

A Work Project, presented as part of the requirements for the Award of a Master's degree in
Economics from the Nova School of Business and Economics.

THE CARBON TRANSITION IN THE MANUFACTURING SECTOR AND REGIONAL
EMPLOYMENT DEPENDENCIES: ANALYSING EXPOSURES AND RESILIENCIES OF
GERMAN ADMINISTRATIVE DISTRICTS USING SPATIAL ANALYSIS

NICOLAS GASSEN

Work project carried out under the supervision of:

Antonieta Cunha e Sá
João Manuel Lameiras Vaz

20/12/2023

0. Abstract

We use spatial analysis to identify exposure and resilience of German administrative districts to carbon transition. Regional shares of employment in five energy-intensive industries and the automotive sector are calculated as a measure of exposure. A set of demographic and socio-economic indicators measure the resilience of these administrative districts. Our results show that exposure is concentrated in a few regions. Resilience differs significantly regionally; interestingly, regions with particular industries show remarkably different resilience prospects. We provide granular data to policymakers aiming to sustainably drive carbon transition, highlighting the need for targeted region- and industry-specific policy measures, supporting communities nationwide.

Keywords: Carbon Transition, Manufacturing Sector, Exposure, Resilience, Spatial Analysis, Germany, NUTS3

This work used infrastructure and resources funded by Fundação para a Ciência e a Tecnologia (UID/ECO/00124/2013, UID/ECO/00124/2019 and Social Sciences DataLab, Project 22209), POR Lisboa (LISBOA-01-0145-FEDER-007722 and Social Sciences DataLab, Project 22209) and POR Norte (Social Sciences DataLab, Project 22209).

1. Introduction

Carbon neutral in 20 years – Germany’s current political goal for combating climate change sets an end to net emitting greenhouse gases by the year 2045 (Deutscher Bundestag 2019).

The legislation requires a swift phase-out of greenhouse gas emissions, called carbon transition, implying a structural shift from fossil-fuel dependence to carbon-neutral technologies.

For Germany, as the fourth largest economy in the world, this is a great challenge, particularly for the sectors of the economy that rely the most on fossil inputs and historically embodied them. These industries, at the core of German wealth (Emons, Steinhaus, and Kraft 2022), are unevenly distributed across the country, causing some regions to experience a greater challenge to the carbon transition, as regional dependency on the respective industries varies.

Simultaneously, regional adaptive capacity to this structural change and the deployment of new production technologies varies considerably, translating into heterogeneous regional resilience. Consequently, some regions are more vulnerable to the carbon transition, as they rely highly on fossil fuel-dependent industries and incorporate low transformational resilience.

Historical examples of regions experiencing structural transformations, such as the Ruhr Area, highlight the need for policies supporting the most vulnerable regions to manage such transitions economically and socially successfully (Goch 2014). Therefore, detailed knowledge of exposure and resilience to carbon transition is pivotal to identifying regional needs and thus provides the basis for targeted policies to achieve climate targets.

This paper aims to deliver such information as it analyses regional exposures to six fossil-dependent industries in the manufacturing sector and further assesses the resilience characteristics of the most exposed regions. In doing so, exposure is measured as the share of regional employment in the following industries: “Food, Beverage, and Tobacco Production”, “Paper Production”, “Chemical Production”, “Glass, Ceramics, and Mineral Production”, “Metal Production”, and “Automotive Production”. The six industries are especially exposed to the

carbon transition since their current production and/or products are highly fossil-fuel-dependent, requiring a structural change in production technologies (German Environment Agency 2022; Goch 2014). Our approach further links regional resilience to exposure to identify the regions needing additional support in managing the carbon transition, following frameworks applied by Raimi et al. and Snyder for the United States of America (Raimi, Carley, and Konisky 2022; Snyder 2018). A focus is put on demographics, accounting for their relevance in affecting a region's adaptive ability to changes in the labour market (Federal Agency for Civic Education 2021a; 2021b). Our analysis adds granularity to existing literature, providing industry-specific exposures and resilience characteristics on the level of Germany's 400 administrative districts. It thereby broadens the knowledge of regional heterogeneity in vulnerability to carbon transition and equips policymakers with in-depth information.

We find great heterogeneity in exposures and resiliencies across regions and industries, highlighting the necessity for targeting policies to local needs. Dependencies on employment are concentrated in a few regions, with numerous showing significant exposure to several industries. Clusters of exposures to metal production, and glass, ceramics, and mineral production are worrisome as the affected regions show low resilience. Accordingly, enhanced support for economic development is needed to address such regions' historically weak economic performance. Further, population characteristics differ greatly, underpinning the need to target policies aiming to increase the adaptive capabilities of individuals in the carbon transition through labour market integration and education on local features.

This paper is structured as follows. The first part provides a general overview of the main climate legislation in the European Union (EU) and Germany, the effects of such on economic performance and employment, and existing literature on the exposure and vulnerability of regions in Germany to carbon transition. In the second part, the methodology of this paper is set

out, introducing so-called “Exposure Indicators” and “Resilience Indicators”. The results of the analysis are presented in the third part and discussed in the fourth part.

2. Literature Review

As climate policies stemming from society’s climate goals drive carbon transition, an overview of the main policies in the European Union (EU) and Germany is essential for this study and, therefore, presented in the first section of the literature review. Following in section two, the economic and employment effects of the policies in place and the carbon transition, in general, are evaluated. The understanding of such is hereby crucial for assessing exposure and resilience. Lastly, section three summarises existing literature on German regions' exposure and economic heterogeneity, providing existing findings.

2.1. Carbon transition policies in Germany and the European Union

Germany and the EU take a three-fold approach to decarbonisation by pricing greenhouse gas emissions, incentivising investments into low-carbon technologies, and directly regulating products (Grubb n.d.). First, the European Emission Trading System (ETS) represents climate policy’s centrepiece, driving emissions down using a market-based pricing approach (European Union 2003). Transitional pressure stemming from the ETS is expected to increase as the phase-out in the allocation of free allowances and the broadening of its scope lead to a steeper price trajectory (European Union 2023a; Pahle, Sitarz, and Osorio 2022). Second, investments in low-carbon technologies are actively supported. On the European level, the Just Transition Mechanism and the Recovery and Resilience Facility represent voluminous frameworks that fund member states deploying green investments (European Commission n.d.; European Union 2021). On the German level, the schemes “Gemeinschaftsaufgabe „Verbesserung der regionalen Wirtschaftsstruktur“” (GRW), and “Dekarbonisierung der Industrie” aim at incentivising investments aligned with the carbon transition in economically weak regions and the industry, respectively (Federal Ministry for Economic Affairs and

Climate Action 2023; Federal Ministry of Finance 2022; Federal Ministry of Justice 1969; The Federal Government of Germany 2020b). Lastly, dedicated programmes are launched to support the sectoral transformation in energy-intensive and automotive industries. The so-called “Kohlekompromiss” reached in 2020 determines the phase-out of coal mining in Germany, representing a holistic approach to managing regional structural change (Federal Ministry of Education and Research 2020). In contrast, actions aimed at supporting the climate-friendly transformations of steel production, the build-up of a hydrogen infrastructure, and the electrification of the mobility sector focus solely on incentivising infrastructural investments and demand (Federal Ministry for Economic Affairs and Climate Action 2022; The Federal Government of Germany 2023a; 2022b; 2020a). In addition, to address the employment effects of the carbon transition, a general training offensive is pursued, which has been reinforced by law, but state support measures are rarely utilised (Bundestag 2023; Kruppe, Lang, and Leber 2021; The Federal Government of Germany 2022a).

