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HETEROGENEOUS EMPLOYMENT EFFECTS OF MINIMUM WAGE POLICIES

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Heterogeneous employment effects of minimum wage policies

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Abstract: We explain the variations in the employment effects with respect to minimum wage changes among different groups of workers. Prior analyses considered only two dimensions, investigating employment effects over time across groups of workers or regions. We propose a multidimensional panel data approach to simultaneously analyze the heterogeneous employment effects of minimum wage changes across age groups, economic sectors, and regions over time. Latent heterogeneities in regional employment reactions are discovered, indicating that the employment effect in the regional labor market is the result of a combination of specific labor market features related to the composition of workers and employers.

Keywords: Employment elasticity, minimum wage, regional labor markets, latent heterogeneities, intra-regional differences, Poland

JEL codes: R23, J21, J31, J38

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I. Introduction

The study aims to analyze and explain the differences in elasticity of employment with respect to minimum wage changes across different groups of workers. Previous literature shows that negative elasticities are expected for less-skilled and less-experienced (younger) workers. Many authors underline the heterogeneity of local labor markets and point to this effect as a cause of lack of consistency among minimum wage elasticity estimates. In our approach, we take advantage of an extensive database of individual wages and employment characteristics and simultaneously analyze the effects of minimum wage changes on employment across four dimensions. We construct a panel using three-dimensional cells formed by 3 age groups, 2 economic sectors, and 16 regions, separately for each year. These cells are our units of observation.

Most prior analyses of how minimum wage changes affect employment have considered only two dimensions, investigating employment effects over time across, for example, age groups, educational groups, or regions. This study adopts a multidimensional panel model to account for latent heterogeneities in the minimum wage effects on employment. Given the contentious background in the minimum wage and employment literature, Wang et al. (2019) argue that the versatility of a panel model in accommodating heterogeneity offers a fresh approach to this long-standing issue.

This multidimensional approach enables an analysis of differences in employment elasticities with respect to relative minimum wages across regions, economic sectors, and age groups. Moreover, we can simultaneously analyze the differences in employment effects within regions: such as, for the same age groups but in different sectors, or in the same sector but for different age groups. For example, we compare the employment elasticity in a group of young workers in an industry in a given region to that of a corresponding group in another region. We can also compare the employment elasticity in a group of young workers in an industry in a given region with the employment elasticity in a group of middle-aged or older workers in the same industry and region. Thus, we can conduct these analyses for all age groups, all economic sectors, and all regions.

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

This study presents the empirical application of this approach in the Polish labor market. Analyzing the employment effects of minimum wage changes in Poland is interesting for several reasons. First, the minimum wage policy, which is 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, its coverage is extensive. According to Eurostat data, Poland's share of minimum wage workers is one of the highest of all European economies.[1] Third, there has been a sustained increase in the national minimum wage in Poland in recent years. Fourth, Poland exhibits large and enduring regional differences.

The majority of research concerning regional effects of minimum wage refers to the US and German labor markets. Polish labor market differs from the US and European labor markets in some key aspects: agriculture's share of employment[2] is higher (a few times higher than in France or Germany), and the share of self-employed (own-account) workers is the one of the highest in the EU (more than two times higher than in Germany).[3] Moreover, many public sector workers are not covered by the minimum wage legislation. Therefore, the minimum wage policy affects a lower share of workers than in other countries.

The Polish regions are strongly diversified. On the one hand, there are agricultural regions accounting for more than 30% of the employed. On the other hand, there are industrial regions where the majority of workers are employed. This strong diversification makes regional labor markets differentially sensitive to the national minimum wage policy. The study adds value by explaining how the differences in the regional structure of employment affect employment elasticity in different age groups and different economic sectors.

We used data on individuals from the Structure of Earnings Survey, the most comprehensive and reliable database on individual wages in Poland. We analyzed employment in non-agricultural private sector firms with at least 10 workers, computing precise minimum wage bite measures based on regional, sectoral, and age-group wage distributions. We constructed two minimum wage bite indicators—nominal and real relative. The latter uses both real minimum wages and real average wages (with different deflators), thereby creating a more robust measure of minimum wage bites. The research period covers 2006–2016.

[1] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Proportion_of_employees_earning_less_than_105_%25_of_the_minimum_wage,_October_2018_(%25).png

[2] In 2020, the share of agriculture in employment was 9.4% in Poland, much higher than, for example, in France (2.2%) or Germany (1.1%; source: Eurostat).

[3] Source: Eurostat.

We began by estimating the average employment elasticity with respect to minimum wages for all cells before applying the slope homogeneity verification test for panel data recently developed by Bersvendsen and Ditzen (2020). After rejecting the homogeneity of the employment effect across cells, we simultaneously varied the parameter of the minimum wage variable across cells (age group, economic sector, and region). Then, we performed a cluster analysis to explain the differences in employment elasticity across clustered cells of workers. Finally, we were able to verify how different labor market structures affect employment reaction to minimum wage changes.

Our results confirm the existence of differences in employment elasticity with respect to minimum wages across regions. Moreover, we discovered latent heterogeneities in the regional employment effect, with some regions simultaneously experiencing both negative and positive employment effects of minimum wage changes for different groups of workers. Negative employment effects are observed mostly for youths, while positive employment effects are predominantly in the groups of workers aged 50 and over. Moreover, stronger negative effects are observed in the industry than market services sector.

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 the prices of goods or services produced. Conversely, positive employment effects are more probable in regions with a high share of workers employed in the public sector and large enterprises. Significantly, these 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 this study proceeds as follows. Section 2 contains the literature review. Section 3 describes the data and empirical approach. Subsequently, Section 4 reports the results and robustness analyses. Section 5 concludes.

II. Review of literature

Considerable research has been conducted on the relationship between minimum wages and employment; however, neither the direction nor strength of this relationship has been unanimously determined. Most studies indicate a small and negative impact of minimum wage growth on employment, particularly among the young and less educated (Neumark and Wascher 2007; Kuddo et al. 2015; Broecke et al. 2017; Neumark and Munguia Corella 2019). The finding that young workers are particularly vulnerable to minimum wage changes has been confirmed for many countries. Recently, Kiss (2018), using a sample of EU countries, found significantly higher negative employment elasticities for young workers than for older workers.

A growing number of authors underline the heterogeneity of labor markets across regions as the main source of inconsistent elasticity estimates at the aggregate level. The differences in both personal and firm characteristics cause differences in the distribution of low-wage workers across economic sectors and regions. Therefore, as Autor et al. (2016) argue, changes in minimum wages may have different impacts across regions, and their effect on employment can induce heterogeneous responses. Analyses performed among US regions indicate that employment elasticity due to minimum wage changes is significantly diversified across states (Williams 1993) and counties (Thompson 2009).

