has a stronger association with the mean employer wage premium than collective bargaining coverage.

Considering the ratio of wages to the marginal revenue product of labour directly in Table 4, we find that the workers at the median plant receive 69% of the marginal revenue product of labour. This number is very similar to the median ratio of 73% for US manufacturing found by Yeh *et al.* (2022).[14] We further find substantial variation across observations with an interquartile range of the ratio of 0.68 (see also Figure 1 that provides a histogram of the log ratio, i.e. $\ln \widehat{\psi}_{it}$).

We finally note that wages differ markedly from the marginal revenue product of labour for the vast majority of plants. Specifically, only about 10% of observations have a ratio ψ_{it} ranging from 90% to 110% and could thus be considered as paying almost marginal-product wages. Disregarding these observations with nearly marginal-product wages, we find wage mark-downs of more than 10% for 65% of observations and wage mark-ups of more than 10% for the remaining 25% of observations.

Bringing plants' industrial relations into the picture, we find that the median ratio is 82% when there is a works council but just 67% when there is none. On the other hand, there are little differences in plants covered by collective bargaining compared to uncovered plants where the median ratio is 70% and 68%, respectively.

On top of the reduced-form ratio of wages to the marginal revenue product, we now

market imperfections (e.g. Dobbelaere *et al.*, 2015; Soares, 2020).

14 Note that Yeh *et al.* (2022) consider the inverse of ψ_{it}, that is the ratio of the marginal revenue product of labour to wages, and report a median of 1.364.

turn to the implied plant-level labour supply elasticity under monopsony $(\varepsilon_W^N)_{it}$ and rent-sharing elasticity under efficient bargaining $(\varepsilon_{QR/N}^W)_{it}$ as structural parameters capturing employers' monopsony and workers' monopoly power, respectively. In other words, we look at the outcomes through the lens of monopsony or efficient bargaining as two models of imperfect labour markets and ask about the values of the structural parameter of the respective model that rationalise the observed wage outcomes.

For the 70% of observations involving wage mark-downs, we find that the median plant-level labour supply elasticity amounts to 1.1, which points at marked monopsony power for employers. This number is not too different from the median of 1,320 elasticity estimates of 1.68 reported in Sokolova and Sorensen (2021) and almost identical to the average elasticity estimate for US firms of 1.08 in Webber (2015), which is one of the rare studies that provides elasticity estimates at the individual employer level as we do, though based on a different methodology. Note, however, that our median elasticity estimate for plants paying a wage mark-down is also consistent with previous studies obtaining larger estimates because the average elasticity for all plants estimated by earlier studies is a weighted average of the elasticity in plants with significant monopsony power and the elasticity in those with none. The latter are plants paying marginal-product wages or wage mark-ups, and thus plants likely to face large elasticities. Also keep in mind that the implied plant-level labour supply elasticity coming from the production-function approach is rooted in observed wage outcomes and thus measures employers' exercise of (rather than their potential for) monopsony power, whereas elasticity estimates in the literature measure employers' potential monopsony power only, but not its pass-through to actual wages (see Manning, 2021, for a detailed discussion).

For the 30% of observations involving wage mark-ups, we observe a median rent-sharing elasticity of 0.3 which is at the upper end of the estimates surveyed by Card *et al.* (2018). But observe, along the lines of the previous paragraph, that these studies report estimates of the average rent-sharing elasticity combining plants paying wage mark-ups and thus plants where substantial rent sharing exists and plants paying wage mark-downs, whereas our estimates are for the former group of plants only.

Turning to plants' industrial relations, we find that the plant-level labour supply elasticity is much bigger in plants with a works council than in plants without (median elasticity of 1.56 vs. 1.07) and a bit bigger in plants covered by collective bargaining than in uncovered plants (median elasticity of 1.15 vs. 1.08).[15] In contrast, there are small differences in the rent-sharing elasticity between plants with and without a works council (median elasticity of 0.33 vs. 0.29) and no differences between covered and uncovered plants (median elasticity of 0.3 in both cases).

In summary, we find that the presence of works councils is accompanied by a lower prevalence of wage mark-downs and a higher ratio of wages to the marginal revenue product of labour in general. We further see that the implied labour supply elasticity of plants paying a wage mark-down is bigger when works councils are present, as is the implied rent-sharing elasticity of plants paying a wage mark-up. The picture is less clear when comparing plants covered by collective bargaining and uncovered plants. These inconsistent correlation patterns, however, may simply reflect confounding factors, such as plant size and sector affiliation. Therefore, we now turn to partial correlations from regressions that control for a rich set of plant characteristics.

6.2 Regression analysis

In a first step, we investigate which factors including industrial relations captured by dummies for collective bargaining coverage and the existence of a works council influence the probability of a wage mark-down or a ratio ψ_{it} below unity (as opposed to a wage mark-up or a ratio ψ_{it} above unity). Table 5 reports average marginal effects for the probability of a wage mark-down from successively richer probit regressions. All models include as controls a full set of region, year, and two-digit sector dummies as well as a dummy for

[15] As said before, the labour supply elasticity coming from the production-function approach is the elasticity as implied from the observed wage outcomes, so the elasticity value that would rationalise the observed wage outcomes in a monopsony framework. In other words, a larger elasticity in plants where organised labour is present points at lower *actual* monopsony power compared to plants without organised labour. That said, it does not necessarily imply that workers' job separations and their labour supply in general are more responsive to wages in organised plants than in non-organised plants which would increase employers' *potential* for rather than their exercise of monopsony power. Consequently, our results are not in contradiction to the Hirschman dichotomy of 'exit' and 'voice' that suggests less wage-elastic job separations in organised than in non-organised plants.

a single-plant company. We then successively include plant size, i.e. log employment, and dummies for plant age (model 2); information on workforce composition, i.e. the share of skilled workers, apprentices, part-time workers, and female workers (model 3); and a dummy for exporting activity (model 4).

Once we add plant size and plant age to the probit regression (models 2–4), we find that the presence of collective bargaining or a works council is associated with a non-negligible reduction in the conditional probability of a wage mark-down. In our richest specification (model 4), collective bargaining is accompanied by an average drop in the probability of 2.9pp and works council existence even by a drop of 5.5pp, both of which are statistically significant at the 1% level. These findings are consistent with the theoretical insights in Falch and Strøm (2007) arguing that organised labour protects workers in that it seems to reduce the likelihood that employers can impose a wage mark-down on them. And in line with the descriptive evidence, works councils existence appears to matter more than collective bargaining coverage. Yet, bear in mind that our regressions rely on cross-sectional variation in industrial relations across plants and thus do not allow us to establish causality. In particular, our sample does not include enough changes in plants' industrial relations over time to rest identification on within-plant variation given the high data requirements when implementing the production-function approach.[16]

We further observe some interesting patterns for the control variables. Plant size shows a positive association with the probability of a wage mark-down, whereas we find the opposite for exporting plants (in line with previous evidence by Dobbelaere and Kiyota, 2018, for Japan). Hence, larger and non-exporting plants seem to be more powerful in the labour market. Finally, the composition of the workforce appears to matter. The probability of a wage mark-down is lower the more skilled workers are employed, whereas it is larger the more apprentices, part-timers, and females are among the workers, suggesting a more pronounced power imbalance for the latter groups.

