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ABSTRACT

Minimum Wages and the Rise in Solo Self-Employment*

Solo self-employment is on the rise despite less favorable working conditions compared to traditional jobs. We show that the introduction of minimum wages in German industries led to an increase in the share of solo self-employment by up to 8.5 percentage points. We explain our findings within a substitution-scale model that predicts a decline in demand and earnings perspectives for high-skilled dependent workers, whenever the negative scale effect (overall decline in industry employment) dominates the positive substitution effect (shift towards high-skilled workers). Such situations can occur during an economic downturn in combination with a strong and rising minimum wage bite.

JEL Classification: J21, J31, J38, J08

Keywords: minimum wages, solo self-employment, synthetic control method

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1 Introduction

The composition of self-employment is changing around the globe: The share of self-employed individuals who operate on their own account without any employees – solo self-employed – is on the rise in most developed countries (Boeri et al., 2020). This development thereby coincides with a more general trend towards alternative work arrangements in these countries (such as agency workers, on-call workers, contract company workers or independent contractors). Understanding the consequences of this development is important, as many of these jobs are related to less favorable working conditions. For instance, solo self-employment typically does not offer the same employment protection, social insurance or pension, compared to dependent employment. Accordingly, solo self-employed individuals share important characteristics with underemployed workers, such as lower earnings and working hours, a higher incidence of part-time and a higher risk of income loss, compared to traditional workers in dependent employment (Boeri et al., 2020; Katz and Krueger, 2017). These atypical jobs may therefore not be entirely voluntary. Yet, little is known about the drivers of such alternative work arrangements; especially, the role of policies and regulations is underexplored.

This paper investigates the impact of minimum wage policies on solo self-employment. For this, we exploit a quasi-experimental setting: Germany introduced its first minimum wages on an industry level, starting with main construction, roofing, electrical trade, and painting. No other industry was subject to a minimum wage regulation at that time, providing us the opportunity to compare a set of treated industries with all other comparable but uncovered industries, using on a long time series of data. For the comparison, we apply the synthetic control group approach proposed by Abadie and Gardeazabal (2003) and Abadie et al. (2010, 2015), which uses systematically more attractive comparisons compared to traditional difference-in-differences designs (Athey and Imbens, 2017; Abadie, 2020). To identify self-employed individuals, defined as firm owners without employees, we exploit a micro-level firm data set (Mannheim Enterprise Panel) that comprises the universe of active firms in Germany. The data contains, among others, detailed industry codes, the level on which the first minimum wage regulations were introduced. We match this data with industry-level workforce data prepared from a two percent random sample of all workers in Germany that are subject to social security contributions (i.e., excluding self-employed and public servants).

Our results show that the minimum wage introduction contributed to the rise in solo self-employment. Depending on the industry and region, the minimum wage raised the share of solo self-employed individuals six years after its introduction by 1.1-8.5 pp. The largest effects are measured in East German industries, where the minimum wage level was set relatively high (relative to median wages). In contrast, the smallest effects are found in West German industries, where the minimum wage was set relatively low when it was introduced.

We explain our findings within an extension of the substitution-scale model by Gregory and Zierahn (2022). In their original model, a minimum wage introduction leads to a substitution of low- by high-skilled workers, due to the change in relative input prices (substitution effect). At the same time, minimum wages raise overall industry costs, inducing the industry to shrink, reducing demand for all workers (scale effect). Whenever the scale effect exceeds the substitution effect, such as during an economic downturn, net demand for high-skilled workers declines (negative spillover effects). Whereas Gregory and Zierahn (2022) focus on dependent employment, we additionally add solo self-employment to the model. In particular, high-skilled workers can now choose between dependent and independent employment (i.e., solo self-employment). High-skilled workers are thereby defined as workers with at least an apprenticeship training and six years of working experience, or any higher degree (e.g., master craftman's degree). In this extended model, a high minimum wage induces a decline in both the demand and wage-compensation for dependent high-skilled employment, which, in turn, sets incentives for these workers to become solo self-employed. Note that due to industry regulations – the so called Meisterzwang –, solo self-employment is restricted to high-skilled workers in our model and context. However, we also discuss the model's implication in case all workers could become solo self-employed, i.e., in case there was no protectionist Meisterzwang regulation (see below).

We then show that the extended substitution-scale model can explain the rising share of solo self-employed individuals observed in our data. To test the model's predictions, we apply a similar synthetic control group approach to both overall and high-skilled employment as well as solo self-employed individuals' earnings (i.e., their revenues). Our empirical results suggest that the minimum wage introduction increased the share of high-skilled workers (substitution effect), while overall employment declined, particularly in high-bite industries in Eastern Germany (scale effect). The scale effect thereby exceeds the substitution effect such that the effect on high-skilled dependent employment is negative (net effect), thus explaining the rise in solo self-employment. In line with our framework, we further find indirect evidence that the rise in solo self-employment is driven by a worsening selection of high-skilled workers, i.e., the minimum wage induced workers with less favorable characteristics to became solo self-employed compared to the time before the minimum wage introduction. In particular, we find that revenues of solo self-employed declined, particularly among young individuals who started their business only after the minimum wage policy was enacted. This suggests that the earnings perspectives of solo self-employed individuals worsened as a result of the policy reform.

Finally, we show that all the above discussed effects crucially depend on the size of the minimum wage bite. To demonstrate this, we exploit additional data on hours worked from German micro-census data, which allows us to construct an industry-region-specific measure of the minimum wage bite – measured by the Kaitz Index, i.e., the minimum wage relative to the median wage. We then relate the Kaitz index (and alternative bite measures) to the size of our treatment effects in industry-region-year cells in order to demonstrate that the effects on solo self-employment, employment and revenues (i.e., earnings) increases with the level of the bite. In particular, we find that an increase in the minimum wage bite by one percentage point increases the effect on solo self-employment by about five percentage points. The analysis may explain why we find strong effects in East Germany, where the Kaitz index lies between 75-92%, whereas we find only moderate effects in West Germany, with Kaitz indices between 58-69%, depending on the industry.

Even though we focus on a set of selected German industries, our stylized framework allows us to draw some general conclusions for other contexts. First, such effects can generally be expected to appear in the long run, whenever the bite of a minimum wage is high and scale effects are likely to be strong and negative, relative to the positive substitution effects. Such situations may, for instance, occur during an economic downturn (see also Clemens and Wither, 2019) in combination with a strong and rising minimum wage bite. Second, the rise in solo self-employment is driven by a worsening selection of all potential solo self-employed. In our context, specific institutional regulation – the Meisterzwang – allow only high-skilled workers to become solo self-employed. However, in situations without such restrictions, also low-skilled workers could be the drivers of such a development. Our results can thus be interpreted as a lower bound estimate. Finally, note that high-skilled workers in our selected industries may rather reflect middle-educated workers in the entire more wider national distribution of skills, as our industries, for instance, hire hardly any academic workers. Generally, the narrower the skill distribution, the larger the substitution effect towards "higher" skilled workers, as tasks are more likely to be close substitutes (and vice versa).

Our paper contributes to several strands of the literature. First, it contributes to work on alternative work arrangement and self-employment. Foremost, Boeri et al. (2020) exploit OECD data to demonstrate an increase in the share of solo self-employed among all self-employed individuals in almost all OECD countries. Their more detailed analysis based on survey data for the US, UK and Italy suggests that solo self-employment differs substantially from self-employment (with employees). In particular, solo self-employed individuals share important characteristics with underemployment, such as lower earnings, hours and liquidity constraints, and a higher vulnerability to idiosyncratic shocks. Focusing on the US economy, other studies suggest a more general shift towards alternative work arrangements (Katz and Krueger, 2019a,b). Again other studies point to the value of such employment relationships in terms of greater flexibility for workers (Mas and Pallais, 2020). We contribute to these studies by providing further evidence on solo self-employment for Germany, as the biggest European labor market, and by analyzing the impact of minimum wage policies and regulations on this atypical work form.[1]

Second, our paper contributes to the literature on the effects of minimum wages on alternative (or non-standard) work arrangements. Existing research in this field suggests two potential links through which a minimum wage may impact solo self-employment.[2] First, as a reaction to a minimum wage (or rising wages), employers adjust their workforce towards independent employment (e.g., contracting out) in order to save labor costs or avoid minimum wage regulations (Abraham and Taylor, 1996; Parker, 2010). Second, workers, who are laid off by employers in reaction to the minimum wage decide to become solo self-employed in search for alternative sources of income (Blau, 1987)[3]. In contrast to these theoretical papers, empirical evidence on the impact of a minimum wage on solo self-employment, and its mechanisms, is missing. Existing studies either provide only suggestive evidence in favor of a positive relationship between minimum wages and solo self-employment (Medrano-Adán et al., 2015), or focus more generally on self-employment without distinguishing between self-employed workers with and without employees (such as Blau, 1987; Bruce and Mohsin, 2006) or look at other forms of alternative

[1] Boeri et al. (2020) acknowledge the potential role of (minimum wage) policies and regulations on the changing nature of self-employment and alternative work arrangements, although they do not further study this.

[2] More links have been discussed for general self-employment (see e.g., Bruce and Mohsin, 2006), which, however, is not the focus of this study. Solo self-employment differs substantially from self-employment (with employees) in that the former shares important characteristics with underemployment, such as low earnings, hours and liquidity constraints, and vulnerability to idiosyncratic shocks Boeri et al. (2020)

[3] Although Blau (1987) do not distinguish between self-employment with and without employees, their theory might also hold for solo self-employed.

work besides solo self-employment (Datta et al., 2019). To our knowledge, we are the first to estimate the effect of a newly introduced minimum wage on solo self-employment.

Third, we contribute to the literature on minimum wage spillovers. There exists a long-standing debate on positive spillover effects of minimum wages on the wages of workers whose initial wages lie above the minimum wage (e.g., Gopalan et al., 2021; Phelan, 2019). Among others, positive spillovers can be explained by a substitution of low-wage for high-wage workers, as a result of the change in relative input prices. However, as discussed above, also negative spillovers can occur when additionally taking into account the scale effect (Gregory and Zierahn, 2022). We contribute to this debate by demonstrating that indirect effects of minimum wage policies may not be limited to adjustments in dependent employment. Allowing for solo self-employment in our extended model, we show how negative spillover effects can induce incentives among high-skilled workers to switch from regular employment to solo self-employment as a result of the policy reform. Moreover, we show how negative spillover effects further reduce the earnings (i.e., revenues) of solo self-employed individuals.

This paper is structured as follows. In Section 2, we develop a theoretical framework to explain how a minimum wage introduction affects solo self-employment and derive testable hypotheses from our theory. In Section 3, we briefly describe the institutional background in Germany. Section 4 introduces the data and provides descriptive statistics, before Section 5 then describes our synthetic control group approach. The main results are then discussed in Section 6 and we empirically study the mechanisms in Section 7. Section 8 provides robustness checks and Section 9 concludes.

2 Theoretical Framework

In this section, we develop a stylized framework to explain how minimum wages affect workers' decisions to become solo self-employed. The framework serves to illustrate the mechanisms through which minimum wages affect solo self-employment and to derive conditions under which the effect of minimum wages on solo self-employment is positive or negative. By shedding light on these mechanisms and conditions, we aim to guide the empirical analyses. Our model builds on the minimum wage spillover model by Gregory and Zierahn (2022), but extends the model to allow high-skilled individuals to choose solo self-employment as an alternative to dependent employment.[4] We first describe the main set-up before discussing the consequences of minimum wages for the labor market and solo self-employment.

2.1 Main Set-Up

Product Demand: Firms produce varieties ω of a final output. The price elasticity of demand for the aggregate output of the firms Q_f is ϵ and P_f is the price index for firms' aggregate output. The demand function for firms' aggregate output is $R_f = P_f^{1-\epsilon} Q_0$, where R are revenues and Q_0 is a constant. Each firm produces a single variety of the output and consumers have Constant Elasticity of Subsitution (CES) preferences over these varieties with elasticity of substitution σ between the varieties. Utility maximization w.r.t. the budget constraint $P_f Q_f = \int_{\omega \in \Omega} q_f p_f d\omega$ provides

$$q_f(\omega) = \left(\frac{p_f(\omega)}{P_f} \right)^{-\sigma} P_f^{-\epsilon} Q_0. \tag{1}$$

We assume an analogous structure for the demand for the varieties and aggregate output produced by self-employed, using index s as opposed to f. Demand for the varieties produced by self-employed thus is identical. The focus of our framework lies on interactions between the two industries on the labor market. We therefore abstract from interactions between firms and entrepreneurs on the product market to keep the analysis simple and traceable.

Production: We model heterogeneous firms based on Melitz (2003). Firms require a fixed white-collar labor input of f and a variable blue-collar-labor input of $n_i(\psi_i) = q_i/\psi_i$, where the wage costs for both are $\bar{w}$. Profit maximization implies that prices are a constant markup over marginal costs, $p_i(\psi_i) = \frac{\bar{w}}{\psi_i} \frac{\sigma}{\sigma-1}$ and profits are $\pi_i(\psi_i) = \frac{r(\psi_i)}{\sigma} - \bar{w} f$, where r are revenues. The price index is $P_f = M^{\frac{1}{1-\sigma}} \frac{\sigma}{\sigma-1} \frac{\bar{w}}{\bar{\psi}}$, where $\bar{\psi}$ is the average productivity of the active firms. There exists a large mass of potential entrepreneurs M_e who have to bear sunk costs f_e for entering the market. Firms randomly draw their productivity ψ_i from a Pareto distribution $g(\psi_i)$, $G(\psi_i)$ with minimum productivity ψ_{min} and shape parameter k. The mass of surviving firms is $M = (1 - G(\psi_i))M_e$. We assume free entry, which implies that new entrepreneurs found firms until expected (average) profits correspond to the sunk cost of entry. The profits of the

[4] While the underlying idea of how the minimum wage affects heterogeneous workers is similar in both models, the model differs in several ways. Most importantly, we allow high-skilled workers to become solo self-employed. In addition, there can be a positive substitution effect on high-skilled workers in our model whereas there is no substitution to high-skilled workers in Gregory and Zierahn (2022). Moreover, our model covers firm heterogeneity.

average firm then are

$$\pi(\tilde{\psi}) = f_e \delta \left(\frac{\psi}{\psi_{min}} \right)^k , \tag{2}$$

where δ is the period-risk of a terminal shock for entrepreneurs and v_e is the expected value of entry. From the profits of the average firm and equation (2) we derive the equilibrium cut-off productivity for firm entry,

$$\psi^* = \left(\frac{\bar{w} f}{\delta f_e} \frac{\sigma - 1}{k + 1 - \sigma} \right)^{1/k} \psi_{min}. \tag{3}$$

The cut-off productivity rises in the wage cost index – rising wage costs force the least productive firms out of the market. We analyze industry employment of blue-collar and do not further consider employment of white-collar workers,

$$N = \int_{\psi^*}^{\infty} n(\psi) M \mu(\psi) d\psi = \bar{w}^{-\tilde{\epsilon}} Q_0 K, \tag{4}$$

where $\mu(\psi)$ is the endogenous productivity density of surviving firms and K is a constant.[5] $\tilde{\epsilon} = \frac{\partial \ln N}{\partial \ln \bar{w}}$ is the wage elasticity of industry labor demand and depends on the price elasticity of demand for firms' output ϵ, the elasticity of substitution between firms varieties σ, and the shape of the productivity distribution of firms k.[6]

Labor Demand: There are two types of workers, high-skilled H and low- and medium-skilled L workers. Their output is combined via a CES technology to the labor input N with elasticity of substitution η between the two types of labor. Firms optimally choose the composition of high-skilled and low-/medium-skilled workers:

$$H = N \left(\frac{w_H}{\bar{w}} \right)^{-\eta}, \tag{5}$$

where $\bar{w}$ is the CES factor cost index for wages, $\bar{w} = \left(w_H^{1-\eta} + w_L^{1-\eta} \right)^{\frac{1}{1-\eta}}$. We combine equations 4 and 5 to derive industry demand for high-skilled workers:

$$H = w_H^{-\eta} \bar{w}^{\eta - \tilde{\epsilon}} Q_0 K. \tag{6}$$

We combine low- and medium-skilled workers to a single worker type L, as apposed to

[5] $K = \left(\frac{f}{f_e \delta} \frac{\sigma-1}{k+1-\sigma} \right)^{\frac{\epsilon-1}{1-\sigma}} \cdot \psi_{min}^{\epsilon-1} \left(\frac{\sigma}{\sigma-1} \right)^{-\epsilon} M_e^{\frac{1-\epsilon}{1-\sigma}} \left(\frac{k}{k+1-\sigma} \right)^{\frac{1}{\sigma-1}}.$

[6] In particular $\tilde{\epsilon} \equiv \epsilon + \frac{\epsilon-1}{1-\sigma} + \frac{\epsilon-1}{k}$.

high-skilled workers H. The reason for this simplification is that, due to industry regulations, only high-skilled workers can become solo self-employed (see Section 3 for more details on the institutional background). Gregory and Zierahn (2022) instead model L as a CES aggregate of low- and medium-skilled workers. In their model, the minimum wage induces substitution from low- to medium-skilled workers. Note, however, that the effect on high-skilled workers in our case would still solely depend on the change in average wages and in the change of wages of high-skilled workers relative to the other workers. The qualitative results would thus remain the same in case we would also model substitution between low- and medium-skilled workers.