Williams (1993) found that elasticity of employment due to minimum wage changes in the US is highly heterogeneous among states, with the lowest elasticity observed in those less developed. Thompson (2009) confirmed the existing differences in employment elasticity with respect to minimum wage across US counties. Numerous studies have been conducted recently on minimum wage effects in Germany. Vom Berge and Frings (2017) found that the minimum wage caused a contraction in employment growth in eastern Germany with a relatively high bite, while the western part experienced no change in employment. These results were confirmed by Ahlfeldt et al. (2018). In Poland, few studies have confirmed significant differences in employment or unemployment elasticity across regions due to minimum wage increases (Melnyk 1996; Majchrowska and Żółkiewski 2012; Broniatowska et al. 2015; Majchrowska et al. 2016; Albinowski and Lewandowski 2020). All of these studies confirmed differences in regional employment reactions, but not the reasons for these differences.

Numerous studies underline the impact of regional labor market structures on the vulnerability of employment levels to minimum wage changes. 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 negative effects on employment (Munguía Corella, 2020). Many studies have used the monopsony model to explain non-negative results, including studies by Katz and Krueger (1992) and Card and Krueger (1994), and more recently by Dube et al. (2010). Azar et al. (2019) provided empirical evidence supporting 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 the literature may mask heterogeneity across different levels of labor market concentration. Munguía Corella (2020) checked how the effects of minimum wages depend on the monopsony power of the market. He constructed a Herfindahl-Hirschman Index (HHI) that measures the concentration of industrial employment in the US at a county level, and estimated the effect on highly monopsonistic labor markets for different levels of 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 be more negative if the minimum wage was more binding.

In addition to labor market structure, product market structure also matters in the employment effects of minimum wage. Harasztosi and Linder (2019) found that employment reaction varies across countries and industries, and that disemployment 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). Bodnár et al. (2018) analyzed firms' reactions to minimum wage increase across central and eastern European countries. They found that the most popular adjustment channels were raising product prices, cutting non-labor costs, and improving productivity; however, Poland had the highest share of firms that reported laying people off as the relevant adjustment channel. These 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), who showed employment effects monotonically decreasing in absolute terms by firm size: moderate in big firms and higher in small firms. However, Arrowsmith et al. (2003) underlined that the impact of the national minimum wage in small firms can be mediated by the informality of employment relations in those 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 the 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, resulting in an increase in the public sector wage bill[4]. 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) highlighted that if the public sector has inelastic labor demand, the associated non-negative employment effect might offset some of the negative employment effect 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 (2021) recently confirmed these 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.

In our study, we follow 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, and the literature has consistently established negative and significant employment effects on these workers. Therefore, the uneven distribution of young or less-educated workers across economic sectors and regions may result in differences in how the minimum wage impacts employment in particular sectors of regional labor markets. Moreover, the structures of both employers and employees may determine the extent to which minimum wage increases will affect employment. Therefore, we apply a multidimensional approach to consider the potentially differentiated effects of

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

minimum wage changes on employment across different groups of workers and analyze which factors are responsible for the differences.

III. 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 Socio-Economic 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 15. The minimum wage in Poland is established at the national level; it is not differentiated by region, sector, or occupation. However, it is important to note that it 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 amount of increase in price levels projected for the following year plus two-thirds of the forecasted GDP growth rate (Minimum Wage Act of October 10^{t}, 2002 with changes). However, based on the evolution of the national minimum wage in Poland during the period analyzed, we see that the actual annual minimum wage growth usually exceeded the minimum value required by law (Table 1).[5]

Table 1. Minimum wage, HICP and GDP growth for Poland for 2006–2016

	(1)	(2)	(3)	(4)	(5)	(6)
	Minimum wage (PLN)	Minimum wage growth y/y (%)	HICP (%)	GDP growth rate (%)	HICP + 2/3 GDP growth	Difference between (2) and (5)
2006	899	5.90	1.3	6.1	5.4	0.5
2007	936	4.10	2.6	7.1	7.3	-3.2
2008	1126	20.30	4.2	4.2	7.0	13.3
2009	1276	13.32	4.0	2.8	5.9	7.5

[5] We compare the minimum wage growth with actual inflation rate and the actual GDP growth instead of the forecasted ones due to data availability. In most of the periods the differences would be small.

2010	1317	3.21	2.6	3.7	5.1	-1.9
2011	1386	5.24	3.9	4.8	7.1	-1.9
2012	1500	8.23	3.7	1.3	4.6	3.7
2013	1600	6.67	0.8	1.1	1.5	5.1
2014	1680	5.00	0.1	3.4	2.4	2.6
2015	1750	4.17	-0.7	4.2	2.1	2.1
2016	1850	5.71	-0.2	3.1	1.9	3.8

Source: Eurostat and the Central Statistical Office of Poland

In 2006–2007, the minimum wage increases were modest, around 5%. In 2008 and 2009, the national minimum wage in Poland increased by 20.3% and 13.3% yoy, respectively, in nominal terms. The increase is mostly due to a substantial increase that occurred between 2008 and 2009.[6] After adjusting for the consumer price index, the real minimum wage increase was still significant: 16% and 10%, respectively (Figure 1). In the following years, the minimum wage growth rate was lower than in 2008–2009, but in almost all years, it exceeded the rule.

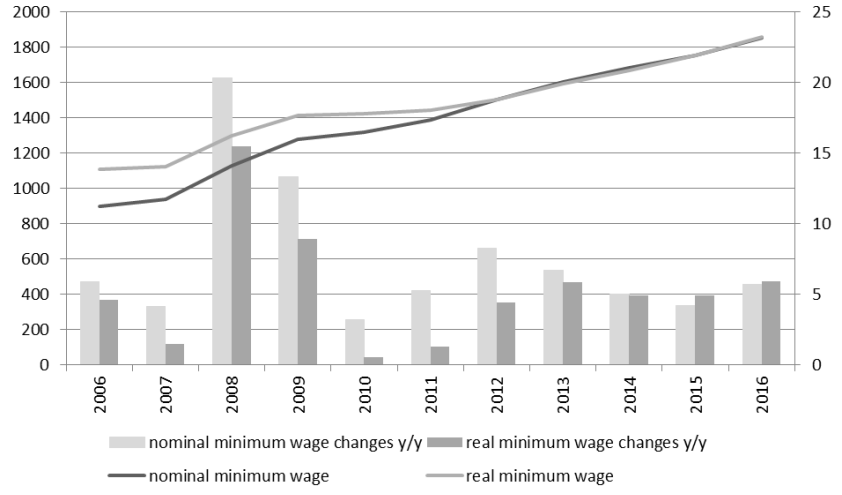

Figure A1.1. Minimum wage level (left scale, PLN) and minimum wage growth (right scale, %) in Poland (2006–2016)

Source: Eurostat and Central Statistical Office of Poland data; author's calculations.