2.2. Economic and employment effects of carbon transition policies

The EU Emissions Trading System (ETS) is pivotal for driving the carbon transition in the European Union. Numerous studies show the EU ETS has not adversely affected economic or employment performance (Löschel, Lutz, and Managi 2019; Martin, De Preux, and Wagner 2014; Wagner, Rehdanz, and Petrick 2014; Verde 2020). However, these results should be carefully evaluated as findings are based on early ETS phases with low emission coverage and carbon prices (Joltreau and Sommerfeld 2019). In contrast, agreed changes to the EU ETS could alter its future impact, potentially raising carbon prices more swiftly with adverse effects, especially for energy-intensive industries and employment in general (Bassi, Yudken, and Ruth 2009; European Union 2023b; Känzig 2023; Pahle, Sitarz, and Osorio 2022). Considering the employment effects of the carbon transition in Germany a study by Bähr et al. estimates that 1.7 million jobs in the manufacturing sector are at risk due to a persistent

energy price disadvantage to global competitors (Bähr et al. 2023). Besides this wide-ranging threat to employment, Marin and Vona find skill bias in the labour effects of the carbon transition, favouring high-skilled jobs as new technologies are deployed (Marin and Vona 2019). As a result, some individuals incur high transition costs due to reskilling, highlighting the need for targeted public support along the socioeconomic needs (European Commission. Directorate General for Economic and Financial Affairs. 2022; Saussay et al. 2022).

2.3. Exposure and vulnerability to carbon transition in Germany's regions

Economic literature acknowledges significant heterogeneity between German administrative districts regarding economic and living standards. In general, two lines of divergence emerge, one between regions in former East Germany and former West Germany and one between rural and urban areas (European Commission 2022). Simplistically speaking, economically strong regions are concentrated in the south of Germany and surrounding urban centres. The economic division is essentially rooted in four historical circumstances: the division of Germany, the decentralised German “Mittelstand”, demographic change and regional deindustrialisation (Federal Ministry of Food and Agriculture 2020; Goch 2014; Hüther, Südekum, and Voigtländer 2019; The Federal Government of Germany 2023b).

Regional divergence in economic robustness is also observed in regional exposure and vulnerability to the carbon transition, as two analyses from McDowall et al. and the Organisation of Economic Cooperation and Development (OECD) demonstrate, considering employment shares in selected energy-intensive industries (McDowall et al. 2023; OECD 2023). The PPMI Group supports the findings, which calculated the share of regional employment working at installations covered by the EU ETS (European Commission and PPMI Group 2021). Analysing regional exposure to ecological and digital transformation and the structural changes in the automotive sector, Dr Lichtblau et al. identify 117 administrative districts especially exposed (Dr Lichtblau et al. 2022). The reports' findings align with other analyses

showing administrative districts in the south of Germany to be structurally strong, implying greater resilience to the changes ahead. At the same time, regions sprawling from an imaginary line from North Rhine-Westphalia to Brandenburg have the highest vulnerabilities. While existing literature provides a thorough indication of general exposures and vulnerabilities, the density of knowledge fades when looking at the level of administrative districts. This paper aims to provide such granularity by offering industry- and regional-specific indicators for employment exposure to six industries most affected by decarbonisation. Our work adds essential information for policymakers as it assesses regions experiencing the highest vulnerability to the carbon transition by connecting exposure to regional resilience.

3. Methodology

Two categories of indicators are introduced to address our research question. *Exposure Indicators* provide information on employment shares in particularly fossil-fuel-dependent industries at the level of administrative districts. Considering economic and socio-demographic data, Resilience Indicators explore regional vulnerability given the necessary structural shifts in employment and the labour markets stemming from the carbon transition.

3.1. Exposure Indicators

Six exposure indicators are introduced to assess the exposure of administrative districts to the carbon transition in the manufacturing sector. In general, higher shares in the six indicators constructed signal higher regional exposure to the carbon transition in the manufacturing sector as labour markets depend more on an industry undergoing a structural change (Table 1). Each indicator provides information on the share of regional employment in an energy-intensive manufacturing industry. The selection of economic branches is based on the energy intensity of industry, as given by data from the Federal Environment Agency (German Environment Agency 2022). Additionally, automotive production was included, accounting

for the sector's economic relevance to the German economy (Federal Ministry for Economic Affairs and Climate Action n.d.).

The indicators are constructed based on two data sets retrieved from the German Federal Labour Office, providing granular data on employment by profession groups (as of December 2021) and employment by economic subsectors (as of June 2022), respectively (Federal Employment Agency 2023; n.d.). The latter data set seems more suitable for answering the research question since it categorises employment into the considered industries. However, due to data gaps related to automotive production and chemical production, the respective indicators are constructed using employment data by professional groups (Federal Institute for Vocational Education and Training (BIBB) 2010). The “petroleum and coking production” sector could not be assigned to any job group; it is therefore not considered.

The difference in the cut-off dates of the two data sets is not considered a significant issue, as drastic changes in employment in the respective time span from December 2021 to June 2022 are not expected to have occurred. In general, higher shares in the six indicators constructed signal higher regional exposure to the carbon transition in the manufacturing sector as labour markets depend more on an industry undergoing a structural change.

The results are presented through visualisation to show geographical variation. A threshold is introduced to account for the distribution of exposure that concentrates in a few regions. Accordingly, regions with values surpassing the sum of the national average plus two times the standard deviation are considered ‘most exposed’. Lastly, an aggregate of the six exposures is calculated to show overall exposure to the six industries analysed.

Table 1: Exposure Indicators

Dimensions		Description	Rationale
1	Share Employees in Food, Beverage, Tobacco Production	The proportion of employees subject to social security contributions by administrative districts who belong to the economic sectors "10 – Food and animal feed manufacturers", "11 – Beverage production", and "12 – Tobacco processing" (June 2022).	Higher shares may indicate greater exposure and subsequently may justify enhanced policy measures
2	Share Employees in Paper Production	The proportion of employees subject to social security contributions by administrative districts who belong to the economic sector "17 – Manufacture of paper and paperboard Paper, cardboard and paper products" (June 2022).	Higher shares may indicate greater exposure and subsequently may justify enhanced policy measures
3	Share Employees in Chemical Production	The proportion of employees subject to social security contributions by administrative districts who belong to the occupational group "413 - Chemistry" (December 2021).	Higher shares may indicate greater exposure and subsequently may justify enhanced policy measures
4	Share Employees in Glass, Ceramics, Mineral Production	The proportion of employees subject to social security contributions by administrative districts who belong to the economic sector "23 – Manufacture of glass, ceramics, non-metallic mineral products" (June 2022).	Higher shares may indicate greater exposure and subsequently may justify enhanced policy measures
5	Share Employees in Metal Production	The proportion of employees subject to social security contributions by administrative districts which belong to the economic sector "24 – Manufacture of basic metals and fabricated metal products" (June 2022).	Higher shares may indicate greater exposure and subsequently may justify enhanced policy measures
6	Share Employees in Automotive Production	The proportion of employees subject to social security contributions by administrative districts which belong to the occupational groups "251 - Mechanical and industrial engineering", "252 - Vehicle, aerospace and shipbuilding technology", "262 - Power engineering", "273 - Technical production" (December 2021).	Higher shares may indicate greater exposure and subsequently may justify enhanced policy measures

3.2. Resilience Indicators

Thirteen economic and socio-economic indicators are introduced to assess regional resilience. Each indicator provides data on one aspect of resilience in the context of the carbon transition, contributing to constructing a granular picture of disparities between administrative districts, thus offering detailed information for targeting policies to local needs.

As the reliance of regional labour markets on fossil-dependent industries is the measure of exposure, the assessment of the resilience of administrative districts focuses on the adaptive capacity of these to changes in employment and labour demands. For this reason, a focus is put on demographic characteristics as they pose extensive implications for adaptive ability.

Younger populations, for example, might find it easier to adjust to structural changes and thus harbour greater resilience. Considering the share of foreign nationals, the interpretation is more ambiguous, as high shares might indicate strong local economies attracting well-educated people from abroad (Munich, for example) or can also signal the need for enhanced integration measures (Offenbach am Main, for example). The full list of indicators and a justification for each indicator's inclusion in this framework is given in Table 2.