Labor Supply and Self-Employment: There exists a large mass of low- and medium-skilled workers L^S who work, if their wage is at least as large as their reservation wage, $w_L \geq \underline{w}$. We assume that their labor supply exceeds labor demand $L^S > L$, so that low- and medium-skilled workers earn their reservation wage, $w_L = \underline{w}$. This assumption is motivated by the empirically large unemployment rate among low-skilled workers. If not employed in the industry, these workers therefore are either unemployed or work in the outside sector.

There exists a finite mass of high-skilled workers $\bar{H}$. High-skilled workers can choose between dependent employment and solo self-employment in the same industry. We do not consider an outside option for them, since occupational mobility among workers is extraordinary low. In German craft, workers hardly switch between industries, as skills acquired through apprenticeship training are not easily transferable across industries.[7]

High-skilled individuals that decide to become solo self-employed produce using their own labor input and intermediate inputs z at prices p_z with technology $z = q_s$, where q_s is their output. Profits hence are $\pi_s = p_s q_s - p_z z$ and profit maximization implies that their prices are a constant mark up over marginal costs, $p_s = p_z \sigma/(\sigma - 1)$. Free entry implies that new solo self-employed enter the market until profits correspond to the outside earnings, which are high-skilled wages, $\pi_s = w_H$. We normalize $p_z \equiv \sigma - 1$ without loss of generalizability. The entry condition for high-skilled workers into solo self-employment then is $w_H = q_s$. Let us assume that high-skilled workers exogenously differ in their managerial ability – some can handle more or larger projects than others. We denote their entrepreneurial ability with ϕ and assume that the volume of projects that they can handle is $q_s(\phi) = \phi$. The cut-off managerial ability level for

[7]Gregory and Zierahn (2022) for example show that only 0.35 % of blue-collar workers in roofing and plumbing changed sectors between 1994 and 2008.

entering solo self-employed then is

$$\phi^* = w_H. \tag{7}$$

The ability distribution of high-skilled individuals is $\phi = (1-s)^\kappa \phi_{max}$, where $0 \leq s \leq 1$ is the share of high-skilled individuals who are solo self-employed, $1-s$ is the share of high-skilled workers, ϕ_{max} is the maximum ability and $\kappa > 0$ is a distributional parameter. The underlying cumulative ability distribution $1-s = G(\phi) = \left(\frac{\phi}{\phi_{max}}\right)^{1/\kappa}$, with support $0 < \phi < \phi_{max}$ and ability density $g(\phi) = \frac{1}{\kappa}\phi_{max}^{-1/\kappa}\phi^{\frac{1-\kappa}{\kappa}}$, is a flexible distribution, which contains the uniform distribution ($\kappa = 1$) and approximates a Pareto distribution for $\kappa \ll 1$. The main advantage of this distribution is that it allows for analytically traceable results.

Using this ability distribution and the cut-off ability level, we derive high-skilled labor supply as

$$H = (1-s)\bar{H} = \bar{H} w_H^{1/\kappa} \phi_{max}^{-1/\kappa}, \tag{8}$$

where $\bar{H}$ is the number of high-skilled individuals. The aggregate price level in the solo self-employed segment then is $P_s = \sigma \left[\phi_{max} - \phi^*\right]^{\frac{1}{1-\sigma}}$.

Equilibrium Wages: With these assumptions, we derive high-skilled workers' equilibrium wages

$$w_H = \left(\bar{w}^{\eta - \tilde{\epsilon}} Q_0 K \phi_{min}^{1/\kappa} \bar{H}^{-1}\right)^{\frac{\kappa}{1+\kappa\eta}}. \tag{9}$$

Jointly with the CES wage cost index $\bar{w}$, this equation describes the equilibrium on our industry labor market.

2.2 Effects of a Minimum Wage

We study the effects of an introduction or a rise of a minimum wage on the industry. The proofs are in Appendix A.1.

Proposition 1 (Scale Effect)**.** *The introduction or rise of a minimum wage*

1. *raises average wage costs,* $\frac{\partial \ln \bar{w}}{\partial \ln w_{min}} > 0$,
2. *reduces industry employment* $\frac{\partial \ln N}{\partial \ln w_{min}} < 0$,
3. *raises the cut-off productivity level for firms* $\frac{\partial \ln \psi^*}{\partial \ln w_{min}} > 0$,

The minimum wage implies a cost shock to the industry. Average labor costs increase, leading to rising prices, declining product demand, and, hence, a decline in industry employment N. The shrinkage of the industry is associated with stricter firm selection – the least productive firms are forced out of the market as the cut-off productivity level increases and the number of firms declines. This effect is our scale effect. It implies a scaling-down of overall employment N. The size of the effect increases in the industry labor demand elasticity $\tilde{\epsilon}$ and in the size of the minimum wage. The effects on high-skilled and low- and medium-skilled workers differ because their relative prices change due to the minimum wage:

Proposition 2 (Substitution Effect)**.** *The introduction or rise of a minimum wage*

1. *reduces high-skilled workers' wages relative to low- and medium-skilled workers' wages,* $\frac{\partial \ln w_H/w_L}{\partial \ln w_{min}} < 0$
2. *raises the ratio of high-skilled to low- and medium-skilled employment,* $\frac{\partial \ln H/L}{\partial \ln w_{min}} > 0$

The minimum wage implies a decline of high-skilled workers' wages relative to low- and medium-skilled workers' wages, inducing firms to substitute low- and medium-skilled for high-skilled workers. The ratio of high-skilled workers to low- and medium-skilled workers, in turn, increases. This is our substitution effect. The size of the effect depends on the elasticity of substitution between worker types η and on the bite of the minimum wage. The net effect on high-skilled workers' wages, employment, and solo self-employment then depends on the relative size of these two effects.

Proposition 3 (Net Effect on High-Skilled Workers)**.** *The introduction or rise of a minimum wage*

1. *raises (reduces) high-skilled workers' wages,*
2. *raises (reduces) high-skilled employment,*
3. *raises (reduces) the cut-off ability level,*

if the elasticity of substitution between the worker types η *exceeds (is lower than) the wage elasticity of aggregate labor demand* $\tilde{\epsilon}$*,*

If the elasticity of industry labor demand ϵ exceeds the elasticity of substitution between worker types η, the negative scale effect dominates the positive substitution effect. In this case, there is insufficient substitution between the worker types to compensate for the decline in industry employment, so that employment and wages for high-skilled workers decline. This pushes high-skilled workers from dependent employment into solo self-employment, as the latter poses an alternative source of income for these individuals. The increase in solo self-employment is thereby driven by a worsening selection into solo self-employment: high-skilled individuals with lower ability now enter solo self-employment. The model therefore suggests that the increase in solo self-employment is driven by push-factors, not by pull-factors. High-skilled individuals become solo self-employed because of declining earning potentials on the labor market. Hence, high-skilled individuals with worse entrepreneurial abilities become solo self-employed, which also implies that their revenues are lower than those of incumbent solo self-employed.[8]

The results (and arguments) are reversed if the elasticity of substitution between worker types η exceeds the elasticity of industry labor demand. If it is sufficiently easy for firms to replace the more expensive low- and medium-skilled workers with high-skilled workers, then we expect demand for high-skilled workers to increase, their wages and employment to increase, and solo self-employment to decrease as the cut-off ability for solo self-employed increases.

3 Institutional Setting and Market Environment

Minimum Wage Regulations. The first minimum wages in Germany were introduced on an industry-level in the construction sector, starting with main construction (Jan 1997), electrical trade (June 1997), roofing (Oct 1997) and painting and varnishing (Dec 2003). See Table A.2 in the Appendix for a detailed definition of these industries.[9] There were two main reasons for the policy introduction: The first reason was the increasing cost pressure from Eastern Europe as a result of the European agreement on the free movement of labor. To protect their firms against relatively cheap foreign labor and distortions to competition, the employers' associations and trade unions in these industries independently decided to introduce a minimum wage for their workers.[10] The second reason was rising wage inequality between workers within the industry,

[8]Note that employment among low- and medium-skilled workers unambiguously declines. These workers leave the industry either towards unemployment or towards other industries. Since we focus on solo self-employment in this paper, and since only high-skilled workers can become solo self-employed in the investigated industries (see Section 3) , we abstract from any further adjustments related to the other skill groups.

[9]For the industry coding, we use the German classification of economic activities 1973 (WZ-73) at the 3-digit level, which covers the same comparable level of detail as the latest 5-digit German classification of economic activities 2008 (NACE Rev 2).

[10]Note that offering services in the industries that introduced a minimum wage required a master craftsman's certificate, which effectively prevented foreign firms to offer such services in Germany, and which also prevented them to start businesses in these industries in Germany, before the end of the Meisterzwang in 2004.

which was supposed to be counteracted by a minimum wage. The final decisions related to the policy introduction depended very much on the industry-specific negotiations and discussions between employer and employee representatives as well as on the way tariff policy is organized on the industry-level. Therefore, not all industries were able to agree on such a policy reform, at least not immediately. For instance, in the three industries that introduced a minimum wage in the late 1990's, employer and employee associations generally adopt regulations at the national level, which facilitated the earlier introduction of minimum wages. In contrast, other industries need to first delegate the collective-bargaining competence from the regional to the national level (Gregory and Zierahn, 2022). This might explain why only from 2007 onwards several further industries agreed on introducing a minimum wage for their workers as well. Given the partly very different industry-specific debates, the introduction of the first minimum wages was hard to anticipate for firms and workers. In 2015, Germany finally introduced a general cross-industry national minimum wage, although industry-specific regulations still apply if their minimum wage level is higher than the general one. In our study, we focus on the four German industries mentioned above, as these industries implemented their minimum wage policies early and thus allow us to study long-run adjustments to the minimum wage, which is at the center of our study. Moreover, these industries are less affected by any anticipation behavior as compared to industries that introduced such policies later.

Minimum wages in our four selected industries vary between industry, region (East/West) and time. Within our observation period, only the construction industry additionally implemented a minimum wage for skilled workers. We abstract from this additional skill differentiation, although we conduct robustness checks without main construction. Judged by the real minimum wage, the differences in the minimum wage level between industries, regions and time are quite substantial (see Figure 5 in the Appendix), which largely explains the corresponding variation in the minimum wage bite that we find (see Section 4.2). Regarding minimum wage coverage, the regulations apply to all firms whose main activities lie in the respective industry. The industry coding, which is available in our data, is therefore a good approximation for the minimum wage coverage on the firm side. On the worker side, all blue-collar workers are covered, with the exception of apprentices, trainees and students. These workers can be identified by our micro data.

Other Regulations and Policy Changes. All minimum wage industries are highly regulated by the German Trade and Crafts Code. The first professional degree that can be achieved is the journeyman ("Geselle"), which requires the completion of an apprenticeship training (duration approximately 3 years). The highest professional degree is the master craftsman ("Meister"), which takes approximately another 1-3 years, depending on whether it is done in part- or fulltime. Running a business in these industries requires a master craftsman's degree or, since the deregulation in 2004, a journeyman certificate together with at least six years of industry working experience (certified by a master craftsman and including management tasks such as supervising apprentices). We define these workers as high-skilled workers (see also Section 4). Industry-specific knowledge is generally not transferable, so that qualification degrees can not simply be used across industries. Note that we conduct robustness checks showing that our main results are robust to these craft-specific regulations (see Section 8).

Further worth mentioning is a parallel policy reform set out in Germany during our observed time period. As part of the German Hartz reforms, a start-up subsidy ("Ich-AG") was introduced in 2003, which aimed at encouraging start-up activity among unemployed individuals. Since the start-up subsidy applies to both treated and untreated industries, it should not contaminate our approach in general. However, it could have enforced the effects through its interaction with the minimum wage policies. Note that this would only affect our point estimates of main construction, roofing and electrical trade seven years after the policy change, whereas those of painting and varnishing from post-reform year one on. We therefore focus on results three and six years after the minimum wage introduction, as they are unaffected by the policy for three of our treated industries.

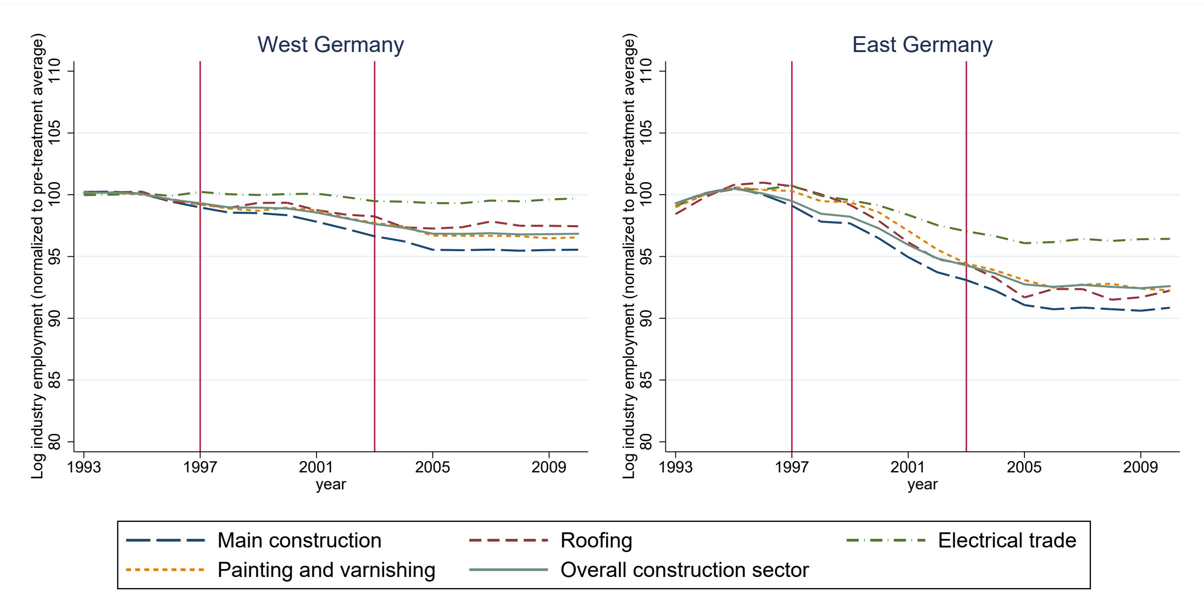
Market Environment. All minimum wage industries are part of the construction sector and share several peculiarities regarding production conditions, competition, employment structure and other regulations. To demonstrate this, Table 1 shows some industry characteristics measured before the policy reform, i.e., average values between 1992-1996 (for details on the data, see Section 4). All industries are quite skill intensive and very male-dominated. Due to high physical demands, workers in these industries are relatively young. Average daily wages are relatively low, especially for high-skilled workers. Competition is relatively high, as judged by the number of firms. The share of solo self-employed individuals is (still) relatively low, as judged by these pre-treatment figures. All industries are part of the construction sector, which experienced a

Table 1: Pre-Reform Industry Characteristics

	All industries	Main construction	Electrical trade	Roofing	Painting and varnishing
Share of high-skilled workers	68.6	79.0	80.5	75.9	82.4
Share of female workers	35.1	9.2	13.4	8.4	11.0
Share of workers by age group					
age 18 to 35	42.4	45.4	56.0	58.7	50.4
age 35 to 50	38.0	34.0	32.4	27.8	32.9
age above 50	20.8	20.6	11.5	13.5	16.7
Daily wage of workers (in €)	60.7	66.7	56.1	60.2	59.2
Daily wage of high-skilled workers (in €)	67.7	69.8	57.9	61.9	60.7
Number of workers (in 1000)	41.2	426.1	90.2	44.2	85.9
Share of solo self-employed	3.7	2.3	4.0	0.9	2.6
Number of firms (in 100)	23.7	559.7	189.1	55.6	150.6
Share of firms with 1 to 9 employees	20.4	19.0	20.9	7.8	17.4

Notes: Numbers are averages over the years 1992-1996.