Turning to the size rather than the direction of the deviation of wages from the

[16] Specifically, in our sample just 770 plants enter or leave collective bargaining coverage and 463 plants introduce or abolish a works council (disregarding plants with multiple switches in their collective bargaining or works council status where information may reflect measurement issues rather than genuine status changes).

marginal revenue product of labour, we examine how industrial relations and the other plant characteristics included in the probit regressions influence the logarithm of the ratio of wages to the marginal revenue product of labour ψ_{it}. Akin to the probit regressions, Table 6 reports estimates from successively richer OLS regressions and underscores that what we found for the direction of the deviation from marginal product-wages, with few exceptions, also shows up for its size. Since the dependent variable is in logs, estimated coefficients are interpretable as (approximate) percentage changes and thus directly inform us on the economic significance of the respective variables.

Once we control for plant size and plant age (models 2–4), we find that the presence of collective bargaining or a works council is associated with a sizeable increase of the ratio of wages to the marginal revenue product of labour. In the richest specification (model 4), collective bargaining is accompanied by an average increase in the ratio of 5.1% and works council existence even by an increase of 9.5%, both of which are statistically significant at the 1% level. Furthermore, we observe the same (mirror-inverted) patterns for the control variables as in the probit regressions for a wage mark-down.[17]

Finally, we examine how industrial relations and the other plant characteristics included in our preferred specification of the probit and OLS regressions (i.e. the richest model 4) influence the logarithm of (i) the implied plant-level labour supply elasticity $(\varepsilon_W^N)_{it}$ in case of a wage mark-down or $\psi_{it} < 1$ and (ii) the implied rent-sharing elasticity $(\varepsilon_{QR/N}^W)_{it}$ in case of a wage mark-up or $\psi_{it} > 1$ (see Table 7). Starting with the 28,390 observations involving a wage mark-down, we find that the existence of collective bargaining or a works council is associated with a significantly larger plant-level labour supply elasticity, which is in line with some suggestive earlier evidence presented by

[17] As stated in fn. 10, 9,730 or 23.1% of the observations in our sample involve estimated price-cost mark-ups below unity that are only sustainable in the short run and may to some extent reflect measurement error. Since the mark-up μ_{it} enters the numerator of the ratio ψ_{it}, we may thus overstate the prevalence and the size of wage mark-downs. To check whether this issue is likely to compromise our findings, we performed two checks of robustness. In the first robustness check, we recomputed the ratio ψ_{it} after setting all below-unity price-cost mark-ups to one and then redid the probit and OLS regressions based on this recomputed ratio. In the second robustness check, we omitted all observations involving below-unity price-cost mark-ups. Reassuringly, in both checks of robustness the partial correlation between the existence of collective bargaining or a works council and the measures of labour market imperfections hardly changed compared to our baseline results (results are available upon request).

Bachmann and Frings (2017). The elasticity is on average 7.3% larger in covered than in uncovered plants and 10.5% larger in plants with a works council than in plants without, where both associations are statistically significant at the 1% level.

We further find the same (mirror-inverted) patterns for the control variables that we obtained from the probit regression for a wage mark-down. The plant-level labour supply elasticity shows a negative association with plant size and a positive with exporting activity. Moreover, it is significantly related to workforce composition. It is larger the more skilled workers are employed and smaller the more apprentices, part-timers, and females are in the workforce. Particularly the latter finding for females is in line with existing evidence that employers possess more monopsony power over female as opposed to male workers (see the recent survey by Hirsch, 2016, and Hirsch *et al.*, 2010, for Germany).

Turning to the 13,737 observations involving a wage mark-up, our results for the rent-sharing elasticity are generally similar to those for the plant-level labour supply elasticity. The existence of collective bargaining is associated with a rise in the rent-sharing elasticity of 8.2% and the presence of a works council even with a rise of 14.6%, both of which are statistically significant at the 1% level. For the control variables we obtain, with few exceptions, the same correlation patterns as for the plant-level labour supply elasticity.

7 Labour market imperfections and employer wage premia

The partial correlations between industrial relations and the direction and size of the deviation of wages from the marginal revenue product of labour are consistent with the view that organised labour protects workers in that it reduces the prevalence of wage mark-downs and raises the ratio of wages to the marginal revenue product in general. That said, the production-function approach as implemented in this paper treats labour as a homogenous production factor and abstracts from differences in worker quality in that it compares the output elasticity of labour to its share in revenues and thus to the *average* wage bill per worker.

Consequently, our findings cannot shed direct light on how labour market imperfections relate to the wage premia paid by employers to their workers, that is to employers' wage levels after accounting for sorting of workers of different quality into plants that differ in labour market imperfections and the size of rents to be split between employers and workers. Yet, answering this question is not only crucial for our research question, but also provides a most welcome opportunity of cross-validating our measures of labour market imperfections, that is examining their predictive power for these employer wage premia.

Up to now, there is scant evidence on this issue, though some recent contributions surveyed by Manning (2021) find that measures of employers' potential monopsony power are associated with wages.[18] This evidence, however, is about individual wages and not about employer wage premia, so worker sorting may contaminate findings. To obtain a measure of employer wage premia that does not suffer from worker sorting, we follow Card *et al.* (2018) and Hirsch and Mueller (2020) and rely on the AKM plant wage effects estimated for our data by Bellmann *et al.* (2020) for the three estimation periods 1998–2004, 2005–2010, and 2011–2017. Since we are interested in how labour market imperfections relate to wage outcomes for a given plant surplus, we further follow Hirsch and Mueller (2020) in controlling for the quasi-rent per worker as the proper measure of this surplus. We provide details on our measures of employer wage premia and plant surplus in Appendix B.

We first provide some descriptive evidence on the correlation between employer wage premia and (i) the quasi-rent per worker and (ii) the log ratio of wages to the marginal revenue product of labour. As is seen from a binned scatterplot (Figure 2) that plots the AKM plant wage effects separately for the three AKM estimation periods that enter our sample (and purged of AKM period effects) against the quasi-rent per worker, there is a positive relationship between employer wage premia and plant surplus that does not change much over time and is pretty similar for the earliest and the latest AKM period.[19]

[18] For instance, Hirsch *et al.* (2022) show that smaller employer monopsony power in denser local labour markets accounts for about half of the urban wage premium in Germany. For the US, Azar *et al.* (2022) observe lower posted wages in more concentrated local labour markets and Benmelech *et al.* (2022) find a negative association between labour market concentration and wages, as does Rinz (2022). Finally, Webber (2015) finds that a larger firm-level labour supply elasticity is associated with higher average wages.

[19] This contrasts with the findings of Alvarez *et al.* (2018) for Brazil who document a less steep relationship between employer wage premia and plant surplus in later periods that substantially contributes to their finding of falling wage inequality over time.

Similarly, a binned scatterplot (Figure 3) that substitutes the log ratio of wages to the marginal revenue product of labour for the quasi-rent per worker shows that the ratio and the AKM plant wage effects are positively related, except for very small values of the ratio.[20] We further see that the relationship does not change much over time and is quite similar for the earliest and the latest AKM period.

To investigate the partial correlation between the measures of labour market imperfections from the production-function approach and employer wage premia, we next regress the standardised AKM plant wage effect on these measures, the quasi-rent per worker to control for the plant surplus, and all the control variables included in the regressions before.[21] To capture the direction of labour market imperfections, we include a dummy variable for the presence of a wage mark-down (i.e. for $\psi_{it} < 1$). To capture their size, we include the logarithm of the ratio of wages to the marginal revenue product of labour ψ_{it} or, in the restricted samples of observations involving either a wage mark-down or a wage mark-up, the logarithm of the plant-level labour supply elasticity $(\varepsilon_W^N)_{it}$ and the logarithm of the rent-sharing elasticity $(\varepsilon_{QR/N}^W)_{it}$, respectively. The results of the four OLS regressions are shown in Table 8.