Most indicators are static, providing information for the year 2021. In contrast, the indicators

“Population Trend” and “GDP Trend” offer historical trends for population growth and growth in GDP per capita since 2000, respectively. The reason for considering trends in these metrics is that they offer information on the structural state of regions. Possible declines in population and GDP per capita are, for example, not reflected in static analysis despite posing crucial information for correctly assessing regions' social and economic backstories.

Data for this section was retrieved from official sites and matched with the respective administrative districts as of 2021 using the official county register from the Federal Statistical Office (Bundeskriminalamt 2023; Federal Employment Agency n.d.; German Federal Statistical Office n.d.; 2022; Statistische Ämter des Bundes und der Länder 2022; n.d.).

The findings of the Resilience Indicators are presented in table format for the most exposed administrative districts for each industry. Regional resilience is thereby assessed by comparing the respective values of an administrative district in each metric against the national distribution. The administrative districts were categorised into deciles according to their respective values in each metric. The presentation of data in this format enables accurate and uninfluenced observation of regional characteristics and thus enables more precise adaptation of policy measures to local conditions.

Further, to showcase the specific resilience attributed to population characteristics, an index was calculated using “Population Trend”, “Population Density”, “Average Age”, and “Foreign Nationals” as inputs. Therefore, an average of the ranks considering deciles of administrative districts in each of the four metrics was calculated. Accordingly, higher averages indicate higher resilience, with the indicator ranging from 1 to 10. The results are presented graphically, for which the online software Datawrapper was used (Datawrapper GmbH n.d.).

Table 2: Overview of Indicators of Category Resilience Indicators

Dimensions		Description	Rationale	Source
7	Population Trend	Change in population from 2000 to 2021	Administrative districts experiencing a decline in population might need additional support to strengthen economic and social structures	Statistische Ämter des Bundes und der Länder
8	Population Density	Population density by administrative district	Policies to support the implementation of the carbon transition might differ depending on an administrative districts' population density	Statistische Ämter des Bundes und der Länder
9	Average Age	Average age of the population of an administrative district	Administrative districts with older populations might be more vulnerable to the carbon transition since an older population might be less adaptable to sudden structural changes in labour markets	Statistische Ämter des Bundes und der Länder
10	Foreign Nationals	Proportion of the population who do not have a German passport	Labour market policies in the carbon transition might differ depending on the heterogeneity of an administrative districts' population	German Federal Statistical Office
11	Care Rate	Proportion of 3-5 year-olds in all-day care	Low shares in care rates might pose negative effects on employment; short-term through lower parental labour force participation; long-term by negatively affecting childrens education prospects	Statistische Ämter des Bundes und der Länder
12	School Dropouts	Proportion of people leaving school without a secondary school leaving certificate	High shares might make additional efforts in education and labour market integration necessary	Statistische Ämter des Bundes und der Länder
13	Children in Families Receiving Unemployment Benefits	Proportion of underage children living in families that receive unemployment benefits	High rates indicate an entrenchment of family economic conditions that negatively impact children's educational and employment prospects and undermine a community's resilience to the carbon transition	Federal Employment Agency
14	GDP per capita	Gross domestic product per citizen	Administrative districts with low GDP to capita ratios might face greater financial constraints in financing the carbon transition	Statistische Ämter des Bundes und der Länder
15	Economic Trend	Change in GDP per capita from 2000 to 2021	Higher growth rates indicate stronger resilience since regional economies seem to be founded on a sustainable economic basis	Statistische Ämter des Bundes und der Länder
16	Youth Unemployment	Proportion of 15 to 24-year-olds who are unemployed	High youth unemployment might require enhanced efforts in labour market integration	Federal Employment Agency
17	Low-Skilled Employment	Share of employees in low-skilled jobs, including occupations requiring one year of training and civil servants in the public sector	Low-skilled occupations could be particularly at risk from carbon transformation	Statistische Ämter des Bundes und der Länder
18	Cash Credits	Total amount of cash credits of an administrative district related to GDP	Higher ratios indicate financial stress of public households possibly limiting an administrative districts' financial resilience in the carbon transition	Police Crime Statistics
19	Deviation in Voter Turnout	Average deviation of voter turnout from the national average in general elections since 1998	Low voter turnout indicates an increasing lack of interest in politics which might undermine the political decisionmaking process, hindering the implementation of the carbon transition	Statistische Ämter des Bundes und der Länder

3.3. Correlation of Indicators

Since the Resilience Indicators aim to provide variability to the dimensions of exposure, independence between Resilience Indicators and Exposure Indicators is important. Running a regression shows only a small correlation between both groups, which is expected given their thematic overlap (see Table 3 in Annexe).

At the same time, some higher correlations are observed within the Resilience Indicators group, warranting further discussion. However, despite showing high correlations, the

respective indicators were kept in the framework to further enrich the picture of the vulnerabilities of German administrative districts and provide nuanced information to policymakers. Unsurprisingly, the metrics reflecting population characteristics, namely “Population Trend”, “Population Density”, “Average Age”, and “Foreign Nationals”, show high correlations with each other and further beyond with indicators “Children in Families Receiving Unemployment Benefits“, „GDP per capita“, and „Economic Trend“. Each indicator provides additional information on the characteristics of local populations, possibly posing implications for policy responses. Considering labour market policies, for example, measures might differ significantly depending on the age and share of foreign nationals in a population. Furthermore, several indicators reflecting on employment and social issues show correlations. Accordingly, “Youth Unemployment” and “Low-Skilled Employment” are correlated with “Care Rate” and “Children in Families Receiving Unemployment Benefits”, and “GDP per capita”, respectively. Nevertheless, the mentioned indicators each offer important granularity considering, for example, targeted measures to incentivise labour market integration of young people or combat child poverty. Lastly, “Deviation in Voter Turnout” is correlated with “Youth Unemployment” and “Children in Families Receiving Unemployment Benefits”. Since the indicator aims to capture democratic legitimization, which is critical for the political management of the carbon transition, it is not omitted.

4. Results

This section uses employment data to visualise the exposure of German administrative districts to the carbon transition in six manufacturing sector industries. The results aim to identify the most exposed regions by industry. Further, information on regional resiliencies is provided, focusing on population characteristics accounting for their importance in designing targeted policies that encourage the transitioning of labour markets along the carbon transition.

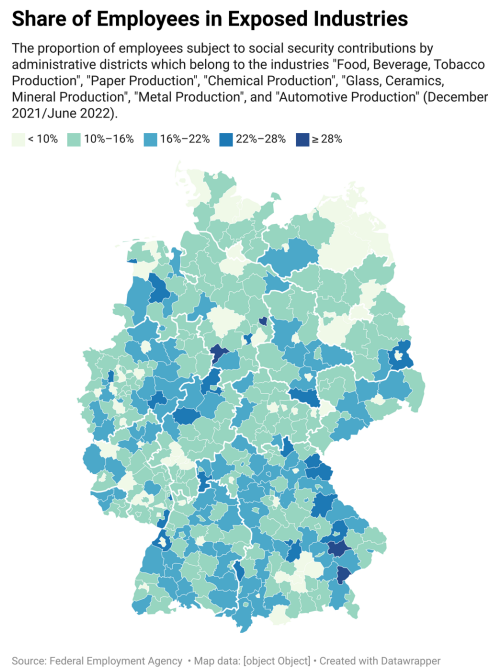
This section is structured into seven parts. First, accumulated regional exposures for the six industries and an index of resilience considering population characteristics are presented. The following six segments present the findings for each Exposure Indicator, with most exposed regions being highlighted in shades of blue. Further, additional metrics on resilience are provided for the administrative districts showing the highest exposures, and significant observations are contextualised.

4.1. Aggregate Exposure and Population Resilience of German Regions

Figure 1 shows the aggregate exposure to employment in the industries considered in this analysis. In general, exposure is widespread across Germany, with regional clusters emerging. Large metropolitan and urban areas exhibit lower exposures, indicating a different specialisation of these local economies, being less reliant of fossil-fuel dependent industries.