Figure 1: Trends in Industry Employment



Notes: Vertical lines represent the introduction of minimum wages in 1997 (main construction, roofing and electrical trade) and 2003 (painting and varnishing).

long-lasting downward trend, particularly in the East, starting in the late 1990s and which lasted until the mid 2000s (see Figure 1). Results of this study should therefore be interpreted in the context of an economic downturn. Note that when using the synthetic control group approach, we ensure to compare our treated industries to control industries that follow a comparable business cycle.[11]

A further particularity of the construction sector is that construction projects are often managed by engineering offices. While being officially in the lead, they subcontract the individual

[11]Our synthetic control group approach ensures that treatment and synthetic control industries follow the same trends before the treatment, removing thus not only differences in levels but also in trends.

crafts and construction works to a variety of firms or solo self-employed individuals.

4 Data and Descriptives

4.1 Data

Mannheim Enterprise Panel. Our data source on absolute numbers of solo self-employed individuals in an industry is the Mannheim Enterprise Panel (MUP) provided by the Leibniz Centre for European Economic Research (ZEW). The data includes basic firm information (location, number of employees, date of foundation and closure), information on its owners (number of owners, age) as well as some financial information (credit rating score, payments, revenues). The data is collected by Creditreform for credit rating purposes and comprises information for the universe of all economically active firms in Germany. These data also provide the source for German firm data in the ORBIS-AMADEUS data base discussed by Gopinath et al. (2017). A firm is registered by Creditreform as active, if it is recorded in official registers (commercial register, register of associations, state register), mentioned in the media or if at least one client asks for the credit rating of the firm. A firm in this data set is defined as an enterprise rather than an establishment. At the end of 2013, the MUP contained information on 7.7 million firms, of which about 3.2 million were still active. Detailed information about the data and comparisons with official registers can be found in Bersch et al. (2014).

Most important, the data allows to identify firm owners without employees, which we define as solo self-employed individuals. This includes sole and multiple ownership as long as there are no dependent employees. In total, the data encompasses 9.8 million yearly observations for 785,000 solo self-employed workers across the time period 1992-2010. As an advantage, the data contains the detailed industry coding of the firm, which is necessary to identify the minimum wage industries. On this detailed industry-level, we observe the number of solo self-employed individuals together with their average revenues. For some analyses, we also restrict these numbers to "young" solo self-employed, i.e., those whose business is less than three years old.

Sample of Integrated Employment Biographies. Data on total industry employment as well as on the structure of the workforce come from the Sample of Integrated Employment Biographies (SIAB) provided by the Institute for Employment Research (IAB).[12] The data

[12]This study uses the weakly anonymous Sample of Integrated Labor Market Biographies (Years 1975 - 2010). Data access was provided via on-site use at the Research Data Centre (FDZ) of the German Federal Employment

includes all workers subject to social security contributions, thus excluding civil servants and self-employed individuals. We use a two percent random sample of the weakly anonymous version, which includes all individuals' employment histories together with several worker characteristics including age, education, experience, gender, daily wage, workplace location and the occupation of a worker. The data is generally available since 1975 for West Germany. Since East German workers are only covered reliably from 1992 onwards and since the MUP data is not available earlier either, we restrict our sample to the years 1992-2010. Similar to the MUP, the data contains the detailed industry coding of the workers' employer. We focus on employment spells that overlap June 30th and exclude minor employment as this is only recorded from 1999 onwards. We further restrict the sample to main employment spells and drop observations with missing industry identifiers. Since wages are top-coded in our data, we follow Dustmann et al. (2009) and Card et al. (2013) and impute wages above the censoring threshold with wages predicted from censored regressions for each year and East and West Germany separately.[13] Note that top-coding is binding mostly for workers with a university degree, whereas we focus on trade industries where even among high-wage earners, only few workers have a university degree and where very few workers' wages are top coded.

We use this micro data to calculate several indicators on employment and wages at the industry level. Among others, we calculate the industry share of high-skilled workers among dependent employees within an industry. We thereby define high-skilled workers as those eligible for running a business, that is either master craftsmen or journeymen with at least 6 years of industry working experience (see Section 3). We further calculate the share of middle-aged workers (between the age of 35 and 50). As wage indicators, we calculate the average daily wage for all workers as well as for high-skilled workers. Finally, we calculate hourly wages by dividing weekly wages by weekly hours worked. Weekly hours worked are generally not available in administrative data. We thus impute hours worked from the Microcensus data provided by the German Statistical Office, which includes information for a one percent random sample of all households in Germany, but which lacks information on wages. In particular, we calculate average weekly hours worked within fine demographic cells in the Microcensus data. We do this using variables that equally exist in the SIAB data. Within the defined cells, we then transfer the cell averages from the Microcensus into the SIAB data in order to construct hourly wages

Agency (BA) at the Institute for Employment Research (IAB) and subsequently remote data Access. Project Number 731. DOI: 10.5164/IAB.SIAB7517.de.en.v1

[13]As covariates, we include gender, education, age, industry, tenure, occupation and region.

(for details, see Appendix A.2).

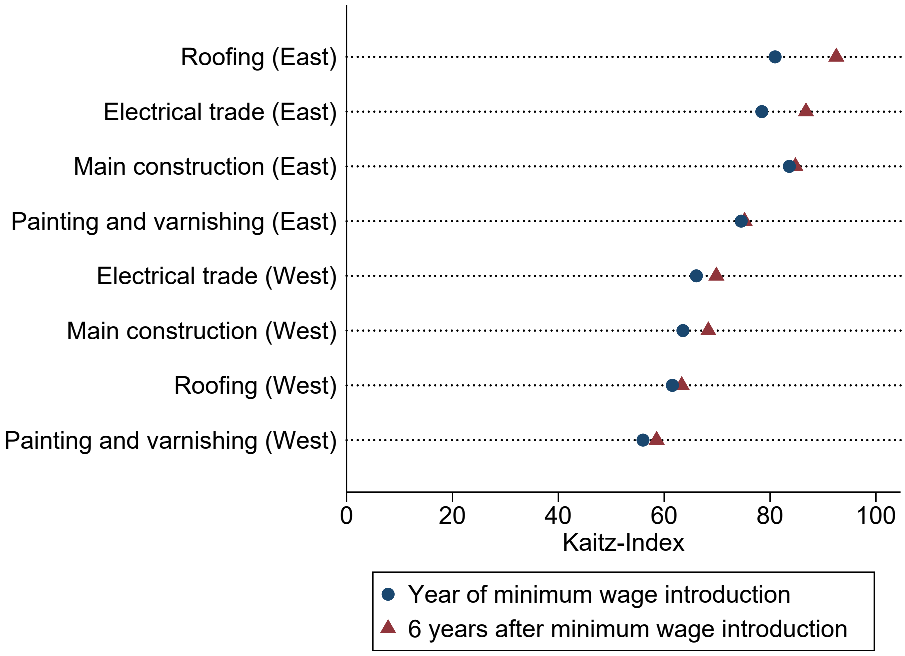
Industry-Region Panel. The aggregate industry statistics from both the MUP and SIAB data are combined to an industry-region panel covering 303 industries, two regions (East and West Germany) and all years from 1992 to 2010. Note that since industry coding changed during the observation period, we re-calculate all industry codes to the 1973 industry coding (WZ 73) using the procedure proposed by Eberle et al. (2014). We collapse industries whenever they are subject to the same minimum wage regulation such as in the case of the main construction industry that consists of several detailed industries. We further exclude industries in which there exist fewer than 50 firms in the MUP data or fewer than 50 employment observations in the SIAB data in any of the years during the observation period. Moreover, we drop industries, which implemented a minimum wage later in the observational period. Finally, we exclude 76 industries that are not profit-oriented (such as theaters, libraries, schools or kinder-gardens), so that we are left with 220 industries for the 19 year period. Based on that final MUP-SIAB industry-year panel, we additionally calculate the share of self-employed individuals among the workforce.[14]

4.2 Minimum Wage Bite

Figure 2 shows the Kaitz-Index, as defined by the ratio of the minimum wage level in period t relative to the median wage in period $t-1$, by industry, region (East/West) and time. The graph reveals large differences in the minimum wage bite across these dimensions. In particular, all industries in East Germany show much higher Kaitz-Indices compared to West Germany. Given that wage levels in East Germany amount to about 75% of West German levels during our time period (Burda, 2006), this is not surprising. However, there are also substantial differences across industries within both parts of the country. Whereas the East German Kaitz-Index in painting and varnishing was 74% in its year of introduction, it was almost 84% in main construction. The bite of the minimum wage grew even stronger over time. For instance, six years after the minimum wage introduction, the Kaitz-Index in East-German roofing reached almost 93%. The figures are in line with Gregory and Zierahn (2022), who provide evidence in favor of a particularly strong bite in roofing, compared to international standards. In our later empirical analysis, we exploit the heterogeneity in the Kaitz-Index besides looking at the first-time adoption

[14] Note that the number of workers (denominator) is based on a two percent random sample of all workers. We thus multiply the figures with 50 to reflect total employment figures.

Figure 2: Minimum Wage Bite by Industry, Region and Time



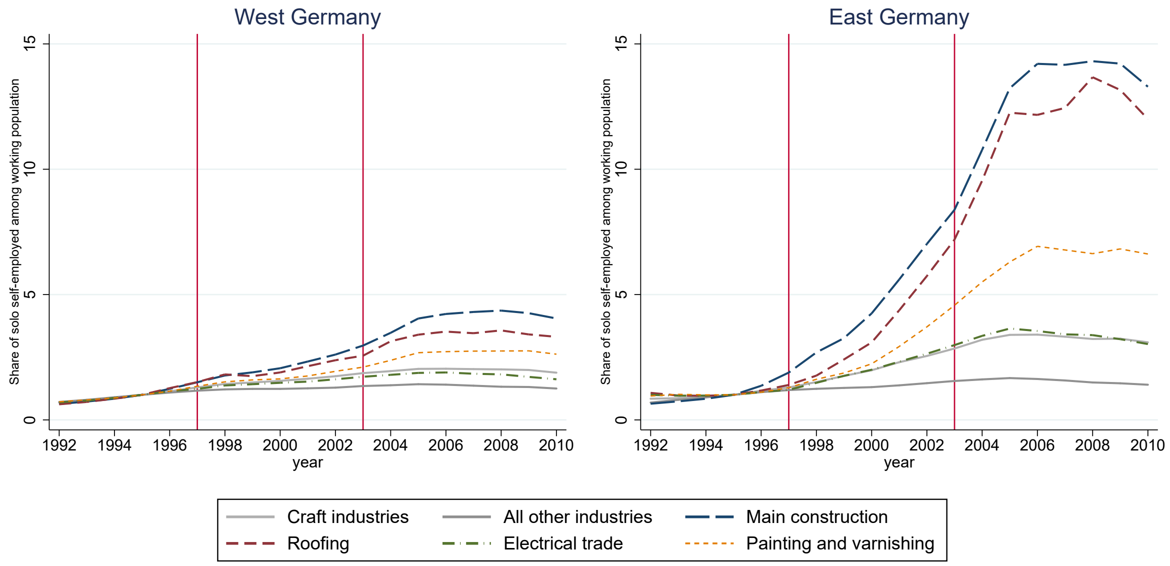
Notes: Calculations based on SIAB and Microcensus data. Circles show the minimum wage level in the year of introduction relative to the median wage one year before the reform. Triangles show the minimum wage level six years after the introduction relative to the median wage one year before. Note that minimum wage levels increase over time.

only. There, we also look at the share of workers with a wage in pre-reform period $t-1$ below the minimum wage in period t. This alternative bite measure yields similar results.

4.3 Trends in Solo Self-Employment

As documented by Boeri et al. (2020), solo self-employment is generally on the rise in many OECD countries. For Germany, we find that the share of solo self-employed individuals among the workforce increased from 2.3% to 4.9% during the observed time period 1992-2010. Large parts of the increase stem from minimum wage industries, as demonstrated in Figure 3. The Figure shows the development of the share of solo self-employed individuals for all four investigated minimum wage industries together with the average value across all non-minimum wage industries and all craft industries, and distinguishes between East and West Germany. For instance, whereas the share of solo self-employed individuals in East Germany rose between 4.5-12 percentage points in minimum wage industries, it only rose by 1.9 percentage points in all other untreated industries (see Appendix Table 10 for details). A similar pattern, albeit less strong, can be observed in West Germany. The growth was particularly pronounced in East Germany, as well as in main

Figure 3: Trends in Solo Self-Employment



Notes: Calculations based on MUP and SIAB. For comparability, figures are normalized to values in 1995. Vertical lines represent the introduction of minimum wages in 1997 (main construction, roofing and electrical trade) and 2003 (painting and varnishing). The panel for all other industries is weighted by the number of employees in each industry.

construction and roofing, which suggests a positive link between solo self-employment and the minimum wage bite (compare Figure 2). Of course, there may be many other forces determining this descriptive picture, which is the reason why we adopt the synthetic control group method in our empirical analysis.

5 Empirical Approach

Synthetic Control Group Estimator. To identify the causal impact of a minimum wage introduction on solo self-employment, we follow the synthetic control method proposed by Abadie and Gardeazabal (2003) and Abadie et al. (2010, 2015). The method is suited to study a policy change on aggregate-level outcomes such as on the level of countries, regions or, in our case, industries.[15] For a recent overview and discussion of the method, see Abadie (2020). The method has already been applied to study the impact of state minimum wage increases in the US (Sabia et al., 2012; Neumark et al., 2014; Allegretto et al., 2013). We use the method to study the first-time adoption of a minimum wage on the industry-level.[16] Applied to our case, the idea is to

[15]The method is increasingly used to study multiple treated units and individual outcomes as well, see Chan et al. (2014), Kreif et al. (2016).

[16]Chung et al. (2016) also apply the method to an industry-level, although they do not study a minimum wage policy.

compare outcomes in the treated industries to a weighted average of untreated industries, rather than relying on only one of them. The synthetic control method thereby chooses the weights such that the weighted average best resembles the treated industry before the intervention. Potential control industries, which are not comparable to the treated industry receive a weight of zero. The synthetic control method thus uses systematically more attractive comparisons compared to traditional Difference-in-Difference designs (Athey and Imbens, 2017). This importantly implies that our synthetic control method not only removes differences in levels, but also differences in trends between treated and control industries.

