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Minimum wage non-compliance: the role of co-determination

Laszlo Goerke[1,2,3,4] · **Markus Pannenberg**[2,4,5]

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Abstract
We analyse how co-determination is related to non-compliance with the German minimum wage, which was introduced in 2015. The Works Constitution Act (WCA), the law regulating co-determination at the plant level, provides works councils with indirect means to ensure compliance with the statutory minimum wage. Based on this legal situation, our theoretical model predicts that non-compliance is less likely in co-determined firms because works councils enhance the enforcement of the law. The economic correlates of co-determination, such as higher productivity and wages, affect non-compliance in opposite directions. The empirical analysis, using data from the German Socio-economic Panel (SOEP) for the years 2016 and 2019, demonstrates that non-compliance occurs less often for employees in co-determined establishments, while there is no correlation between non-compliance and the difference between the minimum wage and the wage actually paid.

Keywords Co-determination · Labour law · Minimum wages · Socio-economic panel (SOEP) · Non-compliance · Works councils

JEL Classification J 30 · J 53 · K 31 · K 42 · M 54

1 Introduction

In 2015, Germany introduced a statutory minimum wage of € 8.50 per hour. Until 2024, it increased to € 12.41. Due to the fact that Germany has a sizeable low-wage sector (OECD, 2022, p. 345), the minimum wage's bite has been substantial,

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Extended author information available on the last page of the article

increasing from around 11% of employees in 2015 to almost 22% in 2022 (Börschlein et al., 2022). Nonetheless, adverse employment consequences are modest and restricted to particular labour market segments (Bossler & Gerner, 2020; Dustmann et al., 2022). One reason was the high demand for labour. Another cause may have been that many firms did not immediately adjust hourly wages but paid less than the minimum wage (Caliendo et al., 2019). Non-compliance with the legislation, or underpayment of minimum wages, requires the consent of the affected employees or, at least, the absence of attempts to enforce the regulation. From an Industrial Relations vantage point, therefore, non-compliance is less likely to arise in settings in which employees have extensive information about a firm's remuneration and personnel policy and can thus influence the employer's decisions in these areas. In Germany, co-determination at plant level provides works councils with information, consultation, and co-determination rights, which are particularly pronounced regarding personnel policy and social affairs. Therefore, co-determination could constitute a mechanism to voice the employees' desire for adequate remuneration and deter non-compliance with minimum wage legislation. From a Law and Economics perspective, the firm's choice whether and to what extent to comply with minimum wage legislation is, in the spirit of Becker (1968), a decision under uncertainty because a violation of the law may be detected and then be punished. In Germany, co-determination increases the expected costs of non-compliance and, therefore, makes it less likely.

In this paper, we provide a theoretical analysis of the aforementioned conjecture that co-determination makes non-compliance with minimum wage legislation less likely and subject it to empirical scrutiny. First, we outline the minimum wage legislation in Germany and clarify the influence the law on works councils, the Works Constitution Act (WCA), grants them regarding the enforcement of minimum wages. Second, we use a simple theoretical model of a competitive labour market to predict the impact of co-determination on the incidence of non-compliance, i.e. the number of underpaid workers in total employment. We show that if works councils are associated with stricter enforcement of minimum wage legislation, co-determined firms will exhibit a lower incidence. We further demonstrate that if co-determined establishments and those without works councils differ in economic parameters, such as productivity and wages, the impact of co-determination on minimum wage non-compliance becomes ambiguous because they affect the incentives to underpay differently. We can obtain comparable predictions about the incidence of non-compliance when analysing a monopsonistic setting. For such a model, the theoretical analysis additionally indicates that the extent of non-compliance, defined as the difference between the minimum wage and the amount actually paid, is more pronounced in co-determined firms. Third, we use data from the German Socio-Economic Panel (SOEP), which contains information about works councils in 2016 and 2019, to conduct a descriptive analysis of the relationship between non-compliance and codetermination in the private sector. We find that the probability of non-compliance for an employee in a co-determined establishment is between 2.2 and 4.1 percentage points lower in comparison to a comparable employee who works in an establishment without a works council. This is a sizeable effect, given that we observe underpayments for 6.3% to 10.8% of all employees. Accordingly, our

empirical findings are consistent with the theoretical prediction related to enforcement activities. They further suggest that works councils may fulfil regulatory tasks for which government institutions are responsible, according to the letter and spirit of the law (cf. Nienhüser, 2020; Rogers & Streeck, 1995). Moreover, we find no evidence that the extent of non-compliance, conditional on its occurrence, is correlated with co-determination.

Our contribution is related to (1) theoretical analyses of minimum wage underpayments, (2) empirical investigations of such behaviour, and (3) studies analysing the effects of works councils. Many theoretical analyses consider minimum wage underpayments in competitive settings (see, for example, Ashenfelter and Smith (1979), Chang and Ehrlich (1985), Chang (1992), Yaniv (2001), Bhorat et al. (2015), or Garneiro and Lucifora (2022)). Yaniv (1988) marks an initial exploration of underpayments in a monopsonistic framework, implying that the firm's labour supply increases in the wage. Later contributions develop the workers' optimal behaviour in Salop (1979) type settings from first principles (see, for example, Basu et al. (2010) and Badaoui and Walsh (2022)). Insofar as the studies consider changes in enforcement parameters, they predict a positive impact of the probability of detecting minimum wage underpayments and of associated fines on compliance with the law.

Empirical analyses of the statutory minimum wage in Germany have often been commissioned by the Minimum Wage Commission (*Mindestlohnkommission*). They cover various aspects, such as its impact on the structure of wages, employment and unemployment, working time, firms' investment behaviour, poverty risk, and consumption and savings patterns.[1] Some investigations also look at non-compliance with minimum wage legislation and document that a significant proportion of employees receive an hourly wage that is below the statutory minimum wage, especially in the years directly following its introduction (see, for example, Bachmann et al. (2022), Beckmannshagen and Fedorets (2021), and Bossler et al. (2022)). The reported numbers vary, inter alia, with the data sets and the methods used to calculate hourly wages. Studies based on SOEP-data compute non-compliance rates between 5% and 12%, with substantial variation across different groups of employees and over time (Bachmann et al., 2022; Burauel et al., 2018; Pusch, 2018).[2]

Empirical investigations concerning the effects of works councils have considered a wide variety of outcomes (see Addison (2009), Jäger et al. (2022), and Mohrenweiser (2022) for summaries and evaluations of relevant contributions). Some of the effects are directly related to regulations of the WCA, such as working time, vacation and health issues. Many studies consider the consequences on wages, productivity and profits, without necessarily being able to pin down the channels by which works councils affect them. One of the mechanisms emphasized to establish council effects is their role as an institutionalized voice (Freeman, 1980; Freeman & Lazear, 1995; Freeman & Medoff, 1984). In the context of minimum wage

[1] See the website of the German Minimum Wage Commission: www.mindestlohn-kommission.de/EN/Home/.

[2] Clemens (2021) and Clemens and Strain (2022) analyse non-compliance with the minimum wage in other countries, especially in the US labour market.

compliance, the safeguards of the WCA allow councils to require adherence to the law at lower expected costs compared to what individual workers face, given the possibility that employers sanction individual requests. Moreover, minimum wage compliance features elements of a collective good if violations of the law affect all comparable workers of a plant. This public good component further strengthens the role of works councils, who are obliged to act to the advantage of the entire workforce. Frick (1996) and Garcia-Serrano and Malo (2002) highlight the role of firm-level voice, such as by works councils, in settings where sectorally negotiated bargaining agreements are applied to all workers in covered firms and unions. Findings that co-determined establishments pay higher wages and are more productive than comparable establishments without a works council are also particularly relevant from our perspective. The wage effect implies that co-determined establishments are less likely to be affected by minimum wage legislation, as documented by Bellmann et al. (2021). The productivity impact constitutes a prerequisite for the wage consequences if works councils do not only redistribute, but also help to create rents.

Despite extensive work on works councils, the link between co-determination and minimum wages has not found much attention yet. As an exception, Pusch (2018) documents a negative correlation between being paid less than the minimum wage and working in a firm with a works council, using the 2016 SOEP wave.[3]

In the remainder of the paper, we describe the legal situation concerning minimum wages and co-determination at plant level in Sect. 2. In Sect. 3, we outline a simple theoretical model of a competitive labour market in which the firm can decide about the number of workers it pays less than the minimum wage. The details of the analysis and the extension to a monopsonistic setting are relegated to an appendix. We commence the empirical part of the paper in Sect. 4 with a description of the approach and the data. Section 5 contains the findings from our main analysis and various extensions. The final Sect. 6 concludes our contribution.

2 Legal background

2.1 Minimum wage legislation

In Germany, a statutory minimum wage of € 8.50 per hour was introduced on January 1, 2015, when the Act Regulating a General Minimum Wage (ARGM, *Mindestlohngesetz*) came into force. The minimum wage successively increased and amounts to € 12.41 since January 2024.[4] It is mandatory for most employees, with some exceptions being employees who are younger than 18 years, apprentices, individuals participating in selected education-related internships, and formerly

[3] Pusch (2018) uses information from the WSI Tarifarchiv to identify industries with sector-specific minimum wages, includes the public sector, and documents no average partial effects. Therefore, we cannot directly compare results. However, his estimated average incidence of non-compliance is similar to our estimates.

[4] The minimum wage increased to € 8.84/hour in 2017, € 9.19 in 2019, € 9.35 in 2020, € 9.60 in 2021, and € 12 in 2022.

long-term unemployed during their first six months of reemployment (§ 22 ARGM). Furthermore, sector-specific minimum wages below the statutory level were allowed in some industries until 2017 if they were based on collective agreements. The minimum wage in Germany is highly binding: it affected about 11% of employees in 2015, and estimates indicate that about 22% of employees earned the minimum wage or less in 2022 (Börschlein et al., 2022).

The minimum wage is computed as the gross wage for each actual working hour. Most extra payments, such as for overtime or work on Sundays, are part of the gross wage. However, one-time payments, such as vacation pay or Christmas bonuses, can only be used to fulfil minimum wage requirements in the month before their payment, because the ARGM requires that the minimum wage is paid to employees within this well-defined time period (§ 2(1) ARGM). In contrast, non-monetary remuneration elements, reimbursements of costs incurred by the employee, or specific bonuses, such as for employee loyalty, do not count as components of the gross wage. The ARGM does not explicitly mention co-determination, as the law establishes an individual legal entitlement of employees against the employer.