Holding constant plant surplus and the other control variables, we find that a wage mark-down is accompanied by a 0.19 standard deviations lower mean wage premium.[22] Note that a standard deviation in wage premia amounts to 24.5 log points in our sample, so this partial correlation is sizeable. There is also a sizeable association between the log ratio of wages to the marginal revenue product of labour and the mean employer wage

[20] We note in passing that Figure 3 suggests that employer wage premia are highest among the employers with the narrowest wage mark-downs. As pointed out by a reviewer to us, this is in line with Burdett and Mortensen's (1998) wage-posting model of oligopsony, but it is at odds with Berger *et al.*'s (2022) model of oligopsony among horizontally differentiated employers where employers with wider mark-downs pay higher wages.

[21] Note that we do not observe AKM plant wage effects for 3,825 plant-year observations. We decided to impute these missing AKM plant effects by the predicted values of a linear regression of the observed AKM plant effects on dummies for two-digit sector, plant size (ten categories), and their interaction, time dummies, dummies for a single-plant company, plant age (four categories), and exporting activity, as well as the share of skilled workers, apprentices, part-time workers, and female workers in the plant's workforce, and the plant's log wage bill per worker. That said, our results hardly change when restricting to those plant-year observations with non-missing AKM plant effects.

[22] We note in passing that we obtain an R^2 of 0.53 in the OLS regression which means that the included regressors can account for the majority of the variation in wage premia, and we further note that the results for the control variables show little surprises, so that we leave them uncommented.

premium. A one standard deviation larger log ratio, which amounts to 0.76 in our sample, is associated with a 0.1 (= 0.76×0.13) standard deviations larger mean employer wage premium, which is statistically significant at the 1% level.

When restricting to the 28,390 observations involving a wage mark-down, we find that a one standard deviation larger log plant-level labour supply elasticity, which amounts to 1.33 in our sample, is accompanied by a 0.09 (= 1.33×0.065) standard deviations larger mean wage premium. Finally, restricting to the 13,737 observations involving a wage mark-up, a one standard deviation larger log rent-sharing elasticity, which is 1.08 in our sample, is associated with a 0.05 (= 1.08×0.043) standard deviations larger mean wage premium, which is a somewhat smaller association than for the labour supply elasticity. That said, both partial correlations are statistically significant at the 1% level.

In summary, our findings suggest that labour market imperfections as measured by the production-function approach are clearly related to employer wage premia and in the way predicted by theory thereby cross-validating these measures. In consequence, both the direction and the size of labour market imperfections relate to the mean employer wage premium while they themselves are clearly related to industrial relations.

8 Conclusions

This paper has investigated the interplay between industrial relations, labour market imperfections, and employer wage premia in Germany and posed two questions. Are labour market imperfections related to industrial relations? And are employer wage premia, in turn, related to labour market imperfections? We addressed these two questions using the production-function approach that allows to infer from production-function estimates whether wages deviate from the marginal revenue product of labour and by how much. Based on representative plant-level data from the IAB Establishment Panel encompassing the years 1999–2016, we answered both questions in the affirmative.

At the descriptive level, we found that wage mark-downs are far more prevalent than wage mark-ups (70% vs. 30% of plant-year observations), so that the vast majority of German employers pay less than the marginal revenue product of labour. In regressions, we found that wage mark-downs are less frequent when collective bargaining and, even more so, when a works council is present. These findings for the direction of labour market imperfections are complemented by results for the ratio of wages to the marginal revenue product of labour where we observed that the ratio is significantly bigger when a works council or collective bargaining exists. Finally, we found that mean employer wage premia are significantly lower when wage mark-downs are present and are positively related to the ratio of wages to the marginal revenue product of labour, holding constant plant surplus.

In short, our results are in line with the notion that industrial relations influence rent splitting in imperfect labour markets, with collective bargaining and worker co-determination shifting market power from employers to workers. Hence, they point at organised labour's erosion as one possible contributor to the falling labour share. That said, our data did not permit us to establish a causal link running from industrial relations to labour market imperfections and from labour market imperfections to employer wage premia, so for instance selection into industrial relation regimes could still play a role. Establishing causality in a rigorous way using exogenous variation in industrial relations remains a promising avenue for future research.

Figures and Tables

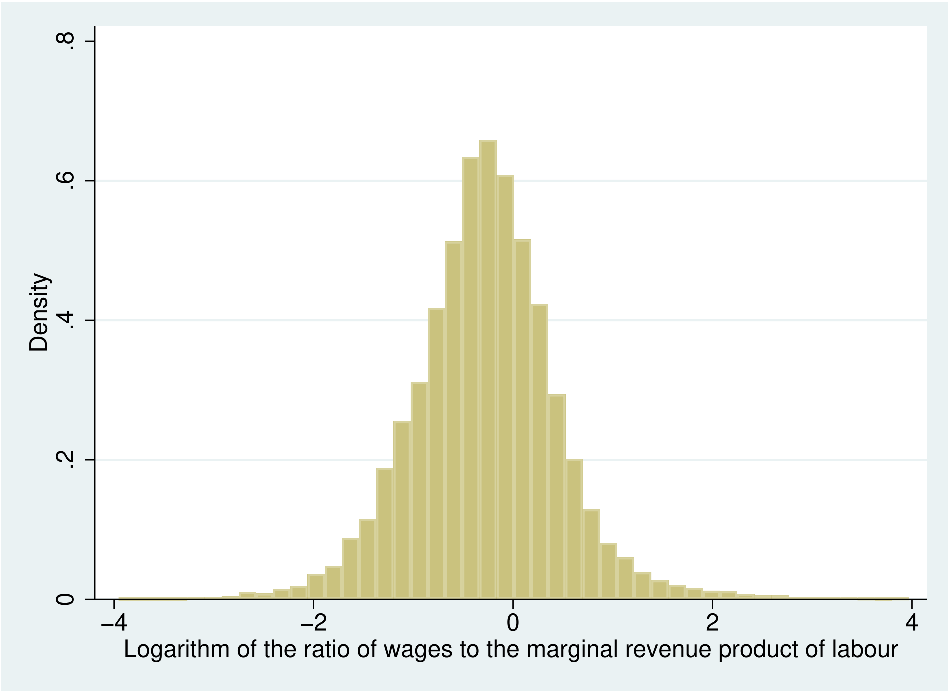

Figure 1: Histogram of the logarithm of the ratio of wages to the marginal revenue product of labour (i.e. $\ln \widehat{\psi}_{it}$)