In particular, we estimate the minimum wage impact on industry-level outcomes in the treated industry $j = 0$ at time t between 1992-2010 as follows[17]:

$$\widehat{\alpha}_{0t} \quad = \quad Y_{0t} - \sum_{j=1}^{J} W_j Y_{jt},$$

that is we take the difference between the outcome of the treated industry (Y_{0t}) and the weighted combination of outcomes of all J untreated industries (donor pool). The vector of weights $\mathbf{W}$ is chosen such that the mean squared error in pre-treatment characteristics between the treated industry ($\mathbf{Z_0}$) and the weighted average of these characteristics among the donor industries ($\mathbf{Z_J W}$), summed over K predictor variables, is minimized such that:

$$\mathbf{W}^* = \arg min \sum_{k=1}^{K} V_k (Z_{0k} - \mathbf{Z_{Jk} W})^2 \quad \text{s.t.} \quad \sum_{j=1}^{J} W_j = 1, W_j \geq 0,$$

where V_k is a weight measuring the relative importance of the k-th predictor.

Outcomes. As outcomes, we look at the log share of solo self-employed individuals (Subsection 6.1). To test the predictions of our substitution-scale model, we also estimate the effect on log industry employment, the log share of skilled workers in the industry as well as log industry employment of skilled workers (Subsection 7.1). To analyze the consequences of the reform for the earnings perspectives of solo self-employed individuals, we further look at log average revenues of solo self-employed individuals (Subsection 7.2). For our employment and revenues outcomes, we additionally normalize the outcome variable by average pre-treatment levels of the outcome variable. The reason is that main construction diverges largely in size[18]. We thus focus

[17]For estimates related to revenues of solo self-employed, we loose the year 1992.

[18]Main construction consists of many sub-industries, see Appendix Table A.2.

on comparing treated and synthetic control industries based on their *relative* outcomes. We do not normalize the share of solo self-employed, as we do not find comparably large deviations in size for this outcome.

Predictor Set. The predictor sets include, if not specified otherwise, the pre-treatment level of the outcome variable in the following ways: For those treated industries that introduced minimum wages in 1997 (main construction, roofing and electric trade), we use the outcome variable for the years 1993, 1995 and 1997. For the industry that adopted a minimum wage in 2003 (painting and varnishing), we include the outcome variable measured in 1993, 1996, 1999 and 2002 in the predictor set. One additional challenge arises due to the fact that we are looking at the minimum wage effects in industries that experienced an economic downturn during our observation period (see also Figure 1). The employment outcomes follow a strong business cycle. In order to make sure that our synthetic control industries are not only comparable in pre-treatment outcome levels, but also in the degree to which they experienced an economic downturn, we additionally add the ratio of post-treatment outcome levels on the higher 1-digit industry-level to corresponding pre-treatment levels, whenever we focus on employment outcomes.[19] The latter variable serves to match on industries that follow comparable overall business cycle trends over the whole time period. While we leave out this predictor for solo self-employment and revenues because no comparable business cycle are apparent for these outcomes, we do show in Section 8 that our results for these outcomes are robust to including this additional predictor.

Inference. Due to limitations in applying traditional inference statistics to synthetic control comparisons, we follow Abadie and Gardeazabal (2003), Abadie et al. (2010) and Abadie et al. (2015) and conduct placebo tests to evaluate the statistical significance of our estimates. The falsification exercises are based on the idea that the confidence in the validity of our estimates should decrease if one finds similarly large (or even larger) results whenever the intervention is artificially reassigned to untreated cases. These untreated cases can either be untreated year observations before the intervention (in-time placebo) or untreated units from the donor pool (in-space placebo[20]). Since we have only few pre-treatment observations, we follow the latter approach. In particular, we estimate the effect of an artificial intervention in each of our control industries from the donor pool. This is done by iteratively reassigning the treatment to each

[19]We leave out treated industries when computing 1-digit-level aggregated indicators. This variable essentially ensures that we match 3-digit industries to other 3-digit industries within the same broader 1-digit aggregates.

[20]In our case, this dimension is industry rather than space (country, state or region).

control industry in our data and estimating the intervention effect (placebo runs). This yields the results of placebo effects (permutation distribution) that can be used for display and visual comparison. The effect is significant, if the magnitude is extreme relative to the magnitude of the placebo effects.

A challenge to this approach is, that even if the synthetic control industry is well able to map the trend of the outcome variable in the treated industry before the intervention, this need not be true for all control industries. We therefore follow Abadie (2020) and set the effect size in relation to the quality of the fit. In particular, we calculate the ratio of the post-intervention effect relative to the pre-intervention fit for every industry and time period. The fit is measured by the root mean squared prediction error (RMSPE). This yields the permutation distribution of ratios for the placebo effects. Based on this test statistic, we then calculate p-values as the fraction of ratios greater than or equal to the ratio estimated for the treated unit, down-scaling the effects of placebo runs with a bad fit.[21] In the following analyses, we use these p-values for evaluating the significance of our synthetic control group estimates. Moreover, we also report the ranking in the permutation distribution of the ratios, as in some cases the low number of placebo runs leads to a large p-value, even through the effect size in relation to the quality of the fit is large.

Construction of Synthetic Control Industries. Following the approach described in Section 5, we construct our synthetic control industries based on weights chosen such that our synthetic control industries best resemble the predictors of solo self-employment shares (and other outcomes) in the treated industries. Appendix Table 11 displays the weights from our synthetic control estimates related to the share of solo self-employed individuals. It shows only weights larger than 0.01 and distinguishes by our four minimum wage industries and by East and West Germany. By construction, weights sum up to 1. Table 2 compares the pre-treatment characteristics that are included in the predictor set between all treated and corresponding synthetic industries. Overall, the results suggest that our synthetic control industries are very comparable to our treated industries. The method thus produces good comparisons to evaluate the minimum wage effect on solo self-employment. Note that we find similar good comparisons

[21] Formally, the ratio between the post-intervention RMSPE, $R_j(T_0+1,T)$, and pre-intervention RMPSE, $R_j(1,T_0)$, for industry j is $r_j = \frac{R_j(T_0+1,T)}{R_j(1,T_0)}$, where $R_j(t_1,t_2) = (\frac{1}{t_2-t_1+1}\sum_{t=t_1}^{t_2}(\widehat{Y}_{jt} - Y_{jt}^N)^2)^{\frac{1}{2}}$ and where $\widehat{Y}_{jt}$ is the outcome of the synthetic control industry in period t . The p-value is then defined as $p = \frac{1}{J+1}\sum_{j=1}^{J+1} I(r_j \geq r_1)$, where I is an indicator function that returns one if $r_j \geq r_1$ and zero otherwise. For details, see Abadie (2020).

Table 2: Pre-Treatment Predictor Means (Industry-Level)

	Main Construction		Roofing		Electrical trade		Painting and varnishing	
	treated (1)	synthetic (2)	treated (3)	synthetic (4)	treated (5)	synthetic (6)	treated (7)	synthetic (8)
East Germany								
Share of solo self-employed ind.								
in 1993	1.09	1.09	0.63	0.63	2.82	2.81	1.94	1.87
in 1995	1.47	1.48	0.65	0.65	2.92	2.91		
in 1996							2.10	2.16
in 1997	2.78	2.64	0.91	0.90	3.50	3.50		
in 1999							3.55	3.80
in 2002							7.04	6.56
West Germany								
Share of solo self-employed ind.								
in 1993	2.63	2.62	0.98	0.98	4.34	4.34	2.96	2.98
in 1995	3.59	3.57	1.37	1.37	5.64	5.64		
in 1996							4.25	4.27
in 1997	5.40	5.37	2.06	2.06	6.97	6.97		
in 1999							5.92	5.94
in 2002							7.19	7.21

for our other outcomes including industry employment, the share of high-skilled employment, industry employment (of high-skilled) and revenues (of young) solo self-employed (see Figures 8, 9 and 10).

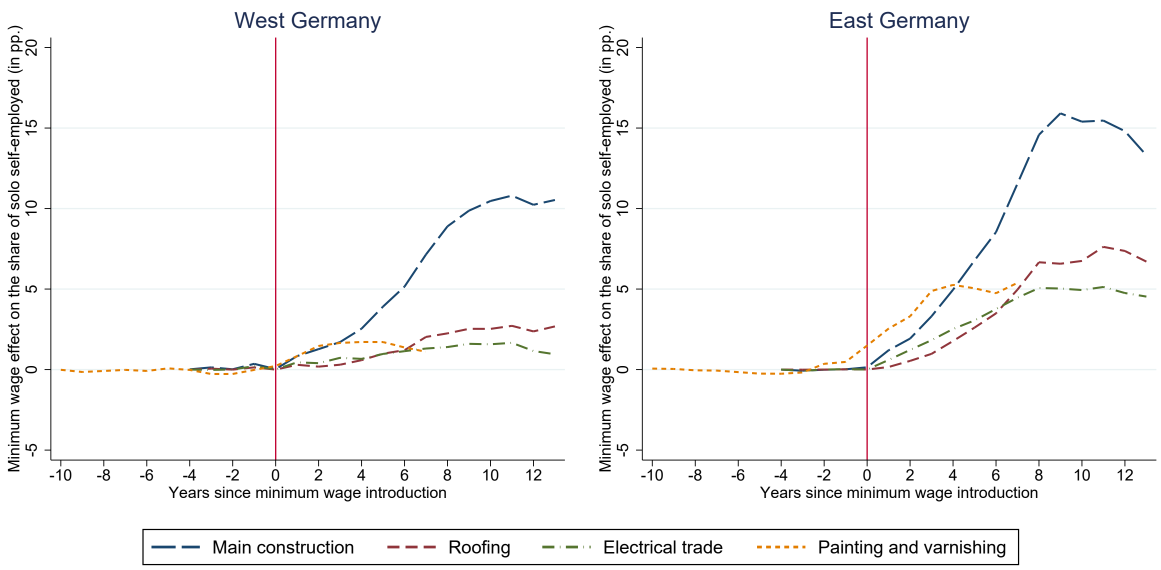
6 Minimum Wage Effects on Solo Self-Employment

Ideally, we would start with a pooled average effect of solo self-employment. Since our aggregate approach exploits the exogenous variation provided by the heterogeneous policy implementation across industries, region and time, we cannot simply pool the results. Instead, we first investigate the effects by these dimensions using the synthetic control method (Subsection 6.1) and then correlate the estimated effects with the minimum wage bite (Subsection 6.2).

6.1 Effects by Industry, Region and Time

Figure 4 shows the estimated effects of the minimum wage introduction on the share of solo self-employed individuals for all our four minimum wage industries by East and West Germany over time. The intervention effects are derived from the difference between the outcomes of the treated compared to the outcomes of the synthetic industries, at each point in time (see Appendix Figure 6 for a graphical representation of both the minuend and subtrahend). Although the estimations were conducted in logs, we report the de-logarithmized values for better interpretation. Note

Figure 4: Effects of the Minimum Wage Introduction on the Share Solo Self-Employed Over Time



Notes: The vertical lines represents the year of minimum wage introduction. See Appendix Figure 6 for a more detailed graphical representation of both the minuend and subtrahend.

that different time periods before and after the minimum wage reflect different implementation years of the minimum wage. Table 3 shows the corresponding accumulated effects 3 and 6 years after the policy introduction together with its significance levels as discussed in Section 5.

The results in Figure 4 show that our synthetic control industries resemble the trajectories of our treated industries very well, indicated by the near-zero gap between the treated and synthetic industries before the minimum wage introduction. As demonstrated by the increasing differences in post-treatment years, the effect of the minimum wage introduction was positive and significant for almost all industries in both parts of the country. However, we find a large heterogeneity w.r.t. the size of the effects. In particular, we find the positive effects to be stronger and more significant in East compared to West Germany. Moreover, we find larger effects in main construction compared to the other industries. The effects rise over time until about 10 years after the policy reform, before decreasing slightly again.

In terms of effect size, the minimum wage introduction significantly increased the share of solo self-employed main construction workers six years after the reform by 8.5 pp in East and 5.2 pp in West Germany (see Column 2 in Table 3). Compared to the shares in the pre-treatment year 1996 (see Table 2), this means that solo self-employment doubled in West Germany and increased sixfold in East Germany. We also find significantly positive accumulated effects six

Table 3: Accumulated Effects of the Minimum Wage Introduction on the Share of Solo Self-Employed

Accumulated effect after years (in pp.):	t+3 (1)	t+6 (2)
East Germany		
Main construction	3.311**	8.536**
	[1]	[1]
Roofing	0.979**	3.493**
	[1]	[1]
Electrical trade	1.829**	3.764**
	[1]	[1]
Painting and varnishing	4.880**	4.744*
	[3]	[4]
West Germany		
Main construction	1.711	5.154*
	[17]	[9]
Roofing	0.303***	1.206***
	[1]	[1]
Electrical trade	0.732***	1.145***
	[1]	[1]
Painting and varnishing	1.657*	1.374
	[7]	[21]

Note: p-values indicated by ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$; rank statistics in square brackets.

years after the policy change for East German roofing (+3.5pp), electrical trade (+3.8pp) and painting and varnishing (+4.7pp).

Altogether, our results show that the minimum wage introduction led to a partly substantial increase in solo self-employment. The size of the effects becomes visible especially in the longer run, in line with recent studies suggesting that the full adjustments to a minimum wage take time (Meer and West, 2016; Sorkin, 2015). Another general finding here is that the effects are larger for industries and parts of Germany where the bite was particularly strong (compare Figure 2). Note that our results are robust to removing industries from the donor pool that did not deregulate access to solo self-employment and using additional predictors. Moreover, we show that results are robust to controlling for the post-treatment change in solo self-employment at the 1-digit sector level. Corresponding robustness checks are discussed in Section 8. This highlights that our results are not driven by business cycle fluctuations.

Without distinguishing between solo self-employment and self-employment in general, Blau (1987) reports a decrease of .019 percentage points in the share of self-employment (only male workers) for a one dollar increase in the minimum wage, using data for the years 1948-82.

However, this number refers to self employment, whereas we focus on the very different group of solo self-employed. The simulations by Medrano-Adán et al. (2015) allow for heterogeneity between the two different forms of self-employment. Simulating an introduction of a minimum wage with a Kaitz-Index of 50%, they infer that 21% of formerly employed workers would be induced to become either involuntarily solo self-employed or unemployed. Hence, depending on the baseline rate, their simulated increases in solo self-employment would be up to 21pp. In line with their results, we find an increase by up to 15.9pp in the East German main construction industry 9 years after the reform (compare Figure 4).

6.2 The Role of the Minimum Wage Bite

As we show above, the results differ across industries, regions and time, as does the size of the minimum wage. We therefore test whether the intensity of the treatment can explain the heterogeneity of the treatment effects. In particular, we regress our treatment effects ($\widehat{\alpha}_{irt}$) produced by our synthetic control method on the minimum wage bite for each minimum wage industry i, region r and year t as follows:

$$\widehat{\alpha}_{irt} = \beta_0 + \beta_1 X_{irt} + \gamma_{ir} + \epsilon_{irt}, \tag{10}$$

where X_{irt} captures the minimum wage bite (Kaitz-Index or share of workers below the next minimum wage) and where γ_{ir} are industry-region fixed effects. As treatment effects on the left hand side, we use the treatment effects related to the share of solo self-employed from the previous section.

Table 4 shows the results related to a basic model without controlling for industry- or region-specific effects (Column 1), a model with industry and region fixed effects (Column 2) as well as our preferred model controlling for industry-region fixed effects (Column 3). The results highlight that the minimum wage effect on solo self-employment is bigger the larger the bite, irrespective of whether we use the Kaitz-Index or the share of affected workers as an indicator of the bite. That is, despite the large heterogeneity across industries, regions and time, there exists a strong positive relationship between the size of the bite and the size of the effects.

In the following sections, we shed more light on the mechanisms through which a minimum wage sets incentives for solo self-employment and demonstrate the role of the bite in moderating these mechanisms.

Table 4: Correlations Between the Minimum Wage Bite and Minimum Wage Effects on Solo Self-Employment

	OLS (1)	OLS (2)	FE (3)
Dependent Variable: minimum wage effect on solo self-employment			
Kaitz-Index	3.59***	5.40***	5.43***
	(0.83)	(1.47)	(0.62)
Share of workers with wage below next MW	6.24***	4.90***	4.91***
	(0.56)	(0.62)	(0.67)
Industry and region FE	No	Yes	No
Region-industry FE	No	No	Yes
N	92	92	92

Notes: standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$; Columns 1 and 2 are clustered by industry-region; Sample contains industry-region observations for years after minimum wage was introduced.