[6] A very large increase in 2008 was the result of bilateral agreements between the government and trade unions. In 2009, the government made concessions to trade unions, which forced a further increase in the minimum wage in Poland. Source: https://wynagrodzenia.pl/artykul/dynamika-placy-minimalnej-w-polsce-i-w-unii-europejskiej (in Polish).

The minimum wage growth led to an increase in the share of minimum wage workers. In 2006, they accounted for 2.5% of all workers employed in firms employing at least 10 workers; the proportion reached 9.0% in 2016 (Table 2). Importantly, almost all minimum wage workers are employed in the private sector, while the share of minimum wage workers in the public sector is negligible.

Table 2. Share of minimum wage workers and workers receiving more than minimum wage but less than 50% of the average wage in Poland in 2006–2016*

	Share (%) of workers receiving:					
	Not more than minimum wage			More than 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

* Data relate only to workers employed in firms with at least 10 workers. Data on the share of workers earning minimum wage or more are collected biannually.

Source: Structure of Earnings Survey, different editions from 2006–2016.

IV. Data and modeling approach

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. The SES is a large enterprise sample survey that provides detailed and comparable information on the relationships between the level of 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, size, and location of the enterprise). The SES, conducted biennially,

covers around 12–15% of all enterprises that employ more than nine workers. We select data from 2006 to 2016, a total of six periods. The advantages of this database include its high reliability and scope; the former comes from the fact that wages are reported by the accounting departments of the enterprises. Each sample is very large—over 660,000 observations in 2006 and nearly 800,000 in 2016.

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). However, the authors estimate that the SES database covers nearly 90% of all contract workers in Poland.[7]

We made adjustments to the initial database. First, we focused on workers for whom the minimum wage is binding; we exclude workers younger than 18 and workers above the retirement age (60 for women and 65 for men) from the initial sample. Second, we included only private sector workers because many of the public sector workers are not covered by the minimum wage legislation (see section 3 and Table 2). Third, we included those employed in non-agricultural sectors. Fourth, we included both full-time and part-time workers, but recalculate the wages of part-time workers as full-time equivalents.

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

From the SES database, we obtained information about monthly salaries and individual worker characteristics. Since the survey sample is randomly drawn every reporting period, it is impossible to create a panel of individuals. However, it is possible to create different sub-groups of workers, such as by *age group*, *economic sector*, and *region*. We constructed three-dimensional cells separately for each year comprising 3 age groups (up to 30 years, 30–50 years, and 50 years and older), 2 economic sectors (manufacturing and construction, and market services), and 16 regions at the NUTS2 level. These cells are our unit of analysis. A drawback

[7] According to the data from the Central Statistical Office in 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).

of cells is that we cannot use variables used to construct cells as explanatory variables in the model.

We followed the standard approach proposed in the literature and estimate the parameters of the log-linear relationship between employment, our minimum wage measure, and other variables. In particular, following the theoretical model proposed by Dickens et al. (1999), 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 local and sectoral demand shocks. We also included country or regional time effects to control for aggregate or local demand shocks. *Population size* approximates supply shocks. *Workers' unemployment rate* approximates business cycle changes. The 4-dimensional panel data model we used in our analyses is expressed as

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

where $empl_{R,N,A,T}$ indicates the logarithm of the number of workers employed[8] in region R (R=1, 2, …, 16), economic sector N (N=1 – industry and construction, 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);

$wrel_{R,N,A,T}$ 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;

$gva_{R,N,T}$ indicates the logarithm of gross value added in region R, economic sector N, at time T (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);

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

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

T_T is country time effects or regional trends;

$\varepsilon_{R,N,A,T}$ 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 10 workers within the non-agricultural, private sector in Poland. Following Caliendo et al. (2018), we used the log employment level, not an

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

employment-to-population ratio, because the latter not only reflects changes in employment levels but also changes in the population. We included population at the cell level as a control variable.

The definition of the minimum wage bite used in the model is crucial to our analysis. Prior studies mainly focus on either the Kaitz index (which measures the ratio between the minimum wage and the mean or median wage adjusted for industry-level coverage) or the proportion of minimum wage workers in the given group—both have advantages and disadvantages (see Caliendo et al., 2018). Our minimum wage bite measure is the simplified Kaitz index—the relative minimum wage calculated as the minimum to average wage ratio for a given cell. For our analysis, we calculated both nominal and real relative minimum wages In the first approach, 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 (average monthly wage of individuals without bonuses) in a given cell. Since the minimum wage is unique to all workers, the variation in this minimum wage bite measure comes from minimum wage differences over time and the differences in average wages across cells over time. This variable—*nominal relative minimum wage*—can be shown as

$$wmin_T - wave_{R,N,A,T} = nwrel \quad (2)$$

where $wmin_T$ is the log of the national minimum wage at time T and $wave_{R,N,A,T}$ is the log of the average wage level in a given cell consisting of region R, economic sector N, and age group A, at time T.

However, as Card and Krueger (1994) observed, in times of prosperity, both employment and average wages rise, causing a decline in the calculated value of the relative minimum wage measure. Similarly, in times of recession, employment and average wages fall, causing a rise in the relative minimum wage. As a result, there is a negative correlation between employment and the relative minimum wage due solely to movements in average wages, regardless of whether employers respond to a higher minimum wage with lower employment or recruitment levels (Belman and Wolfson 2016). Consequently, another method in the literature is to use a real minimum wage measure (Williams 1993)—the ratio of real minimum wage to real average wage. The problem frequently encountered in empirical analyses is the unavailability of regional price indices. We took advantage of the data availability of regional price levels and constructed the real value of the minimum wage and real average wages. The nominator and denominator were deflated using two different price level measures: i) to calculate the real regional average wage, we used the consumer price index published by the

Central Statistical Office of Poland, and, ii) to calculate the real value of the minimum wage at the regional level, we used the information on the minimum subsistence (social) level calculated by the Institute of Labor and Social Studies (see Appendix 1 for more information). The rationale for using two different deflators is straightforward: if we divide the numerator and denominator by the same deflator value, there will be no change at all.

Therefore, for the second approach, we calculated the difference between the log of the real minimum wage in a given region *R,* at time *T* and the log of the real average wage in a given cell. This variable—*real relative minimum wage* —is shown as

$$real\_wmin_{R,T} - real\_wave_{R,N,A,T} = rwrel \quad (3)$$

where $real\_wmin_{R,T}$ is the log of the real minimum wage (nominal minimum wage deflated by the regional price level calculated from the social minimum) in a given region *R*, at time *T,* and $real\_wave_{R,N,A,T}$ is the log of real average wage (nominal average wage deflated by the regional CPI) level in a given region *R*, economic sector *N*, age group *A*, at time *T*[9]. From further analyses, the real relative minimum wage is our superior option as the higher quality minimum wage bite measure. However, having these two minimum wage bite measures allowed us to compare whether the employment effects across different groups of workers are systematic. We used the nominal relative minimum wage in the robustness checks.

