Employment effects of minimum wage changes across regions, age groups, and sectors

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ABSTRACT

Increases in minimum wages in many developed and developing economies in recent years raise the question of whether and how they impact employment. We analyze the employment effects of minimum wage increases for different age groups of workers simultaneously. We construct a panel using three-dimensional cells formed by three age groups, two economic sectors, and 16 regions, separately for each year. We use individual data on employee and employer characteristics from the Structure of Earnings Survey and aggregated data from the Local Data Bank in Poland. The research period covers 2006–2020.

Our results confirm the differences in employment elasticity for different groups of workers. We discover latent heterogeneities with regions simultaneously experiencing both negative and positive employment effects of minimum wage changes for different groups of workers and sectors. Negative employment effects are observed mostly for youths, positive employment effects are predominant in the groups of workers aged 50 and over. The employment reaction to changes in the minimum wage is the result of a combination of regional labor market features. Negative employment effects are more likely in areas with larger proportion of workers in the private sector, in industries in which it is more difficult to increase the prices of goods or services produced, and where small firms are widespread.

The results show that previous analyses at the aggregated level might underestimate the employment effects of the minimum wage. The results also show that the overall minimum wage effects cannot be easily predicted by policymakers.

JEL classification: J21, R23, J31, J38

Keywords: employment elasticity, minimum wage, regional labor markets, multidimensional panel analyses, intra-regional differences, Poland.

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1. INTRODUCTION

Increases in minimum wages in many developed and developing economies in recent years raise the question of whether and how they impact employment. The importance of the topic has grown in times of high inflation and minimum wage raises through various indexation mechanisms. The amount of research on the minimum wage–employment relationship is enormous, but neither the direction of the relationship nor its strength has been unequivocally determined.

Increases in the minimum wage raise production costs. There are a few ways that firms can deal with higher labor costs, including reducing employment or the non-financial benefits for workers to decrease total costs. They may pass higher labor costs on to prices, increasing their income. Firms can also maintain employment levels, non-financial benefits, and prices, but then their markups and profits would be reduced (Lemos, 2008).

The overall effect of minimum wage increases depends on several factors. Since employment reduction is costly, firms first insist on passing the costs to consumers by increasing prices of their products (Harasztosi and Lindner, 2019). Therefore, negative employment effects would be expected in those labor market segments where prices cannot be increased or where worker turnover costs are low, e.g., firms in tradable sectors, firms facing high market competition, small firms, and firms that employ young, low-educated, and less experienced workers.

Literature shows that negative employment effects are observed among less-skilled and less-experienced (younger) workers (see, e.g., Kiss, 2018; Wolfson and Belman, 2019; Neumark and Shirley, 2021). However, the size of the effect depends on the market competition. Munguía Corella (2020) found significant negative employment effects due to minimum wage changes for youth under perfect competition, and insignificant effects under full monopsonistic labor markets. Harasztosi and Linder (2019) found that employment reaction varies across countries and industries, and that unemployment effects were greater in industries that had more difficulty passing wage costs onto consumers. Moreover, a growing number of authors underline heterogeneity of labor markets across regions as the main source of non-significant employment elasticity at the aggregate level (Thompson, 2010; Autor et al., 2019). All of the studies confirmed differences in regional employment reactions due to minimum wage increases, but they did not indicate the reasons for the differences.

Our study follows the approach suggested by Card (1992), which relies on the extent to which regional labor markets are affected by the minimum wage. The minimum wage is intended to affect less skilled and less experienced workers. Therefore, the uneven distribution of young or less-educated workers across economic sectors and regions may result in differences in how minimum wage changes impact employment in particular sectors of regional labor markets. Additionally, structures of both employers and employees may determine the extent to which minimum wage increases will affect employment.

Literature on minimum wage effects on employment is abundant but prior analyses are partial in nature. They usually considered only one or two factors (dimensions), investigating employment effects of minimum wage increases over time and across age groups, educational groups, sectors, or regions separately. Additionally, due to data limitations, effects at the firm level were typically analyzed in isolation from analyses that used workers' characteristics. This paper addresses the gaps by studying employment effects of minimum wage increases on most important factors simultaneously. It creates a novel four-dimensional approach. We estimate the employment elasticities of minimum wage increase for different segments of the labor market in Poland and analyze the factors behind them. Our aim is to investigate and explain employment effects of minimum wage increases by age groups, taking into account sectoral and regional structure of the workforce simultaneously. In particular, we want to explain why in some regions negative employment effects for young workers are observed, while in others they

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are not. The value added of the study is finding and explaining heterogeneities among minimum wage elasticities, it would have been impossible without implementing our four-dimensional approach.

We estimate that employment effects of minimum wages increase for different age groups of workers. In particular we aim to verify the following research hypotheses: (1) In all regions and sectors analyzed negative employment effects in the group of young workers are observed; in the case of other age groups employment effects are not significant. (2) Negative employment effects are more pronounced in the industry sector than in the market services due to higher international competition and lower possibilities to pass higher costs to consumers. (3) Negative employment effects are higher in regions with higher share of workers in industries facing higher international competition.

As a case study we use Polish data. It is worth exploring the topic using Poland for several reasons. First, the minimum wage policy conducted at a national level is simple and has a long history; moreover, there is one minimum wage rate for all regions, occupations, and sectors. Second, according to Eurostat data, Poland's share of minimum wage workers is one of the highest of all European economies. Third, there has been a sustained increase in the national minimum wage in Poland in recent years. Fourth, Poland is one of the largest EU economies, and the minimum wage coverage is extensive. Finally, Poland exhibits large and enduring regional differences.

We use individual data on employee and employer characteristics from the Structure of Earnings Survey, supplementing them with regional data from the Local Data Bank in Poland. The research period covers 2006–2020. We construct a panel using three-dimensional cells formed by three age groups, two economic sectors, and 16 regions, separately for each year. The cells are our units of observation. Using a cell-level approach allows for multiple factors to be taken into account simultaneously. This is a novel approach.

We begin by estimating the average employment elasticity for the whole sample of workers before applying the slope homogeneity test for panel data developed by Blomquivst and Westerlund (2013). After rejecting the homogeneity of the employment effect, we allow the parameter of the minimum wage variable to vary across cells (age group, economic sector, and region simultaneously). In the second stage, we try to explain differences in the minimum wage elasticity estimates. We apply cluster analysis to the three-dimensional cells of workers. Finally, we verify how different labor market structures affect employment reactions to minimum wage changes.

The multidimensional approach has an inevitable advantage over prior studies in that it allows for a more detailed picture of the analyzed phenomenon. The paper makes several contributions to the minimum wage literature. We study differences among regions together with heterogonous reactions to policy changes within regions, observing how regional differences in sectoral and age composition of the workforce affect employment reaction to minimum wage increases. To the best of our knowledge, it is the first study of its kind.

Our results confirm differences in employment elasticity for minimum wages across regions. We also discover latent heterogeneities in the regional employment effect, with regions simultaneously experiencing both negative and positive employment effects of minimum wage changes for different groups of workers and sectors. Negative employment effects are observed mostly for the youth, while positive employment effects are predominantly in the groups of workers aged 50 and over. Stronger negative effects are observed in the industry than market services sector.

We found that the employment effect of changes in minimum wage levels is the result of a combination of regional labor market features. Negative employment effects are more probable in regions with small, private sector firms in the tradable sector, where it is more difficult to increase prices of goods or services produced. Conversely, positive employment effects are

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more probable in regions with a high share of workers employed in the public sector or in large enterprises. Significantly, the two completely different labor market environments can coexist within a given region, which may explain why empirical analyses at a regional level often indicate insignificant values of employment elasticity for minimum wage changes. We have not found similar findings in the literature.

