Working Paper No. 234

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December 2024

The Swiss Leading House on Economics of Education, Firm Behavior and Training Policies is a Research Program of the Swiss State Secretariat for Education, Research, and Innovation (SERI).

www.economics-of-education.ch

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December 13, 2024

Abstract

To increase the attractiveness of vocational education and training and secure a sufficient supply of skilled labor, the German government introduced a statutory minimum wage for apprenticeship contracts. As of January 1, 2020, apprentices starting an apprenticeship that year became entitled to an annually increasing minimum wage. Merging apprenticeship posting data from the Federal Employment Agency with administrative data on apprenticeship contracts, we investigate the causal effect of this minimum wage legislation on labor demand. Exploiting regional and occupational variation in the share of apprenticeships paid at the minimum wage level, we estimate a standard difference-in-differences, a triple difference, and a synthetic difference-in-differences model. Our estimates suggest that the introduction of the minimum wage had no significant effect on the overall number of apprenticeship postings in low-wage occupations in districts with a high prevalence of minimum wage contracts. However, when examining the minimum wage effect in selected low-wage occupations separately, we find substantial differences with no observable impact on health and wellness apprenticeships but a substantial reduction in apprenticeship postings in various low-wage production and manufacturing occupations.

JEL-Code: J23, J3, M53

Keywords: minimum wage, apprenticeship market, labor demand, difference-in-differences, triple difference, synthetic difference-in-differences

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1 Introduction

Statutory minimum wages are a common means for policy makers to ensure that workers receive fair compensation, thereby addressing social justice concerns and encouraging workforce engagement. The German government introduced a statutory minimum wage for apprentices in 2020, recognizing that apprentices contribute to the value creation of firms and deserve appropriate remuneration. The goal of this measure was to increase the attractiveness of apprenticeships and to secure a sufficient supply of skilled labor in the long run (see Bundesministerium für Bildung und Forschung [2023]).

While the objectives of minimum wages are primarily focused on the well-being and engagement of workers, most controversies concern the demand side, i.e., the reaction of firms to this policy. In the debate about the apprenticeship minimum wage in Germany, not only employers' associations such as the German Confederation of Skilled Crafts (ZDH) but also the Institute of Labor Economics (IZA) warned that firms, especially small- and medium-sized ones, might reduce their commitment to training and offer fewer apprenticeship positions in response to a statutory minimum wage (see Roßbach [18.02.2018], Zeitung [03.04.2018]).

Evidence on the demand-side effect of minimum wage introductions, however, is scarce, as most empirical studies in the minimum wage literature examine the impact of minimum wages on employment, that is, on the equilibrium of labor supply and demand. The results of these studies are inconclusive with several studies suggesting that moderate minimum wages do not have a strong effect on employment (see, e.g. Dube [2019] for a meta-analysis). Yet, these analyses do not uncover the underlying mechanisms. Do the moderate effects on employment stem from modest reactions on both demand and supply side? Or is a stronger reaction on one side offset by the response of the other, and in what direction does the effect manifest on each side?

Our study provides insights into firm-side reactions to minimum wages by isolating the effect of the apprenticeship minimum wage on apprenticeship postings – an indicator of firms' investments in training and labor demand – contributing to an area of the minimum wage literature for which there is still little empirical evidence. Beyond advancing research on the impact of minimum wages on labor demand, our study enhances the understanding of how minimum wage policies influence firms' commitment to skill development, with important implications for policy makers seeking to balance fair wage policies with a stable supply of skilled labor. By estimating occupation-specific effects, we further determine the degree of sensitivity to minimum wage policies in different trades.

We merge apprenticeship posting data from the Federal Employment Agency (BA) with administrative data on apprenticeship contracts in order to estimate the effect of the apprenticeship minimum wage on registered apprenticeship positions in occupations with low apprenticeship wages. Using standard difference-in-differences (DiD), a triple difference and a synthetic DiD model (SDiD), we estimate the minimum wage effect by exploiting regional differences in the proportion of apprenticeships paid according to the minimum wage.

Estimates of the effect of the minimum wage on the number of apprenticeships in the low-wage sector as a whole show no significant minimum wage effect in districts with a high prevalence of minimum wage contracts. The analysis of four selected occupation groups, however, reveals considerable differences in the effect of the minimum wage across occupations. While there is no evidence of an impact on apprenticeships in health and wellness, all estimation approaches consistently show pronounced effects of the minimum wage introduction on apprenticeship postings in the considered production and manufacturing occupations with low apprenticeship wages.

To explore possible reasons for the observed differences in firms' reactions to the minimum wage (or lack thereof), we set the estimates of the minimum wage effect in each of the considered occupation groups in the context of labor shortages and cost and benefit estimates for apprenticeships in these occupations (Wenzelmann and Schönfeld [2022]).

The paper proceeds as follows. Section 2 provides some background on the institutional setting of the German apprenticeship system and the apprenticeship minimum wage in Germany. In Section 3, we review the current state of literature on minimum wages with a particular focus on empirical studies on demand-side effect and effects on training. The following section, Section 4, describes the data examined in this study. Section 5 outlines the identification strategy underlying this paper and discusses the assumptions necessary to identify the impact of the apprenticeship minimum wage. The subsequent section (Section 6) summarizes the results and Section 7 concludes.

2 Institutional Setup

2.1 The German Apprenticeship System

In Germany, apprenticeships are organized in a publicly regulated dual system, typically involving three to four years of structured on-the-job training in firms, complemented with lessons at vocational schools which provide the necessary theoretical knowledge and broaden the general knowledge of apprentices. The decision whether and how many apprenticeship positions to offer and which occupations to train is up to the firms. They must, however, follow the training regulations for the corresponding occupation, which specify, among other things, the skill set and content taught. In 2023, there were 327 officially recognized vocational training occupations in Germany (Bundesinstitut für Berufsbildung [2023]). To establish an apprenticeship relationship, firms advertise apprenticeship positions, potential apprentices apply, and then a bilateral apprenticeship contract is concluded between the selected candidate and the firm specifying various details including hours and the apprentice's remuneration.

The apprenticeship system is a key cornerstone of the German education system and serves as an important source of qualified employees for firms. Each year around 500,000 new apprentices start an apprenticeship in one of approximately 420,000 firms (which makes up around

19 % of all firms with employees covered by social insurance in Germany, Bundesinstitut für Berufsbildung [2023]). Approximately 72 % of the apprentices who successfully complete their training are hired by the firm immediately afterward, underscoring the importance of vocational training for firms to develop a skilled workforce (Bundesinstitut für Berufsbildung [2022]). A key strength of the German system is the close collaboration between firms and vocational schools. Firms play an active role in shaping the curriculum, providing hands-on training and mentoring apprentices. This partnership ensures that the skills taught align closely with industry requirements, making graduates highly employable.

2.2 The introduction of the minimum wage for apprentices

Apprentices are remunerated by the training firms as agreed in their apprenticeship contract. Until 2020, there was no statutory minimum wage for apprenticeships in Germany. However, in several occupations, the general, non-apprenticeship-specific collective agreements also contained collectively agreed wages for apprentices. Yet, these were only binding for the respective profession and those firms covered by a collective bargaining agreement; only in rare occasions were the collective wages set as generally binding on state level for all apprenticeships in an occupation. While this system of collective bargaining agreements remains in place, a statutory minimum wage was introduced in 2020, which only comes into effect if no collective agreement applies to the respective apprenticeship position (this is regardless of whether the collective bargaining wage is above or below the minimum wage – however, a collective agreement wage below the minimum wage can only be observed in some 1.6 % of training contracts concluded in 2020).

The statutory minimum wage came into effect on January 1 2020. Apprentices starting an apprenticeship in that same year had to be paid at least 515 € in their first year of training. This amount increased to 550 € in 2021, 585 € in 2022, and 620 € in 2023. Moreover, the minimum wage increases with each year of training: by 18 % in the second year of training, 35 % in the third year, and 40 % in the fourth year (where applicable). The reform was expected to affect about 10 - 15 % of all training firms (see Wenzelmann and Pfeifer [2018]), with the proportion being significantly higher in East Germany and among small and medium-sized enterprises (see Dietrich [2019]).

3 Related Literature

For decades, the effect of minimum wages on employment has received a considerable amount of attention. According to neoclassical economic theory, a minimum wage increase leads to a decrease in employment as higher labor costs make it more expensive for firms to hire and employ workers. However, contradicting neoclassical theory, Card and Krueger [1994] found that employment in New Jersey actually grew after New Jersey's minimum wage rose, suggesting that the relationship between minimum wages and employment may be ambiguous. A quarter century later, a meta-analysis by Dube [2019] of over 200 minimum wage studies revealed an average employment effect close to zero, with some studies indicating a slightly positive and others a slightly negative effect.

Dynamic monopsony models (Manning [2003]) offer a theoretical explanation for these ambiguous findings. If firms have some wage-setting power due to e.g. imperfect information or extensive labor market segmentation, they may set wages below the productivity of an employee. Minimum wages can then lead to rising, falling or unchanged labor demand, depending on how the minimum wage and the productivity of minimum-wage workers relate to each other (see e.g. Ashenfelter et al. [2010]; Loertscher and Muir [2023]). Another possible adjustment mechanism to minimum wage policies involves changes in the provision of firm-financed training. In perfectly competitive labor markets, minimum wages can reduce firm-financed general training as firms not investing in training might attract workers away from training-oriented firms. Conversely, in monopsonistic labor markets, firms might increase their investment in training as minimum wages compress a firm's wage structure, incentivizing enhanced training to maximize value added per worker (see Acemoglu and Pischke [1999]; Acemoglu and Pischke [2003]) (For a comprehensive overview on how firms may adjust to minimum wage increases, see Schmitt et al. [2013] and Clemens et al. [2021].) On the labor supply side, minimum wages can increase search efforts of unemployed workers, improving the quality of matches between workers and firms and thereby offsetting potential negative demand effects (see e.g. van den Berg and Ridder [1998]; Flinn [2006]; Ahn et al. [2011]).

To empirically assess the adjustment mechanisms induced by minimum wage introductions and increases, it is crucial to separately investigate the minimum wage effect on labor supply and demand as well as on firms' investment in training. Empirical evidence for such supply- or demand-side effects, however, is scarce, and relates, if at all, mainly to the U.S. labor market. For the labor supply side, Adams et al. [2022] and Piqueras [2023] find a significant effect of minimum wage increases on job search effort and intensity among individuals looking for work.

Regarding the minimum wage effect on firms' investment in training, empirical findings are mixed: While some studies find a negative effect of minimum wages on firm-financed training (Min [1980]; Hashimoto [1982]; Grossberg and Sicilian [1999]; Neumark and Wascher [2001]), others find either no effect or even slightly positive effects (Acemoglu and Pischke [2003]; Arulampalam et al. [2004]; Fairris and Pedace [2004]; Cardoso [2019]).

To investigate the effect of minimum wage policies on labor demand, various studies assess their impact on job vacancies, an approach we also employ in this study. Dube et al. [2016] find a significant negative effect of minimum wage increases on employment flows, but not on stocks, as both separations and accessions among affected workers decline. Clemens [2021] show that following minimum wage hikes firms increase their requirements for applicants and substitute lower-skilled labor with higher-skilled labor. The paper by Kudlyak et al. [2022] is closely related to our study in terms of data and identification strategy. Utilizing county- and occupation-level vacancy data, they apply a triple-difference approach comparing the change in job vacancies in occupations with a high proportion of employees near the minimum wage after a minimum wage increase with the change in higher-paying occupations in the same states and with the development of vacancies in the same low-wage occupations at national level over the same period. They find that a 10 % increase in the minimum wage is associated with a 2.4 % decrease in vacancies for low-wage occupations in the quarter of the minimum wage introduction, with the effect of the minimum wage increase also being significantly negative some quarters before and after the introduction. This adverse impact is particularly pronounced in occupations characterized by low levels of educational attainment (typically high school or less) and in counties with elevated poverty rates.