In our model, we used contemporary values of minimum wage bite variables. In Poland, information on the minimum wage increase for the next year is usually available in June of the previous year (in September at the latest; see section 3). Therefore, entrepreneurs have sufficient 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 a *demand shock,* which can affect employment. It is measured at 2010 constant prices and lagged one period 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 period. We used the regional male unemployment rate as a measure of the regional business cycle. The unemployment rate in the group of men of working age is perceived as the most vulnerable to changes in aggregate demand.

Following the literature, we added measures of supply shocks affecting employment. In particular, information regarding population size in a given age group and region is used to

[9] Although minimum wage is indexed to inflation, in most cases, minimum wage growth was higher than inflation. This enabled us to causally interpret the results of the regression.

capture the idiosyncratic differences among regions. The population is measured in thousands of inhabitants.[10] Table A1 in Appendix 2 contains descriptive statistics of the variables used in the model across the cells. Table A2 contains additional information about the distribution of employment variables across age groups and economic sectors.[11]

Our main parameter of interest in Model (1) is α_1, which 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. The 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, the intensity with which wages need to change following minimum wage changes is heterogeneous among regions, age groups, and economic sectors. In those cells where the minimum wage *bites* the hardest, adaptations in wages will be stronger, as will those in labor demand.

To test this empirically, we first estimated the 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, which we 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 the method recently developed by Bersvendsen and Ditzen (2020). This method allows verification of slope homogeneity in a panel data context with no correlation (Pesaran and Yamagata 2008), or use of the heteroscedasticity and serial correlation version (Blomquist and Westerlund 2013), which we 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,

[10] We used yearly average for population and biannual data for the working population so that the data are not influenced by temporary migrations or seasonal work.

[11] Studies on minimum wage impact on employment often include a measure of other institutional variables, such as unemployment benefits, that may have impact on employment decision of individuals. Recently, 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 in Poland. 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%).

so that if homogeneity were rejected, we reduced dimensionality. As the test requires a panel setting, we were unable to eliminate the time dimension.

In the third step, we relaxed the assumption of homogeneity of the employment elasticity of the minimum wage variable and allowed the parameter α_1 in Model (1) to vary simultaneously across age groups, economic sectors, and regions. This step allows us to discover heterogeneities which are latent at the regional level. A generalized least squares technique that allows for a heterogeneous error structure was used to correct for heteroscedasticity arising from aggregation. 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.

In the fourth step, we performed cluster analysis and tested the significance of the different regional employment structures on the employment elasticity with respect to minimum wage.

V. Empirical analyses

We first estimated the parameters of Model (1) for the full sample of non-agricultural, private-sector workers in Poland grouped in cells. The real relative minimum wage was used as our main minimum wage bite measure (nominal relative minimum wage is used as a robustness check). The sample included workers from all regions, all age groups, and all economic sectors as defined. To choose the model that best fits the empirical data, the following different specifications were tested: (a) with no cell fixed effects and no time effects, (b) with time effects only, (c) with cell fixed effects only, (d) with both cell fixed effects and time effects, and (e) with cell fixed effects and with region specific time trends instead of country time effects.

Table 2 presents the estimation results for all specifications. In the models without cell fixed effects, (a) and (b), the coefficient of the minimum wage variable is negative and significant. When cell fixed effects are introduced into the model, the results change substantially. The relationship between employment and the relative minimum wage becomes insignificant, independent of time effects. The cell fixed effects are significant in all specifications where they are included. Moreover, region specific time trends seem to better reflect the trends in local labor markets than country time effects. Therefore, our preferable specification contains both cell fixed effects and regional time trends: Model (e) in Table 3.

Table 3. Results of Model (1) with real relative minimum wage bite

	(a)	(b)	(c)	(d)	(e)
rwrel	-0.440***	-0.566***	0.034	0.034	0.157*
	(0.051)	(0.049)	(0.084)	(0.087)	(0.081)
gva(-1)	-0.034	-0.126***	0.372***	0.147	-0.102
	(0.022)	(0.022)	(0.049)	(0.105)	(0.122)
pop	1.357***	1.442***	1.012***	1.068***	1.026***
	(0.029)	(0.026)	(0.080)	(0.078)	(0.074)
urate	-	-0.269***	-0.179***	-0.148***	-0.183***
	0.253***	(0.045)	(0.020)	(0.039)	(0.021)
	(0.030)				
constant	-6.692***	-6.682***	-5.981***	-4.331***	-
	(0.267)	(0.259)	(1.288)	(1.528)	16.159***
					(14.793)
N	480	480	480	480	480
Cell fixed effects	No	No	Yes	Yes	Yes
Country time effects	No	Yes	No	Yes	No
Regional trends	No	No	No	No	Yes

Note. * p<0.1, ** p<0.05, *** p<0.01

Source: Own calculations.

The average employment elasticity for the real relative minimum wage is 0.157, and it is significant at the 10% significance level. The results of the model with the nominal relative minimum wage bite measure are similar, with employment elasticity of 0.179 (see Table A3 in Appendix 2). The sign and the value of the parameter of interest in the full sample follows our intuition and former studies. The sample is based on information from all workers—whether the minimum wage is binding or not. The results of previous research indicate that negative and significant values of employment elasticity for the minimum wage applied only to the most vulnerable groups of workers (young and less educated).

Regarding other variables in the model, we observe that the *gross value added* variable is not significant when country time effects or regional trends are included. Employment is positively correlated *with population* (see Table 3). Moreover, we find a negative correlation

between the local unemployment rate and the level of employment. All the results are in line with economic theory and other research findings.

Our model estimated the average employment elasticity affected by minimum wage changes for the full sample, indicating that we assumed the homogeneity of employment effects across age groups, economic sectors, and regions (cells) in time—this assumption is not necessarily valid. Therefore, we performed the Bersvendsen and Ditzen (2020) homogeneity test. The results, summarized in Table A4 in Appendix 2, indicate that when observations are divided into four-dimensional cells, there are substantial differences in the impact of minimum to average wage on employment. A different picture arises in the case of three-dimensional cells. The most significant factor causing the diversity of employment effects is regional variation in industry composition and age structure. When these were removed from the model, the impact of relative minimum wage on employment remained identical in each cell defined by age group, economic sector, and time. Moreover, in the model with cells defined by regions and time, the homogeneity of employment effect was rejected.