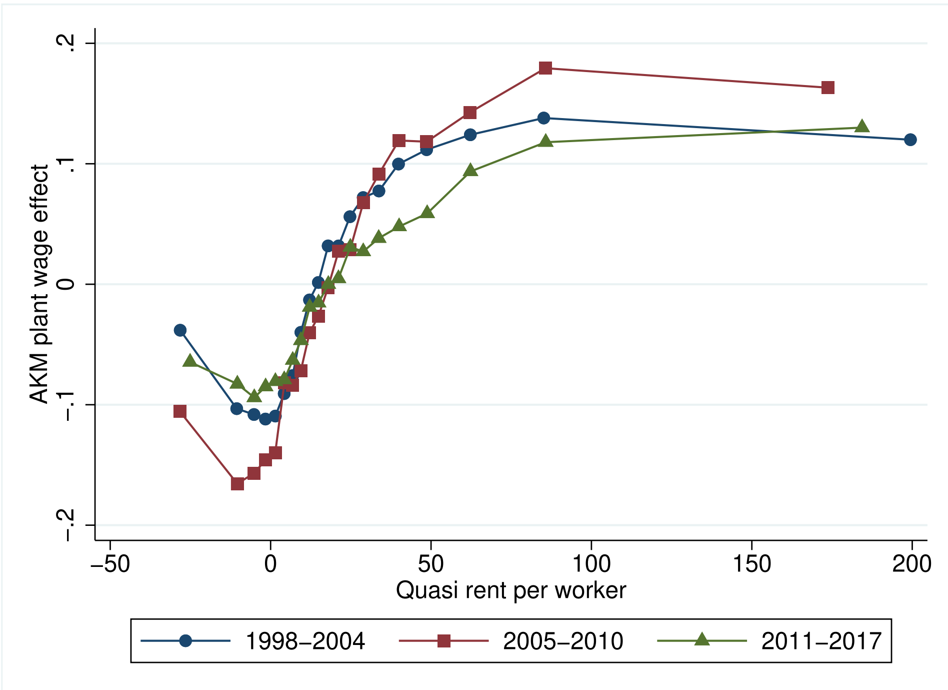

Figure 2: Binned scatterplot of AKM plant wage effects (by AKM estimation period and purged of AKM estimation period effects) against the quasi-rent per worker

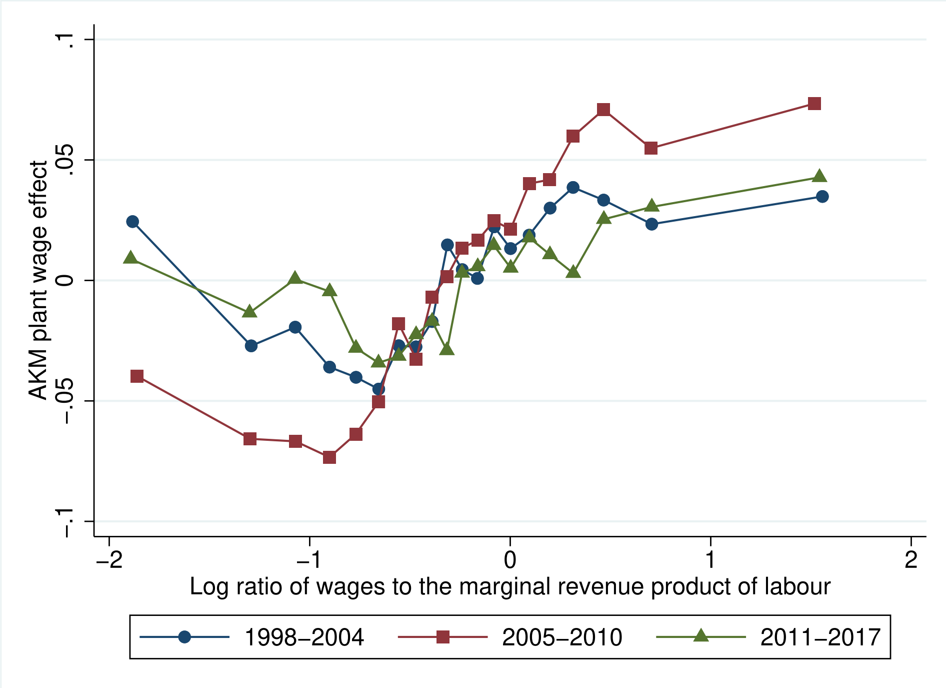

Figure 3: Binned scatterplot of AKM plant wage effects (by AKM estimation period and purged of AKM estimation period effects) against the log ratio of wages to the marginal revenue product of labour (i.e. $\ln \widehat{\psi}_{it}$)

Table 1: Descriptive statistics

	Mean	SD	p25	p50	p75
Real output growth rate (Δq_{it})	–0.001	0.225	–0.088	0.000	0.091
Labour growth rate (Δn_{it})	0.014	0.155	–0.028	0.000	0.074
Intermediate inputs growth rate (Δm_{it})	–0.001	0.428	–0.176	0.000	0.170
Capital growth rate (Δk_{it})	0.006	0.127	–0.054	–0.028	0.027
Revenue share of intermediate inputs (α_{Mit})	0.463	0.194	0.316	0.464	0.606
Revenue share of labour (α_{Nit})	0.298	0.196	0.152	0.258	0.397
$1 - \alpha_{Nit} - \alpha_{Mit}$	0.205	0.217	0.063	0.188	0.350
ln(wage bill$_{it}$)	12.622	1.229	11.769	12.469	13.315
ln(employment$_{it}$)	2.617	0.907	1.946	2.398	3.045
ln(capital$_{it}$)	13.066	1.530	12.103	12.973	13.934
ln(intermediate inputs$_{it}$)	13.182	1.568	12.095	13.043	14.136
ln(output$_{it}$)	14.036	1.301	13.099	13.819	14.794
Capital intensity ($\ln(\frac{K}{N})_{it}$)	10.434	1.130	9.744	10.496	11.173
Value added per worker ($\ln(\frac{Q-M}{N})_{it}$)	10.584	0.796	10.147	10.606	11.051
Solow residual (SR_{it})	–0.028	0.204	–0.097	-0.005	0.068
Works council (dummy)	0.093	0.290	0.000	0.000	0.000
Collective bargaining (dummy)	0.362	0.481	0.000	0.000	1.000
Single-plant company (dummy)	0.856	0.351	1.000	1.000	1.000
Plant age $\leqslant$ 4 years (dummy)	0.051	0.220	0.000	0.000	0.000
Plant age 5–9 years (dummy)	0.121	0.326	0.000	0.000	0.000
Plant age 10–14 years (dummy)	0.102	0.302	0.000	0.000	0.000
Plant age 15–19 years (dummy)	0.075	0.263	0.000	0.000	0.000
Plant age $\geqslant$ 20 years (dummy)	0.651	0.477	0.000	1.000	1.000
Share of skilled workers	0.645	0.250	0.500	0.714	0.833
Share of apprentices	0.047	0.077	0.000	0.000	0.083
Share of part-time workers	0.268	0.249	0.069	0.192	0.400
Share of female workers	0.424	0.290	0.167	0.364	0.684
Exporting activity (dummy)	0.231	0.422	0.000	0.000	0.000
West Germany (dummy)	0.793	0.405	1.000	1.000	1.000
Observations			42,127		
Plants			9,160		

Notes: IAB Establishment Panel, 1999–2016, weighted using sample weights. The Solow residual is defined as $SR_{it} = \Delta q_{it} - \alpha_{Nit}\Delta n_{it} - \alpha_{Mit}\Delta m_{it} - (1 - \alpha_{Nit} - \alpha_{Mit})\Delta k_{it}$.