Unlike other European countries, there are no labour inspectorates in Germany that enforce the statutory minimum wage. Instead, a special division of the German customs authorities, the Unit for the Financial Control of Undeclared Work (*Finanzkontrolle Schwarzarbeit*, FKS), is charged with enforcing the statutory minimum wage (§ 14 ARGM). Inspections are based on random sampling, especially in industries with a higher risk of non-compliance, or on information provided by employees (Mindestlohnkommission, 2023). Should non-compliance be established, employers must pay fines of up to € 500,000 (§ 21(3) ARGM). In case the economic benefits of non-compliance exceed this limit, a higher penalty may be imposed according to § 17(4) of the Act on Regulatory Offences (ARO, *Gesetz über Ordnungswidrigkeiten*). The customs authorities determine the level of the fine, which is an increasing function of the extent of wage underpayments and additional economic benefits. Moreover, its amount is doubled if willful intent of the employer is observed (§ 17(2) and § 17(4) ARO). If non-compliant firms contest the customs authority's decision, a court tends to settle the fine. The fines do not include the back payments of minimum wages. Instead, employees must file their case with a civil court to receive the wage to which they are legally entitled.[5]

A firm that pays a wage below the minimum wage, usually also makes insufficient contributions to social security and transfers an inadequate amount of income taxes it has to withhold to tax authorities. If non-compliance with minimum wage legislation is detected, firms must make up the insufficient tax and social security payments and pay an additional fine for their evasion. The resulting expenditure usually increases the expected costs of minimum wage non-compliance significantly.

[5] For further details of the enforcement of minimum wages in Germany, see, for example, Bosch et al. (2023) or Eurofound (2023).

2.2 Co-determination at plant-level

Co-determination at plant-level is regulated primarily in the Works Constitution Act (WCA, *Betriebsverfassungsgesetz*).[6] Employees can establish works councils in all private sector establishments that have five or more permanent employees who are entitled to vote in a works council election (§ 1 WCA).[7] Currently, about 8% of all relevant plants have a works council. Since they are more prevalent in large establishments, the share of employees working in works council plants amounts to 43% (Hohendanner & Kohaut, 2023). According to the provisions of § 2 WCA, works councils bear a legal obligation to collaborate with management, with the overarching aim of benefiting the workforce and the establishment. They have information, consultation, and co-determination rights, which become more extensive the larger the plant is. The legal entitlements of works councils are most comprehensive regarding personnel policy and social affairs.

The WCA does not explicitly endow a works council with rights concerning minimum wages. However, the paragraph on the general duties of a works council (§ 80 WCA) states that a council "has to ensure that laws, directives, safety regulations, collective bargaining contracts and agreements between a works council and an employer, which benefit employees, are executed" (own translation). These general obligations also relate to a statutory minimum wage and imply that a works council is entitled to obtain the necessary documentation and discuss minimum wage issues with the employer (Düwell & Schubert, 2017; Lakies, 2021). Moreover, the WCA provides the works council with information claims and establishes co-determination rights, for example regarding working time and the structure of compensation (§ 87 WCA), which make it more difficult for a firm to hide minimum wage underpayments. If a works council becomes aware of insufficient remuneration, it can inform the affected employees and help them enforce their legal entitlement (Düwell & Schubert, 2017; Kleinebrink, 2015).[8] Since employees can notify customs authorities of subminimum wage payments, the probability that such illegal remuneration is detected is likely to be higher in works council establishments than in firms without such an institution (see also Eurofound, 2023, p. 52).

Once customs authorities inspect a firm, the works council is obliged to provide information about violations of the ARGM. If the works council had discussed violations of the ARGM with the employer before the inspection and, for example, issued a written complaint and the company continued to pay wages below the legally required level, it will be more difficult to declare the insufficient pay as accidental. At the same time, customs authorities can more easily establish an

[6] There is also mandatory co-determination at the enterprise level in companies with 500 or more employees, which regulates representation on company boards (see Addison (2009) or Jäger et al. (2022) for details).

[7] While the law exclusively uses the expression 'establishment' (*Betrieb*), for stylistic reasons we employ the terms 'plant' and 'firm' as equivalents.

[8] Bonin et al., (2020, p. 107 ff) show that members of a works council help to enforce minimum wage legislation by providing employees with information about their entitlements and the law's content and by verifying the firm's adherence to it.

intentional violation of the law. In the case of willful intent, the fine will be higher for a given underpayment (in accordance with § 17 (2) and § 17 (4) ARO).

In sum, works councils play no direct role in enforcing the statutory minimum wage in Germany (Düwell & Schubert, 2017; Lakies, 2021). However, given their information and co-determination rights in areas related to the calculation and payment of minimum wages, they are likely to know about intentional and substantial underpayments. This knowledge can result in a greater probability that non-compliance is detected by customs authorities and established in court, and in higher penalties for the firm.

3 A simple model of non-compliance in the presence of works councils

The starting point of our theoretical model is the notion that a firm takes both the legal framework, e.g. minimum wage legislation, and labour market institutions, such as works councils, into account when making its choices. In our model, we assume two types of workers; one who is directly affected by minimum wage legislation, whereas the productivity of the other type is so high that the employee earns a wage above the legal minimum level. This feature allows us to distinguish between workers subject to minimum wage legislation and those who are not. In considering the role of the works councils, we take into account that they cannot directly assist in the enforcement of minimum wage legislation, but have an indirect influence, as they can affect the probability that a firm will be inspected by the customs authority and the resulting fine. Furthermore, we examine how the positive productivity and wage effects associated with works councils influence non-compliance. In the main text, we focus on a setting with a competitive labour market. At the end of this section, we briefly describe an extension to a monopsonistic setting, the details of which are presented in the appendix.[9] We consider a competitive and a monopsonistic environment, as the degree of competition observable on German labour markets is compatible with both types of settings (see Popp, 2023).

3.1 Outline of model for competitive setting

We consider a representative, profit-maximising firm. Accordingly, interactions on the input or output market do not affect the non-compliance incentives.[10] As a further consequence of this simplification, we do not incorporate a distribution of firm

[9] Our model extends the analytical frameworks in Yaniv (2001) and Yaniv (1988) by adding a second type of worker who is not affected directly by a minimum wage, interpreting a variety of comparative static predictions with regard to co-determination, and focusing on the incidence of non-compliance and not the number of employees who are underpaid.

[10] Yaniv (2004, 2006) argues that an encompassing minimum wage shifts both the demand and the supply curve, resulting in a decline of the market wage. Our focus on one firm rules out such equilibrium repercussions.

characteristics that could explain heterogeneity in non-compliance choices (see Basu et al., 2010 and Badaoui & Walsh, 2022). Therefore, the model is attuned to our empirical analysis, which relies on individual-level data.

Labour markets are competitive, implying that the market-clearing wages constitute parameters for the firm. It employs two types of workers. High-productivity workers do not supply labour at or below the minimum wage, w^M. We refer to them as *high-wage employees* who obtain a wage of w^H, $w^H > w^M$, which is exogenously given from the perspective of the firm. The second type of worker has a lower productivity and supplies labour at or below the minimum wage. They will henceforth be called *minimum-wage workers*. There is a market-clearing wage, w^C, $w^C < w^M$, for minimum-wage workers, which the firm has to pay if it employs such kind of worker and ignores the minimum-wage legislation. At this wage, it can hire as many minimum-wage workers as desired. However, a wage underpayment can be detected and will then be fined. Therefore, the firm can also decide on the quantity of minimum-wage workers it remunerates according to legal requirements.

The timing is as follows: First, the firm chooses the number, H, of high-wage employees, the number, K, of minimum-wage workers who obtain the minimum wage, w^M, and the number, L, of minimum-wage workers who are underpaid and receive the wage w^C. Subsequently, an inspection may take place. The probability of such an event is p, $0<p<1$. In case of an inspection, underpaid workers obtain a back payment so that they earn w^M. Additionally, the firm is penalised. The incidence, I, of non-compliance with minimum wage legislation is captured by the expected number of minimum-wage workers who receive less than w^M, $(1 - p)L$, relative to total employment, $H+K+L$.

In appendix section "Monopsonistic Setting", we analyse a variant of the model in which the firm has monopsonistic market power, and the labour supply of minimum-wage workers increases in the wage. We can then measure the extent of non-compliance as the difference between the minimum wage, w^M, and the wage the firm chooses to pay. If the firm is a price-taker, this difference is obviously constant.

3.2 Firm

The firm's revenues are given by a function $Q(L+K,H) = \alpha[L+K] + \beta\alpha H + q(L+K,H)$, which is increasing and strictly concave in each argument, such that $Q_L(L+K,H) = Q_K(L+K,H) = \alpha + q_L(L+K,H), Q_H(L+K,H) = \beta\alpha + q_H(L+K,H) > 0 > Q_{LL} = q_{LL} = Q_{KK} = q_{KK} = Q_{LK} = q_{LK}, Q_{HH} = q_{HH}$ and $q_L = q_K, q_H > 0$ hold, where subscripts indicate partial derivatives and square brackets (parenthesis) indicate multiplicative terms (functional relationships). Furthermore, the specification of revenues implies that working hours are normalised to unity and that the productivity of minimum-wage workers is the same, irrespective of whether they are being paid the minimum wage, w^M, or the market wage, w^C.[11] The parameter α, $\alpha \geq 0$, constitutes a (marginal) productivity shifter, which may affect high-wage employees and minimum-wage workers differently ($0<\beta\neq 1$).

[11] If we assume $Q_L \neq Q_K$, very few analytical results can be obtained because the magnitudes of Q_L and Q_K depend on the absolute number of both categories of minimum-wage workers.

In the case of an inspection, the wage bill for minimum-wage workers equals $[L+K]w^M$. Moreover, the firm has to pay a fine, F, which is an increasing and strictly concave function of the extent of underpayments, implying that $F = F(L[w^M - w^C])$, F', $F'' > 0$. The non-linearity of the fine function ensures an interior solution to the firm's optimisation problem.[12]

The assumptions outlined above imply that expected profits $\mathrm{E}(\pi)$ are given by:

$$\begin{aligned}\mathrm{E}(\pi) =& Q(L+K,H) - w^H H - \left[1-p\right]\left[w^C L + w^M K\right] \\ & - p\left[w^M[L+K] + F\left(L\left[w^M - w^C\right]\right)\right]\end{aligned} \tag{1}$$

3.3 Optimal choices

The maximisation of $\mathrm{E}(\pi)$ with respect to H, K, and L yields (see appendix section "Competitive Labour Market" for the derivation and the second-order conditions):

$$Q_H(L+K,H) - w^H = 0 \tag{2}$$

$$Q_L(L+K,H) - w^M = 0 \tag{3}$$

$$1 - p - pF'\left(L\left[w^M - w^C\right]\right) = 0 \tag{4}$$

Due to the feature that minimum wages and non-compliance do not affect the gains and costs of employing high-wage employees, their optimal number, H^*, results from equating marginal revenues, Q_H, with the wage (cf. Equation (2)). A comparable condition governs the optimal number, $K^* + L^*$, of minimum-wage workers (see Eq. (3)). Accordingly, the severity with which the minimum wage is enforced may alter the composition of minimum wage employment, but not its level. This neutrality result is well-established (see, for example, Yaniv (2001), Bhorat et al. (2015), or Garneiro and Lucifora (2022)), and results from the feature that the marginal costs of varying minimum wage employment, $L^* + K^*$, equal w^M, as long as both types of workers are employed ($L^*, K^* > 0$).