The remainder of the study proceeds as follows. Section 2 contains a literature review. Section 3 describes data and an empirical approach. Subsequently, Section 4 reports results and robustness analyses. Section 5 concludes.

2. LITERATURE REVIEW

Considerable research has been conducted on the relationship between minimum wage changes and employment; however, there is still an ongoing debate on the direction and strength of the relationship. Wolfson and Belman (2019) and Neumark and Shirley (2021) present the most recent summaries of evidence from the US. Campolieti (2020) provides a meta-analysis for Canada, and Dube (2019) summarizes the international evidence. Broecke, Forti and Vandeweyer (2017) and Neumark and Mungiua Corella (2021) studied employment effects of minimum wages in developing countries. Most research indicates a negative impact of minimum wage growth on employment among the most vulnerable groups of workers, i.e., the young and less educated (see, e.g., Kiss, 2018 or Marimpi and Koning, 2018).

In theory, negative employment effects are expected in a competitive price-taker setting, but the effect of minimum wages is ambiguous under monopsonistic labor markets. Manning's (2003) model indicates three possible scenarios: (1) firms are unconstrained because the minimum wage is not binding; (2) firms are supply-constrained and increases in minimum wages have positive effects on employment; and (3) firms are demand-constrained, and a high minimum wage has a negative effect on employment (Munguía Corella, 2020).

Many studies have used the monopsony model to explain non-negative results, including Katz and Krueger (1992) and Card and Krueger (1994), and more recently, Dube, Lester, and Reich (2010). Azar et al. (2019) provided empirical evidence to support the monopsony model as an explanation for the near-zero minimum wage employment effect. They suggest that the aggregate minimum wage employment effects estimated in literature may mask heterogeneity across different levels of labor market concentration. Munguía Corella (2020) constructed a Herfindahl-Hirschman Index (HHI) that measures the concentration of industrial employment in the US at the county level and estimated the effect for different levels of the bindingness of the minimum wage. He found negative and significant elasticity of youth employment due to minimum wage changes under perfect competition, and positive, but insignificant, effects under full monopsonistic labor markets (Munguía Corella, 2020). Moreover, the effect on employment was found to increase with the level of bindingness of the minimum wage.

In addition to the labor market structure, product market structure also matters in the employment effects of minimum wage. Harasztosi and Linder (2019) found that the reaction of employment varies across countries and industries, and that unemployment effects were greater in industries that had more difficulty passing wage costs onto consumers. Therefore, raising the minimum wage can be more costly in countries where low-wage jobs are concentrated in manufacturing (e.g., Germany) than in countries where low-wage workers are concentrated in the services sector (e.g., the US).

Using Hungary as a case study, Harasztosi and Linder (2019) confirmed that the first best option for firms as a response to minimum wage increases is to raise product prices. Similar results were obtained by Bodnár et al. (2018), they analyzed firms' reactions to minimum wage increases across Central and Eastern European countries. They found that the most popular adjustment

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channels were raising product prices, cutting non-labor costs, and improving productivity. Despite this, Poland had the highest share of firms that reported laying people off as the relevant adjustment channel. The results also indicated that firm size matters in adjustment; the layoff channel was more relevant in small firms (20–49 employees) than in firms with more workers. Similar results were found by Céspedes and Sánchez (2014), they showed employment effects monotonically decreasing in absolute terms by firm size: moderate in big firms and higher in small firms. However, Arrowsmith, Gilman, Edwards, and Ram (2003) underlined that the impact of the national minimum wage can be mediated by informality of employment relations in small firms. What is also important is that large enterprises pay higher wages than small firms (see Gibson and Stillman, 2009), so their share of workers affected by minimum wage changes is lower than in small enterprises.

Moreover, there is evidence that the size of the public sector in regional labor markets matters for wages and employment in the private sector. Nalban and Smădu (2021) showed that public job creation crowds out private sector employment, while increases in public wages lead to muted spillover effects. Alfonso and Gomes (2014) showed that growth in public sector wages and employment positively affects the growth in private-sector wages. In contrast, the International Labor Organization underlined that changes in minimum wage can have far-reaching effects on wages in the public sector, especially when different groups of workers are paid a multiple of the minimum wage, increasing the public sector wage bill.[2] Lemos (2004) explained that minimum wage increases can have different effects on employment in the private and public sectors. In the private sector, the effects are predicted by standard neoclassical theory and rely on a profit-maximizing firm, while a government employer can cover the increased wage bill by raising taxes or reducing expenditures. Lemos (2004) also noted that if the public sector has inelastic labor demands, the associated non-negative employment effect might offset some of the negative employment effects observed in the private sector, making the overall employment effect less adverse. She estimated the effects of the minimum wage on wages and employment in both private and public sectors. Adverse employment effects were found in the private sector, but no evidence of adverse employment effects was uncovered in the public sector. Navarro and Tejada (2022) recently confirmed the findings using data from Chile. They found that the institutional features of public sector employment reduce labor market frictions and mitigate the negative effect of the minimum wage on unemployment and welfare.

The differences in personal and firm characteristics translate to differences in the distribution of low-wage workers across regions, as well as the differences in the employment response to minimum wage changes at the regional level. Autor, Manning, and Smith (2016) confirmed that changes in minimum wages may have different impacts across regions and their effect on employment can induce heterogeneous responses. Williams (1993) found that elasticity of employment due to minimum wage changes in the US is highly heterogeneous among states, with the lowest (more negative) elasticity observed in the least developed regions. Thompson (2009) confirmed differences in employment elasticity for minimum wages across US counties. Ahlfeldt, Roth, and Seidel (2018) and vom Berge and Frings (2020) found that the minimum wage caused a contraction in employment growth in eastern Germany with a relatively high bite, while the west of the country experienced no change in employment. Significant differences in employment or unemployment elasticity across regions due to minimum wage increases were also found in the literature for Poland (Majchrowska and Żółkiewski, 2012; Broniatowska, Majchrowska, and Żółkiewski, 2015; Majchrowska, Broniatowska, and Żółkiewski, 2016; Albinowski and Lewandowski, 2020).

[2] https://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---travail/documents/genericdocument/wcms_474533.pdf

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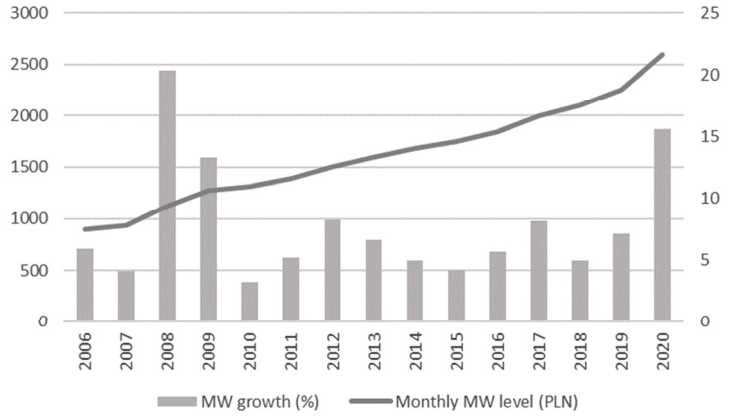
3. MINIMUM WAGE POLICY IN POLAND

The national minimum wage in Poland is regulated by law. The monthly gross minimum wage level is established every year through negotiations within the Social Dialogue Council, composed of representatives chosen from the government, employer organizations, and trade unions. If the Council is unable to reach a consensus, the minimum wage level for the following calendar year is decided solely by the Council of Ministers no later than September 15th. Since 2010, the Social Dialogue Council has not reached an agreement, and each year the decision on increasing the minimum wage has been made solely by the Council of Ministers.