Table 2: Estimated output elasticities and returns to scale by two-digit sector (means)

Sector (NACE Rev.2)		Output elasticity of... labour	intermediate inputs	capital	Returns to scale	Obs.	Plants
Food products	(10)	0.482	0.493	0.111	1.085	1,724	402
Beverages	(11)	0.454	0.571	0.188	1.213	255	44
Textiles	(13)	0.197	0.545	0.230	0.972	464	103
Wearing apparel, leather	(14–15)	0.377	0.786	0.096	1.259	197	49
Wood and wood products	(16)	0.334	0.676	0.086	1.096	973	182
Paper and paper products	(17)	0.393	0.562	0.016	0.971	380	75
Printing and recorded media	(18)	0.504	0.269	0.273	1.046	676	132
Chemicals and petroleum products	(19–20)	0.269	0.659	0.091	1.018	1,141	228
Basic pharmaceutical products	(21)	0.399	0.664	0.060	1.123	156	36
Rubber and plastic products	(22)	0.278	0.700	0.047	1.025	1,410	278
Non-metallic mineral products	(23)	0.396	0.575	0.107	1.077	1,462	284
Basic metals	(24)	0.525	0.470	0.059	1.054	1,466	272
Fabricated metal products	(25)	0.529	0.484	0.083	1.095	3,628	681
Computer and electronic products	(26)	0.559	0.641	0.176	1.376	1,092	257
Electrical equipment	(27)	0.324	0.564	0.108	0.996	1,129	226
Machinery and equipment	(28)	0.361	0.543	0.044	0.948	3,287	650
Motor vehicles and trailers	(29)	0.418	0.620	0.038	1.075	1,262	264
Other transport equipment	(30)	0.378	0.593	0.065	1.036	226	72
Furniture	(31)	0.521	0.502	0.025	1.049	688	132
Other manufacturing	(32)	0.578	0.476	0.058	1.112	1,123	220
Repair, installation of machinery	(33)	0.420	0.556	0.094	1.071	647	154
Wholesale trade (w/ vehicles)	(45)	0.304	0.601	0.130	1.035	1,825	405
Wholesale trade (w/o vehicles)	(46)	0.385	0.715	0.039	1.139	2,998	654
Retail trade (w/o vehicles)	(47)	0.384	0.670	0.026	1.080	4,242	942
Transport and warehousing	(49–53)	0.408	0.595	0.196	1.199	2,520	627
Publishing activities	(58–63)	0.401	0.409	0.207	1.016	1,179	308
Legal and accounting activities	(69)	0.832	0.260	0.099	1.191	1,346	287
Consultancy activities	(70)	0.489	0.570	0.213	1.272	347	96
Engineering activities	(71)	0.569	0.293	0.346	1.208	1,274	299
Scientific research	(72)	0.550	0.411	0.097	1.058	415	103
Advertising, market research	(73)	0.423	0.533	–0.049	0.907	235	59
Other professional activities	(74–75)	0.622	0.382	0.155	1.159	199	44
Rental and leasing activities	(77)	0.666	0.397	–0.018	1.045	76	19
Employment activities	(78)	0.756	0.182	0.238	1.176	469	168
Travel agencies	(79)	0.408	0.572	0.110	1.089	125	35
Security activities	(80)	1.019	0.374	–0.155	1.237	107	33
Services to buildings and landscape	(81)	0.566	0.445	0.145	1.156	1,106	266
Office administration and support	(82)	0.293	0.546	0.032	0.871	278	74
All		0.464	0.537	0.105	1.107	42,127	9,160

Notes: IAB Establishment Panel, 1999–2016, weighted using sample weights.

Table 3: The prevalence of labour market imperfections (percentages)

	All plants	Collective bargaining		Works council	
		Yes	No	Yes	No
Wage mark-down ($\widehat{\psi}_{it} < 1$)	70.4	70.7	70.3	61.9	71.3
Wage mark-up ($\widehat{\psi}_{it} > 1$)	29.6	29.3	29.7	38.1	28.7

Notes: IAB Establishment Panel, 1999–2016, percentages of 42,127 plant-year observations, weighted using sample weights. Based on the estimates of the ratio of wages to the marginal revenue product of labour (equation (20)).

Table 4: The intensity of labour market imperfections

	Ratio of the plant's wage to the marginal revenue product of labour ($\widehat{\psi}_{it}$)			Plant-level labour supply elasticity ($(\widehat{\varepsilon}^N_W)_{it}$ if $\widehat{\psi}_{it} < 1$)			Plant-level rent-sharing elasticity ($(\widehat{\varepsilon}^W_{QR/N})_{it}$ if $\widehat{\psi}_{it} > 1$)		
	p25	p50	p75	p25	p50	p75	p25	p50	p75
All plants	0.42	0.69	1.10	0.54	1.10	2.59	0.15	0.30	0.50
Collective bargaining …									
Yes	0.43	0.70	1.10	0.55	1.15	2.72	0.16	0.30	0.49
No	0.42	0.68	1.10	0.53	1.08	2.52	0.15	0.30	0.50
Works council …									
Yes	0.54	0.82	1.29	0.73	1.56	3.39	0.16	0.33	0.51
No	0.41	0.67	1.08	0.53	1.07	2.51	0.15	0.29	0.50

Notes: IAB Establishment Panel, 1999–2016, 42,127 plant-year observations, weighted using sample weights. Based on the estimates of the ratio of wages to the marginal revenue product of labour (equation (20)). Structural measures of employer monopsony and worker monopoly power are recovered using equations (21) and (22).

Table 5: Average marginal effects on the probability of a wage mark-down from probit regressions

	(1)	(2)	(3)	(4)
Collective bargaining	–0.017**	–0.025***	–0.028***	–0.029***
	(0.009)	(0.009)	(0.009)	(0.009)
Works council	–0.014	–0.074***	–0.056***	–0.055***
	(0.011)	(0.012)	(0.012)	(0.012)
Log employment		0.037***	0.038***	0.040***
		(0.004)	(0.004)	(0.004)
Plant age 5–9 years		0.008	0.006	0.006
		(0.013)	(0.013)	(0.013)
Plant age 10–14 years		–0.002	–0.003	–0.003
		(0.014)	(0.014)	(0.014)
Plant age 15–19 years		0.000	–0.001	–0.001
		(0.015)	(0.015)	(0.015)
Plant age $\geqslant$ 20 years		0.006	0.006	0.005
		(0.013)	(0.013)	(0.013)
Share of skilled workers			–0.075***	–0.075***
			(0.017)	(0.017)
Share of apprentices			0.686***	0.679***
			(0.062)	(0.062)
Share of part-time workers			0.258***	0.252***
			(0.026)	(0.026)
Share of female workers			0.084***	0.086***
			(0.023)	(0.023)
Exporting activity				–0.021**
				(0.009)
Log likelihood	–20,868.11	–20,686.26	–20,122.51	–20,112.69
Number of observations	42,127			

Notes: IAB Establishment Panel, 1999–2016. The dependent variable is a dummy variable for a wage mark-down, i.e. $\widehat{\psi}_{it} < 1$. Reported numbers are average marginal effects on the probability of a wage mark-down with standard errors clustered at the plant level in parentheses. ***/**/* denotes statistical significance at the 1%/5%/10% level. Further covariates included in all specifications are region, year, and two-digit sector dummies as well as a dummy for a single-plant company.