If non-compliance remains undetected, an event occurring with the probability $1 - p$, marginally raising the number of legally paid minimum-wage workers increases wage costs by w^M. With the probability p non-compliance is detected. In this case, all workers obtain the minimum wage. Consequently, marginally raising the number of legally paid minimum-wage workers also drives up wage costs by w^M. Finally, the firm chooses the number, L^*, of underpaid minimum-wage workers so that the probability of not being detected, $1 - p$, equals the change in the expected

[12] If the fine were linear in the extent of underpayments, the firm would either comply with the law or just pay the competitive wage (see, for example, Ashenfelter and Smith (1979), Grenier (1982), or Chang and Ehrlich (1985)). Alternatively, an interior solution can result, for example, if the firm is strictly risk-averse (Yaniv 2001) or faces a detection probability or expected fine that are increasing and strictly convex in the number of underpaid minimum-wage workers (Bhorat et al., 2015; Garneiro and Lucifora 2022).

fine, pF' (cf. Equation (4)). This is the profit-maximising choice because altering the number of underpaid minimum-wage workers has no impact on total wage payments if non-compliance is detected for $K^* > 0$, given that underpaid workers have to be compensated for inadequate remuneration. In a profit-maximum, the expected increase in the fine if expanding the number of underpaid workers, $\left[w^M - w^C\right]pF'$, is set equal to the expected wage costs of employing one more worker of that type without being observed paying an insufficient wage. These costs equal the probability of this event occurring times the savings in wage costs, that is, $\left[1 - p\right][w^M - w^C]$.

3.4 Effects of co-determination

Above we have argued that establishments with a works council are confronted with an elevated detection probability and higher fines than establishments without such an institution. In the present model, we incorporate this possibility by assuming that the probability, p, and the marginal fine, $F^{'}$, are higher in a co-determined firm. Furthermore, there is substantial evidence that productivity and wages are higher in co-determined establishments than in firms without works councils, though causal relationships are difficult to establish (Jäger et al., 2022; Mohrenweiser, 2022). Therefore, we also take these two features into account.

We summarise our findings concerning the effects of enforcement and economic parameters on the optimal numbers of employees, H^*, L^*, and K^*, and the incidence, I, as (see appendix section "Competitive Labour Market" for the derivations):

Proposition

(a) *Enforcement parameters*

An increase in the detection probability, p, *and the marginal fine*, $F^{'}$, *induce the firm to lower the number of underpaid minimum-wage workers*, L^*, *and to raise the quantity of minimum-wage workers paid according to law*, K^*, *by the same number. Since high-wage employment*, H^*, *remains the same, the incidence*, I, *of non-compliance declines.*

(b) *Economic parameters*

An increase in productivity, α, *does not affect the number*, L^* *of underpaid minimum-wage workers. If* $Q_{KH} \geq 0$ *holds, the firm employs more high-wage employees*, H^*, *and minimum-wage workers who are being paid according to law*, K^*, *so that the incidence*, I, *of non-compliance declines.*

A higher wage for high-wage employees, w^H, *reduces their number*, H^*, *does not affect employment*, L^* *of underpaid minimum-wage workers, and lowers the number*, K^*, *of minimum-wage workers who are being paid according to law for* $Q_{KH} \geq 0$, *so that the incidence*, I, *of non-compliance rises.*

Finally, a rise in the market wage, w^C, of minimum-wage workers affects neither employment, H^*, of high-wage employees nor overall employment of minimum-wage workers, $K^* + L^*$, while it increases employment, L^* of underpaid minimum-wage workers and the incidence, I, of non-compliance.

To provide intuition, we may observe that a higher detection probability, p, and a greater marginal fine, F', make non-compliance more costly at the margin. Such a rise in the costs requires the overall extent of minimum wage underpayments, $L[w^M - w^C]$, to fall, given the strict convexity of the fine function (see Eq. (4)). The firm achieves this adjustment by reducing the number, L^*, of underpaid minimum-wage workers. The marginal gains and costs of employing high-wage employees and minimum-wage workers paid according to law are not directly affected by variations in the detection probability and the fine. However, a decline in the number of underpaid minimum-wage workers, L^*, raises the marginal productivity of their correctly paid counterparts. Accordingly, an increase in the quantity, K^*, of minimum-wage workers who are being paid according to law by precisely the number by which employment, L^*, of underpaid minimum-wage workers is reduced, while holding high-wage employment constant, re-establishes marginal productivities at the level prevailing before the rise in the marginal fine, F'. The same reasoning applies with regard to the detection probability, p.

A higher productivity of all workers does not alter the marginal costs and gains of non-compliance, as evidenced by Eq. (4). Therefore, the number of underpaid minimum-wage workers, L^*, remains unchanged. Higher productivity induces the firm to expand the employment of the other two types of workers. If greater employment of high-wage employees does not reduce the marginal productivity of minimum-wage workers, that is, if $Q_{KH} \geq 0$ holds, the expansions in H^* and K^* (weakly) reinforce each other and employment of high-wage and minimum-wage workers paid according to the law rises.

A higher wage of high-wage employees, w^H, does not affect the marginal gains and costs of non-compliance. Therefore, the employment of underpaid minimum-wage workers, L^*, remains constant. The higher wage induces the firm to reduce the number, H^*, of high-wage employees. This lowers the marginal gain from employing correctly paid minimum-wage workers if their marginal productivity rises with high-wage employment. Finally, a higher competitive wage, w^C, for minimum-wage workers reduces the marginal fine for their employment, so that the firm expands the number, L^*, of underpaid minimum-wage workers. Since the wage of high-wage employees and the minimum wage remain unaffected, the firm retains the number of high-wage employees and does not alter the overall employment of minimum-wage workers (see Eqs. (2) and (3)).

The above analysis predicts that the incidence of non-compliance will be lower for workers employed in co-determined establishments than for individuals

employed in firms without works councils, if co-determination affects non-compliance primarily through a stricter enforcement of minimum wage legislation. If co-determined establishments and firms without works councils differ predominantly in economic outcomes, such as productivity and wages, the model provides conflicting predictions about the impact of co-determination on non-compliance with minimum wage legislation.

3.5 Changes in the minimum wage

As outlined in the introduction, the minimum wage has risen over the period we analyse in the empirical part of our paper. These increases altered the incentives to comply with legislation. On the one hand, a higher minimum wage, w^M, raises the extent of underpayments, $w^M - w^C$, and, therefore, the marginal costs of non-compliance. In consequence, the number of underpaid minimum-wage employees falls (see Eq. (3)). On the other hand, a higher minimum wage reduces overall employment of minimum-wage workers, $K^* + L^*$, and possibly also of high-wage employees, H^*. Therefore, the effect on the incidence of non-compliance is theoretically ambiguous (see appendix section "Competitive Labour Market"). Moreover, we can show that the effect of a higher minimum wage on the number of underpaid minimum-wage workers neither varies with the probability of detection of non-compliance, p, nor the marginal fine, F'. This suggests that the impact of works councils on compliance may have been unaffected by minimum wage increases.

3.6 Monopsonistic firms

Since the firm is a price-taker on the labour market, the extent of wage underpayments per worker, $w^M - w^C$, is exogenously given. To endogenise this difference in a partial equilibrium model with a representative firm, we modify our set-up and assume that the firm is a monopsonist on the market for underpaid minimum-wage workers. It can set the wage, w^{Mon}, paid to minimum-wage workers.[13] The labour supply curve of underpaid minimum-wage workers, which the firm faces, increases in the wage, w^{Mon}, implying that $L = L(w^{Mon})$ and $\partial L/\partial w^{Mon} > 0$. Since we are interested in non-compliance, we assume $w^{Mon} < w^M$. The firm can hire as many minimum-wage workers at the wage w^M as it wants. We further retain the assumption that the firm is a price taker on the market for high-wage employees.

Expected profits, $E(\pi)$, of a monopsonistic firm are given by:

[13] Bhorat et al. (2015) assume a firm that can pay more than the market wage, w^C, although it does not have monopsonistic market power, but cannot determine the number of workers who are underpaid. This implies that all workers are being paid below the minimum wage, and allows the firm to influence the aggregate underpayment and, hence, the fine by selecting the difference between the minimum wage and the chosen level. Thus, there are alternative approaches to endogenise the extent of non-compliance. Chang (1992) assumes that the firm can decide on the number of workers and the wage in excess of the market-clearing level. In this set-up, workers would work for less than the wage the firm wants to pay, but the firm would not accept this offer to reduce the expected fine pay.

$$\begin{aligned} \mathrm{E}(\pi) = Q(L+K,H) - w^{H}H - \left[1-p\right]\left[w^{Mon}L + w^{M}K\right] \\ - p\left[w^{M}L + K\right] - pF\left(L\left[w^{M} - w^{Mon}\right]\right) \end{aligned} \tag{5}$$

The firm maximises expected profits by choosing the wage, w^{Mon}, the number of minimum-wage workers paid the minimum wage, K, and the number of high-wage workers, H. Accordingly, it can trade off the number of underpaid minimum-wage workers and of those paid according to the legal requirement, as in the model with a perfectly competitive setting.

The predictions for the monopsonistic setting concerning changes in employment due to variations in the detection probability, p, the marginal fine, F', the productivity parameter, α, and the wage of high-wage employees, w^{H}, are the qualitatively same as for the competitive framework (see appendix section "Monopsonistic Setting" for details of the model and its analysis).[14] This is the case because the modification only affects the firm's trade-off with respect to the number, $L(w^{Mon})$, of underpaid minimum-wage workers (cf. Equation (3)), which it determines by setting the wage optimally. Furthermore, the extent of non-compliance per worker, $w^{M} - w^{Mon}$, rises with a higher marginal fine and detection probability because the monopsonistic firm wants to reduce the number of underpaid workers. It can only do so by reducing the wage, w^{Mon}, paid to them. The extent of underpayments is unaffected by a change in the productivity parameter, α, and in the remuneration of high-wage employees, w^{H}. Finally, a higher minimum wage, w^{M}, lowers the wage paid by the monopsonist, therefore, raises the extent of non-compliance and reduces the number of minimum-wage workers who are paid less than the minimum wage. As the employment change of other workers cannot be signed, the alteration in the incidence of non-compliance due to a higher minimum wage is ambiguous.

3.7 Summary of predictions

We summarise the predictions derived for a competitive setting and a monopsonistic framework in Table 1.