7 Testing the Mechanisms of the Substitution-Scale Model

We have laid out a substitution-scale model in Section 2, in order to demonstrate how a minimum wage impacts solo self-employment. According to our model, a minimum wage driven increase in the wage of low- and medium-skilled workers raises the relative demand for high-skilled workers due to the change in relative input prices (positive substitution effect, Proposition 2). At the same time, the overall labor cost shock driven by the minimum wage introduction reduces employment among all skill groups (negative scale effect, Proposition 1). The net effect on employment and wages of high-skilled workers then depends on the relative size of these two effects (Proposition 3). In subsection 7.1 below, we empirically test these predictions by looking at dependent employment.

As a further prediction of the model, we expect the incomes of solo self-employed individuals to decline in reaction to the intervention, as a worsening selection of high-skilled workers becomes solo self-employed, i.e., those that just pass the ability cut-off (Proposition 3). To test this, we look at revenues of solo self-employment in subsection 7.2.

7.1 Minimum Wage Effects on Dependent Employment

To test the model's predictions for dependent employment, we follow the procedure of Gregory and Zierahn (2022) and decompose the net effect of the minimum wage on high-skilled workers into a scale and substitution effect as follows:

$$\underbrace{\frac{\partial \ln H}{\partial \ln w_{min}}}_{\text{net effect}} = \underbrace{\frac{\partial \ln H/N}{\partial \ln w_{min}}}_{\text{substitution effect}} + \underbrace{\frac{\partial \ln N}{\partial \ln w_{min}}}_{\text{scale effect}} \tag{11}$$

The subsequent effects are estimated again using the synthetic control group approach as described in Section 5. For this, we use log total employment (scale effect), log share of high-skilled workers (substitution effect) as well as log number of high-skilled workers (net effect) as outcome variables. Employment outcomes in our treated industries follow the business cycle of the broader 1-digit construction sector, which differs significantly from other sectors. We therefore additionally control for the post-treatment increase in the employment outcomes at the more aggregated 1-digit sector level (leaving out treated industries). This ensures that we selected industries from the donor pool that follow the same overall business cycle trend as our treated industries.

For log total employment and log number of high-skilled workers, we construct synthetic control industries that well resemble the trajectories of our treated industries, again indicated by the near-zero gap between the treated and synthetic industries before the minimum wage introduction in Appendix Figure 11. Appendix A.4 provides the detailed results of these analyses by industry, region and time. Results differ along these dimensions, as does the bite of the minimum wage. We therefore follow our procedure from the previous section and test whether the intensity of the treatment can explain the heterogeneity of the treatment effects.

Table 5 shows the results correlated with the minimum wage bite as discussed for solo self-employment in 6.2. Results relate to a basic model without controlling for industry- or region-specific effects (Column 1), a model with industry and region fixed effects (Column 2) as well as our preferred model controlling for industry-region fixed effects (Column 3). Panel A provides results for the effects on the total number of workers employed in the industry (scale effect). Similar as for the effect on the solo self-employed individuals, the (negative) scale effect is bigger the larger the bite, both if we use the Kaitz-Index or the share of affected workers as an indicator of the bite. That is, we find a strong positive relationship between the size of the bite and the size of the negative scale effect. Results for the substitution effect (Panel B), as well as for the net effect (Panel C) are also in line with our proposed theoretical explanation: The larger the bite, the larger the increase in the share of high-skilled workers (substitution effect), but the larger also the decline in the number of high-skilled workers (net effect). The latter reflects that the scale effect exceeds the substitution effect, particularly when the bite is large.

Table 5: Correlations Between the Minimum Wage Bite and Minimum Wage Effects on Dependent Employment and Solo Self-Employment

	OLS (1)	OLS (2)	FE (3)
A. Dependent Variable: minimum wage effect on the number of workers			
Kaitz-Index	-0.87*	-1.31*	-0.55*
	(0.43)	(0.67)	(0.29)
Share of workers with wage below next MW	-1.66***	-1.59***	-0.96***
	(0.46)	(0.33)	(0.28)
B. Dependent Variable: minimum wage effect on the share of skilled workers			
Kaitz-Index	0.28**	0.38*	0.32***
	(0.10)	(0.17)	(0.08)
Share of workers with wage below next MW	0.45***	0.41***	0.39***
	(0.11)	(0.06)	(0.08)
C. Dependent Variable: minimum wage effect on the number of skilled workers			
Kaitz-Index	-0.52	-0.88*	-0.33
	(0.40)	(0.43)	(0.20)
Share of workers with wage below next MW	-1.03*	-1.04***	-0.64***
	(0.44)	(0.24)	(0.19)
D. Dependent Variable: minimum wage effect on solo self-employment			
Net effect on skilled workers	-2.14*	-1.50	-2.15***
	(0.96)	(0.84)	(0.39)
Industry and region FE	No	Yes	No
Region-industry FE	No	No	Yes
N	92	92	92

Notes: standard errors in parentheses. $***p < 0.01$, $**p < 0.05$, $*p < 0.1$; Columns 1 and 2 are clustered by industry-region; Sample contains industry-region observations for years after minimum wage was introduced.

Although we cannot directly observe transitions from dependent employment to solo self-employment[22], the institutional regulations (only high-skilled are eligible to become solo self-employed, see Section 3) does suggest a link here. To provide further evidence, we correlate the treatment effect on the share of solo self-employed with the net effect on high-skilled workers in industry-region year cells. In particular, we correlate the minimum wage effects on solo self-employment on the one hand side with the minimum wage effects on the number of skilled workers on the other hand side. The results are depicted in Panel D of Table 5 and show a statistically significant negative correlation: The minimum-wage driven increase in solo self-employment is larger when also the minimum wage induces large declines of high-skilled workers. The findings suggest that those persons who have left their dependent employment are also those who have become solo self-employed.

[22]The employment biographies only cover dependent employment, whereas the enterprise panel only covers enterprises. Linking the two data bases at the micro level is not possible due to data protection regulations.

Overall, we find that the scale effect exceeded the substitution effect, such that the minimum wage introduction reduced the demand for high-skilled workers and led to a drop in earnings perspectives of high-skilled workers. This was particularly true in industries and parts of Germany, where the minimum wage bite was particularly strong, i.e., the Kaitz Index particularly large. This suggests that the size of the minimum wage effects we find depend on the bite of the minimum wage and unfold over time. As we propose throughout this paper, this depression of earnings perspectives for high-skilled workers in dependent employment has pushed them into solo self-employment, which explains the corresponding rise in solo self-employment.

7.2 Minimum Wage Effects on Revenues of Solo Self-Employed

To test the predictions for revenues of solo self-employed (i.e. their incomes), we apply the same synthetic control method as before. Appendix Figure 13 shows that our synthetic control industries well resemble the trajectories of our treated industries for our additional outcomes. The raw developments of revenues in our treated and synthetic control industries can be found in Appendix Figure 12. Results differ by region, industry and time, as does the size of the treatment. We report the detailed results of the Synthetic Control Group approach in Appendix A.5 and follow our procedure from above and correlate the estimated treatment effects with the bite of the minimum wage. Table 6 provides the results. Again, we report the results related to a basic model without controlling for industry- or region-specific effects (Column 1), a model with industry and region fixed effects (Column 2) as well as our preferred model controlling for industry-region fixed effects (Column 3).

Panel A of Table 6 shows that an increase in the bite by one percentage point is associated with an increase in the negative effects on revenues of all solo self-employed by 1.3 percentage points: The stronger the minimum wage bite, the larger the decline in revenues among all solo self-employed. This effect should be stronger for individuals who became solo self-employed only in response to the minimum wage, who we proxy by looking at "young" solo self-employed. Young solo self-employed are defined as individuals who started their business within the last three years.[23] Indeed, the corresponding decline in revenues for young solo self-employed is -1.8 percentage points (Panel B). This highlights that young solo self-employed suffer more from high minimum wages than older solo self-employed. This is in line with our model's prediction that

[23]Note that we choose the three year moving average instead of looking at new cohorts on a yearly basis due to sample size. On average across our four minimum wage industries, 1,139 solo self-employed workers enter the sample per year with non-missing revenues, yet some yearly entrant cohorts consist of only 34 solo self-employed.

Table 6: Correlations Between the Minimum Wage Bite and Minimum Wage Effects on Revenues of Solo Self-Employed

	OLS (1)	OLS (2)	FE (3)
A. Dependent Variable: revenues of solo self-employed			
Kaitz-Index	-0.34*	-0.62	-1.23***
	(0.17)	(0.35)	(0.26)
Share of workers with wage below next MW	-0.59**	-0.54	-1.26***
	(0.24)	(0.45)	(0.26)
B. Dependent Variable: revenues of young solo self-employed			
Kaitz-Index	-0.99***	-1.57**	-1.64***
	(0.19)	(0.49)	(0.29)
Share of workers with wage below next MW	-1.99***	-1.83***	-1.83***
	(0.17)	(0.19)	(0.27)
Industry and region FE	No	Yes	No
Region-industry FE	No	No	Yes
N	92	92	92

Notes: standard errors in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$; Columns 1 and 2 are clustered by industry-region; Sample contains industry-region observations for years after minimum wage was introduced.

the minimum wage worsened the selection of solo self-employed.

These results highlight that the income prospects of an increasing number of solo self-employed individuals have deteriorated. This is in line with Boeri et al. (2020), according to whom solo self-employment reflects a state of underemployment characterized by workers with poor outside options who work less than desired and earn less on an hourly basis compared to traditional jobs. They also face more liquidity constraints and are more vulnerable to idiosyncratic shocks compared to self-employed with employees as they often depend on one major client. Boeri et al. (2020) further state that solo self-employment provides ways to undercut wages of workers in traditional jobs. Altogether, this suggests that solo self-employment is less of a voluntary decision and more of a forced alternative to the diminished job prospects of workers in dependent employment.

8 Robustness

Alternative donor pools. As discussed in Section 3, in December 2003 several craft industries deregulated the requirements to start a business, including becoming solo self-employed. Initially, many craft industries relied on the so called "Meisterzwang", i.e., the obligation to have a master craftsman certificate, before being allowed to start a business. This was deregulated by allowing trained journeymen with at least six years of relevant occupational experience to start a business. Rostam-Afschar (2014) shows that this deregulation increased the probability to become self-employed in craft industries. Although the author does not distinguish between self-employment with and without employees, which has been shown to be very different (Boeri et al., 2020), the deregulation might have increased solo self-employment more strongly in craft industries compared to non-craft industries. To make sure that this does not affect our results, we remove all industries from our donor pool that did not deregulate the "Meisterzwang". Column 2 in Appendix Table 12 contains the corresponding synthetic control method estimates related to the minimum wage effect on the share of solo self-employed based on the restricted donor pool. Column 1 shows the base line effects from Section 6.1 for comparison. The sign and magnitude of the effects are remarkably similar. The results seem to be robust to these craft-specific regulations.

Alternative predictor sets. We test the sensitivity of our results w.r.t. the predictor set, by including further variables as predictors (Column 3 in Appendix Table 12). In particular, we add (all in logs) the share of skilled workers as well as the average daily wage of skilled workers as proxies for the pre-treatment demand for skilled labor. Since the literature suggests that industries with many small firms constitute a favorable environment for the market entry of solo self-employed workers, we further include the share of small firms (less than 10 employees). Finally, we include the share of middle-aged workers (between 36 and 50 years of age), as this has been shown to be a further potential predictor in driving solo self-employment. All other predictor variables remain unchanged. Our results remain robust to these changes across all sectors and both regions.

Macro predictor. For our employment specifications, we add the post-to-pre-treatment outcome ratio as an additional predictor. The underlying reason is that employment in these sectors follows the business cycle of the broader 1-digit construction sector. We did not include the 1-digit (leave-treated-out) post-to-pre-treatment outcome ratio for solo self-employment, because no such business cycle is visible in our data. To check whether our results are driven by heterogeneous business cycles, we control for the 1-digit post-to-pre-treatment share of solo self-employed workers, leaving out the treated industries when computing this control variable in Column 4 of Table 12. Effect sizes drop slightly, but all effects remain positive, large and significant.[24] We conclude that results are qualitatively robust to business cycle fluctuations.

9 Conclusion

Solo self-employment is on the rise in almost all OECD countries, despite being associated with less favorable working conditions. We propose that minimum wage policies might be one explanation for the surge in solo self-employment. To demonstrate this, we assess the long-run impact of a first-time minimum wage policy adoption on solo self-employment in a unique quasi-experimental setting: For political reasons, few German industries introduced minimum wages in the 1990s, while other industries did not do so, or at least not immediately. This allows us to compare changes in outcomes between treated and comparable untreated industries within a synthetic control group approach. Four conclusions can be drawn from our analysis:

First, a minimum wage can induce a substantial increase in solo self-employment. Across several German industries, we find that the first-time adoption of a minimum wage increased the share of solo self-employed individuals between 1.1 and 8.5 pp, depending on the industry and region. For some industries, this meant a sixfold increase in solo self-employed workers compared to pre-treatment years.

Second, an increase in solo self-employment can be explained by a decline in earnings perspectives of potential solo self-employed (due to the German Meisterzwang, these comprise only high-skilled workers). In line with a substitution-scale model, we show that while the minimum wage induced a substitution of low- by high-skilled workers, at the same time all skill groups suffered equally from an overall decrease in labor demand in response to the minimum wage-induced labor cost shock (negative scale effect). As a result, net high-skilled labor demand substantially decreased, pushing them into solo self-employment.

Third, our results indicate that the decision of high-skilled workers to become solo self-employed was not entirely voluntary. Our theoretical model suggests that a high minimum wage pushes high-skilled workers with less favorable characteristics into self-employment, whenever they face worsening perspectives in dependent employment. In line with this hypothesis, we find declining revenues (i.e., incomes) of solo self-employed individuals, especially among those that started their business in reaction to the policy reform. As argued by other studies, this could

[24] The only exception is the electrical trade industry in the East in the first three years. However, note that the electrical trade industry does not follow the same business cycle as it's 1-digit sector already before the introduction of the minimum wage (see Figure 1). Hence, results for electrical trade in this specification likely are downward biased.

reflect firms that outsource work by re-grading their employees as independent self-employed contractors or using other alternative work agreements to buffer the cost shock induced by the minimum wage (Boeri et al., 2020; Datta et al., 2019; Parker, 2010).

Fourth, our study suggests that such minimum wage responses are more likely to arise in a context of an increasing minimum wage bite in an economic downturn. We demonstrate that the magnitude of our effects significantly increase with the size of the Kaitz-index (and other measures). In some of our investigated industries, the Kaitz-Index reached values near 100%, where the minimum wage equals the median wage level. At the same time, all industries investigated experienced a long-lasting economic downturn. Altogether, this suggests that a high minimum wage level in combination with an economic downturn plays a major role in triggering indirect effects from minimum wages, as we find. This insight might be of particular interest, given increasing minimum wage levels and economic recessions observed worldwide.

Whereas our study focuses on selective industries in Germany, our stylized framework highlights that these effects generally occur whenever the scale effect exceeds the substitution effect, such that high-skilled workers face lower labor demand and become solo self-employed. The scale effect can be large in situations where the bite of the minimum wage is large or whenever the economy faces a downturn, forcing increases in wages and prices and triggering declines in demand and output. The substitution effect can be small relative to the scale effect whenever the tasks performed by low-skilled workers differ substantially from the tasks performed by high-skilled workers. In our specific case, only high-skilled workers can become solo self-employed due to industry regulations. However, even in cases where also low-skilled workers can become solo self-employed, we would expect an increase in solo self-employment, which might even be stronger due to the large decline in demand for those workers.