The estimation of the minimum wage effect on apprenticeship postings captures both the effect of the minimum wage on firms' willingness to invest in training and their labor demand. The effect of the minimum wage on the apprenticeship market is still under-researched, which is likely due to the fact that in many countries vocational training is provided in secondary education institutions, while in Germany, among other countries, apprentices are employed in firms and trained on the job (see Section 2.1). In one of the few existing studies, Papps [2020] exploits the UK's age-specific minimum wage rates for apprentices in a regression discontinuity design, finding that the minimum wage increase at the age cutoff significantly reduces training for the affected workers in firms that pay the minimum wage. For the German apprenticeship market, Schumann [2017] reveals that the introduction of a minimum wage in the construction sector in the late 1990's, while only mandatory for regular workers and not for apprentices, decreased both a firm's likelihood to train new apprentices and the overall number of new apprentices. Similarly, Linckh et al. [2023] find that raising the minimum wage for under-age apprentices had a negative effect on their employment, which increases with the size of the minimum wage hike. The negative effect on employment is particularly pronounced for low-qualified apprentices as well as in sectors in which firms adopt a training strategy driven by substitution rather than investment incentives.

Like Linckh et al. [2023] and Kudlyak et al. [2022], several other studies not only assess the overall labor market effect of minimum wages but also effect heterogeneity. There are studies that examine effect heterogeneity of minimum wages on employment in terms of employee characteristics (e.g. Luna-Alpizar [2019]) and job attributes like the required skill level and the degree of routineness and automatability (e.g. Lordan and Neumark [2018]; Aaronson and Phelan [2019]). Several studies, such as the present one, investigate effect heterogeneity by occupations or industries (e.g. Bachmann and Frings [2017]; Bujanda [2020]).

4 Data

For the subsequent analysis, we merge data on registered apprenticeship postings per district and job provided by the Federal Employment Agency (Bundesagentur für Arbeit, BA) with annual register data on apprenticeship contracts (Berufsbildungsstatistik der Statistischen Ämter des Bundes und der Länder, BBS) based on which we identify the share of newly commenced contracts that agree on remuneration at the minimum wage level.

The BBS data contains information on all apprenticeships that were started, ongoing, successfully completed or prematurely terminated in Germany each year. This data is reported by the training firms to the regional chambers, collected by the Federal Office of Statistics and processed by the Federal Institute for Vocational Education and Training (Bundesinstitut für Berufsbildung, BIBB). Since all firms are required to report the requested details for each apprentice they contract, the dataset has the character of administrative register data. In addition to contract specifics and demographic characteristics of the apprentices, the dataset also contains information on the location of the training firm and the apprentice's training occupation, with occupations classified based on the German Classification of Occupations 2010 (KldB 2010, Bundesagentur für Arbeit [2020]), a classification scheme that groups occupations based on their similarity in terms of tasks, skills and expertise. The hierarchical structure of the KldB 2010 classification scheme groups occupations at different levels of granularity, distinguishing 9, 35, 103 or 261 distinct job types in our dataset depending on the hierarchical level selected.[1] Furthermore, the BBS data comprises information on the contractually agreed remuneration for apprenticeship contracts signed on or after January 1, 2020. This allows us to identify commencing contracts that set compensation at the level of the minimum wage in effect at the start of the apprenticeship.

We reduce the data to commencing apprenticeships and focus on the contractually agreed wage for the first year of the apprenticeship in the years 2020 to 2023, since the minimum wage in effect in a given year only applies to new contracts. We then aggregate the data by district, year and the second broadest KldB 2010 level, which distinguishes 35 fields of apprenticeship occupations, to obtain a dataset with the share of contracts with minimum wage remuneration in 2020 to 2023 per district and occupation. Next, we narrow the data down to low-wage occupations, defined as those with a nationwide median wage at or below the 25th percentile of all job-specific median wages in 2020 to 2023 (of 750 €).[2] This is

[1] Note that the KldB 2010 is a general, not-apprenticeship-specific, classification scheme. Some of the 327 government-recognized apprenticeship occupations may fall into different KldB 2010 categories depending on the sector in which the firm operates and the specialization it consequently trains its apprentices in. For example, a digital and print media design apprentice may either be assigned to the KldB 2010 category of "occupations in sales" or "occupations in digital and print media design", depending on whether the focus of the training is on consulting and planning or on conception, design and visualization.

[2] The set of low-wage occupations comprises the occupations in agriculture, forestry, and farming, in plastic-making and -processing, and wood-working and -processing, in textile- and leather-making and -processing, in interior construction, in geology, geography and environmental protection, in non-medical healthcare, body care, wellness and medical technology, as well as in product design, artisan craftwork, fine arts and the making of musical instruments.

due to the fact that in many occupations the general remuneration level for apprentices is substantially higher than the minimum wage and a negligible number of apprenticeships in these occupations, if any, were remunerated at less than the minimum wage in 2020 to 2023. To estimate the effect of the minimum wage, we apply different DiD approaches, all of which exploit the regional differences in the share of apprenticeship contracts with minimum wage compensation. For each estimation, we define the treatment group as the 25 % of districts with the highest proportion of low-wage apprenticeships compensated at the minimum wage in 2020-2023. The control group includes the 25 % of observations with the lowest proportion of low-wage apprenticeships compensated at minimum wage. The remaining districts are excluded from the data. In the treatment group, the average share of contracts in low-wage apprenticeships that offer remuneration at the minimum wage level is 31 %, compared to 5.6 % in the control group.

We merge the data identifying treated and untreated districts with data on the number of apprenticeship postings registered with the employment agencies and job centers. This data is collected by the BA and available by year, district and different KldB 2010 levels.[3] The apprenticeship posting counts include all apprenticeship postings reported to the BA for the BA to advertise them and propose suitable candidates. Since firms are not obliged to register their apprenticeships with the BA, the counts do not reflect the actual number of apprenticeship postings. According to the BA, however, some 75 % of all apprenticeship postings are registered, with this share remaining constant during the period under study (BA, personal communication, June 19, 2024).[4], the apprenticeship contracts used to define treatment statuses for a given year generally align with the registered apprenticeship postings from October 1 of the previous year to September 30 of the same year.)

The data is further merged with a set of control variables at district level, namely GDP, gross earnings, number of employed persons and number of firms, provided by the Federal Statistics Office. In order to assess the development of demand for apprentices both before

[3]For data protection reasons, the exact number of apprenticeship postings is not provided if there are only one or two apprenticeship postings in a given occupation and district. Additionally, in some cases, another cell may be concealed if the value of the anonymized cell can be deduced from the posting counts for occupations that fall into the same broader KldB 2010 category, as well as from counts at higher KldB 2010 levels. Consequently, the apprenticeship posting data at the more detailed KldB 2010 levels is largely unusable for our analysis. The data on the KldB 2010 level that distinguishes 35 occupational groups with apprenticeship postings, however, is largely available. In rare cases where all apprenticeship posting counts at more detailed KldB 2010 levels are smaller than three and thus anonymized, the posting counts at this level may also be unavailable. These missing values can be estimated by assigning a value of 1.5 to all lower-level missing values, summing them, and then randomly rounding the total up or down to the nearest integer.

[4]In contrast to the contract data, which is recorded for calendar years (just as the introduction and adjustments of the minimum wage are scheduled at the beginning of calendar years), the reporting period for the BA apprenticeship posting data is October 1 to September 30 of the following year. Since the vast majority of apprenticeships begin in August or September (according to the BA, only 12,100 apprenticeship positions with a scheduled start in 2023 were registered after September 30, 2023, most of which were already filled earlier in 2023 and registered again due to early contract terminations, Bundesagentur für Arbeit [2024]), with a similar number of newly registered positions in previous years. Compared to the 511,799 apprenticeships scheduled to start in 2023 and registered before September 30, 2023, the number of apprenticeship postings registered for the first time after September 30, 2023 is negligible.

and after the introduction of the minimum wage in 2020, we include data from 2016 to 2023, i.e., the last year for which there is data available.

4.1 Descriptive Statistics

Figure 1 illustrates the distribution of contractually agreed-upon wages for the first year of apprenticeship in low-wage occupations, along with the minimum wage in effect during each respective year. The graphs show that, even across low-wage occupations, the majority of contracts stipulate wages higher than the prevailing minimum wage. Most contracts set wages between 600 and 800 € per month for the first year of apprenticeship, with a gradual increase each year. However, there is also a noticeable peak in the distribution around the minimum wage level. Each year, between 6 and 8 % of apprenticeship contracts set a wage equal to, or very close to, the minimum wage. Those apprenticeships with contractual wages equal to the minimum wages, can be considered to be affected by the minimum wage legislation which is why we define the treatment status of regions based on the share of contracts with wages equal to the minimum wage. Contracts that specify wages significantly below the minimum wage are rare, as this can only happen if a collective bargaining agreement is in place that sets a wage below the minimum wage (see Section 2.2).

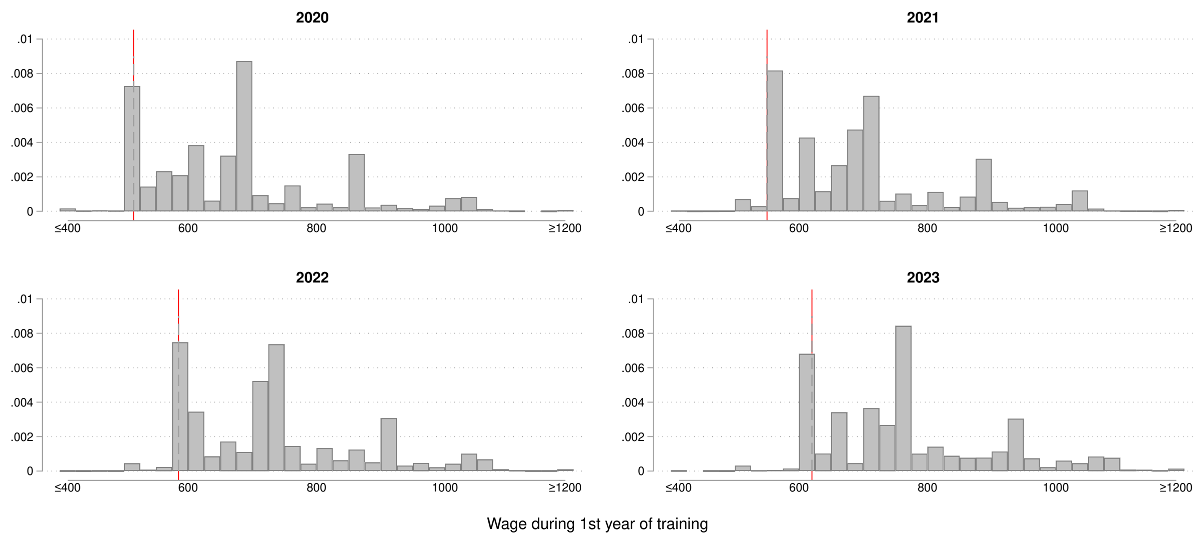

Figure 1: Distribution of contractually agreed-upon wages for the first year of apprenticeship in low-wage occupations in 2020, 2021, 2022 and 2023. The red line indicates the minimum wage in effect in the respective year.

After estimating the impact of the minimum wage effect on the low-wage sector as a whole, we examine four occupational groups in more detail, which are characterized by a particularly high proportion of minimum wage contracts and a substantial number of apprenticeship vacancies in most districts. The wage distribution in these four occupation groups are provided in Appendix A. In Figure A.1, we can observe that for occupations in plastic-making and -processing and wood-working and -processing, the majority of wages clusters around a wage of approximately 700 €, where the high concentration of wages in a single wage bin suggests the existence of a collective bargaining agreement. Additionally, we can observe an increase in minimum-wage contracts in 2021, following a relatively low share of such contracts in the year of the minimum wage introduction.

The wage distributions for apprenticeships in textile- and leather-making (Figure A.2) and those for non-medical healthcare, body care and wellness as well as medical technicians (Figure A.3), show a larger share of contracts with minimum wage compensation. In the latter occupational group, most first-year apprenticeship wages fall between 500 and 800 €, whereas wages in textile- and leather-making are more widely distributed, ranging from 500 to 1,100 €. The distinct peaks in certain wage bins in Figure A.3 suggest the presence of collective bargaining agreements in certain regions and/or occupations in non-medical health- and body-care, wellness and medical technology.

Lastly, the wage distribution for apprenticeships in product design, artisan craftwork, fine arts and the making of musical instruments displays a smaller concentration around the minimum wage compared to the last two occupational groups, with wages ranging between 500 and 1,100 €.