4 Data and empirical strategy

4.1 Data

Our empirical analysis relies on the German Socio-Economic Panel (SOEP), a nationally representative household panel data set (see Goebel et al., 2019). The SOEP provides annual information on various aspects of the respondents' lives, including some characteristics concerning the workplace of employed individuals. However, the crucial information on whether a works council exists at the respondent's workplace is collected in irregular intervals only. Since the introduction of the

[14] The competitive wage for minimum-wage employees, w^{C}, does not play a role in the monopsonistic setting.

Table 1 Summary of comparative static predictions

	Change in						
	Number of underpaid paid minimum-wage employee L^*; $L(w^{Mon})$	Number of correctly paid minimum-wage employees K^*	Total number of minimum-wage employee L^*+K^*; $L(w^{Mon})+K^*$	Number of high-wage employees H^*	Incidence of non-compliance I	Extent of non-compliance in competitive setting $w^M - w^C$	Extent of non-compliance in monopsonistic setting $w^M - w^{Mon}$
Detection probability: p	–	+	0	0	–	0	+
Marginal fine: F'	–	+	0	0	–	0	+
Productivity:α	0	+, if $Q_{KH} \geq 0$	+, if $Q_{KH} \geq 0$	+, if $Q_{KH} \geq 0$	−, if $Q_{KH} \geq 0$	0	0
Wage of high-wage employees:w^H	0	−, if $Q_{KH} \geq 0$	−, if $Q_{KH} > 0$	–	+	0	0
Competitive wage of minimum-wage employees:w^C	+; n.a	–	0; n.a	0	+	–	n.a
Minimum wage:w^M	–	?	–	−, if $Q_{KH} > 0$	?	+	+

–: indicates decline; +: indicates rise; ?: effect is uncertain; n.a.: not applicable

minimum wage, the relevant question has been included in the survey years 2016 and 2019. Hence, we use data from these two years to examine the relationship between non-compliance with minimum wage legislation and co-determination.

Our attention centers on employees in private sector plants with at least five employees, as the WCA only applies to these establishments. All respondents worked either full-time, part-time or were marginally employed in the particular year. Their ages varied between 18 and 67, and they were eligible for the statutory minimum wage. Furthermore, we exclude employees in industries with a collectively agreed minimum wage that applies to the entire industry, e.g. due to coverage extensions by an ordinance of the Federal Ministry of Labor and Social Affairs (so called *Allgemeinverbindlichkeitserklärungen*).[15] We do so for two reasons: First, our focus is on the role of co-determination for non-compliance with the statutory minimum wage. Second, the data does not always allow us to accurately determine the collective agreement according to which an employee is paid and, consequently, the applicable minimum wage.[16]

In order to determine non-compliance with minimum wage legislation, we require evidence concerning the gross wage per working hour. The SOEP provides information about gross monthly earnings and two measures of reported weekly working hours. The first measure indicates hours as specified in the employment contract. The second one refers to actual hours. Using both measures of weekly working hours, we calculate hourly wages as monthly earnings divided by the product of weekly working hours and 4.35.[17] The measure based on contractual working hours is likely to be an upper bound of the legally relevant hourly wage since paid overtime is not included in the number of contractual working hours but, for example, reflected in monthly earnings. The second measure, relying on reported actual hours, presumably represents a lower bound since unpaid overtime is included, even if it is compensated, for instance, through a working time account in accordance with the ARGM regulations. Using both hourly wage measures throughout our empirical work helps us demonstrate the robustness of the results.

We calculate two indicators of non-compliance with minimum wage legislation for both wage variables. First, we generate a dummy variable, indicating the incidence of non-compliance, which equals one if the respective hourly wage is lower than the statutory minimum wage in the respective year. Second, we compute the extent of underpayment, or of non-compliance, as the difference between the

[15] Until 2017, some of these legally binding industry minimum wages could be lower than the nationwide statutory minimum wage. From January 1, 2018, the industry-specific minimum wages has to at least equal the statutory minimum wage (Mindestlohnkommission (2016), p. 18 and Tables A2/A3 in the Appendix, pp. 155–156).

[16] Irrespective of the measurement issue, we have re-estimated our main specifications for an extended sample that includes employees subject to the statutory minimum wage and employees to whom a legally binding industry-specific minimum wage presumably applies. The results reported below are not affected by this expansion of the sample.

[17] Hourly wage = [gross monthly earnings / (weekly working hours * 4.35)], with 4.35 = 365/(12 * 7).

statutory minimum wage and the hourly wage in €, conditional on the incidence of non-compliance in the respective year.

In our regression analyses, we investigate the relationship between non-compliance and the existence of a works council in the firm, conditional on individual and firm characteristics. Hence, the covariate of key interest is a dummy variable which equals one if the respondent works in a firm with a works council. To control for collective wage bargaining between employer associations and trade unions, we employ a dummy variable which equals one if the firm is bound by a collective bargaining agreement.[18] Firm size, industry affiliation and region are included with respective (vectors of) dummy variables. Furthermore, age (in years) and age squared, tenure (in years), dummy variables for gender (male), education (apprenticeship, university degree), white collar status, migration background, being married and a dummy variable for the year 2019 are included. To cater for the employee's wage bargaining power, we include a dummy variable that equals one if the employee is very concerned about job security. Furthermore, dummy variables for working part-time or in marginal employment (so-called "mini-jobs") are incorporated. Table 4 in Appendix presents descriptive statistics.

4.2 Empirical strategy

Ultimately, we are interested in the causal effect of a works council on non-compliance with the minimum wage. Determining such a causal impact would require, for example, an exogenous change in the existence of a works council within an establishment. However, the SOEP data does not contain information to ascertain such exogenous variation. Hence, we examine whether the predictions of our theoretical models are compatible with the results of standard regression analyses. Specifically, we start from the two central predictions of our two models: (1) there is a negative relationship between the existence of a works council in the establishment and the incidence of non-compliance with the statutory minimum wage and (2) there is a non-negative correlation between co-determination and the extent of non-compliance. Taking advantage of a basic rule of probability, expected underpayments, conditional on our vector of covariates, X, $[\mathrm{E}((w^M - w^{Mon})|X)]$ can be defined as the product of the propensity to receive a subminimum wage payment $[\mathrm{P}(I((w^M - w^{Mon}) > 0) = 1|X)]$ and the expected underpayment, conditional on the incidence on non-compliance, $[\mathrm{E}((w^M - w^{Mon})|X,\ I((w^M - w^{Mon}) > 0) = 1)]$, i.e. $\mathrm{E}((w^M - w^{Mon})|X) = \mathrm{P}(I((w^M - w^{Mon}) > 0) = 1|X) \times \mathrm{E}((w^M - w^{Mon})|X, I((w^M - w^{Mon}) > 0) = 1)$. We employ a two-part model specification to analyse the two non-compliance decisions separately (e.g. see Wooldridge (2010), Sect. 17.6, and Drukker (2017)). In order to accomplish this, we use a standard probit specification for the incidence and a standard OLS specification for the extent of

[18] Information on a respondent's membership in a trade union is available in 2019, but not in the 2016 wave.

non-compliance, conditional on its incidence. SOEP survey weights are used in all specifications to account for survey design and panel attrition.

5 Results

In this section we, first, present descriptive evidence. Second, we outline the main regression results for a pooled estimating sample based on observations from both years, 2016 and 2019. We also consider changes over time and scrutinize the role of trade unions in addition to co-determination. Third, we investigate whether the observed effects vary across different types of employees. We consider gender, region (eastern vs. western Germany), working time, and firm size. Finally, we evaluate the robustness of the findings concerning the identification of non-compliance.

5.1 Descriptive evidence

On average, 6.3% to 10.8% of all employees earned less than the statutory minimum wage (see Table 5 in Appendix). Although the minimum wage increased from € 8.50 per hour in 2016 to € 9.19 in 2019, the incidence of non-compliance shrank significantly from 7.3% to 5.4% (*contractual hours*), respectively from 11.8% to 9.8% (*actual hours*) over the same period.[19] [20] Considering the extent of non-compliance, we find that employees who do not receive the statutory minimum wage, earn on average € 1.7–€ 2.0 per hour less than the respective minimum wage (see Table 5 in Appendix). This average extent of non-compliance did not change significantly over time.

Focusing on the relationship between non-compliance and co-determination, we observe a strikingly large difference in the incidence (see Table 2): Employees in firms without a works council face a non-compliance risk three to four times higher than that of employees in co-determined firms. These differences are all significantly different from zero based on t-tests. Hence, the descriptive evidence is in line with

[19] For both wage measures, t-tests indicate that the changes over time are statistically significant. We can compare our estimates of the incidence of non-compliance based on contractual hours with estimates provided by Bachmann et al., (2022, p. 44, Table 3.3) who find a non-compliance rate of 7.5% in 2016 and of 5.9% in 2019. Note that our estimating sample differs from theirs, since we (a) focus on the private sector only, (b) require information on the existence of a works council in the firm, and (c) consider employees who work in a firm with at least 5 employees.

[20] The Federal Statistical Office Germany provides two other data sources for calculating non-compliance rates, namely the "*Verdiensterhebung* (VE)" and the "*Verdienststrukturerhebung* (VSE)". Based on these data sources, non-compliance rates are much lower, amounting to, for example, 3.0% instead of 5.4% (our study) or 5.9% (Bachmann et al., 2022, p. 44) in 2019. These notable differences are partly due to the fact that in the VE/ VSE (a) mini-jobs are not included, where non-compliance is much more prevalent, (b) only information on paid overtime is available, and (c) employers report wage information, which reduces the likelihood of reporting hourly wages that do not comply with the law (see Mindestlohnkommission (2023), Bachmann et al. (2022) or Caliendo et al., (2023, online appendix C) for a detailed discussion).

the theoretical predictions concerning enforcement parameters and productivity effects.

Considering the extent of non-compliance, conditional on its incidence, the raw average underpayment is slightly larger for employees working in a firm with a works council than in one without such an institution. However, the differences in the range of € 0.1–€ 0.5 are never significantly different from zero at the $\alpha = 0.05$-level, based on t-tests. The descriptive evidence with respect to the extent of non-compliance is consistent with the implication of the competitive setting and the prediction for the monopsonistic model in cases in which works councils affect non-compliance primarily through their economic consequences. If co-determination has an impact predominantly via stricter enforcement, the results suggest that the monopsonistic model is not an adequate representation of the labour market.