Therefore, in the third step, we relaxed the assumption of the homogeneity of employment elasticity for the minimum wage variable across cells and simultaneously allowed the parameter α_1 to vary across age groups, economic sectors, and regions:

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

The parameter of the relative minimum wage variable was now allowed to vary across cells. However, because we only had six time periods, we estimated the average employment elasticity for each cell in a given time period. The estimation results of the elasticity of employment due to minimum wage changes are presented in Figure 2[12]—the elasticity of employment differs considerably across cells.

[12] The estimated values of the minimum wage variable parameters are presented in Appendix 2, Table A4.

Figure 2. Elasticity of employment for the real relative minimum wage across 3 age groups, 2 economic sectors, and 16 regions in Poland (2006–2016)

Note. Darker colors denote regions with negative employment elasticity across given age groups and sectors. Lighter colors indicate regional labor markets with positive employment responses. Small, mostly insignificant, employment effects are indicated in white.

Source: Author's calculations.

Indeed, young workers (aged less than 30) in the industrial and market services sectors are the most vulnerable to minimum wage changes (Figure 2). Some regions indicate employment elasticities less than -1, while the employment effect is weaker in others. In general, however, in most regions, we find negative employment elasticities for young workers regardless of the economic sector. Middle-aged workers (30–49 years) are also affected by changes in the minimum wage but to a lesser extent. In about half the regions, employment elasticities for this group of workers are negative regardless of the economic sector; in the remaining regions, the reaction was either positive or insignificant. For workers aged 50 and older in industry, we observe negative employment effects due to minimum wage changes in only three regions, and the elasticity is between -1 and -0.2. In market services, in all almost all regions, positive and significant or insignificant relationships are noted for this age group. For robustness, we estimated models with the nominal instead of the real relative minimum wage; these results confirm the main findings (Figure A2 in Appendix 2).

Noteworthy in our approach is the fact that we can see the existing heterogeneity within regions. These differences are undetectable in one- or two-dimensional approaches. Prior studies indicated that, in some regions, employment is unaffected by minimum wage changes. In contrast, our approach finds that statistically insignificant values of employment elasticity at the regional level very often completely mask diverse employment effects within regions across age groups and economic sectors.

The crucial question is why do employment elasticities differ strongly among regions. Why do minimum wage changes negatively affect young workers in some regions but not in others? Why are middle-aged workers in some regions negatively affected by the minimum wage change but not in others? Why are negative relationships between youth employment and the minimum wage observed in the industrial sector and not in market services in some regions, and vice versa?

To explain these differences in employment elasticity among cells, we further investigated their employment structures. We considered the available data on both employers' and workers' characteristics, including educational structure (share of the population with lower than secondary education), employer size (small versus large firms), and the proportion of workers in the agricultural, manufacturing, and public sectors. We also utilized the proportion of minimum wage workers and the minimum to average wage ratio as measures of bindingness.[13]

Following prior empirical findings (see Section 2), we had expected less-educated workers to be more vulnerable to minimum wage changes, with cells containing a larger share of workers with lower than secondary education indicating greater elasticity of employment. Disemployment 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, the elasticity of employment should also be greater. Similarly, following the empirical evidence, we expected large enterprises to pay higher wages than small firms, given a higher elasticity of employment. Conversely, we expected employment elasticity to be positively correlated with the proportion of workers in the public sector. We expected that in less competitive environments—in cells with a higher proportion of workers in the public sector—the elasticity of employment is lower than in cells with more private-sector workers. Similarly, we expected employment elasticity to be lower in regions with a larger proportion of agricultural workers.

We performed a k-medoid cluster analysis using the Manhattan distance method. We clustered employment elasticities using all factors as data group determinants separately for

[13] We also considered the use of the Hershman-Herfindahl Index (HHI) to measure local monopsony power (see Corella 2020). Unfortunately, due to its representative character, our data cover only 12–15% of all enterprises. Since the sample is drawn independently every period, the shares of small, medium, and large firms may differ. The values of HHI may therefore change over time not due to changes in the monopsony power, but for changes in the sample structure.

each elasticity interval,[14] and chose the best solution according to the Caliński and Harabasz criteria.[15]

The cluster with the highest negative elasticity of employment (less than -1) is composed of young and middle-aged workers. These cells are characterized by a low proportion of workers in the public sector and a relatively high share of employment in manufacturing, which indicates that the effect on employment is greater in a more competitive environment. To a large extent, these cells consist of low-wage workers, especially among the middle-aged and with a relatively high minimum-to-average wage ratio. In these cells, we observe a relatively high proportion of workers in small firms. Interestingly, the group with remarkably high employment elasticities consists of practically the same number of industrial and market services cells.

The cluster with a lower, but negative, elasticity of employment [from -1 to -0.2) includes workers across all age groups. Their characteristics are similar to those noted in the first cluster. This cluster consists of two sub-clusters: i) mostly less-educated middle-aged and older workers, and, ii) young, better-educated workers employed mainly in low-paying jobs. The relationship of the minimum-to-average wage in both sub-clusters is high, as is the share of minimum wage workers. A significant proportion of them are also employed in small manufacturing firms, factors that make these workers vulnerable to minimum wage changes.

Although these clusters have negative employment elasticities, there is a comparable number of cells where employment positively reacts to minimum wage changes. The cluster with the highest (above 1) and the second highest (between 0.2 and 1) positive elasticity of employment consists of middle-aged workers and those aged 50 and older. Positive values of employment elasticity are noted both in the industrial and market services sectors. These cells are characterized by a relatively large share of those employed in big firms (250 or more workers) where both the propensity to and possibility of dismissing workers are lower than in smaller enterprises. Moreover, these cells exhibit the highest share of workers in the public sector, suggesting that private employers are likely to follow public sector wage policy. These features explain why we do not observe negative employment elasticity in these cells despite a sizable proportion of low-wage workers.

In the last step of our analysis, we enlarged model (1) by incorporating those labor market characteristics that appeared to influence the employment reaction to minimum wage changes in the cluster analysis. We added the interaction terms to equation (1) of the relative minimum wage with cell specific characteristics.

[14] Intervals used: $(-\infty, -1)$; $[-1, -0.2)$; $[-0.2, 0.2]$, $(0.2, 1]$, $(1, \infty)$.
[15] The full results of the cluster analysis are available upon reasonable request.

First, 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 can also indicate no heterogeneity in employment elasticity. Second, we interacted the relative minimum wage with the share of workers employed in small firms (10–19 workers). We expected the interaction coefficient to be negative, indicating a stronger employment reaction as the share of those employed in small firms is higher. Third, we interacted the relative minimum wage with the share of those working in manufacturing; again, we expected the interaction coefficient to be negative.