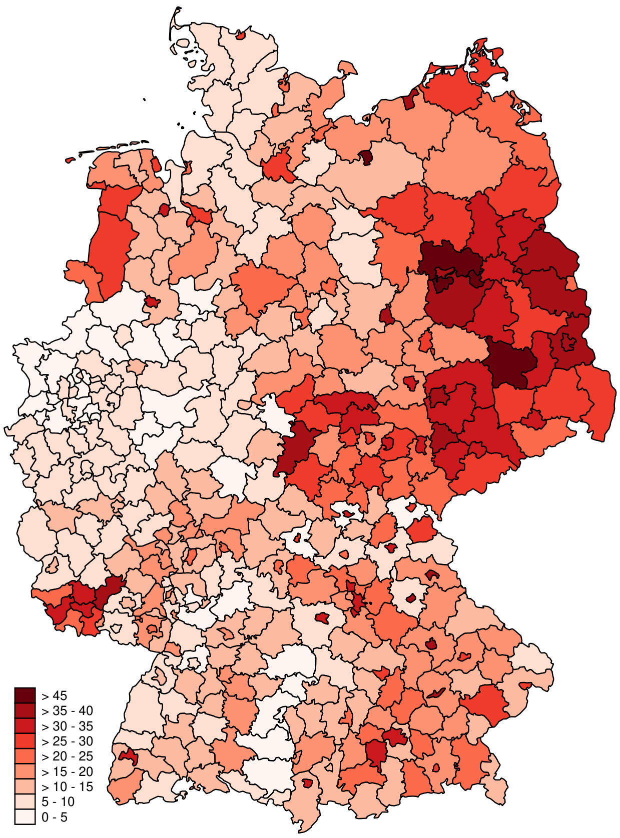

Figure 2: Geographical distribution of the share of minimum-wage contracts in low-wage occupations in Germany in 2020 to 2023.

Figure 2 displays the per-district shares of contracts in low-wage occupations commenced between 2020 and 2023 for which remuneration at minimum wage level was agreed. The figure indicates that the share of minimum-wage contracts is particularly high in East Germany and the Saarland, a small state in the south-west of Germany. In addition, there are some districts in the north-west and in Bavaria, where 25 % or more apprenticeship contracts agree wages at minimum wage level. While the comparably low pay in East Germany and the Saarland can be explained by lower productivity in these regions, the high proportion of minimum-wage contracts in some districts of Bavaria in south-east Germany are rather unexpected, given that Bavaria is one of the states with the highest GDP per capita, the lowest unemployment rate and the highest wages for trained workers. North Rhine-Westphalia in the west, on the other hand, is characterized by low proportions of minimum wage apprenticeship contracts in all districts, despite having several districts that lag behind in terms of productivity and employment. This might partly be due to collective bargaining agreements, as North Rhine-Westphalia has, for example, a generally binding collective agreement for hairdressers which stipulates remuneration above the minimum wage level. In addition, it is also noticeable in the graph that smaller districts, which are mostly urban, tend to have a higher proportion of minimum wage contracts than rural districts.

A look at the development over time (Figure A.5) shows that the proportion of minimum wage contracts is converging nationwide over time. Both the districts with extremely high proportions of contracts at minimum wage level and those with almost 0 % of apprenticeships offering minimum wage remuneration are becoming rarer. In addition, by 2023, the divide between East Germany and the Saarland and the rest of the country in 2023 has largely disappeared.

The four occupation groups under study show very different geographical patterns in the distribution of minimum-wage contracts (see Figure A.6 and A.7 in Appendix A). In Figure A.7, we can observe that for apprenticeships in non-medical healthcare, body care and wellness as well as for medical technicians, the share of minimum wage contracts is consistently high across the country, with only one notable exception: in North Rhine-Westphalia, located in western Germany, the share of minimum-wage contracts is comparably lower. This deviation is likely due to the region's generally binding collective bargaining for hairdressers that mandates a wage above the minimum wage. Apart from that, there are no other pronounced geographical patterns, such as an East-West divide, evident for apprenticeships in non-medical health- and body-care, wellness and medical technology.

The shares of apprenticeships with minimum wage compensation in textile- and leather-making (Figure A.6) as well as product design, artisan craftwork, fine arts and the making of musical instruments (Figure A.7) vary widely between districts. Some districts have no apprenticeships with minimum wage compensation, while in others, the share of such apprenticeships reaches 100%. There are no distinct geographical patterns observable in either group; rather, the maps resemble a patchwork, making these two occupational groups particularly well-suited for analyzing the impact of the minimum wage using DiD.

In plastic-making and -processing and wood-working and -processing (Figure A.6), finally, the districts with high shares of minimum wage contracts are nearly exclusively concentrated in the territory of the former German Democratic Republic.

A look at the geographical distribution of contracts with minimum wage remuneration across these four occupational groups suggests that by analyzing them separately in addition to the full set of low-wage occupations, we not only get insight into effect heterogeneity and specificities of the considered groups. It rather also indirectly serves as a robustness check for potential violations of the parallel trend assumption as in all four estimations, treatment and control group are made up of – partly extremely – different regions.

Finally, we examine the composition of the treatment and control group with respect to the covariates we include in our estimations as well as the share of urban districts and districts in East Germany. Table 1 shows the composition of treatment and control group in the district-level data used to estimate the effect of the minimum wage in low-wage occupations. In the treatment group, the average share of contracts in low-wage apprenticeships that offer remuneration at the minimum wage level is 31 %, compared to 5.6 % in the control group. As expected, the general wage level among trained workers and the GDP per capita are significantly higher in the control group than in the treatment group. There are also statistically significant differences in geographical characteristics: treated districts are more likely to be urban and/or located in East Germany.

While this comparison reveals notable differences between the treatment and control group, the DiD approaches are designed to account for differing treatment and control groups. A look at the development of the characteristics of the treatment and control group can be more revealing – here, we do not find strong deviations in the development of the treatment and control group, at least not in the observable covariates for which we control anyway.

Tables A.1, A.2, A.3 and A.4 in Appendix A compare control and treatment group in the four occupation groups on which we focus in this study.

	Treatment Group			Control Group			Treatment vs.
	'15-'19 Mean	'20-'23 Mean	Diff.	'15-'19 Mean	'20-'23 Mean	Diff.	'Control Group Diff.
Minimum Wage Contracts [%]	.	31		.	5.6		
# Vacancies in Low-Wage S.	126	107	-20	155	134	-21	+28**
Apprentice Median Pay [€]	.	650		.	721		
General Median Pay [€]	2,829	3,168	+340	3,173	3,448	+275	+344***
GDP per capita [€]	39,060	43,454	+4,393	34,427	38,127	3,701	-4,634***
# Businesses, 0 - 10 Employees	9,376	9,011	-366	9,409	9,106	-304	+33
# Businesses, 10 - 50 Employees	1,028	1,197	+169	1,026	1,284	258	-2.6
# Businesses, 50 - 250 Employees	250	282	+31	243	286	42	-7.1
# Businesses, > 250 Employees	45	50	+5.6	44	50	5.6	-0.75
Urban Districts [%]	51	51		24	24		-27***
East German Districts [%]	56	56		0	0		-56***
N	396	396	792	400	400	800	796

Table 1: **Low-wage occupations:** Comparison of covariates in treatment and control group before and after the introduction of the apprenticeship minimum wage. The last column displays the pre-treatment differences between treatment and control groups along with the significance of independent sample t-tests. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

5 Empirical Strategy

We estimate the average treatment effect of the treated (ATT) using the classical DiD framework, the Synthetic DiD (Arkhangelsky et al. [2021]) as well as a triple difference approach (Olden and Møen [2022]). Initially, we assess the effect of the minimum wage introduction on demand for apprentices across all low-wage occupations. Additionally, we separately examine selected occupation groups that collectively represent a substantial portion of apprenticeships across all low-wage occupations: plastic-making and -processing and wood-working and -processing; textile- and leather-making; non-medical healthcare, body care and wellness as well as medical technicians; product design, artisan craftwork, fine arts and the making of musical instruments. In doing so, we may be able to detect potential treatment effect heterogeneity with respect to the occupational sector.

5.1 Discussion of the Underlying Assumptions

All approaches employed in this paper rely on the same three assumptions, i.e. the common trend assumption, the no-anticipation assumption and the stable unit treatment value assumption (SUTVA). To account for potential violations of the common trend assumption due to differences in economic growth across districts that may be linked to distinct developments in demand for apprentices, we include a set of covariates that capture district-level economic trends but are not affected by the apprenticeship minimum wage. These covariates include annual district-level GDP, district-level gross pay in the regular labor market, and the number of employees and firms per district. We test the validity of the common trend assumption in all models by comparing the development of the outcome in the treatment

and control groups between 2016 and 2019 both graphically and through statistical tests.
There are two potential violations of the no-anticipation assumption: First, firms might have brought forward their demand for apprentices, i.e., from 2020 to 2019, in order to avoid the introduction of the minimum wage, or in later years from one year to the year before in order to bypass the annual minimum wage increase. They may have done so in response to the announcement of the introduction of the minimum wage in May 2019, the public debates in advance, or debates in the committees responsible for setting the minimum wage in which unions and employers' associations were involved. However, it is improbable that this led to a significant shift of apprenticeship positions from one year to another since the skills and supervision needs of apprentices in different stages of training vary greatly, making it difficult to substitute apprentices from one year with those from other years. This is reflected, for example, in the cost-benefit survey conducted by the BIBB, in which firms are asked, among other things, about the activities of apprentices in a three-year apprenticeship program: the time spent on activities that are typically assigned to skilled workers increases from 35 days in the first year to 77 days in the third year (+ 120 %); conversely, the time spent on activities suitable for unskilled workers decreases by 39 % from 61 days to 37 days over the same period (Wenzelmann and Schönfeld [2022]).
A more pressing concern regarding the no-anticipation assumption arises from union involvement in setting the minimum wage level. Unions may have used their knowledge of the expected minimum wage level, even before May 2019, to strengthen their position during collective bargaining. This could have influenced wage levels in agreements concluded before the minimum wage came into effect, thereby indirectly affecting the outcome. Although there is no evidence that trade unions actually used their knowledge of the expected minimum wage in collective bargaining prior to its announcement in May 2019, there are some collective agreements that were concluded between the announcement of the minimum wage and before its entry into force in January 2020, in which a wage at minimum wage level was agreed. Among the occupations considered in this study, the only one to establish a collective bargaining wage at the minimum wage level before January 2020 was the hairdressing sector in North Rhine-Westphalia, which did so as early as July 2019. Given that most firms post their apprenticeship positions in the spring, it is unlikely that this agreement significantly influenced firms' decisions about apprenticeship postings in 2019. However, the analysis of apprenticeships in non-medical healthcare, body care, wellness, and medical technicians—including hairdressing—should be interpreted with caution. For the other three occupation groups, no collective bargaining agreements adjusting to the minimum wage were made prior to 2020.
Finally, one part of the SUTVA, namely that there must not be different versions of treatment, is insofar violated as all DiD specifications we employ rely on grouping districts together into treatment and control group that are similar but not equal regarding the share of apprenticeship contracts with minimum wage remuneration. VanderWeele and Hernán

[2013], however, have developed one relaxed version of the SUTVA that allows for different treatment versions, provided there are no different versions of non-treatment and that the treatment versions are assigned randomly conditionally on covariates. In our case, the variation in the level of non-treatment is relatively small as the share of contracts with minimum wage remuneration is mostly equal to zero or very close to zero (see Section 4.1). The variation in the share of minimum wage contracts in the treatment group can to a large extend be explained by the covariates capturing the economic situation in a district (both in general and in the treatment group). Conditionally on the covariates, there remains only a small apparently random variation in the treatment intensity, so that the modified SUTVA holds approximately.

Apart from the DiD assumptions discussed so far, the treatment definition in all our approaches relies on one more assumption: if the implementation of the minimum wage in 2020 led to reductions in the number of apprenticeship positions in the minimum-wage sector, these reductions were proportional to the number of apprenticeship positions affected by the minimum wage introduction. The reason we depend on this additional assumption is that the wage agreed in apprenticeship contracts is only available from 2020 onward. Consequently, we cannot define our treatment based on the share of apprenticeship positions with below-minimum-wage remuneration in 2019 but rather have to use the share of apprenticeship contracts with minimum-wage pay between 2020 and 2023.