5.2 Regression results

5.2.1 Main findings

Our goal is to assess whether the existence of a works council within the firm has predictive power for non-compliance with the statutory minimum wage and the

Table 2 Non-compliance with the statutory minimum wage and works councils

Incidence of non-compliance with statutory minimum wage (in %)						
	Contractual hours			Actual hours		
Works council exists within firm						
	Pooled	2016	2019	Pooled	2016	2019
	2.6	3.0	2.2	4.7	4.6	4.7
N	6209	3035	3174	6518	3189	3329
Works Council does not exist within firm						
	Pooled	2016	2019	Pooled	2016	2019
	10.3	11.9	8.8	17.1	19.1	15.2
N	6120	2979	3141	6737	3222	3515
Extent of subminimum wage payment (conditional on incidence, mean, in €)						
	Contractual hours			Actual hours		
Works council exists within firm						
	Pooled	2016	2019	Pooled	2016	2019
	2.0	1.8	2.2	2.0	1.8	2.1
N	207	117	90	351	174	177
Works Council does not exist within firm						
	Pooled	2016	2019	Pooled	2016	2019
	1.7	1.7	1.7	1.8	1.7	1.9
N	698	377	321	1193	629	564

SOEP 2016, 2019; SOEP survey weights are used

extent of underpayment, conditional on non-compliance. Table 3 displays the results of our main regression exercises.

The estimated average partial effects (APE) indicate that working in a co-determined firm goes along with a significant decrease in the probability of being paid less than the statutory minimum wage of 2.2 percentage points, respectively 4.1 percentage points (col. 1 and 2). This finding is consistent with the theoretical predictions concerning the impact of works councils on enforcement parameters and their correlation with productivity, though not on wages. Given that the raw average non-compliance rates are 6.3 percentage points when focusing on contractual hours and 10.8 percentage points when considering the wage calculated on the basis of actual hours (see Table 5 in Appendix), taken at face value, our results imply that working in a co-determined firm reduces the individual likelihood of non-compliance by roughly 40%.

From Table 3, we also observe that the incidence of non-compliance is lower for males, higher in eastern Germany and for employees who do not work full-time. Individual bargaining power, proxied by a dummy variable that equals one if the employee is very concerned about job security, is positively correlated with the incidence of non-compliance. The contractual hours wage indicator additionally suggests that non-compliance has decreased over time.

Furthermore, Table 3 reveals that the estimated correlations between the existence of a works council and the extent of non-compliance, conditional on its incidence, are positive but not significantly different from zero. The estimated sizes of the APEs are relatively small compared to the absolute magnitude of minimum wages, i.e. less than 5%. Therefore, the findings are consistent with the predictions derived from the competitive model and, concerning the effects of economic parameters, such as wages and productivity, the monopsonistic set-up (see Table 1).

5.2.2 Changes over time?

The statutory minimum wage in Germany rose by around 8% between 2016 and 2019. The theoretical analysis suggests an impact of its level on the incidence of non-compliance, without enabling us to predict the direction of the change. Moreover, the extent of non-compliance, conditional on its occurrence, is projected to rise, irrespective of the degree of competition on the labour market.

Focusing on the incidence of non-compliance, we observe that the estimated coefficients of the time dummy 2019 are significantly different from zero in one out of two specifications (Table 3, col. 1 and 2). This finding is compatible with the ambiguous theoretical prediction and with empirical evidence that the degree of monopsonistic competition in Germany is heterogeneous across industries (Popp, 2023). Looking at the extent of underpayment, we find positive coefficients of the time dummy 2019 in both specifications, which do not differ significantly from zero (Table 3, col. 3 and 4). From a theoretical point of view, the estimates therefore do not allow us to differentiate between the approaches we consider in Sect. 3.

To investigate the relationship between minimum wage dynamics and non-compliance over time further, we extend our main empirical specifications and include

Table 3 Determinants of non-compliance with the statutory minimum wage (average partial effects)

	Incidence of non-compliance with statutory minimum wage		Extent of subminimum wage payment conditional on non-compliance	
	Contractual hours	Actual hours	Contractual hours	Actual hours
Works council	−0.022**	−0.041**	0.305	0.187
	(0.007)	(0.010)	(0.252)	(0.200)
Collective	−0.006	−0.006	0.277	0.130
bargaining	(0.007)	(0.009)	(0.232)	(0.169)
Part-time work	0.029**	0.049**	−0.027	0.028
	(0.009)	(0.012)	(0.229)	(0.170)
Minijob	0.198**	0.231**	0.321	0.640**
	(0.027)	(0.029)	(0.214)	(0.169)
Age (in years)	−0.006**	−0.010**	−0.126*	−0.142**
	(0.002)	(0.002)	(0.054)	(0.037)
Age sqrd	0.0001**	0.0001**	0.001+	0.002**
	(0.000)	(0.000)	(0.001)	(0.000)
Tenure (in years)	−0.003**	−0.004**	0.003	−0.010
	(0.000)	(0.001)	(0.012)	(0.008)
Male	−0.024**	−0.040**	0.166	0.255+
	(0.007)	(0.009)	(0.212)	(0.154)
Migration Background	0.006	0.014	−0.009	−0.125
	(0.007)	(0.009)	(0.210)	(0.162)
Married	−0.007	−0.022**	0.387*	0.279+
	(0.006)	(0.008)	(0.181)	(0.146)
Apprenticeship-	−0.031**	−0.036**	−0.187	−0.267
	(0.009)	(0.012)	(0.228)	(0.174)
University degree	−0.047**	−0.069**	0.737+	0.387
	(0.007)	(0.011)	(0.393)	(0.273)
White-collar worker	−0.046**	−0.064**	−0.553**	−0.488**
	(0.010)	(0.012)	(0.184)	(0.153)
Firm size 10 to 19 empl	−0.006	0.000	−0.198	−0.191
	(0.009)	(0.014)	(0.283)	(0.216)
Firm size 20 to 99 empl	−0.022**	−0.018+	−0.396	−0.534**
	(0.008)	(0.010)	(0.269)	(0.200)
Firm size 100 to 199 empl	−0.026**	−0.034**	−0.195	−0.339
	(0.008)	(0.012)	(0.377)	(0.286)
Firm size 200 to 1999 empl	−0.028**	−0.042**	−0.339	−0.388+
	(0.009)	(0.011)	(0.283)	(0.225)
Firm size ≥ 2000 empl	−0.034**	−0.044**	−0.563	−0.586*
	(0.008)	(0.013)	(0.346)	(0.237)
East Germany	0.038**	0.070**	−0.276	−0.186

Table 3 (continued)

	Incidence of non-compliance with statutory minimum wage		Extent of subminimum wage payment conditional on non-compliance	
	Contractual hours	Actual hours	Contractual hours	Actual hours
	(0.008)	(0.012)	(0.206)	(0.149)
Worried about job security	0.028*	0.037*	0.493+	0.436+
	(0.012)	(0.015)	(0.282)	(0.248)
Year 2019	−0.016**	−0.009	0.276	0.149
	(0.005)	(0.007)	(0.179)	(0.129)
Industry Dummies	yes	yes	yes	yes
N	11,703	12,533	796	1362
(Pseudo) R^2	0.30	0.28	0.18	0.17

SOEP 2016, 2019. Col.1,2: Probit specifications. Col. 3,4: OLS specifications. Clustered standard errors in parentheses. $+p<0.1$, $*p<0.05$, $**p<0.01$. SOEP survey weights are used

an interaction term of the existence of a works council and the 2019-time dummy.[21] We continue to observe a significantly negative correlation between the presence of a works council in the firm and the incidence of non-compliance. In addition, the estimated coefficients of the interaction term are positive and weakly significant in one of the two specifications (see Table 6 in Appendix). With regard to the extent of non-compliance, we obtain no indication of a change in the role of works councils over time. We find comparable results when we estimate the coefficients of interest for separate samples for 2016 and 2019 (results not reported).

In sum, there is no evidence that the role of works councils for compliance with minimum wage legislation has changed substantially over time.

5.2.3 Collective bargaining and union membership

The estimated APEs depicted in row 2 of Table 3 indicate that collective bargaining significantly predicts neither the incidence nor the extent of non-compliance. Therefore, works councils and collective bargaining, as two important labour market institutions in Germany, seem to have different relationships with non-compliance. One possible explanation is that works councillors and employers cooperate at the shop floor level, while collective bargaining agreements are mainly settled at the industry level between employer associations and unions.[22] This view is consistent with empirical evidence that works councils rather than sectoral unions act as the collective voice of employees in the workplace in Germany (Hirsch et al., 2010).

[21] We are grateful to an anonymous referee for this suggestion.

[22] Our finding contrasts with the result presented by Pusch (2018) for 2016 who reports a negative correlation. It should be noted that Pusch (2018) includes public sector employees in his estimating sample, whereas they are excluded from our analysis.

Even if collective bargaining is uncorrelated with non-compliance with minimum wage legislation, trade unions may nonetheless play an important role at the individual level. In particular, it is feasible that membership in a trade union may provide individuals with better information about their wage entitlements, help them enforce payments in accordance with the law and better cope with adverse employer responses in case of demanding the payment of the minimum wage.[23] To investigate such effects, we add a union membership dummy to our baseline specification. This union membership information is available in the SOEP in 2015 and 2019. If we impute union membership for 2016 with this information and rerun the specifications in Table 3, including a union membership dummy as additional covariate, our main results regarding the negative association between co-determination and non-compliance remain almost unaffected. In addition, we find a negative correlation between individual union membership and the incidence of underpayments (see Table 6 in Appendix). With regard to the extent of underpayment, we observe no significant correlations with co-determination (results not reported). To conclude: we obtain some evidence that individual union membership may reduce non-compliance with minimum wage legislation in Germany. Incorporating such an effect does not change our finding concerning the role of co-determination.

5.2.4 Summary

All in all, our analyses indicate that co-determination may constitute an effective institution for the enforcement of minimum wages. This is the case, although the relevant laws do not explicitly endow works councils with corresponding rights. Consequently, they undertake regulatory tasks for which, for example, the Works Constitution Act (WCA) only empowers them indirectly through a general norm, aimed at overseeing the execution of laws designed to safeguard the well-being of the staff. An alternative interpretation, also compatible with our evidence, is that the productivity effects associated with co-determination alter a firm's incentives in such a way that non-compliance becomes less attractive. Interestingly, the extent of non-compliance, given its existence, is unrelated to co-determination at plant level.

5.3 Heterogeneity

The relationship between working in a firm with a works council and non-compliance might vary across groups of employees who are affected differently by the statutory minimum wage. The theoretical model does not allow us to predict how the relationship varies with employee characteristics. An empirical analysis, however, can help to identify group-specific differences. We consider gender, place of residence, working hours and firm size.