Table 6: OLS regressions for the size of the deviation of wages from the marginal revenue product of labour

	(1)	(2)	(3)	(4)
Collective bargaining	0.024	0.038**	0.046***	0.051***
	(0.015)	(0.015)	(0.014)	(0.014)
Works council	–0.010	0.127***	0.098***	0.095***
	(0.019)	(0.020)	(0.019)	(0.019)
Log employment		–0.088***	–0.093***	–0.100***
		(0.008)	(0.008)	(0.008)
Plant age 5–9 years		0.035	0.036	0.036
		(0.023)	(0.022)	(0.022)
Plant age 10–14 years		0.069***	0.065***	0.066***
		(0.025)	(0.024)	(0.024)
Plant age 15–19 years		0.047*	0.039	0.041
		(0.026)	(0.025)	(0.025)
Plant age $\geqslant$ 20 years		0.057**	0.049**	0.050**
		(0.023)	(0.022)	(0.022)
Share of skilled workers			0.166***	0.167***
			(0.028)	(0.028)
Share of apprentices			–1.227***	–1.201***
			(0.102)	(0.102)
Share of part-time workers			–0.570***	–0.553***
			(0.043)	(0.043)
Share of female workers			–0.140***	–0.146***
			(0.038)	(0.038)
Exporting activity				0.069***
				(0.016)
R^2	0.284	0.298	0.329	0.331
Number of observations	42,127			

Notes: IAB Establishment Panel, 1999–2016. The dependent variable is the logarithm of the ratio of wages to the marginal revenue product of labour (i.e. $\ln \widehat{\psi}_{it}$). Reported numbers are coefficients from OLS regressions with standard errors clustered at the plant level in parentheses. ***/**/* denotes statistical significance at the 1%/5%/10% level. Further covariates included in all specifications are region, year, and two-digit sector dummies as well as a dummy for a single-plant company.

Table 7: OLS regressions for the intensity of labour market imperfections

	Log of… plant-level labour supply elasticity ($(\widehat{\varepsilon}_W^N)_{it}$)	Log of… plant-level rent-sharing elasticity ($(\widehat{\varepsilon}_{QR/N}^W)_{it}$)
Collective bargaining	0.073***	0.082***
	(0.027)	(0.032)
Works council	0.105***	0.146***
	(0.038)	(0.040)
Log employment	–0.173***	–0.064***
	(0.015)	(0.016)
Plant age 5–9 years	0.013	0.072
	(0.044)	(0.059)
Plant age 10–14 years	0.098**	0.091
	(0.048)	(0.060)
Plant age 15–19 years	0.094*	0.034
	(0.052)	(0.063)
Plant age $\geqslant$ 20 years	0.118***	0.037
	(0.044)	(0.055)
Share of skilled workers	0.563***	0.058
	(0.053)	(0.061)
Share of apprentices	–1.248***	–1.029***
	(0.171)	(0.236)
Share of part-time workers	–1.104***	–0.091
	(0.070)	(0.093)
Share of female workers	–0.247***	–0.147*
	(0.069)	(0.082)
Exporting activity	0.110***	0.100***
	(0.029)	(0.032)
R^2	0.303	0.120
Number of observations	28,390	13,737

Notes: IAB Establishment Panel, 1999–2016. The dependent variable is the logarithm of the respective labour market imperfection measure. Reported numbers are coefficients from OLS regressions with standard errors clustered at the plant level in parentheses. ***/**/* denotes statistical significance at the 1%/5%/10% level. Further covariates included in all specifications are region, year, and two-digit sector dummies as well as a dummy for a single-plant company.

Table 8: OLS regressions for the employer wage premium

	(1)	(2)	(3)	(4)
Wage mark-down (dummy)	–0.189***			
	(0.015)			
Log of ratio of plant-level wage to the		0.130***		
marginal revenue product of labour ($\widehat{\psi}_{it}$)		(0.011)		
Log of plant-level labour supply			0.065***	
elasticity ($(\widehat{\varepsilon}_{W}^{N})_{it}$)			(0.006)	
Log of plant-level rent-sharing				0.043***
elasticity ($(\widehat{\varepsilon}_{QR/N}^{W})_{it}$)				(0.008)
Quasi-rent per worker (in € 100,000)	0.002***	0.002***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Log employment	0.183***	0.188***	0.205***	0.162***
	(0.006)	(0.006)	(0.008)	(0.010)
Plant age 5–9 years	–0.041*	–0.047*	–0.034	–0.063*
	(0.025)	(0.024)	(0.031)	(0.036)
Plant age 10–14 years	–0.079***	–0.087***	–0.068*	–0.108***
	(0.029)	(0.029)	(0.037)	(0.038)
Plant age 15–19 years	–0.021	–0.027	–0.022	–0.018
	(0.030)	(0.030)	(0.038)	(0.040)
Plant age ⩾ 20 years	0.017	0.008	0.020	–0.009
	(0.024)	(0.024)	(0.031)	(0.032)
Share of skilled workers	0.286***	0.279***	0.257***	0.213***
	(0.031)	(0.031)	(0.037)	(0.046)
Share of apprentices	–0.482***	–0.445***	–0.408***	–0.341*
	(0.102)	(0.103)	(0.115)	(0.175)
Share of part-time workers	0.175***	0.202***	0.341***	0.015
	(0.057)	(0.057)	(0.068)	(0.086)
Share of female workers	–0.346***	–0.343***	–0.219***	–0.526***
	(0.044)	(0.044)	(0.054)	(0.064)
Exporting activity	0.078***	0.073***	0.064***	0.081***
	(0.015)	(0.016)	(0.018)	(0.025)
R^2	0.531	0.532	0.534	0.548
Number of observations	42,127	42,127	28,390	13,737

Notes: IAB Establishment Panel, 1999–2016. The dependent variable is the standardised AKM plant wage effect. Reported numbers are coefficients from OLS regressions with standard errors clustered at the plant level in parentheses. ***/**/* denotes statistical significance at the 1%/5%/10% level. Further covariates included in all specifications are region, year, and two-digit sector dummies as well as a dummy for a single-plant company.

A Derivations for the production-function approach

Plant i's short-run profits at time t are given by

$$\Pi_{it} = R_{it} - W_{it}N_{it} - J_{it}M_{it} \tag{A.1}$$

where $R_{it} = P_{it}Q_{it}$ denotes the plant's revenues, P_{it} the price of the good, and W_{it} and J_{it} the input prices of labour and intermediate inputs, respectively. Then, the plant's optimisation problem involves maximising short-run profits (equation (A.1)) with respect to output Q_{it}, labour N_{it}, and intermediate inputs M_{it}.

A.1 Price-cost mark-ups on the product market

Turning to the plant's product market first, the first-order condition with respect to Q_{it} yields the plant's price-cost mark-up:

$$\mu_{it} = \frac{P_{it}}{(C_Q)_{it}} = \left(1 + \frac{s_{it}\kappa_{it}}{e_t}\right)^{-1} \tag{A.2}$$

where $(C_Q)_{it} = \partial C_{it}/\partial Q_{it}$ denotes the marginal cost of production, C_{it} the cost function, $s_{it} = Q_{it}/Q_t$ the market share of plant i in sector demand Q_t, $e_t = (\partial Q_t/\partial P_t)(P_t/Q_t)$ the own-price elasticity of sector demand, and $\kappa_{it} = \partial Q_t/\partial Q_{it}$ a conjectural variations parameter that captures competitors' quantity response to plant i's output choice.[23]