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A Appendix

A.1 Proofs

Proof for Proposition 1:

Proof. Changes in average wages are $\frac{\partial \ln \bar{w}}{\partial \ln w_{min}} = \alpha + (1-\alpha)\frac{\partial \ln w_H}{\partial \ln w_{min}}$, where α is the steady state share of high-skilled workers. Using this jointly with equilibrium high skilled wages (Equation 9) provides $\frac{\partial \ln \bar{w}}{\partial \ln w_{min}} = \frac{\alpha/\kappa+\eta}{1/\kappa+\alpha\eta+(1-\alpha)\tilde{\epsilon}} > 0$.

This implies a decline in industry employment, $\frac{\partial \ln N}{\partial \ln w_{min}} = -\tilde{\epsilon}\frac{\partial \ln \bar{w}}{\partial \ln w_{min}} < 0$.

Increasing wages imply an increase in the cut-off productivity level for firms, $\frac{\partial \ln \psi^*}{\partial \ln w_L} = \frac{1}{\kappa}\frac{\partial \ln \bar{w}}{\partial \ln w_L} > 0$.

□

Proof for Proposition 2:

Proof. Using the results from Proposition 1 on the response of average wages, we derive $\frac{\partial \ln w_H/w_L}{\partial \ln w_{min}} = -\frac{1/\kappa+\tilde{\epsilon}}{1/\kappa+\alpha\eta+(1-\alpha)\tilde{\epsilon}} < 0$.

Using this in relative labor demand, we get $\frac{\partial \ln H/L}{\partial \ln w_{min}} = \eta\frac{1/\kappa+\tilde{\epsilon}}{1/\kappa+\alpha\eta+(1-\alpha)\tilde{\epsilon}} > 0$. □

Proof for Proposition 3:

Proof. From the equilibrium wage level (eq. 9) and the effect the minimum wage on the average wage from Proposition 1, we derive $\frac{\partial \ln w_H}{\partial \ln w_{min}} = \frac{\alpha(\eta-\tilde{\epsilon})}{1/\kappa+\alpha\eta+(1-\alpha)\tilde{\epsilon}}$ with $0 < \alpha < 1$, $\kappa > 0$, $\eta > 0$ and $\tilde{\epsilon} > 0$.

Using this result in high-skilled labor supply provides $\frac{\partial \ln H}{\partial \ln w_{min}} = \frac{1}{\kappa}\frac{\partial \ln w_H}{\partial \ln w_L}$, which implies that the high-skilled employment response has the same sign as the high-skilled wage response to the minimum wage shock.

Further using the result on high-skilled wages in the cut-off condition provides $\frac{\partial \ln \phi^*}{\partial \ln w_{min}} = \frac{\partial \ln w_H}{\partial \ln w_{min}}$, which implies that the cut-off ability's response also has the same sign. □

A.2 Additional Institutional Background and Data

Industry Coding

Figure 5 plots the real minimum wage level as well as the date of introduction. The minimum wage levels vary between East and West Germany, captured by the point and triangle markers respectively.

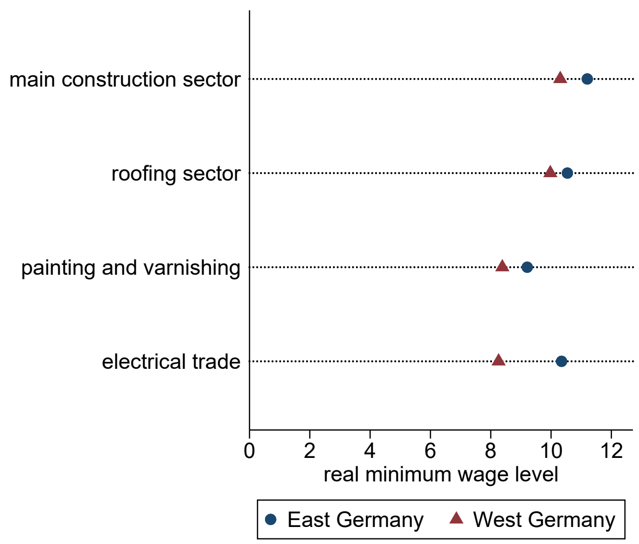
Table 7: Industry classification 1973 Codes for the Minimum Wage Industries

	WZ 73	description
Main construction	590	General civil engineering activities
	593	Construction of chimneys and furnaces
	594	Plasterers and foundry dressing shops
	600	Carpentry and timber construction
	614	Floor tilers and paviours
Roofing	601	Roof covering
Electrical trade	611	Electric installations
Painting and varnishing	613	Paint shops and wall tilers

Table 8: Industries in the Crafts Donor Pool

WZ 73	description
130	Manufacture of rubber products
132	Vulcanization; repair of rubber products
140	Quarrying, cutting, shaping and finishing of stones
162	Manufacture, roughing and smoothing of glass
200	Drawing and cold-rolling of metals
263	Repair shop for agricultural machinery
271	Manufacture of other equipment related to mechanical engineering
300	Service and maintenance of motor vehicles and bicycles
310	Building and repairing of ships
347	Manufacture of television and radio receivers
348	Manufacture of measuring, checking and testing equipment, television and radio transmitters and apparatus for line telephony and line telegraphy
410	Manufacture of builders' carpentry and joinery
412	Cabinet making
545	Bread and pastry shops
562	Butcher's shops (including horse butchery)
610	Plumbing and piping
612	Glazing
615	Stove and furnace fitting
730	Hairdressing

Figure 5: Industry Specific Real Minimum Wages



Notes: Own illustration based on data from German Federal Statistical Office (Destatis). The numbers of workers refer to all workers subject to social security contributions and are taken from the Confederation of German Trade Unions(DGB).

German Microcensus Data

For the computation of hourly wages, we impute hours worked information from the German Microcensus to the SIAB data. The Microcensus is an annual survey of one percent of all households in Germany, conducted since 1957. A total of about 370,000 households with 810,000 persons take part in the survey. Among others, the data includes information on the employment status, occupation, industry, education and, most important, weekly hours worked. Unfortunately, the data does not include wages. To impute the hours worked information, we use the micro data of the survey waves 1997-2010, focus on working individuals between 19-65 and identify our minimum wage industries using the 3-digit industry coding (WZ 08): roofing (439), electrical trade (432), main construction (412, 421,422, 429, 431) and painting and varnishing (433). Note that the 3-digit WZ 08 industry coding does not allow a perfect matching to 3-digit WZ 73, which creates some bias. We then calculate the average weekly hours worked in each of the 5376 cells that are spanned by the following variables shown in Table 9. The large set of variables thereby ensures that we capture the major part of the variation in hours worked. Note that we ensure that we have about 30-50 observations in each cell. We then transfer these cell-specific hours information to the SIAB data based on the exact same cells. Put differently, for each individual in the SIAB data, we assume the cell-specific weekly hours worked calculated in the Microcensus. Together with the wage information in the SIAB data, we then calculate hourly wages for each worker.

Table 9: Variables for Imputation of Weekly Working Hours

Variable	Categories	No of categories
Industry	roofing	4
	electrical trade	
	roofing	
	painting and varnishing	
Year	1997-2010	14
Region	East Germany	2
	West Germany	
Education	without vocational training (ISCED 2011, 1.2)	3
	with vocational training (ISCED 2011, 3.4)	
	with university degree (ISCED 2011, 5, 6, 7, 8)	
Gender	female	2
	male	
Age	younger workers (between 19-40)	2
	younger workers (between 41-65)	
Employment status	full-time	
	part-time	2
Type of workers	blue-collar worker	2
	white-collar worker	

A.3 Additional Results

Table 10: Change in Solo Self-Employment Share over Time by Industry

	Average share of solo self-employed individuals among the workforce		
	pre-treatment years	post-treatment years	difference
West Germany			
All other industries	3.4	5.1	+1.7
Main construction	3.2	11.3	+8.1
Roofing	1.2	3.7	+2.5
Electrical trade	5.1	9.2	+4.2
Painting and varnishing	4.8	9.6	+4.8
East Germany			
All other industries	2.2	3.9	+1.8
Main construction	1.4	13.4	+12.0
Roofing	0.7	5.2	+4.5
Electrical trade	2.9	7.9	+5.0
Painting and varnishing	3.2	11.9	+8.7

Notes: Numbers are average share of solo self-employed among the workforce. Pre-treatment (post-treatment) years include 1992-1996 (1997-2010) for main construction, roofing, and electrical trade; and 1992-2002 (2003-2010) for painting and varnishing..

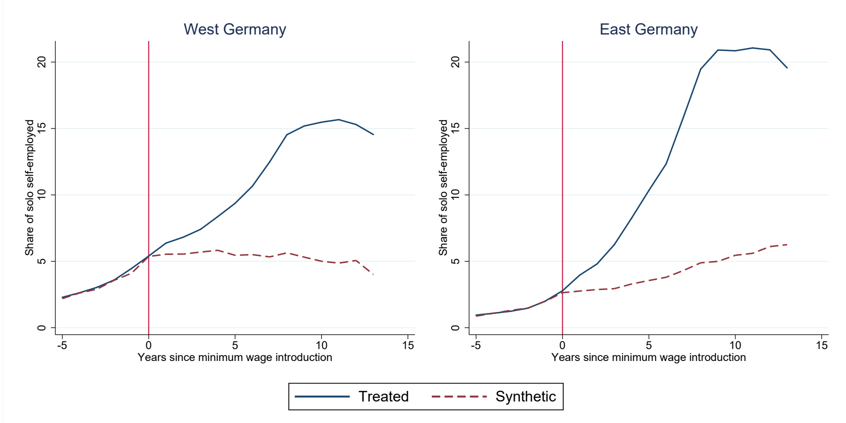
Table 11: Industry Weights in the Synthetic Industries

West Germany			East Germany		
Code	Industry	Weights	Code	Industry	Weights
Synthetic main construction industry					
132	Vulcanization; repair of rubber products	.355	861	Security and storage activities; courier services	.491
731	Services and activities related to cosmetics, manicure and pedicure	.186	97	Manufacture of soap and detergents, cleaning and polishing preparations	.305
529	Manufacture of bed articles, manufacture of other textiles n.e.c.	.16	240	Wagon and lorry building; industrial railway wagon building	.204
525	Manufacture of underwear	.036			
765	Self-employed artists and performers	.02			
410	Manufacture of builders' carpentry and joinery	.015			
Synthetic roofing industry					
132	Vulcanization; repair of rubber products	.317	371	Manufacture of general hardware	.307
529	Manufacture of bed articles, manufacture of other textiles n.e.c.	.193	345	Manufacture of domestic electrical appliances	.216
			220	Locksmithery, welding and grinding	.064
			97	Manufacture of soap and detergents, cleaning and polishing preparations	.036
			865	Labour recruitment and provision of personnel	.026
			120	Processing of plastics	.022
			140	Quarrying, cutting, shaping and finishing of stone	.013
			412	Cabinet making	.012
			790	Solicitor's offices, notary's offices, legal advisory services	.012
Synthetic Electrical trade					
731	Services and activities related to cosmetics, manicure and pedicure	.401	220	Locksmithery, welding and grinding	.381
143	Other mining and quarrying n.e.c.	.092	750	Self-employed teachers, driving schools, zoos	.119
765	Self-employed artists and performers	.031	371	Manufacture of general hardware	.064
525	Manufacture of underwear	.03	865	Labour recruitment and provision of personnel	.044
529	Manufacture of bed articles, manufacture of other textiles n.e.c.	.012	790	Solicitor's offices, notary's offices, legal advisory services	.032
			820	Advertising design and consultancy	.03
			140	Quarrying, cutting, shaping and finishing of stone	.015
			120	Processing of plastics	.012
			410	Manufacture of builders' carpentry and joinery	.011
			851	Renting of moveable objects	.011
Synthetic Painting and varnishing					
410	Manufacture of builders' carpentry and joinery	.249	610	Plumbing and piping	.565
380	Manufacture and repair of musical instruments	.173	865	Labour recruitment and provision of personnel	.285
731	Services and activities related to cosmetics, manicure and pedicure	.161	790	Solicitor's offices, notary's offices, legal advisory services	.103
231	facture of tanks, reservoirs and containers of metal; manufacture of central heating radiators and boilers	.141	410	Manufacture of builders' carpentry and joinery	.047
140	Quarrying, cutting, shaping and finishing of stone	.083			
240	Wagon and lorry building; industrial railway wagon building	.025			
765	Self-employed artists and performers	.012			
529	Manufacture of bed articles, manufacture of other textiles n.e.c.	.011			

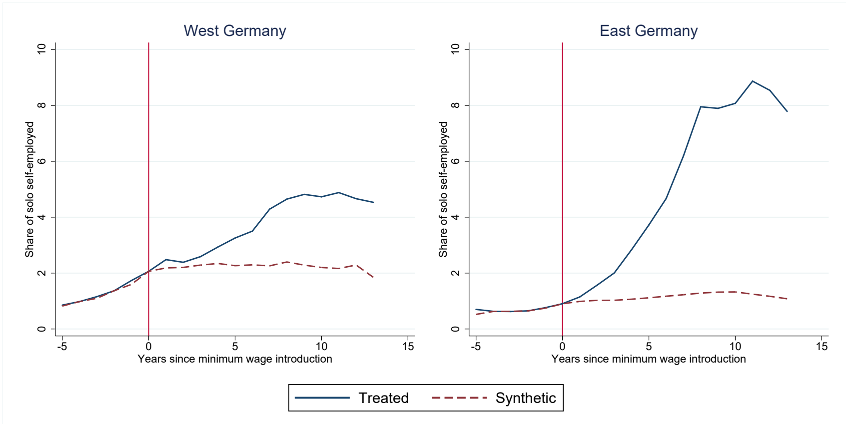
Notes: Only weights larger or equal to 0.01 are displayed.