Table 4 shows the results of model (1) with interactive terms included. For a robustness check, we present two versions of equation (1), with country time effects and regional time effects. Each version also contains cell fixed effects. Two interactions are found to be significant, consistent with our predictions. The higher the public sector share, the lower the employment reaction to minimum wage changes. Conversely, employment elasticity with respect to minimum wage changes is negatively correlated with the share of those employed in small firms. The higher the share of workers employed in small enterprises, the stronger disemployment effects are predicted. The interaction term of minimum wage variable with the share of employed in manufacturing seems to be vulnerable to inclusion of regional trends. When regional trends are included in the model, it is not significant. Conversely, in specification with country time effects, the higher share of workers in manufacturing strengthens the negative employment reaction, accordingly to our predictions.

Table 4. Results of Model (1) using the real relative minimum wage bite with interactions included

	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
rwrel	-0.759***	-1.000***	0.869***	0.777***	1.831***	0.714	1.925***	-0.129
	(0.151)	(0.136)	(0.218)	(0.242)	(0.616)	(0.627)	(0.569)	(0.553)
gva(-1)	0.166*	-0.124**	-0.162	-0.536***	0.234**	-0.120	-0.056	-0.535***
	(0.099)	(0.100)	(0.106)	(0.125)	(0.098)	(0.119)	(0.083)	(0.107)
pop	0.724***	0.587***	1.048***	1.053***	1.122***	1.031***	0.898***	0.596***
	(0.082)	(0.078)	(0.072)	(0.078)	(0.078)	(0.078)	(0.073)	(0.083)
urate	-0.126***	-0.173***	-0.107***	-0.136***	-0.104***	-0.151***	-0.025	-0.097***
	(0.037)	(0.018)	(0.035)	(0.021)	(0.037)	(0.022)	(0.031)	(0.019)
sh_public	0.085**	0.188*					0.067	0.221***
	(0.042)	(0.037)					(0.043)	(0.047)
*sh_public*rwrel*	0.388***	0.473***					0.333***	0.505***
	(0.055)	(0.049)					(0.054)	(0.059)
sh_1019			-0.511***	-0.446***			-0.380***	-0.375***
			(0.070)	(0.072)			(0.074)	(0.071)
*sh_1019*rwrel*			-0.313***	-0.264***			-0.202**	-0.241***
			(0.077)	(0.084)			(0.083)	(0.082)
sh_manu					-0.032	0.148	-0.172	0.216
					(0.146)	(0.149)	(0.131)	(0.134)

*sh_manu*rwrel*					-0.490***	-0.162	-0.561***	-0.124
					(0.167)	(0.168)	(0.151)	(0.154)
constant	-0.537	39.817***	0.407	-66.016***	-5.889***	-26.316***	1.013	-22.593
	(1.464)	(12.395)	(1.653)	(14.760)	(1.508)	(15.086)	(1.426)	(14.200)
N	480	480	480	480	480	480	480	480
Cell fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country time effects	Yes	No	Yes	No	Yes	No	Yes	No
Regional time trends	No	Yes	No	Yes	No	Yes	No	Yes

Note. * p<0.1, ** p<0.05, *** p<0.01

Source: Author's calculations.

VI. Conclusions

Our study aimed to analyze and explain the differences in employment elasticity with respect to minimum wage changes across different groups of workers—the first of its kind to the best of our knowledge. At first, we assumed homogeneity of the employment elasticity of minimum wages. Next, using Bersvendsen and Ditzen's (2020) approach, we tested that assumption and rejected slope homogeneity. Then, we constructed a four-dimensional panel to allow employment elasticity to vary across age groups, economic sectors, and regions simultaneously. Next, we explained the obtained results using cluster analysis. Finally, we enlarged our model by incorporating those labor market characteristics that in the cluster analysis appeared to influence the employment reaction to minimum wage changes.

We confirmed the existence of regional differences in employment elasticity due to minimum wage changes. However, we discovered latent heterogeneities in the regional employment effects. We were able to identify regions with insignificant employment elasticities at the overall regional level but existing internal latent heterogeneities. In many of the regions, the 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. This explains why the average employment elasticity value for all groups is small and insignificant. Finding these heterogeneities would be impossible without implementing our four-dimensional approach.

Age is found to be the most important determinant of employment elasticity diversity. Negative employment effects are observed mostly among the youngest groups of workers. Conversely, positive employment effects are observed mostly in the groups of workers aged 50 and older. The additional robustness checks show that they seem to diminish with time. Among middle-aged workers, both negative and positive reactions are observed. However, the employment reaction to changes in the minimum wage is also the result of a combination of regional labor market features. In some regions, there are highly intense features that increase the probability of negative employment effects; in other regions, there are highly intense features that increase the probability of positive employment effects.

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 the prices of goods or services produced, and where small firms are widespread. In these regions, employers act in a highly competitive environment, have more bargaining power, and

the probability of disemployment is relatively high not only for young workers but also for the middle-aged, especially those less educated.

A positive employment effect is more probable in regions with a high share of workers in the public sector, in agriculture, and in large enterprises. In these regions, private sector employers have less bargaining power because they have to adjust their wage policy to the public sector wages or to the income arising from agricultural production. Being employed in a big firm also diminishes the probability of dismissal, even among less-educated workers. Significantly, these 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 obtained are important for minimum wage research. They show that the previous analyses at the aggregated (national or regional) level might underestimate the employment effects of minimum wage. Small or insignificant employment elasticities obtained might be the result of the existence of significant opposing effects across different groups of workers. The multidimensional approach presented in this study enabled us to uncover these internal heterogeneities.

The results are also important for minimum wage policies as they show that minimum wage effects cannot be easily predicted by the policymakers. Due to the differences in employers and employees characteristics at the regional labor markets, the local employment effects of changes in national minimum wage may substantially differ. Even for the workers with similar personal characteristics, the employment reaction may depend on the size of employer, economic sector, or the degree of local competition. The variety of labor market features that influence employment elasticity makes the prediction of 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, among others, by 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 optimal regional minimum wage rate would be difficult due to large intra-regional heterogeneities in the labor markets.

Like most research, our study has some limitations. First, the data used include only companies with at least 10 workers. Unfortunately, individual data on micro firms in Poland are not available. Small firms are usually found in the market services sector, where labor costs are more important than capital costs, and those firms are probably more intensively affected

by minimum wage changes. This may affect market services, which we have ascertained can be underestimated. The second limitation stems from the ability to construct only a biannual panel, not letting us capture very unsuccessful firms that survived for a short time. Third, there is a discrepancy in the data—since workers are identified in the data through their firms, we inferred the location of the 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, which, being a very broad topic, could be the subject of future research.