The minimum wage in Poland is established at the national level; it is not differentiated by region, sector, or occupation. There is also no subminimum wage rate for younger workers. The minimum wage legislation does not cover several public sector services (teachers, health, and military services), where wages are determined by separate regulations.

The annual minimum wage increase is guaranteed to at least match the increase in price levels (CPI) projected for the following year. Additionally, in 2005, the Polish government introduced an additional rule for the minimum wage increase, reflecting two-thirds of the forecasted GDP growth rate. This rule is set until the minimum wage reaches half of the average wage in the national economy (Minimum Wage Act of October 10th, 2002, with changes). Minimum wage growth was around 7–8% on average between 2006 and 2020 (see Figure 1), and usually, the actual annual minimum wage growth exceeded the minimum value required by law.

Figure 1
Minimum wage level (PLN, left axis) and minimum wage growth (y/y, %, right axis) in Poland, 2006–2020



Source: Eurostat and the Statistics Poland.

After joining the EU in 2004, the minimum-to-average wage ratio in Poland remained around 35%. The permanent increase in minimum wage observed in the analyzed period led to an increase in the minimum-to-average wage ratio up to 50% in 2020 (Eurostat). In the same time, the ratio of the national minimum wage to average wages differs across age groups, sectors, and regions. In the 18–29 age group, this ratio exceeds 60% in industry and 70% in market services in some regions (see Figure 2).

The permanent growth of the minimum wage level also led to an increase in the share of minimum wage workers in Poland. In 2006, they accounted for 2.5% of all workers in Poland employed in firms with at least ten workers; the proportion reached 7.8% in 2020 (Table 1). Importantly, almost all minimum wage workers in Poland are employed in the private sector, while the share of minimum wage workers in the public sector is negligible. In 2020, more than 11% of private sector workers[3] received no more than minimum wage. Thus, analysis of the effect of minimum wage changes in Poland on employment in private sector is of particular importance.

[3] Employed in firms with at least 10 employees.

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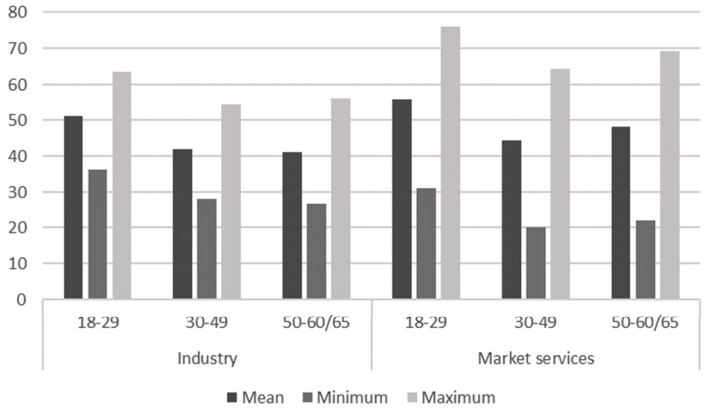
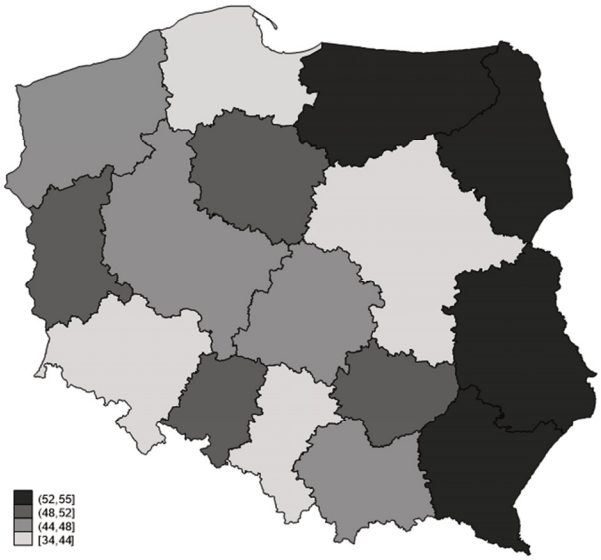
Figure 2
Mean of minimum-to-average wage ratio across age groups and sectors in Poland in 2006–2020 (%)



Source: Eurostat and Statistics Poland.

Figure 3
Mean of minimum-to-average wage ratio across NUTS-2 regions in Poland in 2006–2020 (%)



Source: Eurostat and Statistics Poland.

Table 1
Share of minimum wage workers and workers receiving more than minimum wage but less than 50% of the average wage in Poland, 2006–2020* (%)

	Share (%) of workers receiving:					
	No more than the minimum wage			More than the minimum wage but less than 50% of the average wage		
	Total	Public	Private	Total	Public	Private
2006	2.5	0.1	4.2	17.4	6.6	24.7
2008	4.2	0.1	6.7	14.3	7.2	18.7
2010	5.0	0.1	8.4	12.8	5.5	17.8
2012	7.6	0.4	11.6	11.3	6.4	14.0
2014	8.6	0.5	12.7	10.4	5.1	13.1
2016	9.0	0.6	12.8	8.5	4.2	10.5
2018	7.6	0.4	10.8	8.6	4.3	10.5
2020	7.8	0.3	11.2	5.6	1.5	7.3

* Data related only to firms with at least ten workers. Data on the share of workers earning minimum wage or more are collected biennially.
Source: Structure of Earnings Survey, different editions from 2006–2020.

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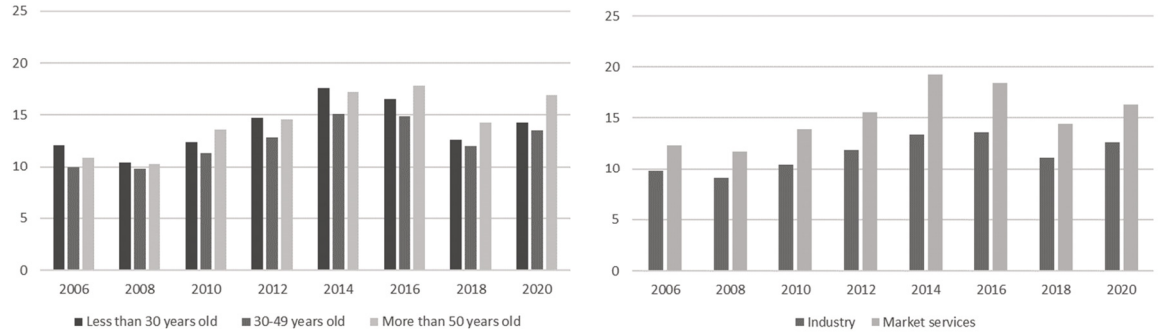
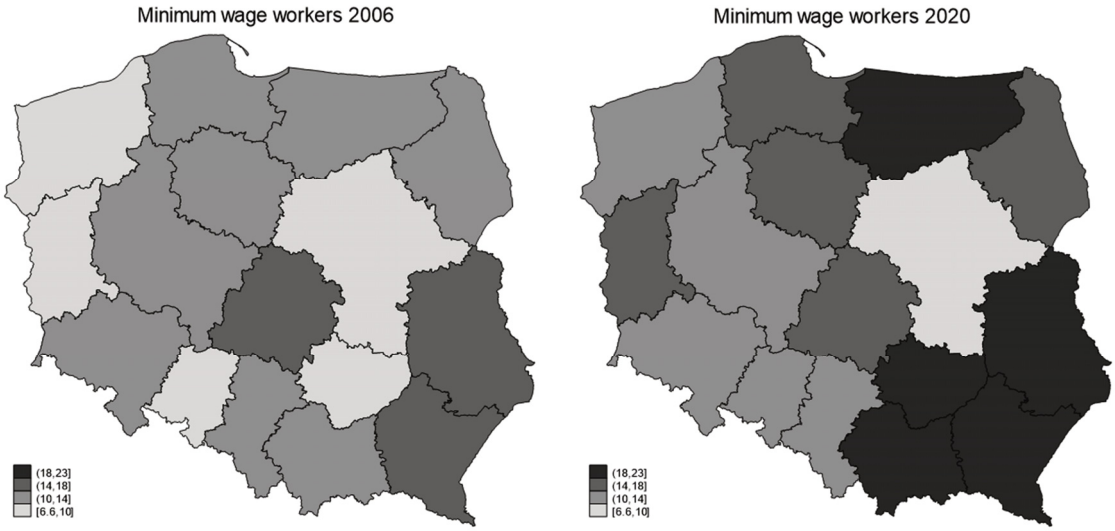
Looking at the distribution of minimum wage workers across regions, age groups, and economic sectors we can notice that both their between-regions and within-region variance is high (see Figure 4 and 5). In contrast to fully developed economies, minimum wage workers in Poland are not concentrated only among young workers; they are in all other age groups. Moreover, in all age groups, the share of minimum-wage workers increased. The share of minimum wage workers is higher in market services than in the industry. Regional differences are significant. In less developed eastern regions of Poland, the share of minimum wage workers reaches or even exceeds 20%. In the Mazowieckie (capital) region, it is below 10% (see Figure 5).