5.2 Methodological Approach

In the baseline approach, we estimate the effect of the minimum wage introduction on apprenticeship postings by means of a random-effects (RE) Poisson model with standard errors clustered at the district level, where the treatment variable is defined as described in Section 4. We estimate a canonical, that is a 2×2, DiD model with the demand for apprentices in the years 2016 to 2019 as pre-treatment outcome and that in 2020 to 2023 as post-treatment outcome. Additionally, we estimate an RE DiD model with dummies for all post-treatment periods to assess how the effect of the minimum wage developed over the years after its introduction. Both estimation approaches are carried out with different sets of covariates X and applied to the data on all low-wage apprenticeship occupations as well as the four selected occupation categories separately.

As a second approach to estimating the ATT, we use the Synthetic DiD, a procedure developed by Arkhangelsky et al. [2021] that combines the strengths of the synthetic control method (Abadie et al. [2010]) and the standard DiD estimator. The Synthetic DiD procedure weighs the pre-treatment observations in the control group in such a way that the pre-treatment demand for apprentices in control and treatment group follows parallel trends. Additionally, it also uses time weights in order to balance pre- and post-treatment time periods. Compared to the standard DiD approach, the Synthetic DiD is more successful in dealing with violations of the (conditional) parallel trend assumption. Other than the synthetic control method, it only requires the paths to be parallel rather than identical among treated and synthetic control units. The Synthetic DiD can serve as a valuable supplementary analysis to the standard DiD as it can help address violations of the parallel trends assumption and substantiate the credibility of the estimated treatment effects.

In the triple difference approach, we include the development of apprenticeship postings in high-wage occupations as an additional level of differencing, where high-wage occupations are defined as those occupations with a nationwide median wage at least as high as the 75th percentile of all job-specific median wages (of 1,000 €). This approach addresses potential violations of the conditional common trend assumption arising from general differences in developments in treatment and control group which cannot be controlled for by means of the considered covariates. The triple difference estimator is equal to the difference between the DiD estimators calculated for the high-wage occupations and the low-wage occupations (or the respective low-wage occupation under study), where the treatment and control districts are defined as in the simple DiD setting. The triple difference estimator does not necessarily require the parallel trend assumption to hold in both DiD estimators. Instead, it relies on the assumption that the bias is the same in both DiD estimators (Olden and Møen [2022]).

To check the validity of the parallel trends assumption in both the DiD and triple difference setting, we follow the approach proposed by Muralidharan and Prakash [2017]. For the DiD estimations, we estimate the difference in trends in the outcome between treatment and control group over the pre-treatment period. To test the parallel trend assumption in the triple difference settings, we regress the pre-treatment outcome on the interaction of the treatment dummy, a dummy for low-wage occupations and a continuous time variable, as well as the corresponding lower-order interaction terms and control variables. The purpose of these checks is mainly to assess how the development of the outcome in treatment and control group compares prior to the treatment, which provides context for interpreting the treatment effect estimates: If the estimated effect and the trend coefficient are of opposite signs, it suggests that the treatment effect estimate is valid and may underestimate the true effect size; if they share the same sign, the opposite is true.

Additionally, we conduct a parallel trend test for DiD estimations with nonlinear regression, as suggested by Wooldridge [2023]. We regress interactions of the treatment group dummy and year dummies, as well as controls where applicable, on the pre-treatment outcome, and then run a cluster-robust Wald test for joint significance of these pre-treatment interaction terms. We adopt a similar setup to run the parallel trend test for triple difference estimations proposed by Olden and Møen [2022]. Specifically, we regress the pre-treatment outcome in low-wage occupations relative to that in high-wage occupations on treatment group × year interaction terms as well as controls, and test for joint significance of these interaction terms. The purpose of this test not so much to evaluate overall pre-treatment trends, but more rather to identify any deviation from the assumed parallel trends. It provides insight into the quality of the parallel trend assumption, also rejecting it if the outcome behaves differently in treatment and control group in single "outlier" years, without indicating whether these deviations could lead to an under- or overestimation of the treatment effect.

6 Results

6.1 Effect Estimates for Low-Wage Apprenticeship Occupations

Table 2 presents the effect estimates of our four estimation approaches for all low-wage apprenticeship occupations. The estimates for the effect of the minimum wage introduction on low-wage apprenticeship postings are of different signs, with the two DiD and the Triple Difference approach suggesting a slightly negative and the Synthetic DiD a small positive effect. Only the effect estimate from the Triple Difference approach is statistically significantly different from zero. However, the parallel trend tests for the Triple Difference approach - just as those for the two DiD settings - reveal serious violations of the parallel trend assumption. The test proposed by Muralidharan and Prakash [2017] shows negative deviations from parallel pre-treatment trends. Likewise, the parallel trend test following Wooldridge [2023] rejects the parallel trend assumption. Consequently, the estimates of the Triple Difference approach DiD - just as those for the two DiD settings - most likely overestimate the true effect in size, making it impossible for us to derive reliable conclusions about the effect of the minimum wage on apprenticeship postings in the low-wage occupations based on these estimations. The standard error of the effect estimate from the Synthetic DiD approach is extremely large in comparison to the effect estimate itself, making it also impossible to draw any reliable conclusions about the impact of the minimum wage from estimation (for a graphical representation of the Synthetic DiD estimation, see Figure 4). Therefore, we can conclude that none of the estimation approaches provide evidence of an effect of the minimum wage on apprenticeship postings.

	(1)	(2)	(3)	(4)
Treatment Effect Estimate	-0.027	-0.007	-0.070*	1.935
	(0.026)	(0.023)	(0.035)	(25.886)
Treated × Post 2019			0.068**	
			(0.025)	
Low-Wage Occ. × Post 2019			-0.025	
			(0.023)	
GDP per capita		✓	✓	✓
General Median Pay		✓	✓	✓
# Bus., 0 - 10 employees		✓	✓	✓
# Bus., 10 - 50 employees		✓	✓	✓
# Bus., 50 - 250 employees		✓	✓	✓
# Bus., > 250 employees		✓	✓	✓
Year FE	✓	✓	✓	✓
Parallel Trend Tests:				
Muralidharan and Prakash [2017] (slope)	-0.025	-0.014	-0.042**	
	(0.010)	(0.010)	(0.014)	
Wooldridge [2023] (p-val.)	0.000	0.004	0.002	
N	1,592	1,592	3,216	1,592

Table 2: Poisson FE treatment effect estimates without controls (1) and with controls (2), Triple Diff effect estimates from Poisson FE regression (3), and Synthetic DiD effect estimates (4), with the Synthetic DiD model estimated as a level-level model. Models (1), (2) and (4) include all low-wage apprenticeships aggregated at the district level; model (3) is estimated with low- and high-wage apprenticeships aggregated at the district level. The estimations include apprenticeship cohorts from 2016-2023 in their first year, excluding those publicly funded, part-time, or earning less than 10 €. The treatment group consists of the 25 % districts with the highest proportion of low-wage apprenticeships compensated at minimum wage in 2020-2023. In these treated observations, at least 23 % and on average 31 % of all apprenticeships are paid a minimum-wage salary. The control group comprises the 25 % of districts with the lowest proportion of apprenticeships paid at minimum-wage level, i.e. districts with no more than 9 % and on average 6 % of apprenticeships paying a minimum-wage salary. Clustered standard errors at the district level are reported in parentheses. The last row reports the p-values for the parallel trends test proposed by Wooldridge [2023]

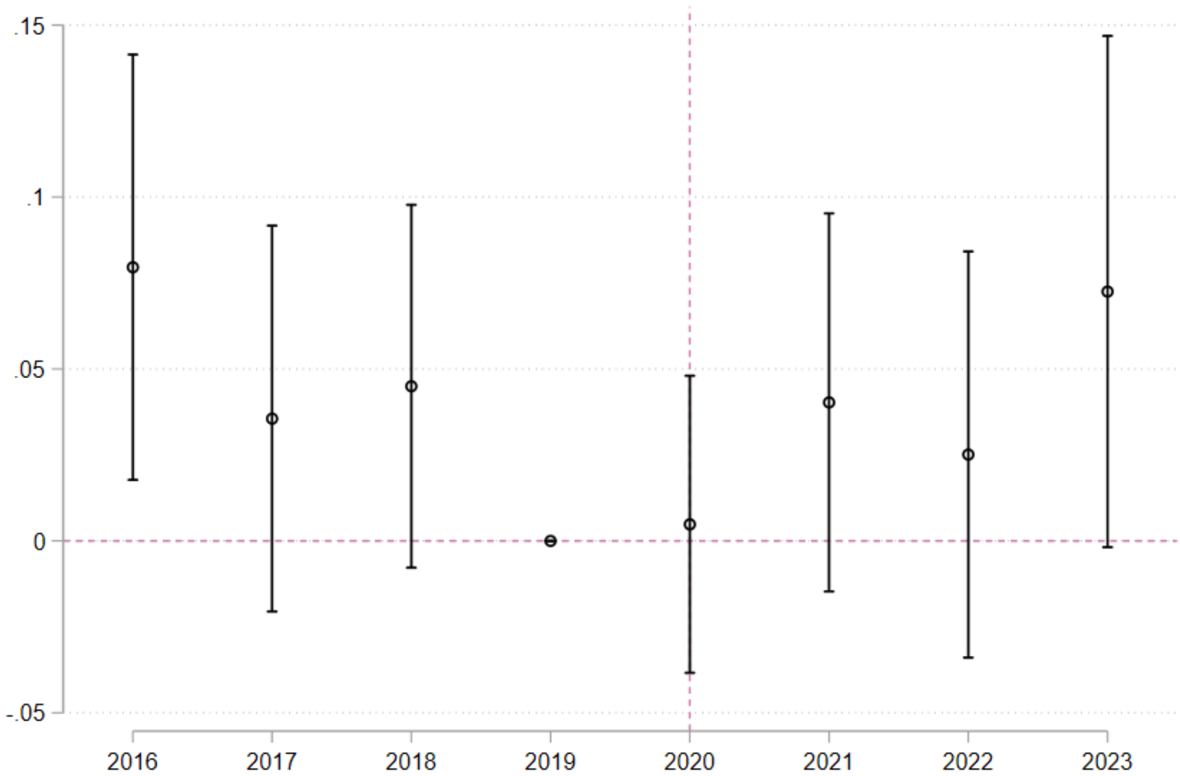

Figure 3: RE effect estimates from regression with controls for low-wage occupations.

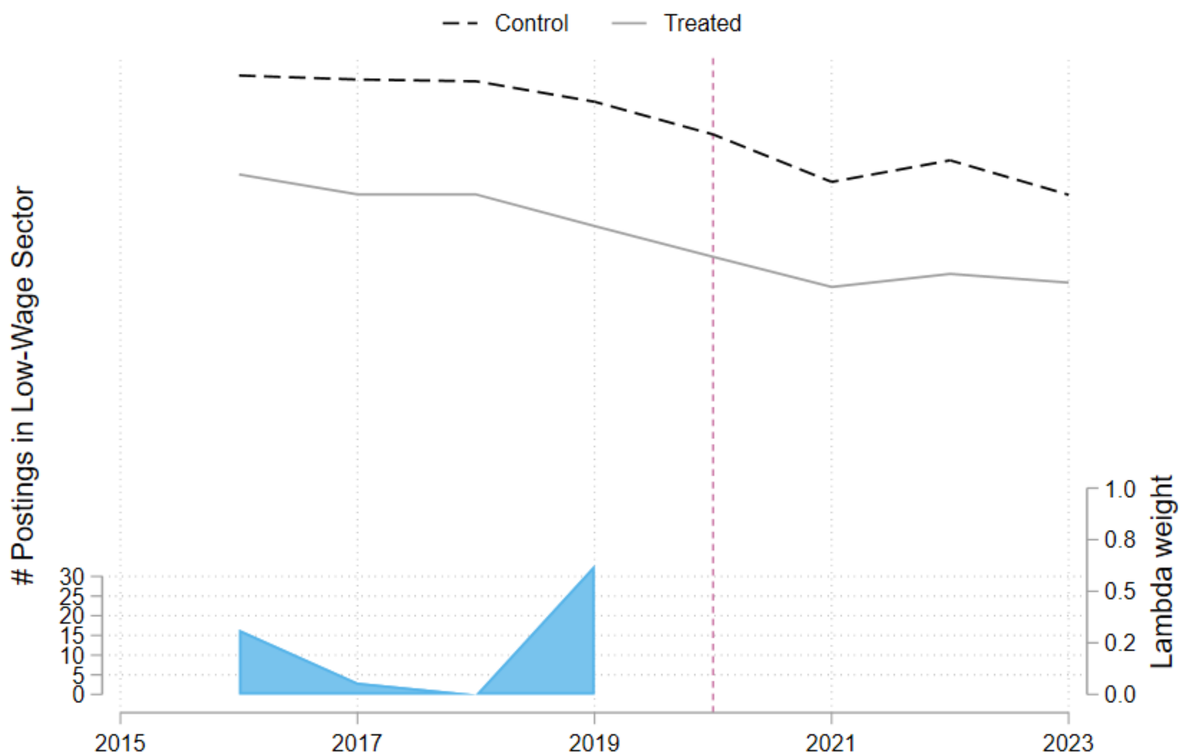

Figure 4: Synthetic DiD estimates for low-wage occupations. The blue area represents the weights (λ) assigned by SDiD to each time period.