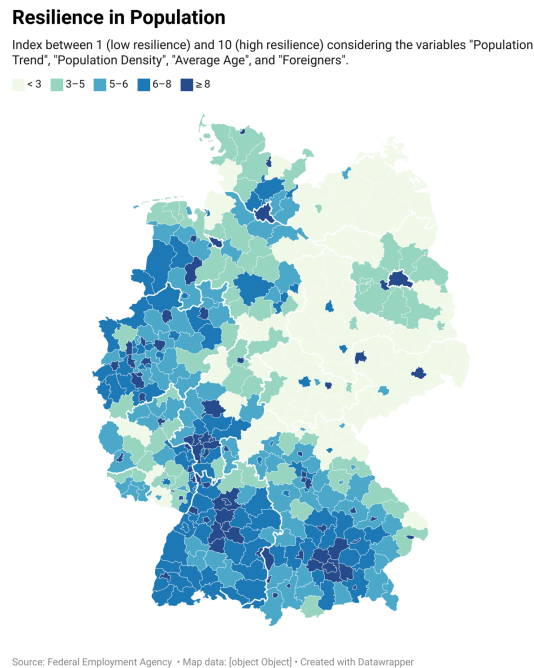
In terms of the origin of regional exposures, exposure to metal production is pronounced in regions on the border between the federal states of North-Rhine Westphalia and Hesse, while glass, ceramics, and mineral production plays a significant role for administrative districts in the northeast of Bavaria. Employment in automotive production is more widespread but generally concentrated in the South. Lastly, exposure to food, beverage and tobacco production is found especially in northern Germany, while reliance on chemical production, and paper production is only spread over a few regions.

Figure 1: Share of Employees among Industries Exposed to the Carbon Transition



The division in economic and living standards acknowledged by literature is also evident in population characteristics (Figure 2). In general, resilience stemming from population features is higher in urban areas, with regions around metropolitan centres also experiencing improved resilience. Furthermore, a division between the former East and West Germany is evident, with an especially strong South emerging. A key driver of the distribution of resilience is the demographic trend after the German reunification that has led to a strong migratory movement from the former East to the West, causing populations in the former East to overage.

Figure 2: Resilience of Populations Characteristics

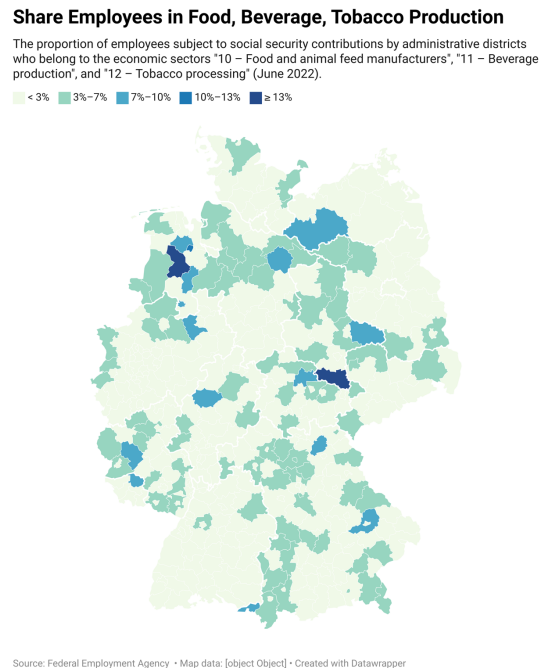


4.2. Exposure through Employment in Food, Beverage, and Tobacco Production

The food, beverage, and tobacco industry represents an important source of employment, especially in rural areas. With 6% of primary energy consumption attributable to the industry, it faces a significant transformational challenge by the carbon transition due to the required phase-out of fossil fuels (German Environment Agency 2022). Exposures to employment in food, beverage and tobacco production vary greatly, with the national median at 2%. Seventeen administrative districts show disproportionately high dependencies, ranging from 6.6% to 16.7% (Table 4). Regions with high exposures are thereby clustering in northern Germany, especially in regions in or adjacent to the federal state of Lower Saxony (Figure 3).

In 2021, 16.7% of total employment in the administrative district of Cloppenburg was in food, beverage and tobacco production, making it the most exposed region in Germany. The administrative district ranks close to the national average in most socioeconomic dimensions but scores poorly in childcare.

Figure 3: Share of Employees in Food, Beverage, and Tobacco Production

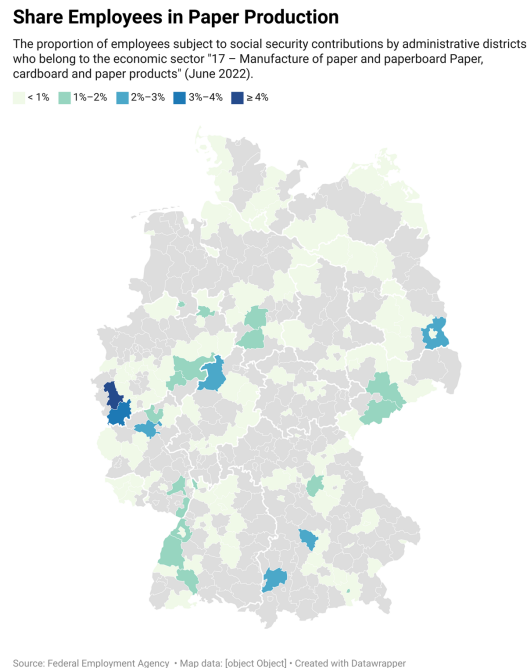


Most high-exposed regions have a rural structure. Despite relatively strong growth in GDP per capita, the measure ranks below the national average, increasing the vulnerability to the carbon transition. Furthermore, a group of six administrative districts emerges, suffering from significant declines in population since 2000, indicting structural economic weakness. With the share of low-skilled employment and youth unemployment elevated in numerous regions, targeted schemes to reskill people might be needed. Lastly, considering voter turnout, several of the most exposed districts experience significant negative deviations in voter participation, possibly indicating an alienation from politics.

4.3. Exposure through Employment in Paper Production

Labour market dependencies on employment in the paper industry are highly concentrated in seven administrative districts, with shares between 2.3% and 5.4%. The regions showing the highest exposures are distributed across Germany (Figure 4).

Figure 4: Share of Employees in Paper Production

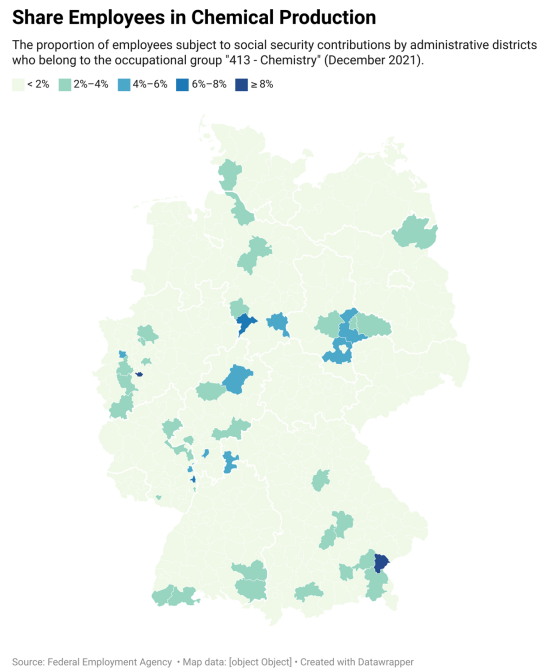


Ranked third regarding employment exposure, the administrative district Spree-Neiße records worrisome resilience, as the population has declined by one-fourth since 2000, with the population's average age at the top 20% nationwide (Table 5). Furthermore, high shares of school dropouts and low-skilled employment indicate the need for additional educational policies. Thereby, the cohort generally shows unfavourable results in the dimensions of cash credits and voter turnout. Considering the case of Spree-Neiße, the region exhibits a comparably strong GDP per capita ratio and a strong historic economic development, which is, however, in parts based on coal extraction that is to be phased out.