Figure 4
Share of minimum wage workers* in Poland across age groups and economic sectors in 2006–2020 (%)



* According to Eurostat, minimum wage workers are those earning not more than 105% of the minimum wage in a given year.
Source: Structure of Earnings Survey, various editions.

Figure 5
Share of minimum wage workers* in Poland across NUTS-2 regions in 2006–2020 (%)



* According to Eurostat, minimum wage workers are those earning not more than 105% of the minimum wage in a given year.
Source: Structure of Earnings Survey, various editions.

4. DATA AND EMPIRICAL APPROACH

4.1. Data

To identify how the minimum wage affects employment across subgroups of workers, we need comprehensive and reliable wage data on the eligible population and their employment level; thus, we use individual data on wages and employment characteristics from the Structure of Earnings Survey (SES) in Poland. This is part of the large European-wide survey coordinated

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by Eurostat. The SES is a large enterprise sample survey that provides detailed and comparable information on the relationships between remuneration and individual worker characteristics (gender, age, occupation, work experience, and the highest educational level attained, among others) and those of their employers (economic activity, ownership sector, NACE section, size, and enterprise location). The SES covers around 12–15% of all enterprises that employ more than nine workers. We select data from 2006 to 2020; as the SES is conducted biennially, we have eight periods.

The advantages of the database include its high reliability (wages are reported by the accounting departments of the enterprises) and scope. Each sample is very large: over 660,000 observations in 2006 and over 760,000 in 2020. Although the database represents only entities employing more than nine workers, the employment structure in Poland has a very high share of self-employed individuals operating without job contracts (own-account workers). We estimate that the SES database covered 84% of all contract workers in Poland in 2020.[4]

We made adjustments to the initial database. We focused on workers for whom the minimum wage is binding; we excluded workers younger than 18 and workers over retirement age (60 for women and 65 for men) from the initial sample. We included only private sector workers because many public sector workers are not covered by the minimum wage legislation (see section 3 and Table 2). We concentrated on workers in the industry and market services sector, including both full-time and part-time workers; we recalculated the wages of part-time workers as full-time equivalents.

The SES database is our data source for the number of employed workers and their average wages. The other data included in the model (regional and sectoral gross value added, population by age group, and unemployment rate) is based on the 16 regions according to the NUTS2 level of regional classification. They are taken from the Local Data Bank of Statistics Poland, Poland's largest publicly available database on the economy, society, and environment.

4.2. Modelling approach

The SES database provided information about monthly salaries and individual worker characteristics. Since the survey sample is randomly drawn in every reporting period, it is impossible to create a panel of individuals, although it is possible to create different sub-groups of workers, e.g., by age group, economic sector, and region. We constructed three-dimensional cells separately for each year comprising three age groups (up to 30 years, 30–50 years, and 50 years and older), two economic sectors (industry and market services), and 16 regions at the NUTS2 level. We cannot construct finer groups due to the low number of observations in some cells. The cells are our unit of analysis.

We followed the standard approach proposed in the literature and estimated the parameters of the log-linear relationship between employment, our minimum wage measure, and other variables. Following Dickens, Machin, and Manning's (1999) theoretical model, we included both demand and supply-side variables in the model. We used gross value added in economic sectors and regions as a measure of regional and sectoral demand shocks. We also included country time effects[5] to control for aggregate demand shocks. Population size approximates supply shocks. Unemployment rate controls for the size of the labor force available in the regional labor market. To consider differences in the market concentration in regional labor markets, the Herfindahl-Hirschman index (HHI) calculated for 2-digit occupational groups at each cell was included (Munguía Corella, 2020).

[4] According to the data from Statistics Poland, only 34% of workers in micro firms in 2016 were employed on a job contract. Source: https://stat.gov.pl/obszary-tematyczne/podmioty-gospodarcze-wyniki-finansowe/przedsiebiorstwa-niefinansowe/dzialalnosc-gospodarcza-przedsiebiorstw-o-liczbie-pracujacych-do-9-osob-w-2016-roku,1,11.html (in Polish).

[5] For the robustness check we estimated also model with regional trends included. The results are similar and available upon request.

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The 4-dimensional panel data model used in our analyses is expressed as follows:

$$empl_{R,N,A,T} = \alpha_0 + \alpha_1 wrel_{R,N,A,T} + \alpha_2 gva_{R,N,T-1} + \alpha_3 pop_{R,A,T} + \alpha_4 urate_{R,T} + \\ + \alpha_5 HHI_{R,N,A,T} + \sum \delta_{R,N,A} + \sum T_T + \varepsilon_{R,N,A,T}, \quad (1)$$

where:

$empl_{R,N,A,T}$[6] – indicates the logarithm of the number of workers employed in region R ($R = 1, 2, \ldots, 16$), economic sector N ($N = 1$ – industry, 2 – market services), age group A ($A = 1$: less than 30 years, 2: 30–49, 3: 50 and above) in year T ($T = 2006$, 2008, 2010, 2012, 2014, 2016, 2018, 2020);

$wrel_{R,N,A,T}$ – represents the logarithm of the relative minimum wage (minimum-to-average wage ratio) in region R, economic sector N, age group A, at time T;

$gva_{R,N,T-1}$ – indicates the logarithm of gross value added in region R, economic sector N, at time $T-1$ (millions of PLN, constant 2010 prices);

$pop_{R,A,T}$ – denotes the logarithm of the population in region R, age group A, at time T (thousands of people);

$urate_{R,T}$ – is the logarithm of the unemployment rate of male workers of working age in region R, at time T (%);

$HHI_{R,N,A,T}$ – is the standardized Herfindahl-Hirschman index calculated at the 2-digit occupational groups in region R, economic sector N, age group A, at time T;

$\delta_{R,N,A}$ – is the cell specific effect;

T_T – is country time effects;

$\varepsilon_{R,N,A,T}$ – represents the error term.