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Appendix 1. Calculating the minimum wage deflator at the regional level

The Local Data Bank of the Central Statistical Office of Poland (CSO) does not provide any data on regional variations in price levels. The only data at the regional (NUTS2) level includes price dynamics as chain indices. However, to calculate real minimum wages at the regional level, we need data on regional price levels. To overcome this problem and to anchor wage dynamics, we used data from the Institute of Labor and Social Studies (ILSS) on the minimum subsistence (social) level. The social minimum is defined as the bundle of resources needed for a person to lead a minimally decent life in society.[16] The social minimum is calculated separately for different types of households, defined by the number of adults and their ages, and the number of children and their ages. As the information regarding the number of households of different types is not available annually, we computed the average social minimum value for all types of households, excluding retired persons (Figure A1).

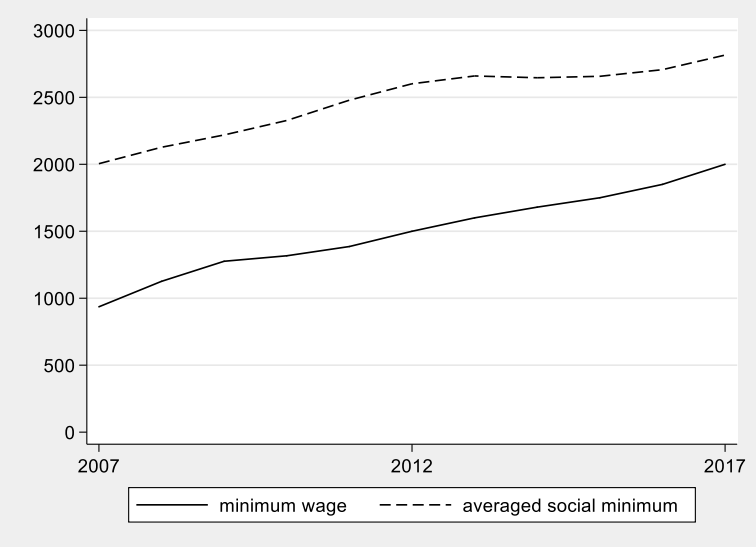

Figure A1. Minimum wage level and social minimum level in Poland (2007–2017) at current prices, PLN

Source: Author's calculations based on CSO data.

Significantly, the dynamics of minimum wage and the average social minimum are quite similar. The actual correlation coefficient between these two measures is 0.96. For instance, until 2012, the social minimum level for a one-person household was about 70% of the minimum wage level. Additionally, the consumption structure of households with a single minimum wage earner is similar to the consumption structure of a social minimum household.

[16] See: https://www.ipiss.com.pl/?zaklady=minimum-socjalne

ILSS provides data on the social minimum not only at the national level but also separately for each NUTS2 region. We used this variation to mimic the variation in the real minimum wage level across regions in the beginning of the period of analysis. For the subsequent years, we used the dynamics of the social minimum to deflate the minimum wage in a given region.

Appendix 2

Table A1. Descriptive statistics of the age group-economic sector-region cells

		N=576, n=96, T=6			
		Mean	**Standard deviation**	**Minimum**	**Maximum**
EMP (number of workers)	overall	48,065	49,760	4538	408,199
	between		48,895	6272	326,111
	within		10,301	-69,501	130,153
NWREL (%)	overall	45.4	9.1	20.1	72.4
	between		7.9	22.4	66.6
	within		4.6	30.5	60.5
RWREL (%)	overall	43.8	8.8	19.7	70.4
	between		8.2	20.8	67.5
	within		3.4	30.7	57.8
GVA (millions of PLN, constant 2010 prices)	overall	33,174	31,229	6,407	200,264
	between		30,835	8,324	169,831
	within		5,718	-174,569	63,607
POP (number of people)	overall	508,703	294,911	150,288	1,652,661
	between		294,462	179,200	1,524,174
	within		31,926	366,669	637,190
UR (%)	overall	9.2	2.9	4.4	16.7
	between		1.4	6.8	12.0
	within		2.5	4.2	15.7
SHARE_1019 (%)	overall	14.4	7.0	3.9	43.5
	between		6.2	6.7	30.8
	within		3.5	2.0	32.5
SHARE_MANU (%)	overall	43.4	9.6	14.2	76.1
	between		8.7	17.7	60.6
	within		4.2	32.3	60.6
SHARE_PUBLIC (%)	overall	14.0	9.8	1.2	51.2
	between		8.3	2.1	39.6
	within		5.3	-0.04	39.1

Note. EMP: number of employed, NWREL: nominal relative minimum wage (ratio of nominal minimum wage to nominal average wage), RWREL: real relative minimum wage (ratio of real minimum wage to real average wage; different deflators used), GVA: gross value added, POP: total population, UR: male unemployment rate, SHARE_1019: share of employed in firms employing 10-19 workers in total employment, SHARE_MANU: share of employed in manufacturing in total employment, SHARE_PUBLIC: share of employed in public firms in total employment.

Source: Author's calculations.

Economic sectors	Age groups	Mean	Standard deviation	Minimum	Maximum	Number of observations
Industrial	18-29	36,162	22,448	9,985	91,756	16
	30-49	81,919	47,765	23,415	206,933	16
	50-60/65	30,907	17,810	8,398	82,725	16
Market services	18-29	45,003	51,065	5,998	239,057	16
	30-49	72,125	77,984	12,321	408,199	16
	50-60/65	22,273	18,157	4,538	90,276	16

Table A2. The descriptive statistics of the employment variables across age groups and economic sectors

Source: Own calculations.

	(a)	(b)	(c)	(d)	(e)
rwrel	-0.354***	-0.645***	0.126	0.063	0.179**
	(0.052)	(0.047)	(0.078)	(0.088)	(0.081)
gva(-1)	-0.006	-0.121***	0.304***	0.147	-0.104
	(0.023)	(0.021)	(0.064)	(0.105)	(0.122)
pop	1.342***	1.424***	1.026***	1.070***	1.026***
	(0.031)	(0.026)	(0.081)	(0.078)	(0.074)
urate	-0.264***	-0.269***	-0.179***	-0.147***	-0.183***
	(0.031)	(0.044)	(0.020)	(0.039)	(0.021)
constant	-6.670***	-6.689***	-5.364***	-4.344***	-10.817***
	(0.280)	(0.255)	(1.342)	(1.527)	(15.166)
N	480	480	480	480	480
Cell fixed effects	No	No	Yes	Yes	Yes
Country time effects	No	Yes	No	Yes	No
Regional time effects	No	No	No	No	Yes

Table A3. Results of Model (1) using the nominal relative minimum wage bite

Note. * p<0.1, ** p<0.05, *** p<0.01

Source: Own calculations.

Dimensions	Number of cells	Delta	p-value
4: Region, Age, NACE, Time	16 x 3 x 2 = 96	9.350	0.000
3: Age, NACE, Time	3 x 2 = 6	1.734	0.083
3: Region, NACE, Time	16 x 2 = 32	5.467	0.000
3: Region, Age, Time	16 x 3 = 48	7.044	0.000
2: Region, Time	16	3.514	0.000

Table A4. Results of the Bersvendsen and Ditzen (2020) homogeneity test

Note. Null hypothesis: Slope homogeneity

Source: Own calculations.