6.2 Effect Estimates for Selected Occupational Groups

To explore potential heterogeneity in the impact of the minimum wage across different occupations, which may have offset each other, we examine four specific low-wage occupation groups more closely. These groups are characterized by a particularly high share of minimum wage contracts and a substantial number of apprenticeship postings in most districts.
Table B.1 in Appendix B displays the effect estimates for occupations in plastic-making and -processing and wood-working and -processing. All estimation approaches suggest a negative effect of the minimum wage introduction on apprenticeship postings. Unlike in the estimation for the entire low-wage sector, the parallel trend test for the DiD and triple difference approaches show much less concerning results. Notably, in the DiD model with controls, the average pre-treatment deviation from parallel trends is very close to zero. In contrast, the triple difference approach shows a relatively larger pre-treatment deviation from parallel trends (which is of the same sign as the effect estimate), making this estimator less reliable than the DiD estimator with controls. The Synthetic DiD estimate suggests that the introduction of the minimum wage brought about a decrease of about 1.7 apprenticeship postings in plastic and wood production per treated district and year. Compared to the average of 27.3 postings in treated districts in the pre-treatment period this makes up about 6.3 %, which is slightly less than the estimated decrease of 9.7 % from the simple DiD approach with controls.

Next, we examine apprenticeship occupations in textile and leather-making, which are also part of the raw materials production and manufacturing sector. The treatment effect estimates for this occupational group can be found in Table B.2. The effect estimates from the DiD and triple difference estimators are larger in size than those for plastic and wood production apprenticeships. The corresponding parallel trend tests suggest no strong deviations from parallel trends in the pre-treatment period and have opposite signs from the treatment effect estimate. For the triple difference approach, the test by Wooldridge [2023] also suggests that the parallel trends assumption holds. The effect estimate from the Synthetic DiD indicates a decrease by 0.29 apprenticeship postings, which represents about 10.5% of the 2.7 textile and leather-making apprenticeship postings in treated municipalities during the pre-treatment period. Overall, the point estimates from the different approaches suggest a minimum-wage induced decrease in apprenticeship postings of some 8 - 16 %.
To properly compare these estimates with those for plastic and wood production apprenticeships, we must consider the differences in the composition of treatment and control group regarding the share of minimum-wage contracts. In both estimations, the control group consists solely of observations with no minimum-wage contracts. The treatment group, however, differs substantially between both estimations. In the plastic and wood production estimation, it includes districts with at least 9 % and on average 28 % minimum-wage contracts. In contrast, treated observations in the estimation on textile and leather-making

apprenticeships are characterized by shares of at least at least 50 % and on average 77% of minimum-wage contracts. Consequently, the difference between treatment and control group is much larger in the estimation on textile and leather-making apprenticeships compared to that on plastic and wood production apprenticeships. In light of these differences in treatment bites the actual effect of the minimum wage introduction on plastic and wood production apprenticeship postings may be comparable to or even larger than that on textile and leather-making apprenticeship postings.

Table B.3 shows the effect estimates for apprenticeships in non-medical healthcare, body care, wellness and medical technicians. Here, the parallel trend tests indicate that the assumption of parallel trends is highly problematic in both the DiD and triple difference approaches. The only effect estimate that - by construction - can be considered uncritical regarding the parallel trend assumption is the Synthetic DiD estimate. It suggests that the minimum wage introduction brought about an increase of approximately 0.8 apprenticeship postings per district in this occupational group. However, in light of the extremely high standard error it is impossible to deduct any reliable statements from this point estimate. Nevertheless, when simply looking at the Synthetic DiD point estimate and the estimates from the DiD and triple difference approaches alongside the corresponding pretreatment deviations from parallel trends, the estimation results suggest that the impact of the minimum wage on apprenticeship postings for health and wellness is smaller than the overall effect observed across the low-wage occupations and may even be positive.
With an average of 39 health and wellness apprenticeship postings in treated districts during the pre-treatment period, this occupation group accounts for nearly one-third of the entire low-wage apprenticeship sector considered. The observed violation of the parallel trend assumption, along with the slightly positive Synthetic DiD estimate for the entire low-wage sector, may therefore be at least partly driven by health and wellness apprenticeships, while the effect of the minimum wage on the occupation groups of textile and leather manufacturing as well as plastics and wood manufacturing, which are much smaller in size, may have been offset by the behavior of firms offering health and wellness apprenticeships.
The last occupational group we examine is that of occupations in product design, artisan craftwork, fine arts and the making of musical instruments, with the estimation results available in Table B.4. In the DiD models, the deviations from parallel trends in the pre-treatment period are of opposite signs compared to the effect estimates, suggesting that these effect estimates may slightly underestimate the true effect size. The triple difference estimate indicates a slight positive effect of the minimum wage introduction on apprenticeship postings, but this is likely due to the comparably strong positive deviation from parallel trends before treatment. The Synthetic DiD estimate suggests a decrease of 0.16 apprenticeship postings in this occupational group, which accounts for 4.3 % compared to the average of 3.7 postings in treated municipalities prior to the treatment. This estimate is slightly larger than those

from the DiD approaches, which, however, likely underestimate the true effect, yet larger than the effect indicated by the triple difference approach. Overall, the point estimates suggest that the effect of the minimum wage on apprenticeship postings in product design, artisan crafts and fine arts is substantially smaller than those in textile and leather manufacturing as well as plastics and wood manufacturing (also when considering differences in treatment bites). Figure B.1 in Appendix B shows the Synthetic DiD estimates over time for the four occupational groups. .

To sum up, the estimates for selected occupation groups suggest that the minimum wage introduction had a comparably large effect on apprenticeship postings in textile- and leather-making, as well as plastic and wood production. In comparison, the estimated effect on apprenticeship postings in product design, artisan crafts and fine arts is smaller. For non-medical healthcare, personal care, wellness, and medical technician roles, we found no discernible effect of the minimum wage on apprenticeship postings.

6.3 Effect Estimates in the Context of Labor Market Shortage and Net Apprenticeship Costs

There are numerous factors that potentially influence how the minimum wage affects the demand for apprentices, including labor shortages and the cost-benefit analysis of training. If training costs rise due to the introduction of the minimum wage, firms might find it more cost-effective to hire already-trained workers. This is particularly likely if training apprentices was already very costly before the introduction of the minimum wage. However, if trained workers are scarce, firms may still need to rely on training programs, even if they are not financially beneficial (see e.g. Mason et al. [2012]). Therefore, we will closely examine the labor shortage situation and the cost-benefit estimates for vocational training in the occupational groups under study using the skilled labor shortage statistics of the BA (Statistik der Bundesagentur für Arbeit [2024]) and the cost-benefit survey by the BIBB (Wenzelmann and Schönfeld [2022]).

The labor shortage statistics by the Statistik der Bundesagentur für Arbeit [2024] provide a score indicating the degree of labor shortage in various occupational groups[5] based on six statistical indicators.[6] The scores range from 0 to 3, where a score of 2.0 or higher indicates an occupation facing a labor shortage. Conversely, a score below 1.5 signifies that the occupation is not considered to have a labor shortage. Occupations scoring between 1.5 and 2.0 are classified as under observation. Among the four occupation groups under study, textile

[5] The labor shortage indicators are provided at a more detailed aggregation level than our occupational groups. Therefore, for each of the four occupational groups under study, we calculate the mean score across all underlying subgroups where a dual apprenticeship is possible. For calculating the mean scores, we weight the subgroup scores by the number of employees with social security coverage in the subgroup. We first calculate the mean scores separately for each year, and then average the scores for 2020 to 2023.

[6] The six indicators are: vacancy duration of advertised positions, job seeker-to-open positions ratio, occupation-specific unemployment rate, change in the proportion of foreign employees with social security coverage, exit rate from unemployment, development of average wages

and leather making occupations have the lowest average score of 1.2, followed by product design, artisan crafts and fine arts with 1.5. The group of non-medical healthcare, body care, wellness and medical technology has a score of 1.8 and occupations in plastic and wood production show the highest prevalence of labor shortage, with an average score of 1.9. Consequently, while none of our four occupation groups appear to be strongly affected by labor shortage, the plastic and wood production group, along with non-medical healthcare, body care, wellness, and medical technology, are considered under observation.

We would expect a negative effect of the minimum wage on apprenticeship postings in those occupational groups where the score indicates no labor shortage and negative in those occupational groups with the highest labor shortage scores. However, this assumption is only partially met. The occupational group of textile and leather making actually experiences the largest decrease in apprenticeship postings, while the decrease in product design, artisan crafts and fine arts is smaller and there is no clear effect on apprenticeship postings in non-medical healthcare, body care, wellness, and medical technology. The behavior of apprenticeship postings in plastic and wood production, however, does not align with expectations. Despite this group having the highest labor shortage score, we find a substantial negative effect of the minimum wage on apprenticeship postings in this sector. This implies that the premise that the availability of skilled workers can explain differences in the minimum wage's impact on apprenticeship postings is not entirely reliable.

Finally, we take a closer look at the cost-benefit survey conducted among training firms during the 2017/18 training year (Wenzelmann and Schönfeld [2022]), i.e. before the introduction of the minimum wage. Out of the 41 occupations included in the cost-benefit analysis, only two fall into our occupation groups. In the group of plastic and wood production occupations, data is available for carpenters, whose apprenticeships generate relatively high net costs. In 2017/18, carpenter apprentices ranked seventh in terms of net costs among the 41 occupations analyzed. These high net costs are mainly driven by comparably high labor costs for trainers, along with significant expenses for facilities, materials, fees, and administration, while the returns generated by carpenter apprentices were below average. For the occupational group of non-medical healthcare, body care, wellness and medical technology, data is available for hairdressers. Hairdressers represent the largest share of apprenticeships in this occupational group, though their cost-benefit structure might not be very representative for another large subgroup, namely that of medical technicians. The relatively low net costs for hairdressing apprenticeships before the minimum wage were mainly due to their extremely low labor costs. In contrast, labor costs for trainers and other expenses like facilities, materials, fees, and administration were only slightly below average.

At first glance, the difference in net costs between carpentry and hairdressing apprenticeships might seem to explain why the minimum wage had a strong negative impact on apprenticeships in plastics and wood production, but no significant effect on apprenticeships in health and body care, wellness, and medical technology. However, since the low net costs for hairdressing apprenticeships are largely driven by low labor costs, the minimum wage introduction likely caused a sharper increase in net costs for hairdressing than for carpentry apprenticeships.[7] Ultimately, this second explanatory approach does not satisfactorily account for the observed variations in the effect of the minimum wage on apprenticeship postings either.

7 Conclusion

Our study provides important insights into the effects of the 2020 introduction of a minimum wage for apprentices in Germany, focusing specifically on the demand side of the apprenticeship market. Estimates of the effect of the minimum wage on the number of apprenticeships in the low-wage sector as a whole show no significant minimum wage effect in districts with a high prevalence of minimum wage contracts.