Figure 6: Solo Self-Employment: Treated vs. Synthetic Industry

(a) Main construction industry



(b) Roofing industry



(c) Electrical trade industry

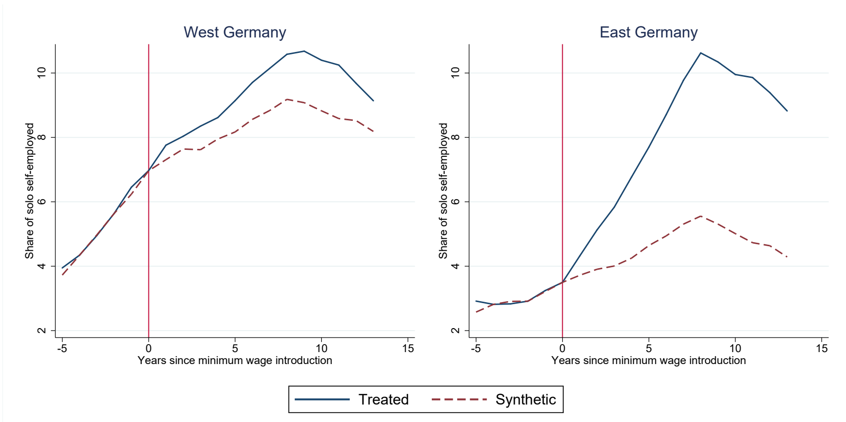
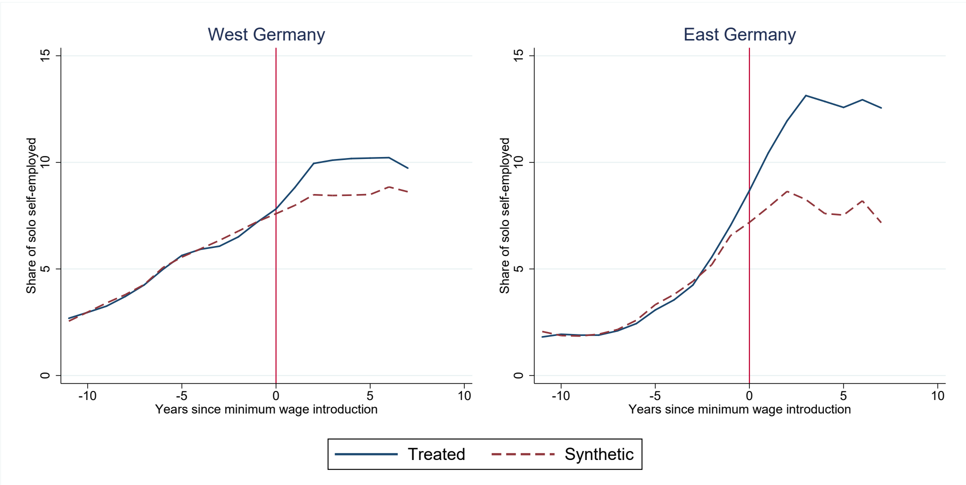


Figure 6: Solo Self-Employment: Treated vs. Synthetic Industry

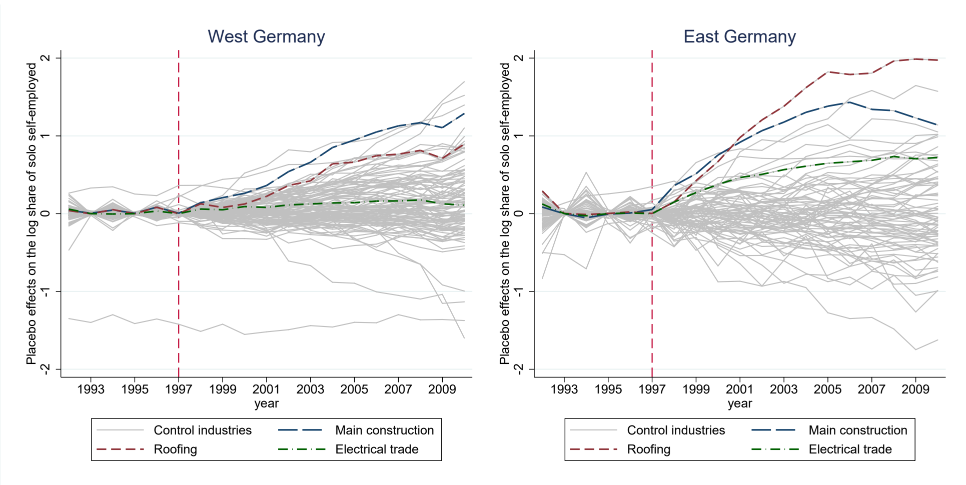
(d) Painting and varnishing



Notes: Figures show the more detailed graphical representation of both the minuend and subtrahend shown in Figure 4.

Figure 7: Solo Self-Employment: Placebo Effects

(a) 1997 minimum wage industries



(b) 2003 minimum wage industry

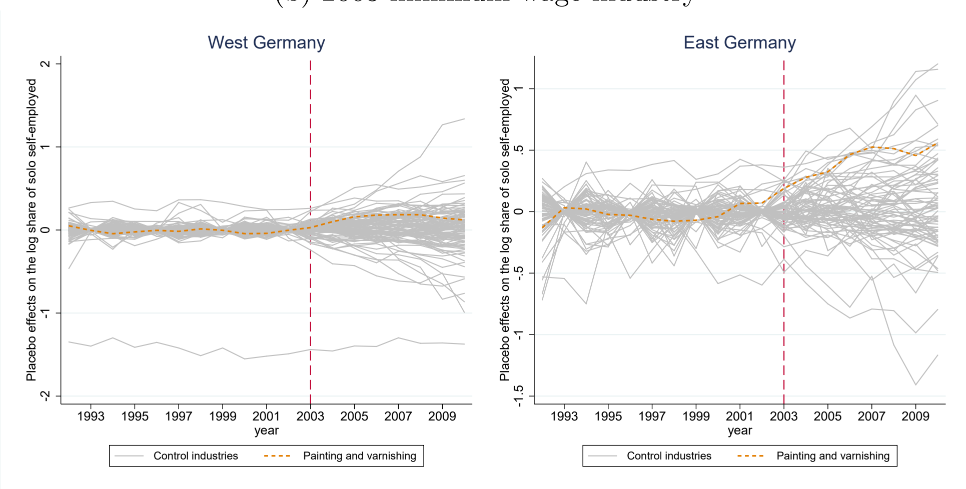
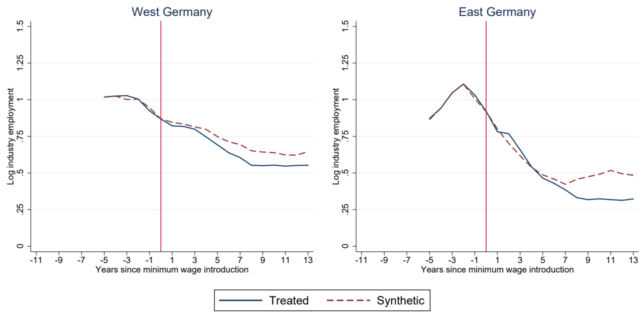
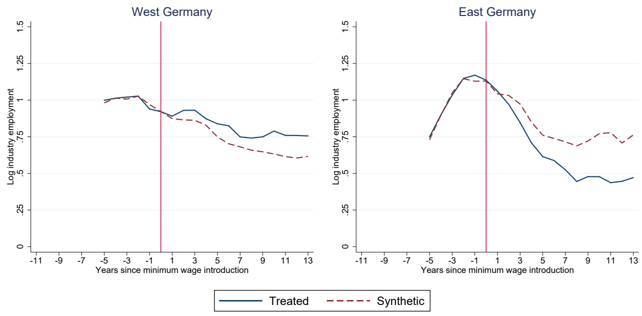


Figure 8: Scale Effect: Treated vs. Synthetic Industry

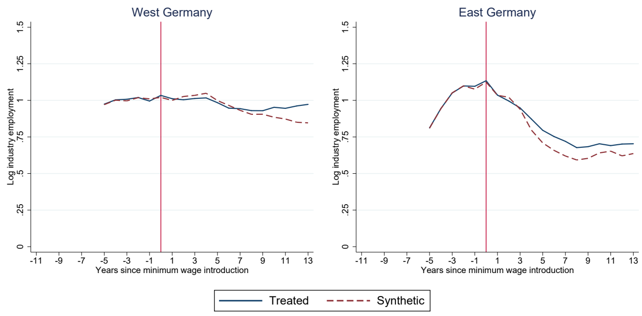
(a) Main construction industry



(b) Roofing industry



(c) Electrical trade industry



(d) Painting and varnishing

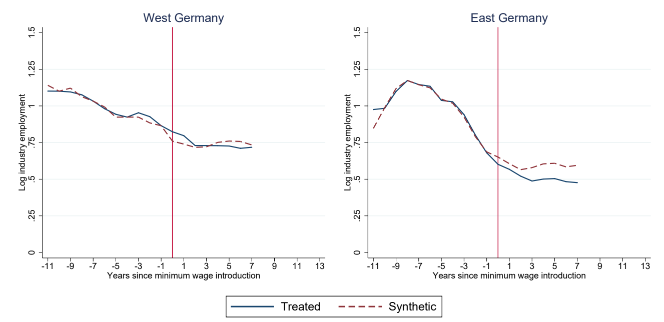
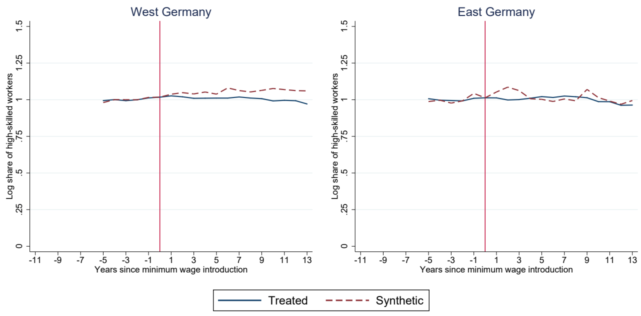
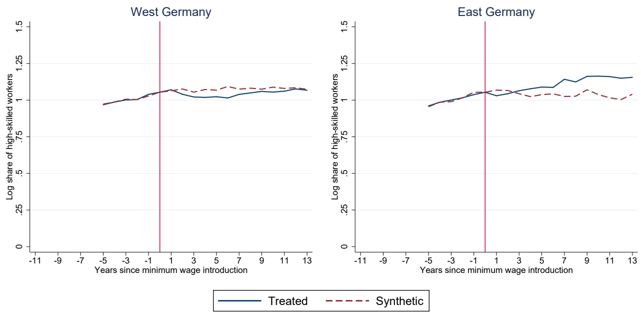


Figure 9: Substitution Effect: Treated vs. Synthetic Industry

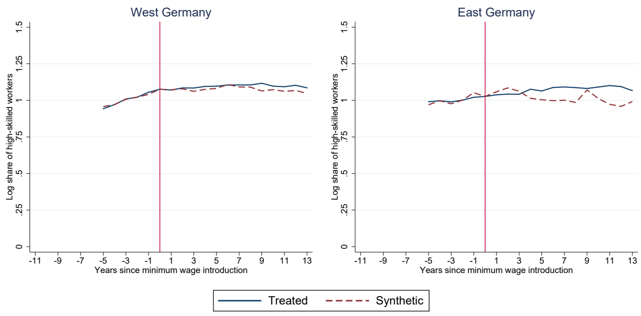
(a) Main construction industry



(b) Roofing industry



(c) Electrical trade industry



(d) Painting and varnishing

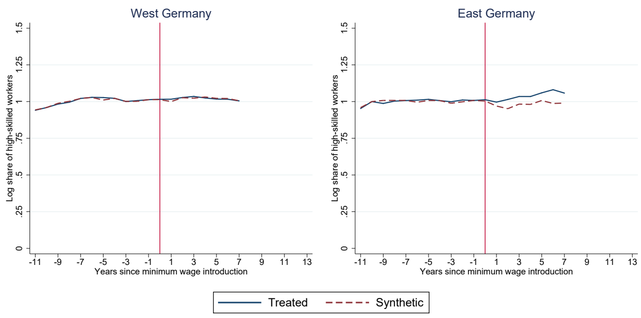
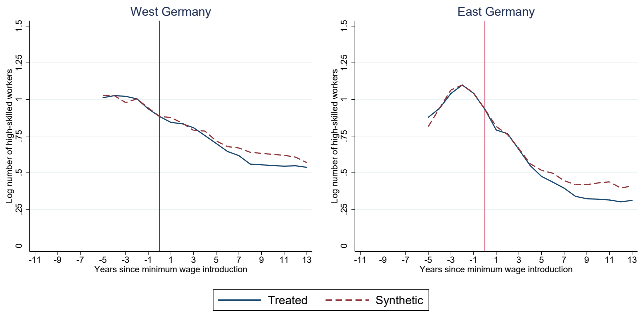
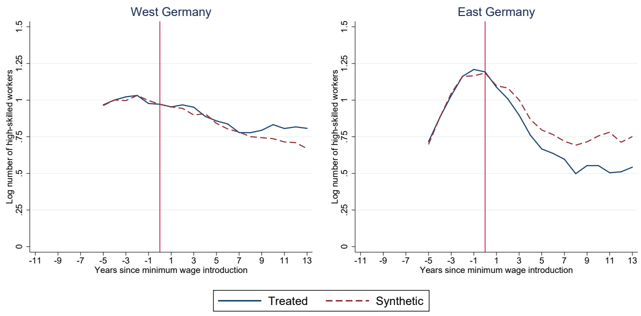


Figure 10: Net Effect: Treated vs. Synthetic Industry

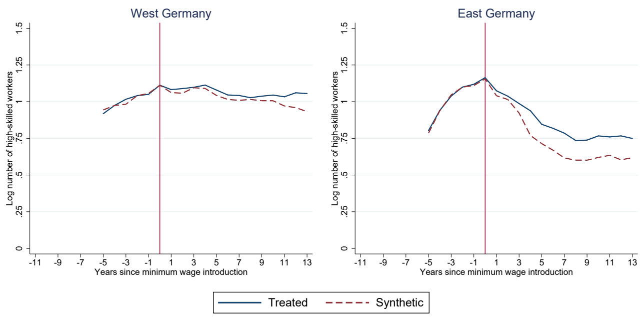
(a) Main construction industry



(b) Roofing industry



(c) Electrical trade industry



(d) Painting and varnishing

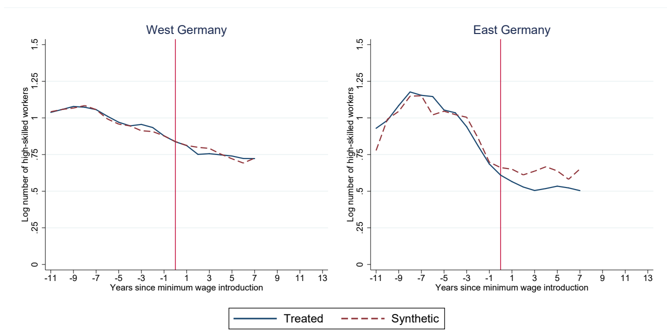
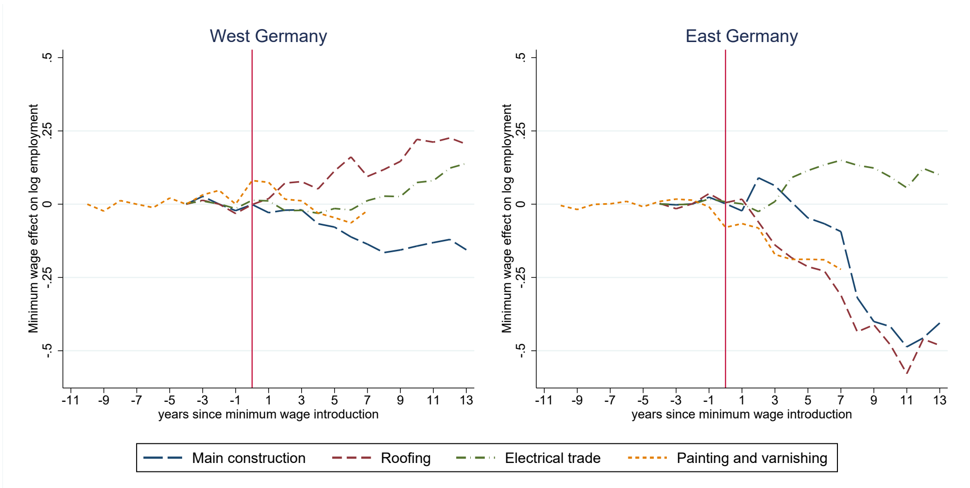
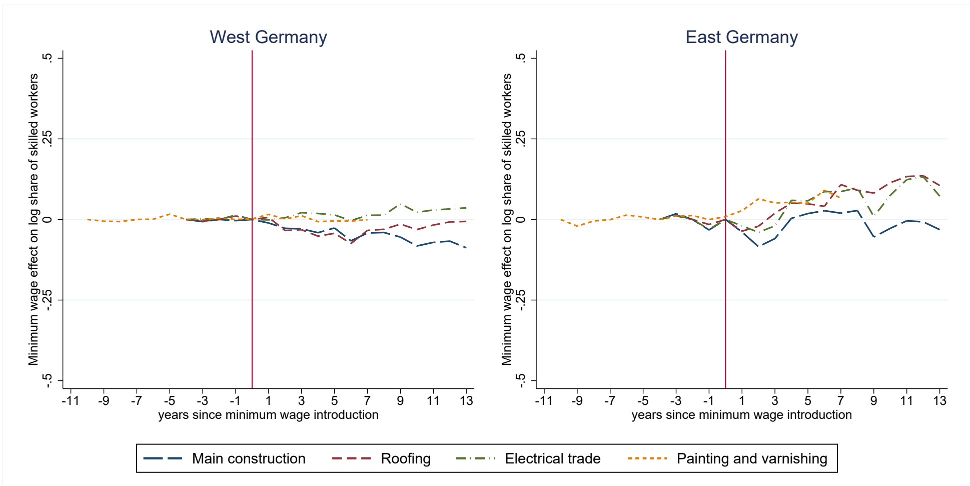