The reasons for taking a closer look along these four dimensions are as follows: First, the introduction of the statutory minimum wage has reduced the regional

[23] Goerke and Pannenberg (2011), for example, show that union members are less likely to lose their jobs than non-members in Germany due to an insurance effect of individual union membership.

gender wage gap, with the effect being most pronounced for low-paid individuals (Caliendo & Wittbrodt, 2022). In line with these results, we find that female employees face a higher risk of being underpaid than male employees (see Table 3). This suggests that works councils can play a more significant role for females because there is a greater scope for their influence. However, works council members are still predominantly male (Goerke & Pannenberg, 2023), implying that we may expect stronger effects for male employees if works councils act primarily on behalf of their main constituency. Second, the bite of the statutory minimum wage was and still is more pronounced in eastern than in western Germany (e.g. Börschlein et al., 2022). Moreover, our results indicate that non-compliance is more prevalent in the eastern part of the country (see Table 3). This suggests that the works councils' scope for influence is greater there. Third, the incidence of non-compliance is higher for employees working in marginal and in part-time employment (labelled 'other employees' for simplicity) than for full-time employees (see Table 3). Therefore, the scope for works council activities is greater for the former group of employees. Finally, Table 3 indicates that the incidence of non-compliance with minimum wage legislation tends to decrease with firm size. One reason could be that larger firms pay higher wages. Moreover, our theoretical model suggests that the gains from non-compliance do not depend on firm size, while the expected costs rise with the number of employees who are not paid according to law. This penalty effect may constitute another reason for a lower non-compliance rate of larger firms. Both aspects mentioned above suggest that the scope for a works council effect is greater in smaller firms. However, in establishments with more than 200 employees, there is a legal entitlement for at least one works councilor to be released from normal work obligations and to become a full-time councilor. Moreover, the number of full-time counselors increases with employment. Accordingly, professionalism of works councils can be argued to rise with firm size, suggesting a more pronounced works council impact.

To analyse whether such group-specific heterogeneities play a role, we focus on the incidence of non-compliance because our main specifications do not indicate a correlation between the extent of non-compliance and co-determination. We estimate separate probit specification for males and females, inhabitants of western and eastern Germany, full-time and other employees and individuals working in firms with 5 to 199, between 200 and 1999, and 2000 or more employees.

We find that working in a co-determined firm reduces the risk of non-compliance for females much more than for males, in eastern Germany more than in the western part of the country, for other employees more than for full-time employees, and more for employees working in smaller than in larger establishments (see Table 7 in Appendix). In sum, there is some evidence that a positive effect of co-determination on compliance with minimum wage legislation might be stronger for groups of employees who earn lower wages and are on average more affected by minimum wage laws.

5.4 Measurement issues

Legal requirements of the ARGM cannot always be perfectly mapped using the SOEP data. In this section, we document some robustness tests to show that our main results are not affected by the measurement issues that may ensue because of the imperfect mapping (see Table 8 in Appendix).

5.4.1 Variable pay

One-time payments, such as vacation pay, Christmas or profit-sharing bonuses, can be used to fulfil minimum wage requirements only in the month prior to their payment (§ 2(1) ARGM). Unfortunately, the SOEP provides information on such bonuses retrospectively, and the exact date of their payment is not known. Hence, we do not use this information in our main empirical work. To account for this aspect, we divide the sum of all individual one-time payments by twelve and add the resulting number to the individual monthly earnings measure, making non-compliance with minimum wage legislation less likely. Based on the new earnings measure, we re-estimate the probit specifications and find no differences to our main results.

5.4.2 Working time recording

To calculate the hourly wage according to the regulations of the ARGM, reliable information on working hours is required. Non-compliance with the minimum wage due to incorrect recording of working time is an issue in Germany (e.g. Mindestlohnkommission, 2023). Accordingly, the ARGM (§ 17) stipulates that working hours must be recorded in a very detailed manner in some sectors deemed to be especially susceptible to non-compliance with minimum wage regulations and for marginal employees ("mini-jobs"). Because works councils have information and co-determination rights regarding working time (§ 87 WCA), a positive correlation between their existence and the presence of a system of working time recording is likely.

The SOEP provides information on different types of working time recording (*by hand, time recording system, or none*) in 2018 and 2020 only. When we merge this information with an estimating sample of workers who stayed with their firm in 2018 and 2019, 2019 and 2020 or 2018 to 2020, we find a significantly positive correlation between the existence of a works council and the presence of a working time recording system in the firm. However, when we estimate specifications that include covariates for the existence of a works council and the presence of a working time recording system, our main results regarding the correlation between non-compliance and the existence of a works council do not change.

5.4.3 Two further measurement issues

To convert weekly hours into monthly hours, the customs authority uses a factor of 4.33 = (52 weeks/ 12 months), although the value of 4.35 = (365 days/ (12 months

*7 days)), which we have used, is more accurate. Our main results are very similar if we apply the factor of 4.33.

Most respondents report their monthly gross earnings as a multiple of five, which indicates rounding. To address this potential measurement error, we used 0.95 times the observed minimum wage as the threshold for calculating the non-compliance indicator variable, which makes misclassification of non-compliance with the statutory minimum wage less likely.[24] When we re-estimate the probit specifications with the lower minimum wage thresholds, the main results in terms of non-compliance still hold.

6 Summary and Conclusions

Our empirical analysis indicates that employees in co-determined establishments face a lower risk of being paid less than the statutory minimum wage than comparable employees in plants without works council. This descriptive result is in line with the predictions of the simple theoretical models if works councils primarily affect the enforcement of minimum wage legislation. Furthermore, the result is consistent with the view that the economic consequences associated with co-determination impact non-compliance predominantly via the productivity channel. Given the prevalence of non-compliance, we do not observe a correlation between co-determination and the difference between the minimum wage and the amount paid. All in all, our results suggest that even though the WCA does not explicitly grant works councils competences to enforce a minimum wage, their information and co-determination entitlements in other areas provide them with powers, that, in principle, allow them to substantially reduce non-compliance or mitigate incentives to underpay.

Most of the research on co-determination at the plant level has focused on economic outcomes on which works councils could have a *direct* impact, such as wages, productivity, or profitability (e.g. Jäger et al., 2022; Mohrenweiser, 2022). This paper examines an outcome on which works councils may have an *indirect* impact only. However, the combination of a general statutory obligation to ensure that laws must be executed, notable co-determination rights, and enforcement by government agencies apparently creates sufficient incentives for labour market institutions such as works councils to support the enforcement of a law. Consequently, instead of trying to optimise law enforcement, e.g. through stricter legal regulations, it might make more sense from a regulatory perspective, to provide economic incentives to increase the prevalence of labour market institutions that indirectly impact the outcomes of interest. To achieve the desired outcome, it would be irrelevant if co-determination affected non-compliance via enhancing enforcement directly or by mitigating the incentives to underpay, for example, because of associated productivity effects. Both channels would result in a positive assessment of the enforcement of minimum wage laws through co-determination. In addition, lower non-compliance with the minimum

[24] Estimated average non-compliance rates based on these lower thresholds range from 5.1% (contractual hours) to 8.6% (actual hours). They are therefore still substantial from an economic point of view.

wage is associated with higher social security contributions and higher income tax payments. This points to another public good created by co-determination.

However, potential adverse effects should also be considered. If firms ignore minimum wage legislation and works councils restrict such activities, the incentives to prevent the establishment of plant-level co-determination may be strengthened. Moreover, relying on works councils means that minimum wages are enforced unevenly, as councils exist in less than 10% of all eligible private sector establishments.

Additionally, enforcing a minimum wage may be desirable from a welfare perspective only if the level of the minimum wage is sufficiently low. Otherwise, enforcement may have adverse employment consequences. The empirical evidence for Germany suggests that neither the increasing minimum wage nor the declining non-compliance rates have had a noticeable negative effect on overall employment (e.g. Dustmann et al., 2022; Mindestlohnkommission, 2023). Against this background, our use of theoretical models in which the degree of enforcement has no impact on total employment seems justified for analysing the indirect enforcement effects of labour market institutions. However, this assessment could change due to the more pronounced recent increases in the statutory minimum wage.

From a conceptual vantage point, our analysis suggests that the decision to comply with labour law is affected by implicit enforcement mechanisms or indirect determinants of the gains and costs of law abidance. Therefore, a standard Law and Economics perspective in which the detection probability is approximated by the frequency of inspections by the customs authorities may be inadequate. Instead, a more comprehensive interpretation of legal enforcement parameters in the light of interactions with labour market institutions such as works councils provides valuable insights.

Appendix

Competitive Labour Market

First-order conditions:

Maximisation of expected profits, as defined in (1), with respect to L, K, and H yields:

$$\frac{\partial \mathrm{E}(\pi)}{\partial H} := \pi_H = Q_H(L+K,H) - w^H = 0 \tag{6}$$

$$\begin{aligned}\frac{\partial \mathrm{E}(\pi)}{\partial L} =& Q_L(L+K,H) - \left[1-p\right]w^C - pw^M - pF'\left(L\left[w^M - w^C\right]\right)\left[w^M - w^C\right] \\ =& Q_L(L+K,H) - w^M + \left[w^M - w^C\right]\left[1 - p - pF'\left(L\left[w^M - w^C\right]\right)\right] = 0\end{aligned} \tag{7}$$

$$\frac{\partial \mathrm{E}(\pi)}{\partial K} := \pi_K = Q_L(L+K,H) - \left[1-p\right]w^M - pw^M = Q_L(L+K,H) - w^M = 0 \tag{8}$$

Substituting (8) into (7) yields $\pi_L = 0$ because:

$$\left[1-p\right]\left[w^M - w^C\right]\underbrace{\left[1-p-pF'\left(L\left[w^M - w^C\right]\right)\right]}_{=\pi_L=0} = 0 \tag{9}$$

Second-order derivatives and conditions:

For further use note that $\pi_{KL} = \pi_{KK}$ and $\pi_{HL} = \pi_{HK} = \pi_{KH} = Q_{LH}$, while $\pi_{LK} = \pi_{LH} = 0$. The employment levels H^*, L^*, and K^*, which ensure that the derivatives in (6), (7) and (9) are zero, define a maximum of expected profits if the second-order conditions hold. They are $\pi_{HH} = Q_{HH} < 0$, $\pi_{KK} = Q_{LL} < 0$ and:

$$\pi_{LL} = -\left[w^M - w^C\right]pF''\left(L\left[w^M - w^C\right]\right) < 0 \tag{10}$$

$$\pi_{HH}\pi_{KK} - \pi_{KH}^2 = Q_{HH}Q_{LL} - Q_{KH}^2 > 0 \tag{11}$$

$$D = \pi_{HH}\pi_{LL}\pi_{KK} - \pi_{KH}^2\pi_{LL} = \pi_{LL}\left[\pi_{HH}\pi_{KK} - \pi_{KH}^2\right] < 0 \tag{12}$$

Totally differentiating the first-order conditions (6), (7) and (9) with respect to the endogenous variables and an exogenous parameter x, $x = p$, F', α, we obtain:

$$\begin{bmatrix} \pi_{HH} & \pi_{KH} & \pi_{KH} \\ 0 & \pi_{LL} & 0 \\ \pi_{KH} & \pi_{KK} & \pi_{KK} \end{bmatrix}\begin{bmatrix} dH \\ dL \\ dK \end{bmatrix} = \begin{bmatrix} -\pi_{Hx} \\ -\pi_{Lx} \\ -\pi_{Kx} \end{bmatrix}[dx] \tag{13}$$

Probability of fine payment ($x = p$):

The derivatives of the first-order conditions with respect to p are $\pi_{Hp} = \pi_{Kp} = 0$ and $\pi_{Lp} = -\left[1 + F'\right]$. Applying Cramer's rule, we obtain $\mathrm{d}H^*/\mathrm{d}p = 0$ and:

$$\frac{\mathrm{d}L^*}{\mathrm{d}p} = -\frac{\mathrm{d}K^*}{\mathrm{d}p} = \left[1 + F'\right]\frac{\pi_{HH}\pi_{KK} - \pi_{KH}^2}{D} < 0 \tag{14}$$

As $[1 - p]L^*$ declines with p, while $H^* + L^* + K^*$ remains unaffected, the incidence, I, falls.