However, our findings reveal notable differences across occupational groups. While we find no significant effect for non-medical healthcare, body care, wellness, and medical technology occupations, we observe pronounced declines in apprenticeship postings in low-wage production and manufacturing occupations, particularly in textile and leather-making as well as plastic and wood production occupations. In occupations in product design, artisan crafts and fine arts, the impact is smaller but still noticeable. These heterogeneities in the effect of the minimum wage introduction cannot be fully attributed to differences in skilled labor shortages and net costs of apprenticeships between the occupational group under study.

[7] As noted before, we cannot observe the pre-minimum wage apprenticeship salaries in our data. However, collective bargaining agreements in the hairdressing industry support the impression that the wage adjustments to meet the minimum wage may have been larger in hairdressing than in other occupations.

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A Descriptive Statistics

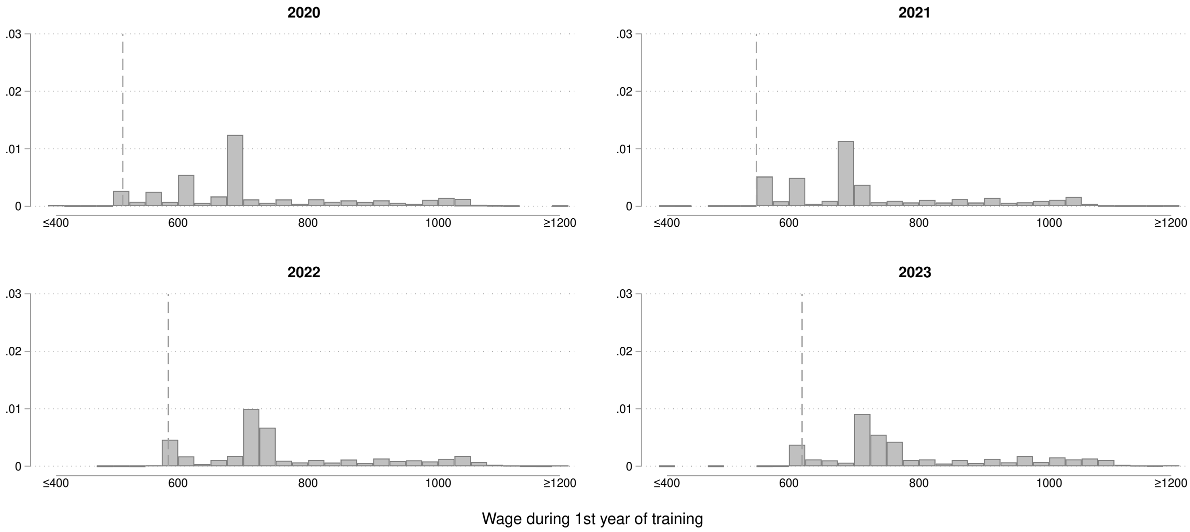

Figure A.1: **Occupations in Plastic-Making and -Processing, and Wood-Working and -Processing:** Distribution of contractually agreed-upon wages for the first year of apprenticeship in occupations in 2020, 2021, 2022 and 2023. The red line indicates the minimum in effect in the respective year.

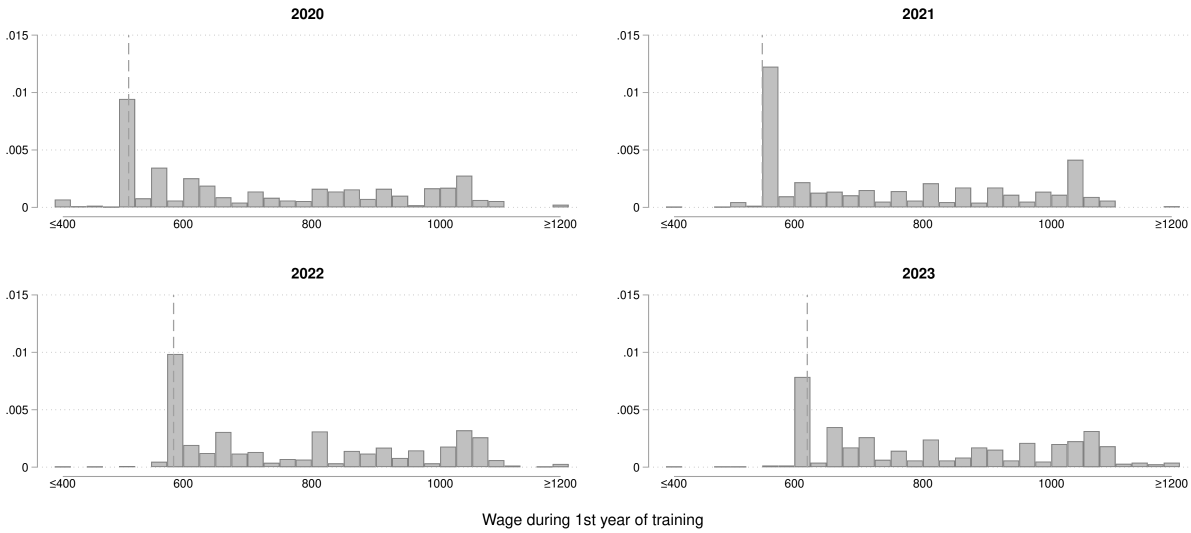

Figure A.2: **Occupations in Textile- and Leather-Making:** Distribution of contractually agreed-upon wages for the first year of apprenticeship in 2020, 2021, 2022 and 2023. The red line indicates the minimum in effect in the respective year.

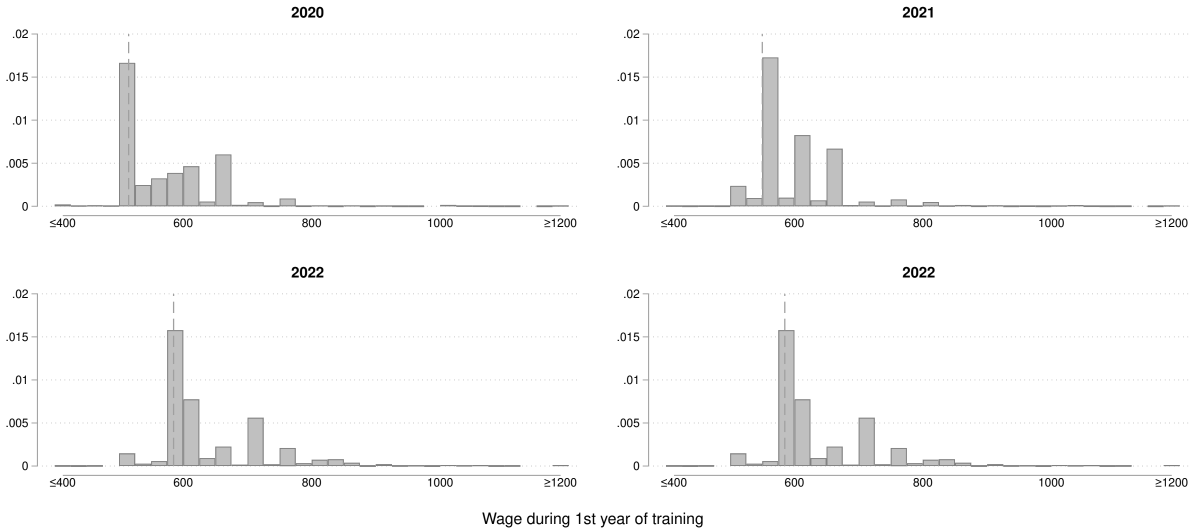

Figure A.3: **Occupations in Non-Medical Healthcare, Body Care and Wellness as well as Medical Technicians:** Distribution of contractually agreed-upon wages for the first year of apprenticeship in 2020, 2021, 2022 and 2023. The red line indicates the minimum in effect in the respective year.

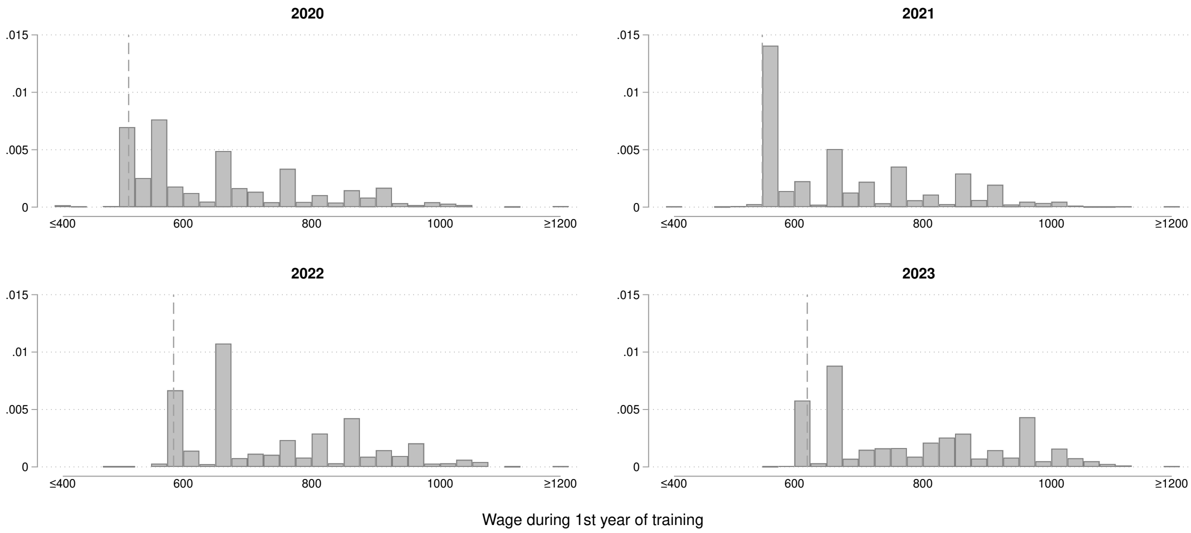

Figure A.4: **Occupations in Product Design, Artisan Craftwork, Fine Arts and the Making of Musical Instruments:** Distribution of contractually agreed-upon wages for the first year of apprenticeship in 2020, 2021, 2022 and 2023. The red line indicates the minimum in effect in the respective year.

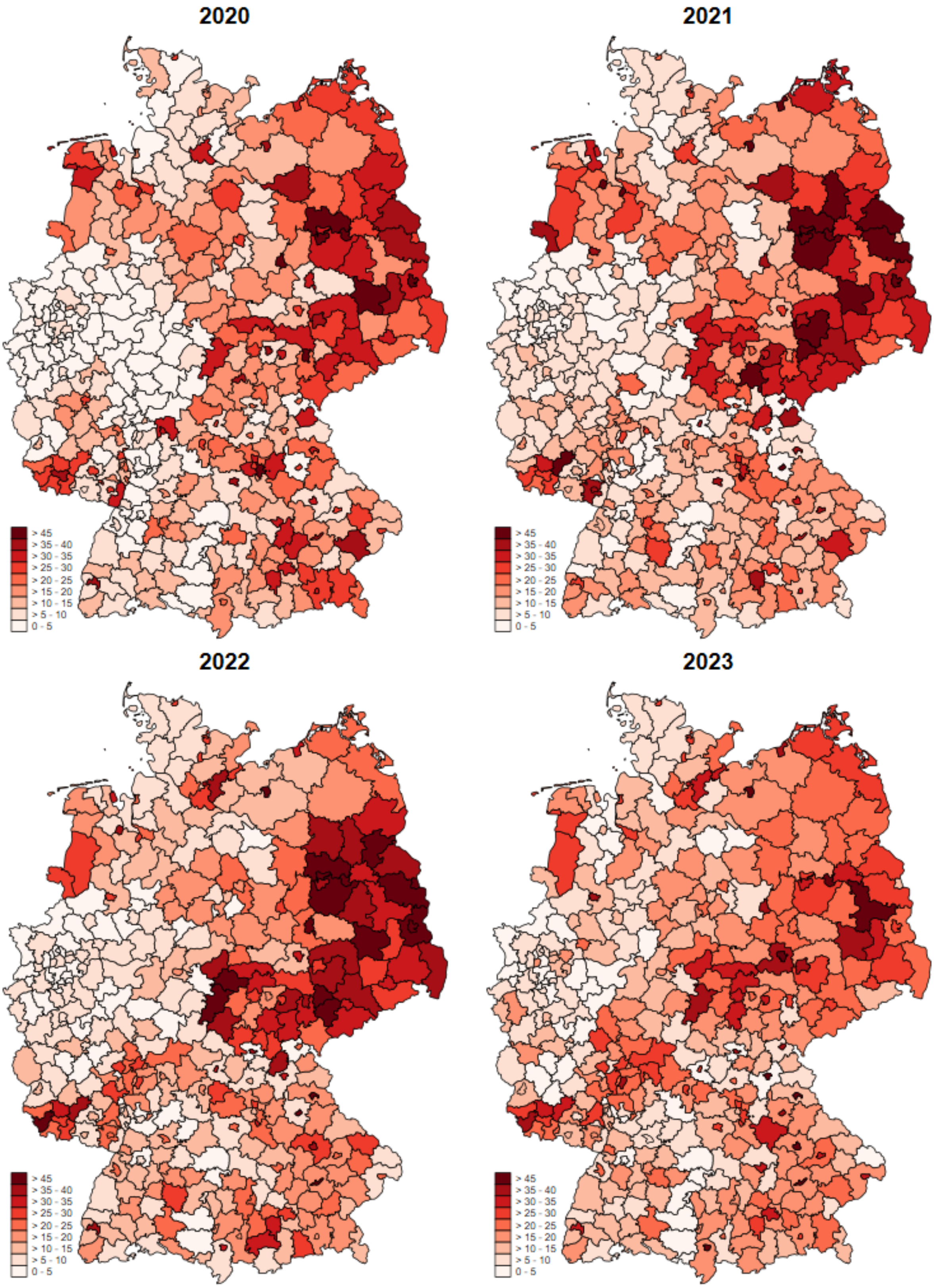

Figure A.5: Geographical distribution of the share of minimum-wage contracts in occupations with low-apprenticeship wages in Germany in 2020, 2021, 2022 and 2023 [%].