Turning to plant i's choice of intermediate inputs next, the first-order condition with respect to M_{it} yields $(Q_M)_{it} = \mu_{it}J_{it}/P_{it}$ where $(Q_M)_{it} = \partial Q_{it}/\partial M_{it}$ denotes the marginal product of intermediate inputs. Multiplying this expression by M_{it}/Q_{it} yields

$$(\varepsilon_M^Q)_{it} = \mu_{it}\alpha_{Mit} \tag{A.3}$$

[23] Specifically, under Cournot competition with plants producing a homogenous good and competing in quantities, $\kappa_{it} = \partial Q_t/\partial Q_{it} = 1$ with a single sector-wide output price in equilibrium $P_{it} = P_t$. Hence, in this case the price-cost mark-up is $\mu_{it} = P_t/(C_Q)_{it} = (1 + s_{it}/e_t)^{-1}$. Under Bertrand competition with plants producing a horizontally differentiated good and competing in prices instead of quantities, $\partial P_t/\partial P_{it} = 1$ and thus $\kappa_{it} = \partial Q_t/\partial Q_{it} = e_t/(s_{it}e_{it})$ with $e_{it} = (\partial Q_{it}/\partial P_{it})(P_{it}/Q_{it})$ denoting plant i's own-price elasticity of residual demand. Hence, in this case the price-cost mark-up is $\mu_{it} = P_{it}/(C_Q)_{it} = (1 + 1/e_{it})^{-1}$.

with the output elasticity of intermediate inputs $(\varepsilon_M^Q)_{it} = (\partial Q_{it}/\partial M_{it})(M_{it}/Q_{it})$ and their revenue share $\alpha_{Mit} = J_{it}M_{it}/R_{it}$. Hence, in the optimum the output elasticity of intermediate inputs equals the share of their expenditures in output evaluated at the marginal cost of production. Using equation (A.3), the price-cost mark-up is given as:

$$\mu_{it} = \frac{(\varepsilon_M^Q)_{it}}{\alpha_{Mit}} \tag{A.4}$$

A.2 Wage mark-downs and wage mark-ups on the labour market

Unlike the price of intermediate inputs that the plant takes as given, wage formation depends on possible labour market imperfections. If there is perfect competition in the labour market, the first-order condition with respect to N_{it} is analogous to intermediate inputs $(Q_N)_{it} = \mu_{it}W_{it}/P_{it}$ where $(Q_N)_{it} = \partial Q_{it}/\partial N_{it}$ denotes the marginal product of labour. Multiplying this expression by N_{it}/Q_{it} yields

$$(\varepsilon_N^Q)_{it} = \mu_{it}\alpha_{Nit} \tag{A.5}$$

with the output elasticity of labour $(\varepsilon_N^Q)_{it} = (\partial Q_{it}/\partial N_{it})(N_{it}/Q_{it})$ and its revenue share $\alpha_{Nit} = W_{it}N_{it}/R_{it}$. As with intermediate inputs, this condition means that in the optimum the output elasticity of labour equals the share of the plant's wage bill in its output evaluated at the marginal cost of production.

Absent labour market imperfections, comparing equations (A.3) and (A.5) shows that there exists no gap between the output elasticities of intermediate inputs and labour and their respective revenue shares:

$$\psi_{it} = \frac{(\varepsilon_M^Q)_{it}/\alpha_{Mit}}{(\varepsilon_N^Q)_{it}/\alpha_{Nit}} = 1 \tag{A.6}$$

What is more, ψ_{it} gives the ratio of the employer's wage to the marginal revenue product of labour (see Caselli *et al.*, 2021; Yeh *et al.*, 2022), as is seen from rewriting equation

(A.6) as:

$$\psi_{it} = \frac{(\varepsilon_M^Q)_{it}/\alpha_{Mit}}{(\varepsilon_N^Q)_{it}/\alpha_{Nit}} = \frac{\mu_{it}}{\frac{(Q_N)_{it}N_{it}}{Q_{it}}\frac{P_{it}Q_{it}}{W_{it}N_{it}}} = \frac{W_{it}}{P_{it}(Q_N)_{it}/\mu_{it}} = \frac{W_{it}}{(R_N)_{it}} \tag{A.7}$$

where the second equality makes use of equation (A.4) for the price-cost mark-up μ_{it} and the last equality uses that the marginal revenue product of labour is given by $(R_N)_{it} = P_{it}(Q_N)_{it}/\mu_{it}$. From equation (A.7) we thus see that ψ_{it} provides a reduced-form plant-level measure of how much wages deviate from the marginal revenue product of labour. A below-unity ratio ψ_{it} indicates a wage mark-down and an above-unity ratio ψ_{it} a wage mark-up.

A.3 Implied labour supply elasticity in case of wage mark-downs

That said, we can also transform a given value of ψ_{it} into the implied labour supply elasticity in case of a wage mark-down or $\psi_{it} < 1$ and into the implied rent-sharing elasticity in case of a wage mark-up or $\psi_{it} > 1$ that rationalise the observed wage outcomes in a monopsony or efficient bargaining framework. We first consider the case of a wage mark-down or $\psi_{it} < 1$ under monopsony.

In this case, plants' wage-setting power stems from the fact that the labour supply curve faced by a single plant is upward-sloping rather than horizontal as it would be under perfect competition. Let the labour supply faced by the plant paying W_{it} be $N_{it}(W_{it})$ and its inverse $W_{it}(N_{it})$. Plugging the latter into the plant's profits (equation (A.1)), maximising these with respect to N_{it} yields the first-order condition

$$(R_N)_{it} = (W_N)_{it}N_{it} + W_{it}(N_{it}) \tag{A.8}$$

where $(W_N)_{it} = \partial W_{it}/\partial N_{it}$ is the slope of the labour supply curve to the plant.

Using equation (A.7) for the ratio ψ_{it} and substituting equation (A.8) in the ratio ψ_{it} gives:

$$\psi_{it} = \frac{W_{it}}{(R_N)_{it}} = \frac{(\varepsilon_W^N)_{it}}{(\varepsilon_W^N)_{it} + 1} \tag{A.9}$$

where $(\varepsilon_W^N)_{it} = (\partial N_{it}/\partial W_{it})(W_{it}/N_{it})$ is the wage elasticity of plant-level labour supply. Solving equation (A.9) for the labour supply elasticity yields:

$$(\varepsilon_W^N)_{it} = \frac{\psi_{it}}{1-\psi_{it}} \tag{A.10}$$

The labour supply elasticity informs us on the plant's monopsony power as implied by the observed wage outcomes. Under perfect competition, the plant-level labour supply curve is horizontal with $(\varepsilon_W^N)_{it} = \infty$ and workers obtain the marginal revenue product of labour or $\psi_{it} = 1$. Under monopsony or $\psi_{it} < 1$, the plant's wage-setting power is negatively related to the labour supply elasticity $(\varepsilon_W^N)_{it}$ which, in turn, is positively related to ψ_{it}.

A.4 Implied rent-sharing elasticity in case of wage mark-ups

We now turn to the case of a wage mark-up of $\psi_{it} > 1$. As an underlying structural model rationalising a wage mark-up, we consider efficient bargaining (McDonald and Solow, 1981) between a risk-neutral plant and its risk-neutral workforce, though other structural models are possible as well. For instance, Stole and Zwiebel (1996) consider wage bargaining between individual workers and their employer when incomplete labour contracts provide incumbent workers with hold-up power.