4.4. Exposure through Employment in Chemical Production

Due to the rise in energy prices following the Russian war on Ukraine, the chemical industry, which relies on fossil energy input, experienced a significant reduction in production (Verband der Chemischen Industrie e.V. 2023). Production facilities are thereby concentrated in a limited number of regions across Germany. Twelve administrative districts are especially exposed to employment in the chemical industry, with shares ranging from 3.8% to 17.4%, compared to 0.6% in the national median (Figure 5).

Figure 5: Share of Employees in Chemical Production



Interpreting the Resilience Indicators of these regions, an ambiguous picture emerges with significant heterogeneity between indicators and administrative districts (Table 6). In general, numerous regions show low voter turnout, an ageing and declining population, and increased rates of school dropouts and children living in families receiving unemployment benefits. Accordingly, targeted measures to qualify young people and fight child poverty might be necessary in those regions.

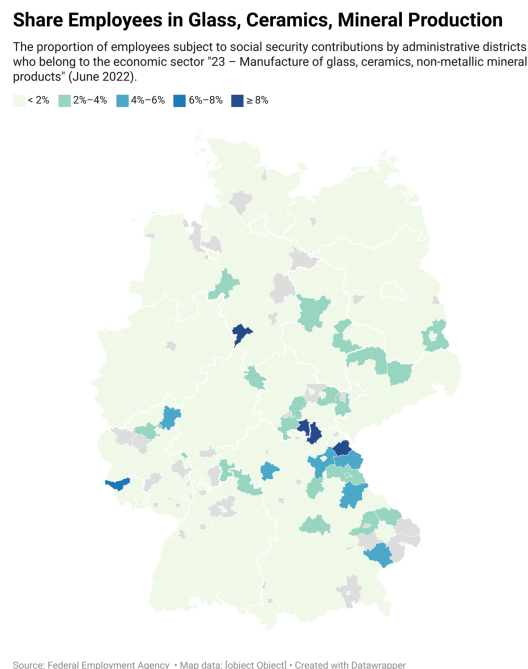
Furthermore, five administrative districts in the central federal states of Lower Saxony, Saxony-Anhalt, and Hesse show low resilience regarding population characteristics. Considering the case of the administrative district of Holzminden, the ratio of cash credits to public debt is a cause for concern, as it indicates a limited fiscal capacity in the carbon transition.

Considering economic development since 2000, the cities of Leverkusen, Ludwigshafen am Rhein, and Krefeld are among the 10% of regions performing the worst, indicating insufficient growth prospects.

4.5. Exposure through Employment in Glass, Ceramics, and Mineral Production

Eleven administrative districts are identified as most exposed to employment in glass, ceramics, and mineral production. While the national median is 0.5%, the share ranks between 4.3% and 11.6% in the most affected regions. The administrative districts showing exposure are geographically widely distributed across Germany (Figure 6). A cluster with regions showing high exposures stretches south from the border of the federal states of Bavaria and Thuringia to the German-Austrian border.

Figure 6: Share of Employees in Glass, Ceramics, and Mineral Production



The three administrative districts identified as the most exposed show a concerning level of resilience throughout the observed indicators. As for numerous of the top 11 regions, the population has declined significantly since 2000, and local populations are comparable old (Table 7). At the same time, the share of foreign nationals ranks low. Increased efforts to reskill and integrate, especially younger people, into the labour market might be necessary, considering high youth unemployment and school dropouts.

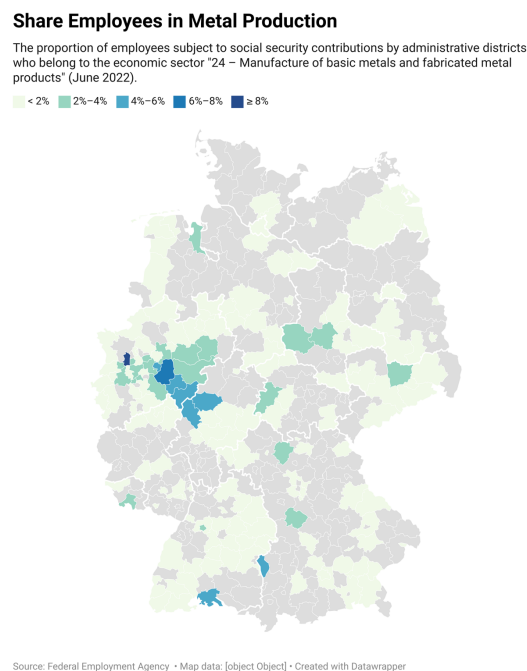
The cluster of exposed regions in northeast Bavaria is especially concerning as exposure is widely evident in a region under demographic stress. However, while economically weak

compared to the rest of Bavaria, most regions of this cluster perform better than the German median in GDP per capita and have shown strong economic development since 2000. An exception is the city of Bayreuth, which ranks below the national median on economic strength and reports little growth.

4.6. Exposure through Employment in Metal Production

German metal production is on a decade-long decline. Due to the heat required in producing metals, the industry aims to use climate-neutral hydrogen, which requires considerable investment at the current production facilities. Exposures to employment in the industry are highly concentrated in nine administrative districts, showing dependency rates ranging from 4.2% to 10.8% compared to the national median of 0.5%. Thereby, highly exposed regions are clustered in the regional states of North-Rhine Westphalia, stretching into Hesse (Figure 7).

Figure 7: Share of Employees in Metal Production



Duisburg is the most exposed region, with over 10% of local employees working in the metal industry, matching Duisburg as Germany's main location of steel production. Corresponding to the industry's decline, populations are shrinking in most administrative districts (Table 8). As for numerous regions in the cohort of most exposed administrative districts, Duisburg

experiences high child poverty and deficits in education. While GDP per capita ranks relatively high for most of the top nine, economic developments since 2000 fall significantly behind the national trend. Furthermore, cash credits of administrative districts are elevated, especially for the two regions located in the regional state of Hesse.

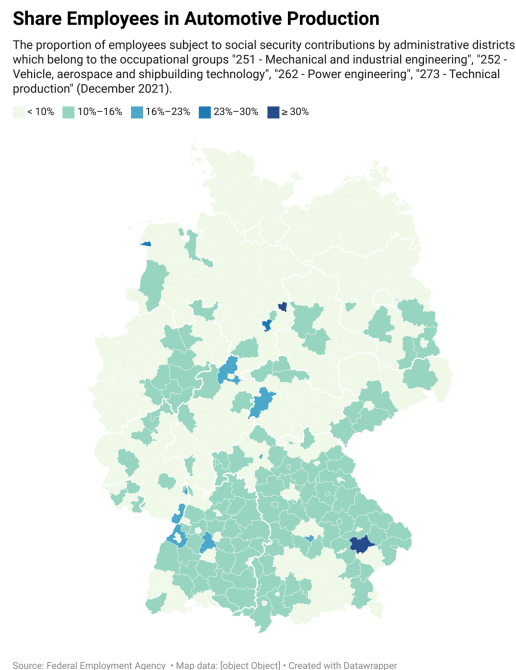
In general, despite a robust economic situation in terms of GDP per capita, enhanced efforts should be conducted to lower child poverty and increase the education prospects of young adults. In doing so, observed high shares of foreign nationals in the total population must be accounted for in implementing such programmes, considering linguistic accessibility.

4.7. Exposure through Employment in Automotive Production

The automotive sector is the most important manufacturing industry in the German economy, reflected in a median exposure ranking at 8.5%, thereby being more pronounced as for the other industries. With the shift to electric vehicles, the industry faces a structural, technological change, putting employment and economic prospects at risk. New drive technologies require fewer work steps, and German carmakers are under increasing pressure from new competitors in the global markets (Heymann and Mau 2023).