Figure 11: Effect of the Minimum Wage Introduction on (High-Skilled) Employment Over Time

(a) Log industry employment (scale effect)



(b) Log share of high-skilled employment (substitution effect)



(c) Log high-skilled employment (net effect)

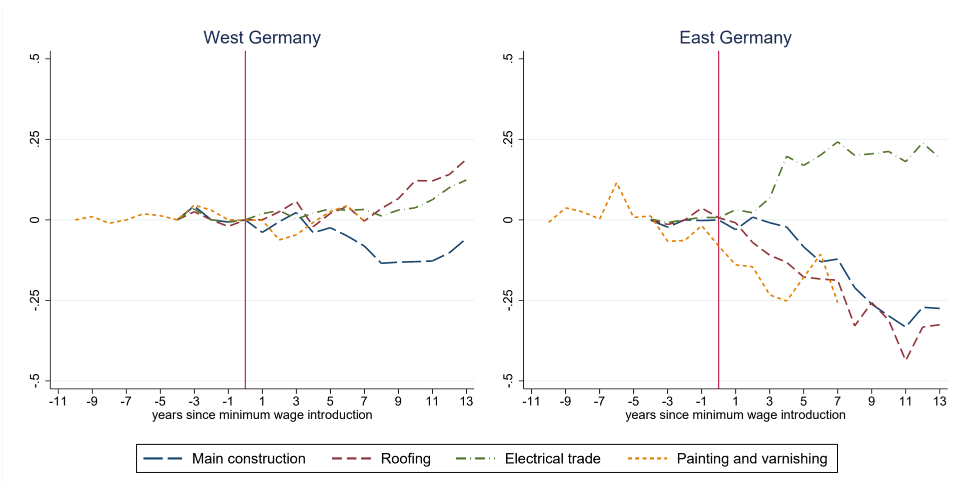


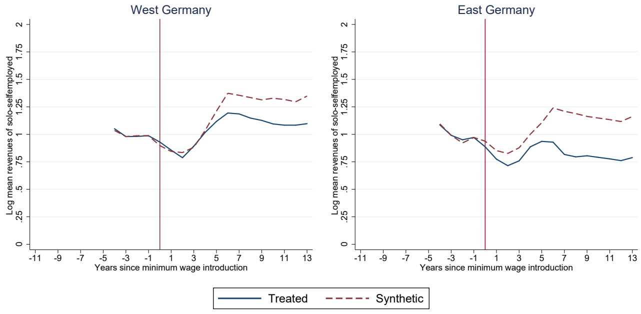
Table 12: Accumulated Effects of the Minimum Wage on Solo Self-Employment at Different Years after Introduction in East and West Germany, Different Specifications

Specification:	(1) Main	(2) No master industries	(3) Additional predictors	(4) Incl. macro predictor
	Donor pool size (MW: 1997/2003)			
East Germany	78/76	76/74	78/76	78/76
Main construction				
t+3	3.311**	3.311**	2.396**	1.845**
	[1]	[1]	[3]	[3]
t+6	8.536**	8.536**	6.793**	5.335*
	[1]	[1]	[2]	[7]
Roofing				
t+3	0.979**	0.980**	0.617**	0.430**
	[1]	[1]	[1]	[1]
t+6	3.493**	3.495**	3.019**	2.412**
	[1]	[1]	[1]	[1]
Electrical trade				
t+3	1.829**	1.811**	1.080**	-0.177**
	[1]	[1]	[1]	[1]
t+6	3.764**	3.720**	2.683**	0.265**
	[1]	[1]	[1]	[1]
Painting and varnishing				
t+3	4.880**	4.897**	4.890**	4.808*
	[3]	[3]	[3]	[5]
t+6	4.744*	4.760*	4.749*	4.668*
	[4]	[4]	[4]	[7]
	Donor pool size			
West Germany	110/108	107/105	110/108	110/108
Main construction				
t+3	1.711	1.684	0.984**	2.267**
	[17]	[15]	[3]	[3]
t+6	5.154*	5.121**	3.240**	5.927**
	[9]	[5]	[2]	[2]
Roofing				
t+3	0.303***	0.304***	0.338***	0.676***
	[1]	[1]	[1]	[1]
t+6	1.206***	1.203***	1.236***	1.772***
	[1]	[1]	[1]	[1]
Electrical trade				
t+3	0.732***	0.714***	0.579***	0.770***
	[1]	[1]	[1]	[1]
t+6	1.145***	1.115***	0.755***	1.233***
	[1]	[1]	[1]	[1]
Painting and varnishing				
t+3	1.657*	1.791*	1.391**	1.599
	[7]	[8]	[5]	[14]
t+6	1.374	1.478	1.642*	1.367
	[21]	[21]	[9]	[26]

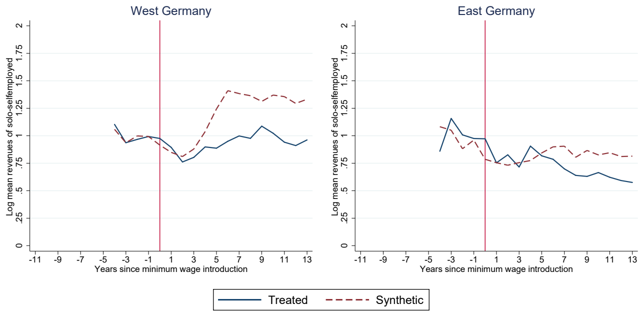
Note: p-values indicated by ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$; rank statistics in square brackets; Respective donor pool size indicated above each column.

Figure 12: Revenues of Solo Self-Employed: Treated vs. Synthetic Industry

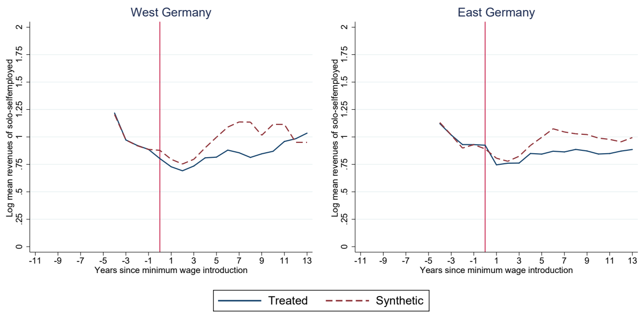
(a) Main construction industry



(b) Roofing industry



(c) Electrical trade industry



(d) Painting and varnishing

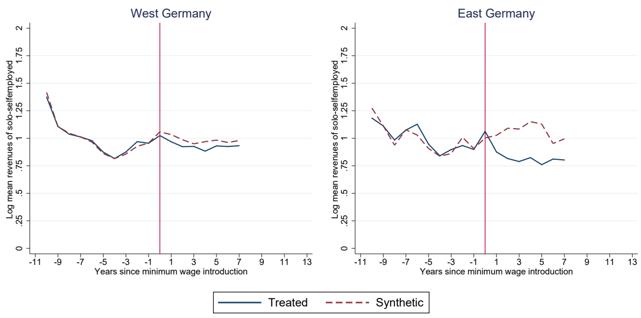
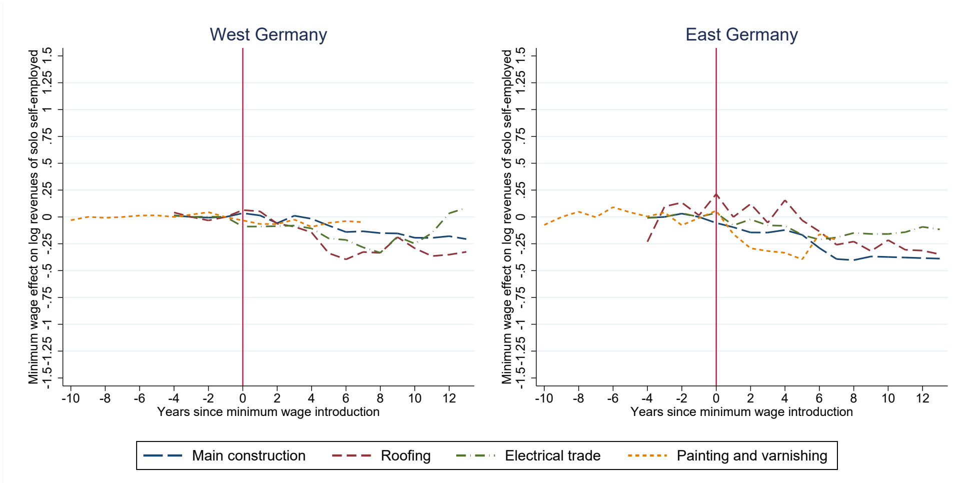
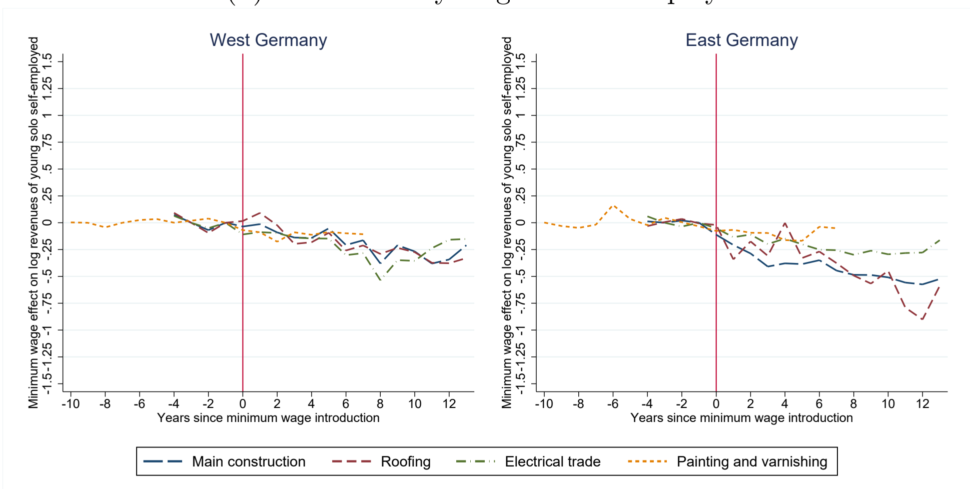


Figure 13: Effects of the Minimum Wage Introduction on Revenues of Solo Self-Employment Over Time

(a) Revenues of solo self-employed



(b) Revenues of young solo self-employed



A.4 Detailed Results for Dependent Employment

Table 13 shows the results of the Synthetic Control Group approach for dependent employment three and six years after the minimum wage introduction. The raw developments of overall employment, the share of high-skilled workers, and employment of high-skilled workers in our treated and synthetic control industries can be found in Appendix Figures 8, 9, and 10. Six years after the reform, the results mostly provide evidence in favor of large reductions in overall employment (negative scale effect) that exceed the increase in the share of high-skilled workers (substitution effect), resulting in overall negative net employment effects on skilled workers (net effect). However, the effects are quite heterogeneous: First, they appear to unfold only over longer time periods and are less visible in the first three years after the reform. Second, they are larger in the East than the West, as expected given the larger bite in the former compared to

Table 13: Accumulated Effects of the Minimum Wage Introduction on (High-Skilled) Employment

Dependent variable:	Log industry employment (scale effect) in %		Log share of high-skilled workers (substitution effect) in pp.		Log number of high-skilled workers (net effect) in %	
Accumulated effect after years:	t+3 (1)	t+6 (2)	t+3 (3)	t+6 (4)	t+3 (5)	t+6 (6)
East Germany						
Main construction	0.063*	-0.067	-0.059	0.027	-0.009	-0.130
	[8]	[20]	[31]	[50]	[79]	[59]
Roofing	-0.139**	-0.228**	0.020**	0.041**	-0.110**	-0.184**
	[1]	[1]	[1]	[1]	[1]	[1]
Electrical trade	0.009**	0.134**	-0.020**	0.086**	0.068**	0.201**
	[1]	[1]	[1]	[1]	[1]	[1]
Painting and varnishing	-0.171	-0.190	0.051**	0.091**	-0.233	-0.107
	[19]	[19]	[4]	[3]	[21]	[39]
West Germany						
Main construction	-0.019	-0.112	-0.029	-0.066	0.023	-0.050
	[88]	[64]	[32]	[26]	[74]	[84]
Roofing	0.077***	0.161***	-0.032***	-0.075***	0.057***	0.042***
	[1]	[1]	[1]	[1]	[1]	[1]
Electrical trade	-0.021***	-0.020***	0.021***	-0.004***	0.003***	0.030***
	[1]	[1]	[1]	[1]	[1]	[1]
Painting and varnishing	0.012	-0.064	0.012	-0.005	-0.047	0.044
	[65]	[98]	[46]	[86]	[40]	[71]

Note: p-values indicated by ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$; rank statistics in square brackets.

the latter.

Not all effects are significant throughout, particularly for the main construction industry. The latter can be explained by the fact that this industry is larger than our other industries on the donor pool, so that the placebo tests for these industries – which are used to construct the inference statistic – are more sensitive to the treated industry, which makes it harder to identify significant effects.

One major exception is the electrical trade industry. This industry follows a different business cycle to other industries of the same 1-digit sector already before the introduction of the minimum wage. In particular, it is less affected by the overall crisis. This implies that matching the industry to other industries that did experience a downturn results in an upward bias of the results for levels of (high-skilled) employment, while resulting in an downward bias for the share of high-skilled workers. Indeed, when not controlling for the 1-digit post-treatment to pre-treatment outcome ratio in the synthetic control group approach, results are more in line with the other industries.

Table 14: Accumulated Effects of the Minimum Wage Introduction on Revenues of Solo Self-Employed

Dependent variable:	Log mean revenues of solo self-employed		Log mean revenues of young solo self-employed	
	t+3	t+6	t+3	t+6
	(1)	(2)	(3)	(4)
East Germany				
Main construction	-0.145	-0.289	-0.408	-0.349
	[4]	[10]	[7]	[7]
Roofing	-0.054**	-0.135**	-0.308**	-0.268**
	[1]	[1]	[1]	[1]
Electrical trade	-0.078**	-0.211**	-0.199**	-0.251**
	[1]	[1]	[1]	[1]
Painting and varnishing	-0.318*	-0.161	-0.096	-0.037
	[2]	[5]	[18]	[21]
West Germany				
Main construction	0.011	-0.140	-0.138	-0.208
	[28]	[26]	[30]	[29]
Roofing	-0.090**	-0.396**	-0.197**	-0.259**
	[1]	[1]	[1]	[1]
Electrical trade	-0.080**	-0.214**	-0.139**	-0.302**
	[1]	[1]	[1]	[1]
Painting and varnishing	-0.025	-0.039	-0.089	-0.098
	[11]	[12]	[6]	[9]

Note: p-values indicated by ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$; rank statistics in square brackets.

Results hence differ across industries, regions and time, as does the size of the minimum wage. We therefore test whether the intensity of the treatment can explain the heterogeneity of the treatment effects in our main paper in Section 7.1.

A.5 Detailed results for Revenues of Solo Self-Employed

Table 14 shows the results of the Synthetic Control Group approach for log mean revenues of solo self-employed individuals (Columns 1-2) as well as the log mean revenues of new entries to solo self-employment, which are defined as solo self-employed individuals who started their business within the last three years (Columns 3-4).[25]

Table 14 shows that the minimum wage reduced average revenues of solo self-employed individuals. The effects unfold over time and are larger six relative to 3 years after the reform. The effects are larger in the East, where the bite was larger. Moreover, effects are larger in the main construction and roofing industries, which are also those industries that implemented higher minimum wages. The results hold similarly for young solo self-employed, suggesting that the

[25]Note that we choose the three year moving average instead of looking at new cohorts on a yearly basis due to sample size. On average across our four minimum wage industries, 1,139 solo self-employed workers enter the sample per year with non-missing revenues, yet some yearly entrant cohorts consist of only 34 solo self-employed.

earnings of new solo self-employed have deteriorated over time in reaction to the minimum wage introduction. The latter is in line with our model's expectations according to which a worsening selection among all dependent high-skilled workers become solo self-employed.