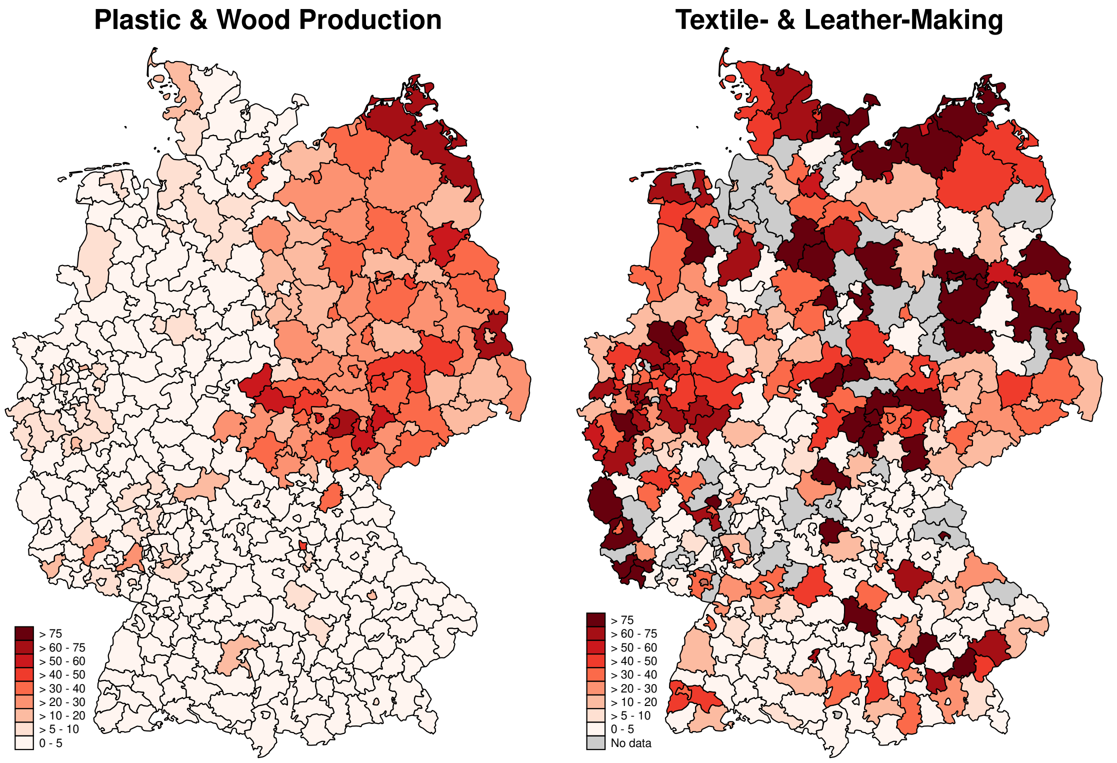

Figure A.6: Geographical distribution of the share of minimum-wage contracts in plastic-making and -processing and wood-working and -processing (left) as well as textile- and leather-making (right) in Germany in 2020 to 2023.

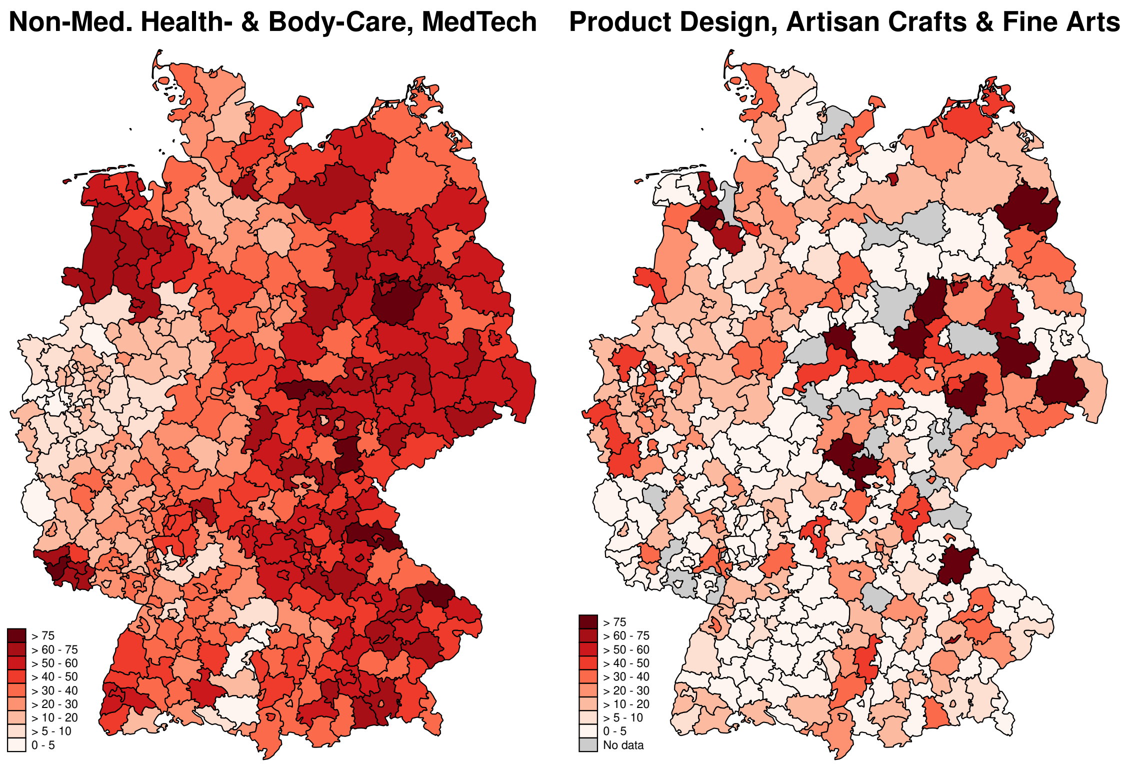

Figure A.7: Geographical distribution of the share of minimum-wage contracts in occupations in non-medical healthcare, body care and wellness as well as medical technicians (left) as well as in product design, artisan craftwork, fine arts and the making of musical instruments (right) in Germany in 2020 to 2023.

	Treatment Group '16-'19 Mean	'20-'23 Mean	Diff.	Control Group '16-'19 Mean	'20-'23 Mean	Diff.	Treatment vs. 'Control Group Diff.
Minimum Wage Contracts [%]	.	28		.	0		
# Apprenticeship Postings	27	23	-4.1	26	25	-1.9	-.83
Apprentice Median Pay [€]	.	634		.	810		
General Median Pay [€]	2,599	2,949	350	3,165	3,451	286	567***
GDP per capita [€]	29,672	33,573	3,901	38,662	42,576	3,915	8,989***
# Businesses, 0 - 10 employees	7,957	7,642	-315	6,008	5,831	-176	-1,950
# Businesses, 10 - 50 employees	875	1,012	137	655	806	151	-220
# Businesses, 50 - 250 employees	203	226	23	148	171	24	-55
# Businesses, > 250 employees	32	36	4.2	26	29	3.3	-6.1
Urban Districts [%]	25	25		25	25		0
East German Districts [%]	76	76		0	0		-76***
N	100	100	200	156	156	312	256

Table A.1: **Occupations in Plastic-Making and -Processing and Wood-Working and -Processing:** Comparison of covariates in treatment and control group before and after the introduction of the apprenticeship minimum wage. The last column displays the pre-treatment differences between treatment and control groups along with the significance of independent sample t-test. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

	Treatment Group '16-'19 Mean	'20-'23 Mean	Diff.	Control Group '16-'19 Mean	'20-'23 Mean	Diff.	Treatment vs. 'Control Group Diff.
Minimum Wage Contracts [%]	.	77		.	0		
# Apprenticeship Postings	3.5	2.5	-.94	4.1	3.5	-.66	.67
Apprentice Median Pay [€]	.	595		.	779		
General Median Pay [€]	2,928	3,234	305	3,148	3,442	294	220***
GDP per capita [€]	33,952	38,025	4,073	39,685	43,444	3,759	5,733**
# Businesses, 0 - 10 employees	10,793	10,501	-292	6,303	6,100	-203	-4,491*
# Businesses, 10 - 50 employees	1,143	1,382	239	683	832	149	-460*
# Businesses, 50 - 250 employees	264	305	40	155	179	23	-109*
# Businesses, > 250 employees	49	56	6.7	27	30	3	-22*
Urban Districts [%]	26	26		23	23		-3.1
East German Districts [%]	30	30		7	7		-23***
N	91	91	182	129	129	258	220

Table A.2: **Occupations in Textile- and Leather-Making:** Comparison of covariates in treatment and control group before and after the introduction of the apprenticeship minimum wage. The last column displays the pre-treatment differences between treatment and control groups along with the significance of independent sample t-test. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

	Treatment Group			Control Group			Treatment vs.
	'16-'19 Mean	'20-'23 Mean	Diff.	'16-'19 Mean	'20-'23 Mean	Diff.	'Control Group Diff.
Minimum Wage Contracts [%]	.	62		.	12		
# Apprenticeship Postings	39	26	-13	54	39	-15	15
Apprentice Median Pay [€]	.	571		.	602		
General Median Pay [€]	2,793	3,118	325	3,197	3,473	276	404***
GDP per capita [€]	33,767	37,888	4,121	35,448	39,417	3,969	1,681
# Businesses, 0 - 10 employees	9,015	8,739	-275	9,745	9,436	-309	731
# Businesses, 10 - 50 employees	976	1,154	178	1,064	1,330	266	88
# Businesses, 50 - 250 employees	226	256	31	256	299	44	30
# Businesses, > 250 employees	39	44	4.9	47	53	6.2	7.9
Urban Districts [%]	23	23		35	35		12
East German Districts [%]	47	47		1	1		-46***
N	98	98	196	99	99	198	197

Table A.3: **Occupations in Non-Medical Healthcare, Body Care and Wellness as well as Medical Technicians:** Comparison of covariates in treatment and control group before and after the introduction of the apprenticeship minimum wage. The last column displays the pre-treatment differences between treatment and control groups along with the significance of independent sample t-test. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