Marginal fine ($x = F'$):

The relevant derivatives with respect to the marginal fine, F', equal $\pi_{HF'} = \pi_{KF'} = 0$, and $\pi_{LF'} = -p$. Therefore, the changes in employment are given by $\mathrm{d}H^*/\mathrm{d}F' = 0$ and:

$$\frac{\mathrm{d}L^*}{\mathrm{d}F'} = -\frac{\mathrm{d}K^*}{\mathrm{d}F'} = p\frac{\pi_{HH}\pi_{KK} - \pi_{KH}^2}{D} < 0 \tag{15}$$

A fall in L^* and constant overall employment result in a lower incidence, I.

Productivity ($x = \alpha$):

The relevant derivatives are $\pi_{L\alpha} = 0$, $\pi_{H\alpha} = \beta$ and $\pi_{K\alpha} = 1$. We obtain $\mathrm{dL}^*/\mathrm{d}\alpha = 0$ and:

$$\frac{\mathrm{d}H^*}{\mathrm{d}\alpha} = \pi_{LL}\frac{\pi_{KH} - \beta\pi_{KK}}{D} \tag{16}$$

$$\frac{\mathrm{d}K^*}{\mathrm{d}\alpha} = \pi_{LL}\frac{\beta\pi_{KH} - \pi_{KK}}{D} \tag{17}$$

For $\pi_{KH} = Q_{KH} \geq 0$, employment, H^*, of high-wage workers and, K^*, of minimum-wage workers paid according to law certainly rise. Because, the number, L^*, of underpaid minimum wage-workers remains unaffected, the incidence, I, declines.

Wage of high-wage employees ($x = w^H$):

The relevant derivatives with respect to w^H, are $\pi_{Hw^H} = -1$ and $\pi_{Kw^H} = \pi_{Lw^H} = 0$. Applying Cramer's rule, we obtain $\mathrm{d}L^*/\mathrm{d}w^H = 0$ and:

$$\frac{\mathrm{d}H^*}{\mathrm{d}w^H} = \frac{\pi_{LL}\pi_{KK}}{D} < 0 \tag{18}$$

$$\frac{\mathrm{d}K^*}{\mathrm{d}w^H} = -\frac{\pi_{LL}\pi_{KH}}{D} \tag{19}$$

For $\pi_{KH} = Q_{KH} > 0$, employment, K^*, of minimum-wage workers paid according to law falls. As $[1 - p]L^*$ does not vary with w^H, while $H^* + L^* + K^*$ surely falls for $\pi_{KH} \geq 0$, the incidence, I, rises.

Competitive wage of minimum-wage employees ($x = w^C$):

The derivatives of the first-order conditions with respect to w^C, are $\pi_{Hw^C} = \pi_{Kw^C} = 0$, and $\pi_{Lw^C} = pF''L > 0$. Applying Cramer's rule yields $\mathrm{d}H^*/\mathrm{d}w^C = 0$ and:

$$\frac{\mathrm{d}L^*}{\mathrm{d}w^C} = -\frac{\mathrm{d}K^*}{\mathrm{d}w^C} = -pF''L\frac{\pi_{HH}\pi_{KK} - \pi_{KH}^2}{D} > 0 \tag{20}$$

As $[1 - p]L^*$ rises with w^C, while $\mathrm{d}(H^* + L^* + K^*)/\mathrm{d}w^C = 0$, the incidence, I, increases.

Minimum wage ($x = w^M$):

The derivatives of the first-order conditions with respect to w^M, are $\pi_{Hw^M} = 0$, $\pi_{Kw^M} = -1$, and $\pi_{Lw^M} = -pF''L < 0$. Using Cramer's rule, and (10) and (12) in (22) yields:

$$\frac{\mathrm{d}H^*}{\mathrm{d}w^M} = -\frac{\pi_{LL}}{D}\pi_{KH} \tag{21}$$

$$\frac{\mathrm{d}L^*}{\mathrm{d}w^M} = pF''L\frac{\pi_{HH}\pi_{KK} - \pi_{KH}^2}{D} = pF''L\frac{\pi_{HH}\pi_{KK} - \pi_{KH}^2}{\pi_{LL}\left[\pi_{HH}\pi_{KK} - \pi_{KH}^2\right]} = -\frac{L}{w^M - w^C} < 0 \tag{22}$$

$$\frac{\mathrm{d}K^*}{\mathrm{d}w^M} = \frac{\pi_{HH}\pi_{LL}}{D} - \frac{dL^*}{dw^M} \tag{23}$$

From (22) and (23) it follows that minimum wage employment, $L^* + K^*$, declines. If $\pi_{KH} \geq 0$, this will surely also be the case for total employment. As the changes in total employment and employment of minimum-wage workers who are paid less than w^M depend on different components, the incidence, I, varies with minimum wage, w^M, in an ambiguous manner. The extent of non-compliance, $w^M - w^C$, increases. Note, finally, that the fall in the number of minimum-wage workers, L^*, paid less than w^M is independent of p and F'.

Monopsonistic Setting

Maximising the objective (5) of the monopsonistic firm with respect to the wage, w^{Mon}, paid to underpaid minimum-wage workers, the number of minimum-wage workers paid the minimum wage, K, and the number of high-wage workers, H, yields:

$$\begin{aligned}\frac{\partial \mathrm{E}(\pi)}{\partial w^{Mon}} =& Q_K(L+K,H)L_w - \left[1-p\right]\left[L + w^{Mon}L_w\right] - pw^M L_w\left[1+F'\right] + pF'\left[L + w^{Mon}L_w\right] \\ =& Q_K(L+K,H)L_w - \left[L + w^{Mon}L_w\right] + \underbrace{p\left[1+F'\right]\left[L + w^{Mon}L_w - w^M L_w\right]}_{\text{expected marginal costs of non-compliance}}\end{aligned} \tag{24}$$

$$\frac{\partial \mathrm{E}(\pi)}{\partial K} := \pi_K = Q_K(L+K,H) - w^M = 0 \tag{25}$$

$$\frac{\partial \mathrm{E}(\pi)}{\partial H} := \pi_H = Q_H(L+K,H) - w^H = 0 \tag{26}$$

As Yaniv (1988), we assume the expected marginal costs of non-compliance, $p\left[1+F'\right]\left[L + w^{Mon}L_w - w^M L_w\right]$ to be negative. Inserting (25) into (24), we have:

$$\begin{aligned}\frac{\partial \mathrm{E}(\pi)}{\partial w^{Mon}} =& Q_K(L,H)L_w - \left[L + w^{Mon}L_w\right] + p\left[1+F'\right]\left[L + w^{Mon}L_w - w^M L_w\right] \\ =& w^M L_w - \left[L + w^{Mon}L_w\right] + p\left[1+F'\right]\left[L + w^{Mon}L_w - w^M L_w\right] \\ =& \underbrace{\left[1 - p - pF'\left(L\left[w^M - w^{Mon}\right]\right)\right]}_{:=\pi_w}\left[L + w^{Mon}L_w - w^M L_w\right] = 0\end{aligned} \tag{27}$$

Given that the second factor in (27) is non-zero, $\pi_w = 0$ holds.

Note that $\pi_{Kw} = \pi_{KK}L_w$ and $\pi_{Hw} = \pi_{HK}L_w = \pi_{KH}L_w = Q_{KH}L_w$, while $\pi_{wK} = \pi_{wH} = 0$. The wage, w^{Mon}, high-wage employment, H^*, and the number of minimum-wage workers, K^*, paid w^M, which ensure that the derivatives in (25) to (27) are zero, define a maximum if the second-order conditions hold. They are $\pi_{KK}, \pi_{HH} < 0$ and:

$$\pi_{ww} = pF''\left[L + w^{Mon}L_w - w^M L_w\right] < 0 \tag{28}$$

$$\pi_{HH}\pi_{KK} - \pi_{KH}^2 = Q_{HH}Q_{LL} - Q_{KH}^2 > 0 \tag{29}$$

$$D = \pi_{HH}\pi_{ww}\pi_{KK} - \pi_{KH}^2\pi_{ww} = \pi_{ww}\left[\pi_{HH}\pi_{KK} - \pi_{KH}^2\right] < 0 \tag{30}$$

Totally differentiating the first-order conditions (25) to (27), we obtain:

$$\begin{bmatrix} \pi_{HH} & \pi_{KH}L_w & \pi_{KH} \\ 0 & \pi_{ww} & 0 \\ \pi_{KH} & \pi_{KK}L_w & \pi_{KK} \end{bmatrix}\begin{bmatrix} dH \\ dw^{Mon} \\ dK \end{bmatrix} = \begin{bmatrix} -\pi_{Hx} \\ -\pi_{wx} \\ -\pi_{Kx} \end{bmatrix}[dx] \tag{31}$$

Probability of fine payment ($x = p$):

The derivatives of the first-order conditions (25) to (27) with respect to p are $\pi_{Hp} = \pi_{Kp} = 0$ and $\pi_{wp} = -\left[1 + F'\right]$. Applying Cramer's rule, we obtain $\mathrm{d}H^*/\mathrm{d}p = 0$ and:

$$\frac{\mathrm{d}w^{Mon}}{\mathrm{d}p}L_w = -\frac{\mathrm{d}K^*}{\mathrm{d}p} = \left[1 + F'\right]L_w\frac{\pi_{HH}\pi_{KK} - \pi_{KH}^2}{D} < 0 \tag{32}$$

As L falls, given the decline in w^{Mon}, while $L\left(w^{Mon}\right) + K^*$ remains constant, given $\mathrm{d}\left[L\left(w^{Mon}\right) + K^*\right]/\mathrm{d}p = L_w\mathrm{d}w^{Mon}/\mathrm{d}p + \mathrm{d}K^*/\mathrm{d}p$, $H^* + L\left(w^{Mon}\right) + K^*$ is unaffected. Therefore, the incidence, I, falls. The extent of non-compliance, $w^M - w^{Mon}$, rises.