Under efficient bargaining, the negotiated wage-employment pair maximises both parties' joint surplus and follows from maximising the generalised Nash product

$$\Omega = [N_{it}(W_{it} - \overline{W}_{it})]^{\phi_{it}}[R_{it} - W_{it}N_{it} - J_{it}M_{it}]^{1-\phi_{it}} \tag{A.11}$$

with respect to W_{it} and N_{it} where $\overline{W}_{it}$ denotes workers' outside option and $0 < \phi_{it} < 1$ the part of the surplus accruing to workers, which captures workers' bargaining power. In the generalised Nash product, workers' net gain is the amount by which their payroll exceeds the alternative wage while the plant's net gain is its short-run profits.[24]

[24] This formulation of efficient bargaining assumes that all employed union members immediately return to the external labour market when negotiations fail. Yet, results do not change when considering a sequence of bargaining sessions between the plant and a union of declining size whose members gradually lose jobs when disagreement continues (Dobbelaere and Luttens, 2016).

The first-order condition with respect to W_{it} and N_{it}, respectively, gives:

$$W_{it} = \overline{W}_{it} + \frac{\phi_{it}}{1-\phi_{it}} \left[\frac{R_{it} - W_{it}N_{it} - J_{it}M_{it}}{N_{it}} \right] \tag{A.12}$$

$$W_{it} = (R_N)_{it} + \phi_{it} \left[\frac{R_{it} - (R_N)_{it}N_{it} - J_{it}M_{it}}{N_{it}} \right] \tag{A.13}$$

Combining the two first-order conditions yields the so-called contract curve that characterises efficient wage-employment pairs:

$$(R_N)_{it} = \overline{W}_{it} \tag{A.14}$$

The equality of the marginal revenue product of labour and workers' outside option means that the term in brackets on the right-hand side of equation (A.13) represents the quasi-rent per worker QR_{it}/N_{it}.

Using equation (A.13), the elasticity of the wage with respect to the quasi-rent per worker, that is the rent-sharing elasticity, is given by:

$$(\varepsilon^{W}_{QR/N})_{it} = \frac{\phi_{it}QR_{it}/N_{it}}{(R_N)_{it} + \phi_{it}QR_{it}/N_{it}} = \frac{W_{it} - (R_N)_{it}}{W_{it}} = \frac{\psi_{it} - 1}{\psi_{it}} \tag{A.15}$$

where the last equality uses $\psi_{it} = W_{it}/(R_N)_{it}$. The rent-sharing elasticity informs us on what fraction of a one percent increase in plant surplus shows up in workers' wages and thus on workers' monopoly power as implied by the observed wage outcomes. Under perfect competition, there is no rent sharing with $(\varepsilon^{W}_{QR/N})_{it} = 0$ and workers obtain the marginal revenue product of labour or $\psi_{it} = 1$. Under efficient bargaining or $\psi_{it} > 1$, the rent-sharing elasticity $(\varepsilon^{W}_{QR/N})_{it}$, which captures workers' bargaining power, is positively related to ψ_{it}.

B Measuring employer wage premia and surplus

To measure employer wage premia and plant surplus, we follow Card *et al.* (2018) and Hirsch and Mueller (2020). Our measure of wage premia builds on an AKM decomposition that splits up a worker's individual wage into a worker-specific and a plant-specific component. Specifically, the log wage of worker m in period t is decomposed as:

$$\ln W_{mt} = \zeta_m + \theta_{i(m,t)} + \mathbf{X}'_{mt}\boldsymbol{\beta} + \upsilon_{mt} \tag{B.1}$$

In equation (B.1), ζ_m is a permanent log wage component specific to worker m, $\theta_{i(m,t)}$ is a permanent component specific to plant i employing worker m at time t, $\mathbf{X}'_{mt}\boldsymbol{\beta}$ is a time-varying component stemming from time-varying worker characteristics $\mathbf{X}_{mt}$ that are rewarded equally across plants, and υ_{mt} is an idiosyncratic component.

In the AKM framework, ζ_m reflects the worker's permanent skills, such as education and ability, $\mathbf{X}'_{mt}\boldsymbol{\beta}$ mirrors the worker's time-varying skills, such as experience, that affects the worker's productivity no matter where the job is held, and $\theta_{i(m,t)}$ is the percentage wage premium paid to every worker of plant i. The crucial assumption for this interpretation of the AKM decomposition to hold is that the idiosyncratic log wage component υ_{mt} is unrelated to the sequence of employers $\{i(m,t)\}_t$, for which Card *et al.* (2013) provide supporting evidence in their AKM wage decomposition for Germany. For a critical assessment of the validity of the AKM framework in the US context, we refer to Lamadon *et al.* (2022).

To measure the plant surplus to be split between employers and workers, we follow Abowd and Lemieux (1993) and use the quasi-rent per worker, with the plant's quasi-rent QR_{it} being defined as:

$$QR_{it} = P_{it}Q_{it} - J_{it}M_{it} - \overline{R}_{it}K_{it} - \overline{W}_{it}N_{it} \tag{B.2}$$

That is, the quasi-rent QR_{it} is revenues $P_{it}Q_{it}$ net of the value of intermediate inputs $J_{it}M_{it}$ and capital inputs $\overline{R}_{it}K_{it}$, where $\overline{R}_{it}$ denotes the competitive rental rate of capital, and net of the value of labour inputs $\overline{W}_{it}N_{it}$ priced at workers' outside option $\overline{W}_{it}$.[25]

[25] Note that we compute the competitive rental rate of capital $\overline{R}_{it}$ from the plant's capital stock and in doing so distinguish between prices for debt and equity at the two-digit sector level because the IAB data do not contain such information at the plant level. Specifically, we use the information on the 'cost of equity and capital' for Europe issued by Aswath Damodaran on 5th January 2019 at `http://pages.stern.nyu.edu/~adamodaran` and the 10-year long-term treasury bond rate for Germany to calculate the average rental rate of capital at the two-digit sector. Our average rental rate of capital is 9.9% for the years 1998–2004, 9.0% for 2005–2010, and 6.9% for 2011–2016.

When constructing workers' outside option $\overline{W}_{it}$, we follow the idea in Abowd and Allain (1996) and calculate workers' outside option as:

$$\ln \overline{W}_{it} = \overline{\ln W}_{st} + (\bar{\zeta}_{it} - \bar{\zeta}_{st}) - (\bar{\theta}_{st} - \theta_{st}^{p25}) \tag{B.3}$$

In (B.3), $\overline{\ln W}_{st}$ is the average log wage (i.e. plant-level wage bill per worker) in the respective two-digit sector s, $\bar{\zeta}_{it}$ is the average AKM worker wage effect in plant i, $\bar{\zeta}_{st}$ is the average AKM worker wage effect, $\bar{\theta}_{st}$ is the average AKM plant wage effect, and θ_{st}^{p25} its 25th percentile in the two-digit sector. The term $\bar{\zeta}_{it} - \bar{\zeta}_{st}$ captures the deviation in worker quality between plant i and the sector average and thus accounts for unobserved quality differences between plants' workforces. Moreover, subtracting the spread between the average AKM plant effect and its 25th percentile $\bar{\theta}_{st} - \theta_{st}^{p25}$ in the respective two-digit sector accounts for the influence of wage premia paid by future employers on workers' current outside option. Specifically, we assume that risk-averse workers expect to receive just a modest pay premium at the 25th percentile when switching employers.

As detailed in Hirsch and Mueller (2020), this way of constructing workers' outside option involves quite some decisions, and some of these may seem somewhat arbitrary. Yet, as also discussed there, in general different choices, such as using the 10th percentile of wage premia rather than the 25th percentile, make only little difference.

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