As a measure of employment, we took the number of workers in a given cell – those employed in enterprises with at least ten workers in the private sector in Poland. Following Caliendo et al. (2018), we used the log employment level, not the employment-to-population ratio, because the latter reflects changes in both employment level and population. We included the population at the cell level as a control variable.

Our minimum wage bite measure is the simplified Kaitz index – the relative minimum wage calculated as the ratio of minimum wage in a given year to the average wage in the previous year for a given cell. We used the difference between the log of the nominal minimum wage level applicable in a given year and the log of nominal average wages in the previous year[7] in a given cell. Since the minimum wage is unique to all workers, the variation in the minimum wage bite measure comes from minimum wage differences over time and the differences in average wages across cells over time.

Our model used the values of current minimum wage bite variables divided by the average wage lagged by one year. In Poland, information on the minimum wage increase for the next year is available usually in September of the previous year (see section 3). By lagging the average wage, we consider that entrepreneurs need time to adjust their firms' policies to upcoming changes in labor costs.

We used gross value added in a given economic sector and region as a measure of demand shock, it can affect employment. It is measured at 2010 constant prices and lagged one period, i.e., two years, to avoid simultaneity problems – a recently increased minimum wage may influence both employment and production levels. Production can be modeled as a persistent stochastic process, and changes in the current minimum wage level do not affect production levels in the previous periods. We used the regional male unemployment rate to approximate the existing

[6] We use small letters for the variables in logarithms, and capital letters for the variables in real values.

[7] Average wages are calculated as the mean of the monthly wage of individuals in a given cell without bonuses.

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surplus of the available labor force. The unemployment rate in the group of men of working age is perceived as more vulnerable to changes in the business cycle (see An et al., 2022).

Following literature, we added measures of supply shocks that affect employment. In particular, information regarding population size in a given age group and region is used to capture the idiosyncratic differences among regions. Population is measured in thousands of inhabitants.[8] The HHI measures the market concentration at the 2-digit level of classification of occupations at every cell defined by region, age group and sector. Descriptive statistics of all the variables used in the model across the cells are presented in Table A1 in the Appendix.[9]

Our main parameter of interest in model (1) is α_1, it shows the direction and strength of the relationship between the minimum wage bite and employment. Our identification strategy is based on Card's (1992) observation that "a rise in local (state) minimum wage will typically affect a larger fraction of workers in some regions (states) than in others". The induced variation creates a simple natural experiment for measuring the effect of a minimum wage change. Intensity of how wages need to change under a new minimum wage should be related to the fraction of workers initially earning less than the new minimum wage (Caliendo et al., 2018). Specifically, intensity with which wages need to change following minimum wage changes is heterogeneous among regions, age groups, and economic sectors. In the cells where the minimum wage *bites* the hardest, adaptations in wages will be stronger, as will those in labor demand.

To test it empirically, we first estimated parameters of equation (1) for the full sample to obtain an average value of the parameter of interest. We assumed homogeneity of the employment elasticity concerning the minimum wage variable across cells, used as the units of observation. However, both theoretical considerations and previous empirical results emphasize that minimum wage increases affect different groups of workers to different extents.

Thus, our second step was to test the slope homogeneity of the coefficient of the minimum wage bite measures across cells using Bersvendsen and Ditzen' (2020) Stata procedure. This method makes it possible to verify slope homogeneity in a panel data context with no correlation (Pesaran and Yamagata, 2008) or use the heteroscedasticity and serial correlation version (Blomquist and Westerlund, 2013), as employed due to the differences in our cell sizes. The influence of control variables such as gross domestic product, population, and the unemployment rate is held constant. We started with 4-dimensional cells to reduce dimensionality if homogeneity were rejected. As the test requires a panel setting, we were unable to eliminate the time dimension.

In the third step, we relaxed the assumption that employment elasticity of the minimum wage variable is homogeneous and allowed parameter α_1 in model (1) to vary first, separately across age groups, sectors, and regions and second, simultaneously across all dimensions. To choose the model that best fits the empirical data, we tested several specifications.[10] We started from the ordinary least squares, tested the presence of fixed and random effect, and finally a generalized least squares (GLS) technique that enables a heterogeneous error structure and panel-specific AR1 autocorrelation was used to correct for heteroscedasticity arising from aggregation and potential autocorrelation. We did not weight the units of observations in the model, and treated each cell as a separate observation since we were interested in estimating employment elasticity separately for each cell and comparing them with each other.

[8] We used yearly average for population and biennial data for the working population so that the data is not influenced by temporary migrations or seasonal work.

[9] Studies on minimum wage impact on employment often include a measure of other institutional variables, such as unemployment benefits, which may impact individuals' employment decisions. Majchrowska and Strawiński (2021) analyzed the impact of unemployment benefits on employment in local labor markets in Poland. They showed that social security benefits do not affect employment decisions there. The replacement ratio of unemployment benefits to minimum wage in Poland is low (41% in 2020), much lower than in Germany (78%) or France (65%; OECD data).

[10] We do not present all estimation results in the text due to limited space; all results are available upon request.

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In the fourth step, we performed a cluster analysis to find out which factors may explain differences in employment elasticity across cells. Then we expanded our model to account for those factors which explain differences in employment elasticity to highest extent.

5. RESULTS

5.1. Employment elasticity across various groups of workers

We first estimated the parameters of model (1) for the sample of private-sector workers grouped in cells. The sample included workers from all 16 NUTS-2 regions, three age groups, and two economic sectors.

Table 2
Results of model (1) with average elasticity of employment in the sample (a) and allowing employment elasticity to vary across age groups (b) and economic sectors (c)

	(a)	(b)	(c)
wrel	0.267*** (0.077)		
*wrel*age1829*		–0.581*** (0.142)	
*wrel*age3049*		–0.549*** (0.135)	
*wrel*age50plus*		0.348*** (0.073)	
*wrel*industry*			0.072 (0.093)
*wrel*market services*			0.375*** (0.082)
Lagged gross value added	0.391*** (0.081)	0.285*** (0.075)	0.511*** (0.084)
Population	0.903*** (0.047)	0.874*** (0.068)	0.891*** (0.045)
Unemployment rate	–0.063** (0.025)	–0.057** (0.023)	–0.053** (0.024)
Herfindahl-Hirschman index	0.032*** (0.007)	0.034*** (0.007)	0.030*** (0.007)
Constant	–4.914*** (1.111)	–0.581*** (0.142)	0.072 (0.093)
N	672	672	672
Cell specific effects	Yes	Yes	Yes
Country time effects	Yes	Yes	Yes

Note: * $p<0.1$, ** $p<0.05$, *** $p<0.01$.
Note: *wrel*age1829* – minimum-to-average wage ratio in the 18–29 age group old; *wrel*age3049* – minimum-to-average wage ratio in the 30–40 age group; *wrel*age50plus* – minimum-to-average wage ratio in the 50–59/64 age group; *wrel*industry* – minimum-to-average wage ratio in the industry sector; *wrel*market services* – minimum-to-average wage ratio in the market services sector.
Source: Own calculations.

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Table 2 presents the estimation results. Column (a) in Table 2 presents the average values of parameters for the analyzed sample. The parameter by the gross value added variable is significant at the 1% significance level and positive. The value of 0.4 indicates that an increase in GVA by 1% was on average accompanied by an increase in total employment by 0.4%, on average. Employment is also positively correlated with population and workers' concentration measure (HHI for occupational groups). The latter shows that higher market concentration comes with higher employment. We also found a negative correlation between the regional *unemployment rate* and the level of employment. All the results are in line with economic theory and other research findings.