Twelve administrative districts are identified as especially exposed, corresponding to some of the locations of car manufacturers – the shares of employment working in automotive production amongst this group range between 16.6% and 33.8% (Figure 8). While the regions showing the highest exposures are not forming eminent clusters, regions with at least 10% of local employment working in the industry cluster especially in the south of Germany; consistent with the location of headquarters of numerous car manufacturers and suppliers.

Figure 8: Share of Employees in Automotive Production



The cohort of most exposed administrative regions shows high economic strength, measured by GDP per capita and generally strong population robustness (Table 9). A comparably low average age and increased population since 2000 reinforce the impression of resilient regions. The administrative districts of Kassel and Wartburgkreis are an exception to this general trend, both experiencing low values in GDP per capita. Considering the city of Kassel's slow economic growth since 2000 strengthens the image of a region under economic stress. Numerous administrative districts record youth unemployment rates above the national median. Child poverty is also a problem, especially in urban environments. Enhanced efforts aimed at reskilling employees might be justified considering the transformational change of the automotive sector and the observed shares of low-skilled employment that rank above the German median in most regions (Dispan 2013).

Furthermore, a significant negative deviation in voter turnout to the national average is widespread among most exposed administrative districts, possibly undermining democratic legitimacy in the carbon transition.

5. Discussion

The applied framework holds several limitations considering scope and precision. First and foremost, as exposure is measured through employment, the analysis does not reflect other channels through which the carbon transition could affect local communities. Furthermore, using employment by professional groups to calculate exposure neither clearly distinguishes between jobs at risk and jobs not at risk nor includes non-production-related jobs at companies operating in the industries analysed. A second restriction is the non-consideration of possible cross-sectoral exposures along supply chains.

Despite the limitations, our results highlight the need for targeted policy measures to successfully manage the carbon transition, as regional exposure to energy-intensive industries and resilience vary significantly. Subsequently, transformation costs associated with the carbon transition are distributed unequally, with a small number of administrative districts showing disproportionately high exposures to the respective industries. Interestingly, socioeconomic characteristics also differ between industries, affecting resilience prospects. In consequence, industry-specific support measures are required to address the dissimilar needs of administrative districts, especially regarding changes in the skills requirements of employment.

Considering industry-specific characteristics, exposure to metal production and glass, ceramics, and mineral production clusters in regions with stressed resilience. We find great heterogeneity in the resilience indicators between the administrative districts exposed to one of the two industries. However, a pattern surfaces in which population characteristics emerge as a problem for regions exposed to glass, ceramics, and mineral production. In contrast, economic stagnation since 2000 weighs on the resilience of regions exposed to metal production, expressing the need for structural economic development.

Regarding automotive production, respective exposure ranks higher generally, but the highest exposures concentrate on regions showing strong resilience in population characteristics and

economy. Still, due to high regional employment concentrations in automotive production of over 20% and beyond, regional transformation challenges might prove too demanding for some administrative districts.

Viewing accumulated exposures, we identify numerous regions experiencing significant exposure to more than one industry. However, this cohort's overall resilience and individual socioeconomic characteristics differ greatly, not allowing for drawing universal conclusions. Individual sectors in respective regions generally drive high aggregate exposure, while significant overlapping of exposures explains the widespread and elevated level of exposure, driven especially by automotive production and food, beverage and tobacco production. In contrast, aggregate resilience stemming from population characteristics follows an East-West and rural-urban divide, with urban areas showing the strongest resilience.

The carbon transition symbolises a rapid technological change like previous industrial revolutions. While employment in energy-intensive industries and the automotive sector might be at risk more generally, the employment effects will likely see a skill bias, favouring people with higher skills in the labour market. The public sector has a vital role to play in this process. Active industrial policy schemes, such as the ones currently in place supporting industrial transitions, are needed to support the regions most dependent on fossil-fuel-dependent industries.

However, considering the labour market effects of the carbon transition, targeted incentives to support reskilling, the integration of young people into the labour market, and the educational prospects of the youth must complement efforts to strengthen infrastructure. In consequence, current schemes in place supporting the transition in energy-intensive industries through subsidising infrastructural investments must be complemented by enhanced efforts in managing the skill-biased transition of labour markets.

6. Conclusion

Phasing out carbon emissions in manufacturing is a critical priority in mitigating human-made global warming. The transition questions the operating basis of fossil-fuel-dependent industries, which account for a disproportionately high share of industry emissions. This work assesses exposures in Germany to the carbon transition in the manufacturing sector by showing regional dependencies of labour markets to six industries most affected by the transformation. Despite the approach's limitations, considering the precision of classifying jobs to at-risk sectors, this analysis highlights the need for a differentiated policy design that accounts for regional and industry-specific characteristics to implement the carbon transition successfully. The results show exposures varying greatly across regions and industries, with the highest dependencies concentrating on only a few administrative districts. In general, exposures to the analysed sectors of metal production, and glass, ceramics, and mineral production are strongly clustering in the states of North-Rhine Westphalia and Bavaria, respectively, with affected regions performing below the national average considering the studied resilience indicators. Regions showing high exposure to metal production have experienced low economic growth since 2000, requiring enhanced structural economic development. In contrast, exposure to automotive production is widespread, while the most affected regions show relatively strong resilience. However, due to the high percentage shares of employment in the respective industry, broader schemes to reskill and upskill employees could be recommended, anticipating skill-biased employment effects as electrification of the automotive industry progresses. Generally, population characteristics vary greatly as well, underpinning the need to consider regional differences, especially in policies aiming to increase the adaptive capabilities of individuals in the carbon transition through labour market integration and education.

7. References

- Bähr, Cornelius, Dr. David Bothe, Georg Brändle, Dr. Hilmar Klink, Dr. Karl Lichtblau, Lino Sonnen, and Benita Zink. 2023. ‘Die Zukunft energieintensiver Industrien in Deutschland’. Dezernat Zukunft. <https://www.dezernatzukunft.org/wp-content/uploads/2023/09/Baehr-et-al.-2023-Die-Zukunft-energieintensiver-Industrien-in-Deutschland.pdf>.
- Bassi, Andrea M., Joel S. Yudken, and Matthias Ruth. 2009. ‘Climate Policy Impacts on the Competitiveness of Energy-Intensive Manufacturing Sectors’. *Energy Policy* 37 (8): 3052–60. <https://doi.org/10.1016/j.enpol.2009.03.055>.
- Bundeskriminalamt. 2023. ‘PKS 2021 Kreis - Falltabellen’. Bundeskriminalamt. 2023. https://www.bka.de/DE/AktuelleInformationen/StatistikenLagebilder/PolizeilicheKriminalstatistik/PKS2021/PKSTabellen/KreisFalltabellen/kreisfalltabellen_node.html.
- Bundestag. 2023. ‘Gesetz zur Stärkung der Aus- und Weiterbildungsförderung’. Bundesgesetzblatt. https://www.recht.bund.de/bgbl/1/2023/191/regelungstext.pdf?__blob=publicationFile&v=2.
- Datawrapper GmbH. n.d. Datawrapper GmbH. Accessed 18 November 2023. <https://www.datawrapper.de>.
- Deutscher Bundestag. 2019. ‘Bundes-Klimaschutzgesetz (KSG)’. Federal Ministry of Justice. <https://www.gesetze-im-internet.de/ksg/KSG.pdf>.
- Dispan, Jürgen. 2013. *Elektromobilität: Schlüsselfaktor Qualifikation: Ergebnisse der ELAB-Studie zu Kompetenzanforderungen und Qualifikationsbedarfen*. Red.-Schluss: 30.06.2012. Informationsdienst / IMU-Institut, 2013,1. Stuttgart: IMU-Institut.
- Dr Lichtblau, Karl, Johannes Ewald, Thorsten Dr Lang, Wolfgang Prof. Schroeder, and Daniel Prof. Dr. Buhr. 2022. ‘Transformationsstrategien für besonders betroffene Regionen’. Netzwerk Zukunft der Industrie e.V. <https://buendnis-zukunft-der->

industrie.de/2023/05/09/release-der-studie-transformationsstrategien-fuer-besonders-betroffene-regionen/.