Marginal fine ($x = F'$):

The derivatives of (25) to (27) with respect to F' equal $\pi_{HF'} = \pi_{KF'} = 0$ and $\pi_{wF'} = -p$. Therefore, the changes in employment and the wage are given by $\mathrm{d}H^*/\mathrm{d}F' = 0$ and:

$$\frac{\mathrm{d}w^{Mon}}{\mathrm{d}F'}L_w = -\frac{\mathrm{d}K^*}{\mathrm{d}F'} = pL_w\frac{\pi_{HH}\pi_{KK} - \pi_{KH}^2}{D} < 0 \tag{33}$$

The number of underpaid minimum-wage workers, $L\left(w^{Mon}\right)$ declines, while the overall number of minimum-wage workers, $L\left(w^{Mon}\right) + K^*$, remains constant. A fall in $L\left(w^{Mon}\right)$ and constant overall employment result in a lower incidence, I. Finally, a lower wage, w^{Mon}, results in a higher extent of non-compliance, $w^M - w^{Mon}$.

Productivity ($x = \alpha$):

The derivatives of (25) to (27) with respect to α, are $\pi_{w\alpha} = 0$, $\pi_{H\alpha} = \beta$ and $\pi_{K\alpha} = 1$. Applying Cramer's rule, we obtain $\mathrm{d}w^{Mon}/\mathrm{d}\alpha = 0$ and:

$$\frac{\mathrm{d}H^*}{\mathrm{d}\alpha} = \pi_{ww}\frac{\pi_{KH} - \beta\pi_{KK}}{D} \tag{34}$$

$$\frac{\mathrm{d}K^*}{\mathrm{d}\alpha} = \pi_{ww}\frac{\beta\pi_{KH} - \pi_{KK}}{D} \tag{35}$$

For $\pi_{KH} = Q_{KH} \geq 0$, employment, H^*, of high-wage workers and, K^*, of minimum-wage workers paid according to law certainly rise. Because employment of underpaid minimum-wage workers, $L(w^{Mon})$, remains unaffected, the incidence, I, declines. The extent of non-compliance, $w^M - w^{Mon}$, does not change.

Wage of high-wage employees ($x = w^H$):

The derivatives of (25) to (27) with respect to w^H, are $\pi_{Hw^H} = -1$ and $\pi_{Kw^H} = \pi_{ww^H} = 0$. Applying Cramer's rule, we obtain $\mathrm{d}w^{Mon}/\mathrm{d}w^H = 0$ and:

$$\frac{\mathrm{dH}^*}{\mathrm{d}w^H} = \frac{\pi_{ww}\pi_{KK}}{D} < 0 \tag{36}$$

$$\frac{\mathrm{d}K^*}{\mathrm{d}w^H} = -\frac{\pi_{ww}\pi_{KH}}{D} \tag{37}$$

For $\pi_{KH} = Q_{KH} > 0$, employment, K^*, of minimum-wage workers paid according to law falls. As $[1-p]\,L\,(w^{Mon})$, is unaffected, while $H^* + L\left(w^{Mon}\right) + K^*$ surely falls for $\pi_{KH} \geq 0$, the incidence, I, then rises.

Minimum wage ($x = w^M$):

The derivatives of (25) to (27) with respect to w^M, are $\pi_{Hw^M} = 0$, $\pi_{Kw^M} = -1$, and $\pi_{ww^M} = -pF''L < 0$. Applying Cramer's rule yields:

$$\frac{\mathrm{d}H^*}{\mathrm{d}w^M} = -\frac{\pi_{ww}}{D}\pi_{KH} \tag{38}$$

$$\frac{\mathrm{d}w^{Mon}}{\mathrm{d}w^M} = pF''L\frac{\pi_{HH}\pi_{KK} - \pi_{KH}^2}{D} = \frac{L}{L + w^{Mon}L_w - w^M L_w} < 0 \tag{39}$$

$$\frac{\mathrm{d}K^*}{\mathrm{d}w^M} = \frac{\pi_{HH}\pi_{LL}}{D} - \frac{dw^{Mon}}{dw^M} \tag{40}$$

From (39) and (40) it follows that employment of workers not paid the minimum wage, $L(w^{Mon})$, and minimum wage employment, $L(w^{Mon}) + K^*$, decline. If $\pi_{KH} \geq 0$, total employment surely falls. As the changes in total employment and $L(w^{Mon})$ depend on different components, the incidence, I, varies with minimum wage, w^M, in an ambiguous manner. The extent of non-compliance, $w^M - w^{Mon}$, rises with w^M.

Tables

(See Tables 4, 5, 6, 7, 8).

Table 4 Descriptive statistics—Covariates

Variable	Mean	Sd.
Collective bargaining	0.42	0.49
Part-time work	0.20	0.40
Mini-job	0.06	0.23
Age (in years)	43.93	11.68
Tenure (in years)	10.72	10.41
Male	0.56	0.50
Migration background	0.24	0.43
Married	0.57	0.49
Apprenticeship	0.61	0.49
University	0.26	0.44
White-collar worker	0.76	0.42
Firm size 10 to 19 employees	0.09	0.29
Firm size 20 to 99 employees	0.18	0.39
Firm size 100 to 199 employees	0.08	0.28
Firm size 200 to 1999 employees	0.23	0.42
Firm size ≥ 2000 employees	0.31	0.46
East Germany	0.16	0.37
Worried about job security	0.07	0.26
Manufacturing	0.33	0.47
Wholesale	0.15	0.36
Transport	0.06	0.24
Education	0.03	0.16
Health	0.09	0.29
Other private industry	0.19	0.39
Year 2019	0.51	0.50

SOEP 2016, 2019; N = 12,533. SOEP survey weights are used

Table 5 Non-compliance with the statutory minimum wage

Incidence of non-compliance with statutory minimum wage (in %)					
Contractual hours			Actual hours		
Pooled	2016	2019	Pooled	2016	2019
6.3	7.3	5.4	10.8	11.8	9.8
Extent of subminimum wage payment (conditional on incidence, mean, in €)					
Contractual hours			Actual hourse		
Pooled	2016	2019	Pooled	2016	2019
1.8	1.7	1.8	1.9	1.8	2.0

SOEP 2016, 2019. N_pooled_incidence = 12,329/13255; N_2016_incidence = 6014/6411; N_2019_incidence = 6315/6844. N_pooled_extent = 905/1544; N_2016_ extent = 494/803; N_2019_ extent = 411/741. SOEP survey weights are used

Table 6 Non-compliance with the statutory minimum wage—Time effects, collective bargaining and union membership

Incidence of non-compliance with statutory minimum wage		
	Contractual hours	Actual hours
Time effects		
Works council	−0.030**	−0.054**
	(0.009)	(0.012)
Works council* 2019	0.019	0.030*
	(0.013)	(0.009)
Collective bargaining	−0.005	−0.006
	(0.007)	(0.009)
N	11,703	12,533
Pseudo R^2	0.30	0.28
Collective bargaining and union membership		
Works council	−0.019*	−0.035**
	(0.007)	(0.011)
Union Membership	−0.017*	−0.037**
	(0.008)	(0.010)
Collective bargaining	−0.005	−0.003
	(0.007)	(0.009)
N	10,554	11,276
Pseudo R^2	0.29	0.28

SOEP 2016, 2019. Probit specifications. Clustered standard errors in parentheses. $+p<0.1$, $*p<0.05$, $**p<0.01$. SOEP survey weights are used

Table 7 Non-compliance with the statutory minimum wage—Heterogeneity

	Incidence of non-compliance with statutory minimum wage (average partial effects)					
By gender						
	Contractual hours			Actual hours		
	Male	Female		Male	Female	
Works council	−0.005	−0.042**		−0.022*	−0.064**	
	(0.008)	(0.011)		(0.011)	(0.017)	
N	5966	5737		6487	6046	
Pseudo R^2	0.35	0.27		0.31	0.25	
By region						
	Contractual hours			Actual hours		
	West	East		West	East	
Works council	−0.014+	−0.058**		−0.025**	−0.110**	
	(0.008)	(0.019)		(0.009)	(0.029)	
N	9431	2272		10,107	2426	
Pseudo R^2	0.30	0.32		0.29	0.27	
By employment status						
	Contractual hours			Actual hours		
	Full-time	Other		Full-time	Other	
Works council	−0.008	−0.074**		−0.028**	−0.086**	
	(0.007)	(0.020)		(0.009)	(0.025)	
N	8146	3557		8635	3898	
Pseudo R^2	0.25	0.19		0.24	0.17	
By firm size						
	Contractual hours			Actual hours		
	Number of employees			Number of employees		
	5 to 199	200 to 1999	≥2000	5 to 199	200 to 1999	≥2000
Works council	−0.039**	−0.017+	−0.016*	−0.058**	−0.044**	−0.025*
	(0.012)	(0.009)	(0.007)	(0.016)	(0.013)	(0.011)
N	5670	2631	3402	6201	2736	3596
Pseudo R^2	0.23	0.36	0.44	0.20	0.34	0.42

SOEP 2016, 2019. Clustered standard errors in parentheses. $+p<0.1$, $*p<0.05$, $**p<0.01$. SOEP survey weights are used

Table 8 Non-compliance with the statutory minimum wage—Robustness checks (average partial effects)

Incidence of non-compliance with statutory minimum wage		
	Contractual hours	Actual hours
Variable pay		
Works council	−0.022**	−0.041**
	(0.007)	(0.009)
N	11,703	12,533
Pseudo R^2	0.30	0.28
Working time recording system		
Works council	−0.017*	−0.026*
	(0.008)	(0.012)
N	5303	5704
Pseudo R^2	0.31	0.29
Rounding and reporting errors		
Works council	−0.012+	−0.035**
	(0.006)	(0.009)
N	11,703	12,533
Pseudo R^2	0.31	0.28
Conversion of weekly into monthly working hours		
Works council	−0.022**	−0.039**
	(0.007)	(0.010)
N	11,703	12,533
Pseudo R^2	0.30	0.28

SOEP 2016, 2019. Probit specifications. Clustered standard errors in parentheses. $+p<0.1$, $*p<0.05$, $**p<0.01$. SOEP survey weights are used

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Declarations

Conflict of interest The authors declare no competing interests.

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Authors and Affiliations

Laszlo Goerke[1,2,3,4] · Markus Pannenberg[2,4,5]

✉ Laszlo Goerke
goerke@iaaeu.de

Markus Pannenberg
markus.pannenberg@hsbi.de

[1] Trier University, Institute for Labour Law and Industrial Relations in the European Union (IAAEU), 54286 Trier, Germany

[2] IZA, Bonn, Germany

[3] CESifo, Munich, Germany

[4] GLO, Essen, Germany

[5] Department of Business and Economics, Bielefeld University of Applied Sciences and Arts (HSBI), Interaktion 1, 33619 Bielefeld, Germany