Our main parameter of interest (minimum wage employment elasticity) equals 0.27 and is significant at the 1% significance level. The positive sign indicates that, on average, in the analyzed period, a higher minimum-to-average wage ratio was accompanied by higher employment. The positive sign may be because the sample is based on information from all workers: those for whom the minimum wage is binding and those for whom it is not. Literature shows that negative and significant values of minimum wage employment elasticity apply only to the most vulnerable groups of workers (i.e., the young and less educated).

Our model estimated the average employment elasticity affected by minimum wage changes for the full sample, indicating that we assumed homogeneity of employment effects across age groups, economic sectors, and regions (cells) in time – the assumption is not necessarily valid. Therefore, we perform the Blomquivst and Westerlund's (2013) homogeneity test using Bersvendsen and Ditzen's (2020) Stata procedure. Results are summarized in Table A2. They indicate that when observations are divided into 4-dimensional cells, substantial differences in the impact of minimum-to-average wage on employment are observed. A different picture arises for the 3-dimensional cells. The most significant factor that causes diversity of employment effects is regional variation in industry composition and, to a lesser extent, age structure. When regional variation is completely removed from the model, the impact of relative minimum wage on employment remains identical in each cell defined by age group, economic sector, and time. In the model with cells defined by regions and time, homogeneity of the employment effect is not rejected. It implies that the interaction of industry composition and local characteristics is likely to be responsible for the heterogeneous reaction of employment to changes in the minimum wage.

Therefore, in the third step, we relaxed the assumption of homogeneity of employment elasticity for the minimum wage variable and allowed the parameter by the minimum wage variable to vary separately across regions, age groups, and economic sectors. Column (b) in Table 2 presents results for age groups. The parameter by the minimum wage variable is significant for all age groups. The sign of the parameter is negative for young and middle-aged workers and positive for workers aged 50+. The results suggest that if firms dismiss workers, they reduce employment among those who are least costly, i.e., young and less experienced workers. The results indicate that employers do not dismiss experienced older workers since their layoff costs are higher. Subsequently, we allowed the parameter by the minimum wage variable to vary across the two economic sectors (see Column (c) in Table 2). The parameter estimate by the minimum wage variable is insignificant for the industry sector but significant and positive for market services. Lastly, we allowed the parameter by the minimum wage variable to vary across 16 NUTS2 regions. In most regions, the parameter is significant, but interestingly, the sign of the parameter estimate differs; in two regions, it is negative, and in eight, it is positive (see Table 3). The results show that the reaction of employment to minimum wage changes is diversified across age groups, economic sectors, and regions.

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Table 3
Results of model (1) allowing employment elasticity to vary across 16 NUTS2 regions

	Estimated parameters	Standard errors
*wrel*dolnoslaskie*	0.357*	(0.193)
*wrel*kujawsko-pomorskie*	–0.382**	(0.169)
*wrel*lubelskie*	0.340**	(0.160)
*wrel*lubuskie*	–0.385*	(0.224)
*wrel*lodzkie*	1.197***	(0.270)
*wrel*malopolskie*	0.506***	(0.128)
*wrel*mazowieckie*	0.725***	(0.123)
*wrel*opolskie*	0.717***	(0.187)
*wrel*podkarpackie*	0.781***	(0.203)
*wrel*podlaskie*	0.239	(0.179)
*wrel*pomorskie*	0.212*	(0.110)
*wrel*slaskie*	0.462***	(0.102)
*wrel*swietokrzyskie*	–0.291*	(0.156)
*wrel*warminsko-mazurskie*	–0.811***	(0.186)
*wrel*wielkopolskie*	0.840***	(0.138)
*wrel*zachodniopomorskie*	0.121	(0.157)
Lagged gross value added	0.141	(0.097)
Population	0.902***	(0.045)
Unemployment rate	–0.080***	(0.028)
Herfindahl-Hirschman index	0.027***	(0.007)
Constant	–2.088*	(1.266)
N	672	672
Cell specific effects	No	No
Country time effects	No	Yes

Note: * p<0.1, ** p<0.05, *** p<0.01, *wrel*name of the region* – minimum-to-average wage ratio in the given NUTS2 region.
Source: own calculations.

Therefore, in the next step, we extended the analysis and allowed the parameter by the minimum wage variable to vary across age groups, economic sectors, and regions simultaneously:

$$empl_{R,N,A,T} = \beta_0 + \beta_{R,N,A} wrel_{R,N,A,T} + \beta_2 gva_{R,N,T-1} + \beta_3 pop_{R,A,T} + \beta_4 ur_{R,T} + \\ + \beta_5 HHI_{R,N,A,T} + \sum \gamma_{R,N,A} + \sum T_T + \epsilon_{R,N,A,T}. \quad (2)$$

Due to the relatively small number of observations in time,[11] we estimated the average employment elasticity for each cell. Figure 6 presents results for the group of young workers. We can observe negative elasticity of employment for young workers in the industry sector in 11 out of 16 Polish regions. In the other five regions the impact of minimum wage changes

[11] SES is conducted every two years. The research period covers 2006–2020, and we have lagged gross value added in the model; therefore, the number of periods is reduced from eight to seven.

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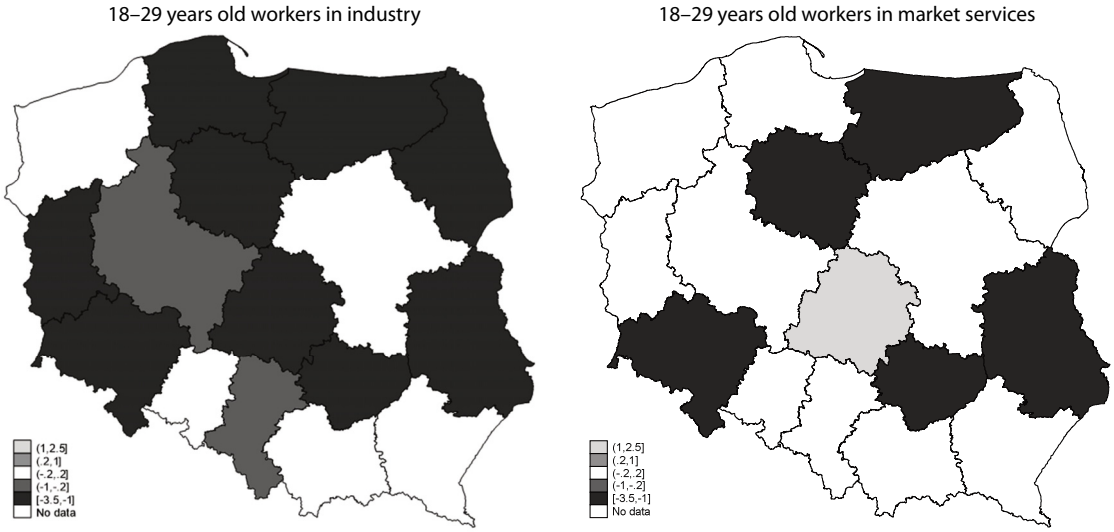
on youth employment was insignificant. The opposite situation was noted in market services. A negative employment reaction among young workers was found only in five regions. In the others the relationship was insignificant.

We observe similar picture in the case of workers aged 30–49. In most of the regions increased minimum-to-average ratio was accompanied by decreased employment of 30–49 years old workers in the industry sector. Similarly as in the case of young, the employment reaction was less pronounced in the market services (see Figure 7).

Figure 6
Elasticity of employment with respect to minimum wage changes for the group of workers aged 18–29 across sectors and regions in Poland (on average, 2006–2020)



Note: Dark colors indicate regions with negative employment elasticity across given age groups and sectors (black: employment elasticity lower than –1; dark grey: employment elasticity between –1 and 0.2). Light colors indicate regional labor markets with positive employment responses (light grey: employment elasticity between 0.2 and 1; medium grey: employment elasticity higher than 1). Areas with insignificant employment effects are in white.