Name of Region	Age group	Industry		Market services	
		Parameter value	Standard error	Parameter value	Standard error
Dolnoslaskie	18-29	-1.538*	0.901	-1.753*	0.983
	30-49	0.960	1.147	-2.210***	0.897
	50 plus	0.187	0.398	2.200***	0.339
Kujawsko-pomorskie	18-29	-1.107*	0.605	-0.528	0.398
	30-49	-2.682***	0.753	0.071	0.345
	50 plus	0.338	0.518	1.119***	0.293
Lubelskie	18-29	-0.536	1.513	-1.376*	0.820
	30-49	0.688	1.679	-0.063	0.727
	50 plus	2.838***	0.695	0.955***	0.274
Lubuskie	18-29	-2.265*	1.377	-0.574	0.962
	30-49	-5.738***	2.088	-0.970	0.751
	50 plus	-0.293	1.857	-0.164	0.518
Lodzkie	18-29	-4.135***	1.642	-5.041	5.302
	30-49	0.233	0.855	-0.541	1.622
	50 plus	-0.686	1.148	-0.253	0.515
Malopolskie	18-29	-1.666*	1.014	-0.634	0.698
	30-49	-0.087	0.738	0.365	0.547
	50 plus	0.708***	0.265	0.227	0.527
Mazowieckie	18-29	-2.045***	0.486	-0.677	0.426
	30-49	-1.611	1.169	-0.364	0.556
	50 plus	0.135	0.666	0.300	0.342
Opolskie	18-29	0.854	0.987	1.112	0.693
	30-49	0.775	0.669	0.746	0.577
	50 plus	1.267**	0.564	1.753**	0.908
Podkarpackie	18-29	-3.043*	1.847	-1.096**	0.455
	30-49	0.065	1.049	-0.099	0.730
	50 plus	1.253***	0.277	0.473***	0.139
Podlaskie	18-29	-2.147**	1.080	0.879***	0.319
	30-49	-2.913**	1.308	1.124***	0.306

	50 plus	0.611	0.730	1.517***	0.381
Pomorskie	18-29	-1.811***	0.481	-1.405	0.895
	30-49	-0.959	1.010	-0.713*	0.418
	50 plus	0.721*	0.409	1.404**	0.673
Slaskie	18-29	-1.427**	0.662	-2.549***	0.580
	30-49	-0.311	0.673	-0.853	0.748
	50 plus	0.583*	0.314	-0.038	0.531
Swietokrzyskie	18-29	-0.824	0.833	-1.318	1.009
	30-49	-0.390	0.424	-2.331***	1.018
	50 plus	0.678*	0.374	0.978	0.607
Warminsko-mazurskie	18-29	0.962	2.396	-0.773**	0.342
	30-49	1.074	1.551	-0.650*	0.397
	50 plus	0.872	0.559	0.772	0.987
Wielkopolskie	18-29	-1.302**	0.627	-0.120	0.405
	30-49	-0.788	1.174	0.690	0.470
	50 plus	0.354	0.489	0.968***	0.270
Zachodniopomorskie	18-29	-2.896**	1.286	-0.488	0.850
	30-49	-3.491***	0.501	-0.519	0.590
	50 plus	-0.868	0.882	0.120	0.289

Table A5. Results of model (1) allowing different employment elasticity across cells (real relative minimum wage used)

Note. * p<0.1, ** p<0.05, *** p<0.01. Source: Own calculations.

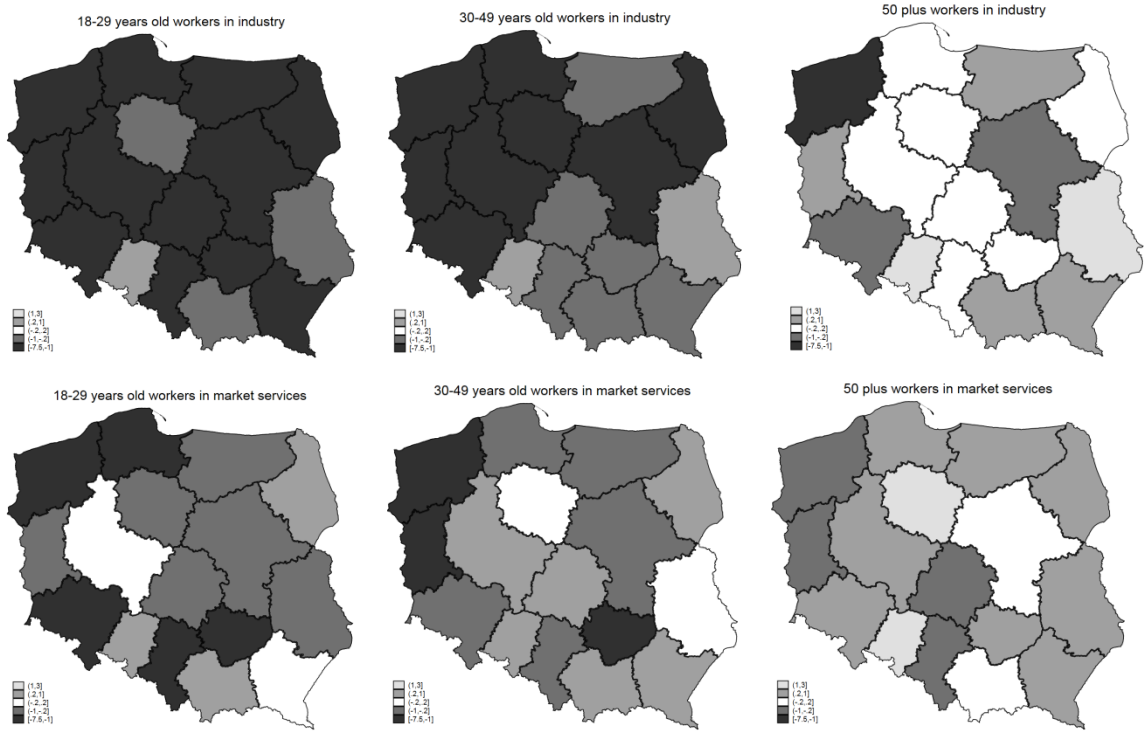

Figure A2. Elasticity of employment with respect to the nominal relative minimum wage across age groups, economic sectors, and regions in Poland (2006–2016)

Note. Dark colors indicate regions with negative employment elasticity across given age groups and sectors. Light colors indicate regional labor markets with positive employment responses. Areas with small and mostly insignificant employment effects are in white.

Source: Own calculations.

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