Emons, Oliver, Henrik Steinhaus, and Stephan Kraft. 2022. 'VOLKSWIRTSCHAFTLICHE BEDEUTUNG DES INDUSTRIELLEN SEKTORS IN DEUTSCHLAND'. 73. Mitbestimmungsreport. Hans Böckler Stiftung. https://www.imu-boeckler.de/fpdf/HBS-008297/p_mbf_report_2022_73.pdf.

European Commission. 2022. 'Eighth Report on Economic, Social and Territorial Cohesion'. 9 February 2022. https://ec.europa.eu/regional_policy/information-sources/cohesion-report_en.

European Commission. Directorate General for Economic and Financial Affairs. 2022. *The Possible Implications of the Green Transition for the EU Labour Market*. LU: Publications Office. <https://data.europa.eu/doi/10.2765/583043>.

European Commission, and PPMI Group. 2021. 'European Emissions Trading System (ETS) – Calculations on the Regional Employment Impact of ETS Installations : Analytical and Methodological Report'. European Commission. https://www.cde.ual.es/wp-content/uploads/2021/09/KN0921336ENN.en_.pdf.

European Union. 2003. 'DIRECTIVE 2003/87/EC'. Official Journal of the European Union. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32003L0087>.

———. 2023a. 'DIRECTIVE (EU) 2023/959'. Official Journal of the European Union. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023L0959&qid=1693823257321>.

———. 2023b. 'REGULATION (EU) 2023/956'. Official Journal of the European Union. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R0956&qid=1693834833214>.

Federal Agency for Civic Education. 2021a. 'Arbeitslosenquoten Nach Geschlecht Und Staatsangehörigkeit'. Federal Agency for Civic Education. 12 October 2021.

[https://www.bpb.de/kurz-knapp/zahlen-und-fakten/soziale-situation-in-deutschland/162491/arbeitslosenquoten-nach-geschlecht-und-staatsangehoerigkeit/#:~:text=Bei%20einer%20Unterscheidung%20nach%20Staatsangeh%C3%B6rigkeit,gegen%C3%99ber%206%2C3%20Prozent\).](https://www.bpb.de/kurz-knapp/zahlen-und-fakten/soziale-situation-in-deutschland/162491/arbeitslosenquoten-nach-geschlecht-und-staatsangehoerigkeit/#:~:text=Bei%20einer%20Unterscheidung%20nach%20Staatsangeh%C3%B6rigkeit,gegen%C3%99ber%206%2C3%20Prozent).)

———. 2021b. 'Dauer Der Arbeitslosigkeit'. Federal Agency for Civic Education. 12 October 2021. [https://www.bpb.de/kurz-knapp/zahlen-und-fakten/soziale-situation-in-deutschland/162491/arbeitslosenquoten-nach-geschlecht-und-staatsangehoerigkeit/#:~:text=Bei%20einer%20Unterscheidung%20nach%20Staatsangeh%C3%B6rigkeit,gegen%C3%99ber%206%2C3%20Prozent\).](https://www.bpb.de/kurz-knapp/zahlen-und-fakten/soziale-situation-in-deutschland/162491/arbeitslosenquoten-nach-geschlecht-und-staatsangehoerigkeit/#:~:text=Bei%20einer%20Unterscheidung%20nach%20Staatsangeh%C3%B6rigkeit,gegen%C3%99ber%206%2C3%20Prozent).)

Federal Employment Agency. 2023. 'Branchen im Fokus'. 2023. <https://statistik.arbeitsagentur.de/DE/Navigation/Statistiken/Interaktive-Statistiken/Branchen-im-Fokus/Branchen-im-Fokus-Nav.html;jsessionid=484A2024FA4E5352E83AC3603FA1EB0B#bst-51891238>.

———. n.d. 'Datenbanken Beschäftigungsstatistik'. Statistik Arbeitsagentur. Accessed 18 November 2023a. <https://statistik.arbeitsagentur.de/DE/Navigation/Statistiken/Interaktive-Statistiken/Datenbanken/Datenbanken-BST-Nav.html>.

———. n.d. 'Kinder in Bedarfsgemeinschaften - Deutschland, West/Ost, Länder und Kreise (Monatszahlen)'. Statistik Arbeitsagentur. Accessed 18 November 2023b. https://statistik.arbeitsagentur.de/SiteGlobals/Forms/Suche/Einzelheftsuche_Formular.html;jsessionid=66444857BC60F1146A3AC728FBACE4BB?nn=20656&topic_f=kinder.

Federal Institute for Vocational Education and Training (BIBB). 2010. 'KldB 2010 - Berufsgruppen'. Federal Institute for Vocational Education and Training (BIBB).

https://www.bibb.de/dokumente/pdf/naa309/naa309_2021_berufsgruppenzuordnung_kldb2010_3.pdf.

Federal Ministry for Economic Affairs and Climate Action. 2022. ‘Bekanntmachung der Richtlinie zur Förderung des Absatzes von elektrisch betriebenen Fahrzeugen’. Federal Ministry of Justice. https://www.bmwk.de/Redaktion/DE/Downloads/B/bundesanzeiger-foerderrichtlinie-umweltbonus-elektroautos.pdf?__blob=publicationFile&v=1.

———. 2023. ‘Beschluss des Koordinierungsausschusses der Gemeinschaftsaufgabe „Verbesserung der regionalen Wirtschaftsstruktur“ (GRW) zur Förderung auf Grundlage der BKR-Bundesregelung Transformationstechnologien (zu Abschnitt 2.8 TCTF)’. https://www.bmwk.de/Redaktion/DE/Downloads/B/202309013-beschluss-grw-koordinierungsausschuss.pdf?__blob=publicationFile&v=8.

———. n.d. ‘Automobilindustrie’. Federal Ministry for Economic Affairs and Climate Action. Accessed 12 December 2023.

<https://www.bmwk.de/Redaktion/DE/Textsammlungen/Branchenfokus/Industrie/branchenfokus-automobilindustrie.html#:~:text=Die%20Automobilindustrie%20ist%20die%20größte,beschäftigten%20direkt%20knapp%20786.000%20Personen>.

Federal Ministry of Education and Research. 2020. ‘Stukturstärkungsgesetz Kohleregionen’. Bundesgesetzblatt. https://www.bmbf.de/bmbf/shareddocs/downloads/files/strukturstaerkungsgesetz-kohleregionen-kopie.pdf?__blob=publicationFile&v=2.

Federal Ministry of Finance. 2022. ‘Bundeshaushaltsplan 2023 – Einzelplan 60’. <https://www.bundeshaushalt.de/static/daten/2023/soll/epl60.pdf>.