Source: Author's calculations.

Figure 7
Elasticity of employment with respect to minimum wage changes for the group of workers aged 30–49 across sectors and regions in Poland (on average, 2006–2020)

Note: Dark colors indicate regions with negative employment elasticity across given age groups and sectors (black: employment elasticity lower than –1; dark grey: employment elasticity between –1 and 0.2). Light colors indicate regional labor markets with positive employment responses (light grey: employment elasticity between 0.2 and 1; medium grey: employment elasticity higher than 1). Areas with insignificant employment effects are in white.

Source: Author's calculations.

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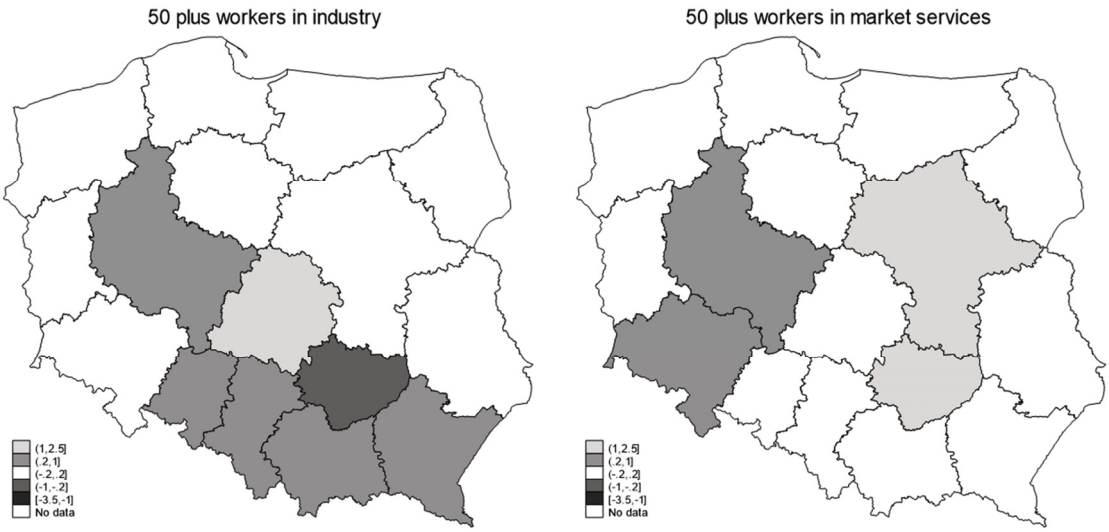
Finally, we observe a completely different picture in the case of workers aged 50 and more. A negative employment reaction in this group was observed only in one, less-developed region. Contrary, in six regions we observe a growth of employment of workers aged 50 and more in the industry sector and in four regions – in the market services. In most of the regions the minimum wage growth did not affect employment among the 50 plus workers either in industry or in market services (see Figure 8).

Figure 8
Elasticity of employment with respect to minimum wage changes for the group of workers aged 30–49 across sectors and regions in Poland (on average, 2006–2020)



Note: Dark colors indicate regions with negative employment elasticity across given age groups and sectors (black: employment elasticity lower than –1; dark grey: employment elasticity between –1 and 0.2). Light colors indicate regional labor markets with positive employment responses (light grey: employment elasticity between 0.2 and 1; medium grey: employment elasticity higher than 1). Areas with insignificant employment effects are in white.

Source: Author's calculations.

The results are in line with theoretical predictions. More negative employment effects are observed in the industry, firms are more exposed to international competition and cannot increase product prices. To maintain profits, they reduce employment among those who are the least costly, i.e., less experienced and less educated workers. We observe the most negative employment effects in underdeveloped regions of Poland, confirming the findings of Majchrowska (2022), who found higher minimum wage pass-through effects on prices in richer, highly developed regions of Poland. For robustness, we estimated cell employment effects in a model with regional trends instead of common time effects included; the results confirm the main findings.[12]

Noteworthy in our approach is that we can see the existing heterogeneity within regions. The differences are undetectable in one- or two-dimensional approaches. Prior studies indicated that, in some regions, regional employment effects were insignificant. Our approach finds that statistically insignificant values of employment elasticity at the regional level very often mask diverse employment effects within the region: across age groups and economic sectors.

5.2. Determinants of differences in employment elasticity

In this part of the study, we aim to ascertain why employment elasticities for groups of workers defined by age and sector differ strongly among regions. In particular, we want to find out why we report negative employment elasticities for young or middle-aged workers in some regions but not in others.

[12] Available upon request.

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To explain the differences in employment elasticity among cells, we performed a k-medoid cluster analysis using the Manhattan distance. We clustered three-element vectors of employment elasticity, the share of workers in manufacturing, and the share of workers employed in the public sector. We chose the best solution according to the Caliński and Harabasz criterion.[13]

Following prior empirical findings, unemployment effects are expected to be more pronounced in industries where it is difficult to pass higher wage costs on to consumers. Therefore, in cells with a larger share of workers employed in the tradable sector, approximated in our study by manufacturing, employment elasticity should also be negative. We expected employment elasticity to be positively correlated with the proportion of workers in the public sector; in less competitive environments – in cells with a higher proportion of workers in the public sector – employment elasticity should be lower than in cells with more private-sector workers.

The cluster analysis results indicate that we should choose the solution with seven clusters. The first comprises two cells with positive employment elasticity, i.e., the cells with middle-aged workers and workers aged 50+ employed in market services in the capital region (Mazowieckie). Another cluster with positive employment elasticity comprises cells mostly of workers aged 50+ in other regions with big agglomerations (Wroclaw, Krakow, Katowice). The cells are characterized by a high share of low-educated workers but also a relatively low share of public sector workers, a low share of workers in manufacturing, and a high share of workers employed in firms with 250 and more employees.

There are also two clusters with strong negative employment elasticity. One group mostly comprises cells for young workers in industry and market services, mostly in underdeveloped regions. The second consists mostly of cells for middle-aged workers in both industry and market services, again mostly in underdeveloped regions. The latter cells are characterized by a high share of employment in manufacturing, a low share of employment in the public sector, and a high share of workers with a low level of education. Unfortunately, the remaining clusters have no clear interpretation.

In the last step of our analysis, we enlarged model (1) by incorporating the labor market characteristics that describe variation in employment elasticity to minimum wage changes. We interacted the relative minimum wage with the share of public sector workers in a given cell. We expected the interaction coefficient to be positive, indicating that elasticity is not as adverse when more public firms are present. If the coefficient of the interaction term is not significant, it may also indicate no heterogeneity in employment elasticity between the public and private sectors. Additionally, we interacted the relative minimum wage with the share of those working in manufacturing and expected the interaction coefficient to be negative. A significant share of firms in the manufacturing sector is exposed to international competition, and if there are increased labor costs, they cannot pass them on to consumers, so they decide to lower their employment.

Table 3 shows results of model (1) with interaction terms included. Each specification contains cell specific effects.[14] The interactions were found to be significant, which is consistent with our predictions. The higher the public sector share, the less negative the employment reaction to minimum wage changes. Conversely, employment elasticity with respect to minimum wage changes is negatively correlated with the share of people employed in manufacturing. The higher the share of workers in manufacturing, the stronger the unemployment effects predicted.

[13] The full results of the cluster analysis are available upon reasonable request.

[14] Table 4 presents results of the model with country time effects. For robustness check we estimated also the model with regional trends. The results are very similar and are available upon request.