	Treatment Group			Control Group			Treatment vs.
	'16-'19 Mean	'20-'23 Mean	Diff.	'16-'19 Mean	'20-'23 Mean	Diff.	'Control Group Diff.
Minimum Wage Contracts [%]	.	44		.	0		
# Apprenticeship Postings	4.3	3.7	-.56	3.4	3.1	-.34	-.87
Apprentice Median Pay [€]	.	629		.	723		
General Median Pay [€]	2,887	3,195	308	3,064	3,352	288	177**
GDP per capita [€]	34,645	38,616	3,971	34,861	38,387	3,526	216
# Businesses, 0 - 10 employees	7,172	6,930	-242	5,527	5,332	-195	-1,645*
# Businesses, 10 - 50 employees	829	994	165	608	745	137	-221**
# Businesses, 50 - 250 employees	193	221	28	137	159	22	-56**
# Businesses, > 250 employees	32	36	4.2	23	26	2.4	-8.4*
Urban Districts [%]	25	25		23	23		-2
East German Districts [%]	33	33		14	14		-19**
N	95	95	190	142	142	284	237

Table A.4: **Occupations in Product Design, Artisan Craftwork, Fine Arts and the Making of Musical Instruments:** Comparison of covariates in treatment and control group before and after the introduction of the apprenticeship minimum wage. The last column displays the pre-treatment differences between treatment and control groups along with the significance of independent sample t-test. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

B Effect Estimates for Selected Occupational Groups

	(1)		(2)		(3)		(4)
Treatment Effect Estimate	-0.089	**	-0.102	**	-0.103	*	-1.715
	(0.033)		(0.032)		(0.043)		(0.987)
Treated × Post 2019					0.015		
					(0.029)		
Low-Wage Occ. × Post 2019					-0.009		
					(0.024)		
GDP per capita			✓		✓		✓
General Median Pay			✓		✓		✓
# Bus., 0 - 10 employees			✓		✓		✓
# Bus., 10 - 50 employees			✓		✓		✓
# Bus., 50 - 250 employees			✓		✓		✓
# Bus., > 250 employees			✓		✓		✓
Year FE	✓		✓		✓		✓
Parallel Trend Tests:							
Muralidharan and Prakash [2017]	-0.019		-0.002		-0.018		
	(0.018)		(0.024)		(0.022)		
Wooldridge [2023] (p-val.)	0.721		0.687		0.086		
N	2,048		2,048		4,096		2,048

Table B.1: **Occupations in Plastic-Making and -Processing, and Wood-Working and -Processing:** Poisson FE treatment effect estimates without controls (1) and with controls (2), Triple Diff effect estimates from Poisson FE regression (3), and Synthetic DiD effect estimates (4), with the Synthetic DiD model estimated as a level-level model. The estimations include apprenticeship cohorts from 2016-2023 in their first year, excluding those publicly funded, part-time, or earning less than 10 €. The treatment group consists of the 25 % districts with the highest proportion of apprenticeships in plastic-making and -processing, and wood-working and -processing compensated at minimum wage in 2020-2023. In these treated districts, at least 9 % and on average 28 % of all apprenticeships are paid a minimum-wage salary. The control group includes districts with no minimum-wage apprenticeships (39 % of all districts). Clustered standard errors at the district × job level are reported in parentheses. The last rows report the pre-treatment deviation from parallel trends as suggested by Muralidharan and Prakash [2017], as well as the p-values for the parallel trends test proposed by Wooldridge [2023]. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

	(1)	(2)	(3)	(4)
Treatment Effect Estimate	-0.133	-0.165	-0.087	-0.291
	(0.105)	(0.123)	(0.109)	(0.421)
Treated × Post 2019			-0.029	
			(0.029)	
Low-Wage Occ. × Post 2019			-0.105	
			(0.067)	
GDP per capita		✓	✓	✓
General Median Pay		✓	✓	✓
# Bus., 0 - 10 employees		✓	✓	✓
# Bus., 10 - 50 employees		✓	✓	✓
# Bus., 50 - 250 employees		✓	✓	✓
# Bus., > 250 employees		✓	✓	✓
Year FE	✓	✓	✓	✓
Parallel Trend Tests:				
Muralidharan and Prakash [2017]	0.025	0.006	0.048	
	(0.067)	(0.080)	(0.069)	
Wooldridge [2023] (p-val.)	0.035	0.027	0.807	
N	1,760	1,760	3,520	1,760

Table B.2: **Occupations in Textile- and Leather-Making:** Poisson FE treatment effect estimates without controls (1) and with controls (2), Triple Diff effect estimates from Poisson FE regression (3), and Synthetic DiD effect estimates (4), with the Synthetic DiD model estimated as a level-level model. The estimations include apprenticeship cohorts from 2016-2023 in their first year, excluding those publicly funded, part-time, or earning less than 10 €. The treatment group consists of the 25 % districts with the highest proportion of apprenticeships in textile- and leather-making compensated at minimum wage in 2020-2023. In these treated districts, at least 50 % and on average 77% of all apprenticeships are paid a minimum-wage salary. The control group includes districts with no minimum-wage apprenticeships (37 % of all districts). Clustered standard errors at the district × job level are reported in parentheses. The last rows report the pre-treatment deviation from parallel trends as suggested by Muralidharan and Prakash [2017], as well as the p-values for the parallel trends test proposed by Wooldridge [2023]. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

	(1)	(2)	(3)	(4)
Treatment Effect Estimate	-0.076	-0.040	-0.143	0.831
	(0.043)	(0.034)	(0.043)	(17.01)
Treated × Post 2019			0.083	
			(0.026)	
Low-Wage Occ. × Post 2019			-0.191	
			(0.030)	
GDP per capita		✓	✓	✓
General Median Pay		✓	✓	✓
# Bus., 0 - 10 employees		✓	✓	✓
# Bus., 10 - 50 employees		✓	✓	✓
# Bus., 50 - 250 employees		✓	✓	✓
# Bus., > 250 employees		✓	✓	✓
Year FE	✓	✓	✓	✓
Parallel Trend Tests:				
Muralidharan and Prakash [2017]	-0.036	-0.020	-0.043 *	
	(0.020)	(0.019)	(0.020)	
Wooldridge [2023] (p-val.)	0.000	0.000	0.004	
N	1,576	1,576	3,152	1,576

Table B.3: **Occupations in Non-Medical Healthcare, Body Care and Wellness as well as Medical Technicians:** Poisson FE treatment effect estimates without controls (1) and with controls (2), Triple Diff effect estimates from Poisson FE regression (3), and Synthetic DiD effect estimates (4), with the Synthetic DiD model estimated as a level-level model. The estimations include apprenticeship cohorts from 2016-2023 in their first year, excluding those publicly funded, part-time, or earning less than 10 €. The treatment group consists of the 25 % districts with the highest proportion of apprenticeships in non-medical healthcare, body care, wellness and medical technology compensated at minimum wage in 2020-2023. In these treated districts, at least 53 % and on average 62 % of all apprenticeships are paid a minimum-wage salary. The control group comprises the 25 % of districts with the lowest proportion of apprenticeships paid at minimum-wage level, i.e. districts with no more than 22 % and on average 12 % of apprenticeships paying a minimum-wage salary. Clustered standard errors at the district × job level are reported in parentheses. The last rows report the pre-treatment deviation from parallel trends as suggested by Muralidharan and Prakash [2017], as well as the p-values for the parallel trends test proposed by Wooldridge [2023]. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

	(1)	(2)	(3)	(4)
Treatment Effect Estimate	-0.036	-0.028	0.011	-0.159
	(0.087)	(0.090)	(0.090)	(0.288)
Treated × Post 2019			-0.020	
			(0.025)	
Low-Wage Occ. × Post 2019			-0.057	
			(0.062)	
GDP per capita		✓	✓	✓
General Median Pay		✓	✓	✓
# Bus., 0 - 10 employees		✓	✓	✓
# Bus., 10 - 50 employees		✓	✓	✓
# Bus., 50 - 250 employees		✓	✓	✓
# Bus., > 250 employees		✓	✓	✓
Year FE	✓	✓	✓	✓
Parallel Trend Tests:				
Muralidharan and Prakash [2017]	0.006	0.005	0.007	
	(0.040)	(0.040)	(0.012)	
Wooldridge [2023] (p-val.)	0.070	0.019	0.658	
N	1,896	1,896	3,792	1,896

Table B.4: **Occupations in Product Design, Artisan Craftwork, Fine Arts and the Making of Musical Instruments:** Poisson FE treatment effect estimates without controls (1) and with controls (2), Triple Diff effect estimates from Poisson FE regression (3), and Synthetic DiD effect estimates (4), with the Synthetic DiD model estimated as a level-level model. The estimations include apprenticeship cohorts from 2016-2023 in their first year, excluding those publicly funded, part-time, or earning less than 10 €. The treatment group consists of the 25 % districts with the highest proportion of apprenticeships in product design, artisan craftwork, fine arts and the making of musical instruments compensated at minimum wage in 2020-2023. In these treated districts, at least 25 % and on average 44 % of all apprenticeships are paid a minimum-wage salary. The control group includes all districts with no minimum-wage apprenticeships (38 % of all districts). Clustered standard errors at the district × job level are reported in parentheses. The last rows report the pre-treatment deviation from parallel trends as suggested by Muralidharan and Prakash [2017], as well as the p-values for the parallel trends test proposed by Wooldridge [2023]. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

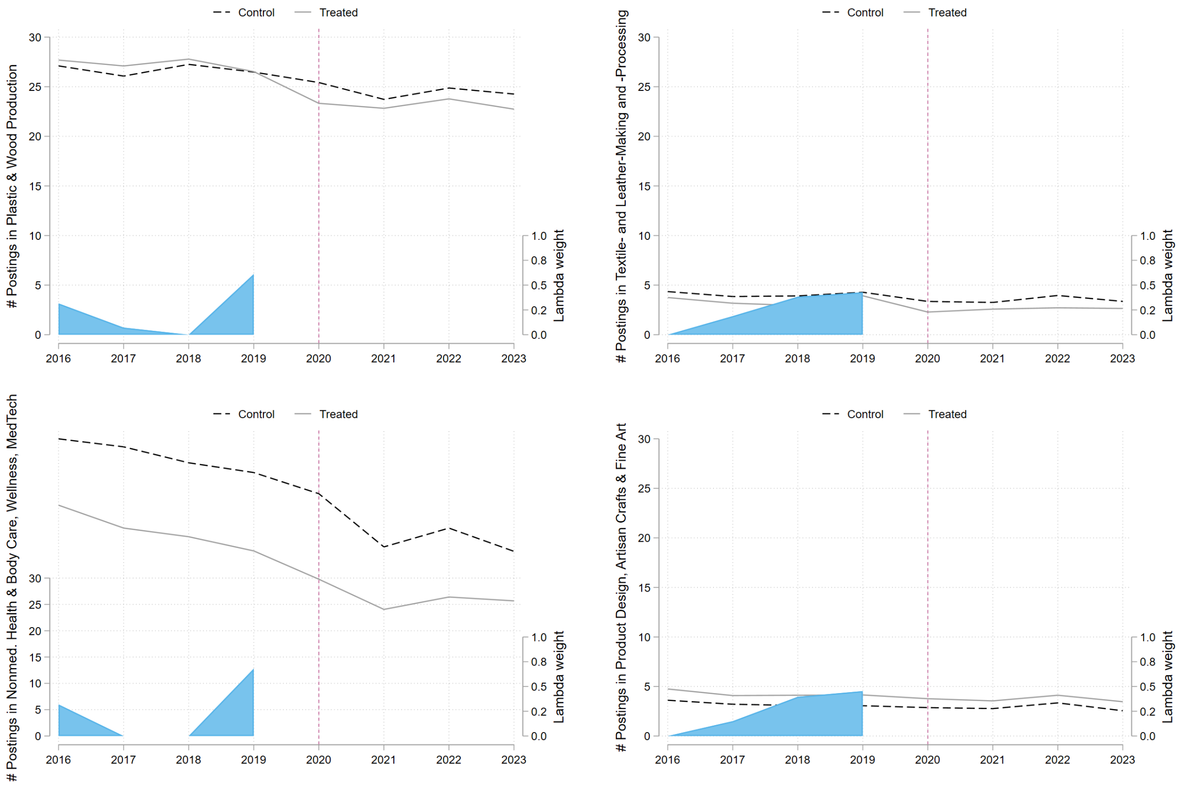

Figure B.1: Synthetic DiD effect estimates for occupations in plastic-making and -processing, and wood-working and -processing (top left) and in textile- and leather-making and -processing (top right), in non-medical healthcare, body care, wellness and Medical Technology (bottom left) and occupations in product design, artisan craftwork, fine arts and the making of musical instruments (bottom right).