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Table 3
Results of Model (1) with interactions included

	(1a)	(2a)	(3a)
Minimum to average wage ratio	–0.857***	3.578***	2.800***
	(0.130)	(0.435)	(0.423)
Lagged gross value added	0.518***	0.306***	0.394***
	(0.066)	(0.080)	(0.069)
Population	0.535***	0.975***	0.639***
	(0.045)	(0.045)	(0.046)
Unemployment rate	–0.062***	–0.065***	–0.079***
	(0.021)	(0.023)	(0.020)
Herfindahl-Hirschman index	0.023***	0.032***	0.025***
	(0.006)	(0.007)	(0.006)
Share of public sector	0.084***		0.067**
	(0.030)		(0.030)
*Share public*wrel*	0.462***		0.421***
	(0.041)		(0.043)
Share of manufacturing		–0.267***	–0.423***
		(0.096)	(0.084)
*Share manufacturing*wrel*		–0.893***	–0.972***
		(0.120)	(0.110)
Constant	–2.131**	–3.826***	–0.427
	(0.881)	(1.193)	(0.999)
N	672	672	672
Cell specific effects	Yes	Yes	Yes
Country time effects	Yes	Yes	Yes

Note. * p < 0.1, ** p < 0.05, *** p < 0.01.
Source: Author's calculations.

6. CONCLUSIONS

Literature shows that negative employment effects are observed among less-skilled and less-experienced workers. Moreover, a growing number of authors underline heterogeneity of the labor markets across regions as a possible source of non-significant employment elasticity at the aggregate level. The paper analyzes which factors determine the size of employment effects with respect to minimum wage increases. We estimate employment elasticities of minimum wage increase for different segments of the labor market in Poland simultaneously and analyze factors behind them.

At first, we assumed homogeneity of employment elasticity of minimum wages. Next, using the Blomquist and Westerlund's (2013) test, we rejected slope homogeneity. We then allowed

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employment elasticity to vary across age groups, economic sectors, and regions simultaneously. It creates a novel four-dimensional approach. Using cluster analysis, we searched for similarities among estimated employment elasticities. Finally, we enlarged our model by incorporating the labor market characteristics that described the obtained clusters of workers. To the best of our knowledge, the study is the first of its kind.

We confirmed regional differences in employment elasticity due to minimum wage changes and discovered latent heterogeneities in the regional employment effects. In many regions, insignificant and close-to-zero overall results include both strongly positive and strongly negative values of employment elasticities due to minimum wage changes for different groups of workers. Finding the heterogeneities would have been impossible without implementing our four-dimensional approach.

Age and sector were found to be the most important determinants of employment elasticity diversity. Negative employment effects were observed mostly among the youngest groups of workers, while positive effects were observed mostly in the groups of workers aged 50+. Among middle-aged workers, both negative and positive reactions were observed. Employment reaction depends also on the economic sector: negative effects are observed more often in industry than in market services. Conversely, positive elasticities are more likely in market services.

We cannot confirm that negative employment effects of minimum wage increases for young workers are observed in all regions. We found out that the employment reaction to changes in the minimum wage is the result of a combination of regional labor market features. In some regions, there are highly intense features that increase probability of negative employment effects; in other regions, the opposite is true.

Negative employment effects are more likely when there is a larger proportion of workers in the private sector, where there are industries in which it is more difficult to increase prices of the goods or services produced, and where small firms are widespread. In the regions, employers act in a highly competitive environment, have more bargaining power, and the probability of unemployment is relatively high for young workers and the middle-aged, and especially for those less educated.

A positive employment effect is more probable in regions with a high share of workers in the public sector and in large enterprises. In the regions, private sector employers have less bargaining power because they have to adjust their wage policy to the public sector wages. Being employed in a big firm also diminishes the probability of dismissal, even among less-educated workers. Significantly, the two completely different labor market segments coexist within a given region, as in Poland, which explains why empirical analyses at the regional level have often resulted in insignificant values for the minimum wage parameter.

The results are important for the minimum wage research. They show that previous analyses at the aggregated (national or regional) level might underestimate employment effects of minimum wage. The small or insignificant employment elasticities obtained might be the result of significant opposing effects across different groups of workers. The multidimensional approach presented in the study enabled us to uncover internal heterogeneities.

The results are also important for minimum wage policies, as they show that minimum wage effects cannot be easily predicted by policymakers. Due to the differences in the characteristics of employers and employees in regional labor markets, the local employment effects of changes in the national minimum wage may substantially differ. Even for workers with similar personal characteristics, the employment reaction may depend on the employer's size, the economic sector, or the degree of local competition. The variety of labor market features that influence employment elasticity makes predicting total effects related to minimum wage changes very difficult.

Our results are also important for policymakers in Poland. They undermine the purposefulness of the regional differentiation of Poland's minimum wage proposal, endorsed by, among others, the OECD, which emphasized: "Consider differentiating the minimum wage across regions depending on local labor market conditions" (OECD 2018). Our results show that finding an

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optimal regional minimum wage rate would be difficult due to large intra-regional heterogeneities in labor markets.

Like most research, our study has some limitations. First, the data used includes only companies with at least ten workers. Unfortunately, individual data on micro-firms in Poland is not available. Small firms are usually found in the market services sector, where labor costs are more important than capital costs, and the firms are probably more intensively affected by minimum wage changes. It may impact results for market services, which we have ascertained can be underestimated. The second limitation stems from the ability to construct only a biannual panel; it does not let us capture very unsuccessful firms that survived for a short time. Third, there is a discrepancy in the data¾since workers are identified in the data through their firms, we inferred the location of a worker's residence as the same as that of the firm. However, workers can commute to work over long distances, and therefore, spatial interactions should be considered. As it is a very broad issue, it could be the subject of future research.

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APPENDIX

Table A1
Descriptive statistics of the variables used in the model

		N = 768 / n = 96 / T = 8			
		Mean	**Standard deviation**	**Minimum**	**Maximum**
Number of employed (number of workers)	overall	49,832	54,390	4,538	514,313
	between		53,000	6,846	370,172
	within		13,224	–111,795	193,973
Minimum-to-average wage ratio (%)	overall	47.1	9.5	20.1	76.0
	between		7.9	24.0	67.5
	within		5.3	28.7	63.4
Gross value added (millions of PLN constant 2010 prices)	overall	35,586	34,350	6,346	235,409
	between		33,503	9,006	184,881
	within		8,225	–11,963	86,113
Population (number of people)	overall	501,426	302,147	125,885	1,721,540
	between		300,166	168,972	1,570,209
	within		44,894	313,801	669,541
Unemployment rate (%)	overall	7.8	3.5	1.7	16.7
	between		1.3	5.5	10.3
	within		3.3	1.8	16.0
Herfindahl-Hirschman index	overall	0.09	0.02	0.05	0.21
	between		0.02	0.06	0.19
	within		0.01	0.05	0.18

Note. The Herfindahl-Hirschman index is calculated for 2-digit occupational groups.
Source: Authors' calculations.

Table A2
Results of the Blomquist and Westerlund (2013) homogeneity test

Dimensions	**Number of cells**	**Delta**	**p-value**
4: Region, Age, NACE, Time	16 x 3 x 2 = 96	4.296	0.000
3: Age, NACE, Time	3 x 2 = 6	–1.323	0.186
3: Region, NACE, Time	16 x 2 = 32	2.274	0.023
3: Region, Age, Time	16 x 3 = 48	3.668	0.000
2: Region, Time	16	0.815	0.415

Note: Null hypothesis: Slope homogeneity.
Source: own calculations.

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