Federal Ministry of Food and Agriculture. 2020. ‘Das Land lebt! Dritter Bericht der Bundesregierung zur Entwicklung der ländlichen Räume’. Federal Ministry of Food and

- Agriculture. https://www.bmel.de/SharedDocs/Downloads/DE/_laendliche-Regionen/regierungsbericht-laendliche-raeume-2020.pdf?__blob=publicationFile&v=5.
- Federal Ministry of Justice. 1969. ‘Gesetz über die Gemeinschaftsaufgabe “Verbesserung der regionalen Wirtschaftsstruktur”’. Federal Ministry of Justice. <https://www.gesetze-im-internet.de/wistruktg/BJNR018610969.html>.
- German Environment Agency. 2022. ‘<https://www.umweltbundesamt.de/Daten/Umwelt-Wirtschaft/Industrie/Branchenabhaengiger-Energieverbrauch-Des#der-Energiebedarf-Deutschlands>’. German Environment Agency. 25 September 2022. <https://www.umweltbundesamt.de/daten/umwelt-wirtschaft/industrie/branchenabhaengiger-energieverbrauch-des#der-energiebedarf-deutschlands>.
- German Federal Statistical Office. 2022. ‘Alle politisch selbständigen Gemeinden mit ausgewählten Merkmalen am 31.12.2021’. 15 September 2022. https://www.destatis.de/DE/Themen/Laender-Regionen/Regionales/Gemeindeverzeichnis/Administrativ/Archiv/GVAuszugJ/31122021_Auszug_GV.html.
- . n.d. ‘Ausländer: Kreise, Stichtag, Geschlecht’. Genesis. Accessed 18 November 2023. <https://www-genesis.destatis.de/genesis//online?operation=table&code=12521-0040&bypass=true&levelindex=1&levelid=1701604427474#abreadcrumb>.
- Goch, Stefan. 2014. ‘Strukturwandel Im Ruhrgebiet - Eine Erfolgsgeschichte?’ *Moving the Social*, September, 159-190 Pages. <https://doi.org/10.13154/MTS.22.1999.159-190>.
- Grubb, Michael. n.d. ‘Three Pillars of EU Climate Policy’. Presented at the CEPS workshop, Brussels. Accessed 14 December 2023. <https://climatestrategies.org/wp-content/uploads/2014/11/Michael-Grubb-Three-pillars-of-EU-climate-policy.pdf>.
- Heymann, Eric, and Jule Mau. 2023. ‘E-Mobilität: Wettbewerb um Marktanteile wird intensiver’. Deutsche Bank Research. https://www.dbresearch.de/PROD/RPS_DE-PROD/PROD0000000000529005/E-

Mobilität%3A_Wettbewerb_um_Marktanteile_wird_inten.PDF;REWEBJSESSIONID=B166769498E93D2FEDF981E8F33B5526?undefined&real-load=0sixn/wWgbXzhwBvTSM5uEj97CqocgldpMqC7WJ89JBXRm3H7hh30shg-OHOubcAj.

Hüther, Michael, Jens Südekum, and Michael Voigtländer. 2019. 'Die Zukunft der Regionen in Deutschland – Zwischen Vielfalt und Gleichwertigkeit'. Institut der deutschen Wirtschaft. https://www.iwkoeln.de/fileadmin/user_upload/Studien/Externe_Studien/2019/IW-Regionalstudie_2019.pdf.

Joltreau, Eugénie, and Katrin Sommerfeld. 2019. 'Why Does Emissions Trading under the EU Emissions Trading System (ETS) Not Affect Firms' Competitiveness? Empirical Findings from the Literature'. *Climate Policy* 19 (4): 453–71. <https://doi.org/10.1080/14693062.2018.1502145>.

Känzig, Diego. 2023. 'The Unequal Economic Consequences of Carbon Pricing'. w31221. Cambridge, MA: National Bureau of Economic Research. <https://doi.org/10.3386/w31221>.

Kruppe, Thomas, Julia Lang, and Ute Leber. 2021. 'Nur jeder zehnte Betrieb nutzt die Weiterbildungsförderung der Bundesagentur für Arbeit'. 17 May 2021. <https://www.iab-forum.de/nur-jeder-zehnte-betrieb-nutzt-die-weiterbildungsfoerderung-der-bundesagentur-fuer-arbeit/>.

Löschel, Andreas, Benjamin Johannes Lutz, and Shunsuke Managi. 2019. 'The Impacts of the EU ETS on Efficiency and Economic Performance – An Empirical Analyses for German Manufacturing Firms'. *Resource and Energy Economics* 56 (May): 71–95. <https://doi.org/10.1016/j.reseneeco.2018.03.001>.

- Marin, Giovanni, and Francesco Vona. 2019. 'Climate Policies and Skill-Biased Employment Dynamics: Evidence from EU Countries'. *Journal of Environmental Economics and Management* 98 (November): 102253. <https://doi.org/10.1016/j.jeem.2019.102253>.
- Martin, Ralf, Laure B. De Preux, and Ulrich J. Wagner. 2014. 'The Impact of a Carbon Tax on Manufacturing: Evidence from Microdata'. *Journal of Public Economics* 117 (September): 1–14. <https://doi.org/10.1016/j.jpubeco.2014.04.016>.
- McDowall, Will, Tobias Reinauer, Panagiotis Fragkos, Michal Miedzinski, and Jennifer Cronin. 2023. 'Mapping Regional Vulnerability in Europe's Energy Transition: Development and Application of an Indicator to Assess Declining Employment in Four Carbon-Intensive Industries'. *Climatic Change* 176 (2): 7. <https://doi.org/10.1007/s10584-022-03478-w>.
- OECD. 2023. *Regional Industrial Transitions to Climate Neutrality*. OECD Regional Development Studies. OECD. <https://doi.org/10.1787/35247cc7-en>.
- Pahle, Dr. Michael, Joanna Sitarz, and Dr. Sebastian Osorio. 2022. 'The EU-ETS Price through 2030 and beyond: A Closer Look at Drivers, Models and Assumptions'. Potsdam-Institut für Klimafolgenforschung. https://ariadneprojekt.de/media/2023/01/Ariadne-Dokumentation_ETSWorkshopBruessel_December2022.pdf.
- Raimi, Daniel, Sanya Carley, and David Konisky. 2022. 'Mapping County-Level Vulnerability to the Energy Transition in US Fossil Fuel Communities'. *Scientific Reports* 12 (1): 15748. <https://doi.org/10.1038/s41598-022-19927-6>.
- Saussay, Aurélien, Misato Sato, Francesco Vona, and Layla O'Kane. 2022. 'Who's Fit for the Low-Carbon Transition? Emerging Skills and Wage Gaps in Job and Data'. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.4260227>.
- Snyder, Brian F. 2018. 'Vulnerability to Decarbonization in Hydrocarbon-Intensive Counties in the United States: A Just Transition to Avoid Post-Industrial Decay'. *Energy*

Research & Social Science 42 (August): 34–43.

<https://doi.org/10.1016/j.erss.2018.03.004>.

Statistische Ämter des Bundes und der Länder. 2022. ‘Bruttoinlandsprodukt/Bruttowertschöpfung nach Wirtschaftsbereichen - Jahressumme - regionale Tiefe: Kreise und krfr. Städte’. <https://www.statistikportal.de/de/vgrdl/ergebnisse-kreisebene/bruttoinlandsprodukt-bruttowertschoepfung-kreise>.

———. n.d. ‘Bruttoinlandsprodukt, Bruttowertschöpfung (Kreise)’. Statistikportal. Accessed 18 November 2023a. <https://www.statistikportal.de/de/vgrdl/ergebnisse-kreisebene/bruttoinlandsprodukt-bruttowertschoepfung-kreise>.

———. n.d. ‘Regionalatlas Deutschland’. Regionalatlas Deutschland. Accessed 18 November 2023b. <https://regionalatlas.statistikportal.de>.

The Federal Government of Germany. 2020a. ‘Für eine starke Stahlindustrie in Deutschland und Europa!’ Federal Ministry for Economic Affairs and Energy. https://www.bmwk.de/Redaktion/DE/Publikationen/Wirtschaft/handlungskonzept-stahl.pdf?__blob=publicationFile&v=12.

———. 2020b. ‘Förderrichtlinie Zur Dekarbonisierung in Der Industrie’. https://www.verwaltungsvorschriften-im-internet.de/bsvwvbund_16122020_8360002.htm.

———. 2022a. ‘Nationale Weiterbildungs- strategie’. https://www.bmas.de/SharedDocs/Downloads/DE/Aus-Weiterbildung/nws-fortfuehrung-und-weiterentwicklung.pdf?__blob=publicationFile&v=3.

———. 2022b. ‘Masterplan Ladeinfrastruktur II der Bundesregierung’. https://bmdv.bund.de/SharedDocs/DE/Publikationen/G/masterplan-ladeinfrastruktur-2.pdf?__blob=publicationFile.

———. 2023a. ‘Update Der Nationalen Wasserstoffstrategie: Turbo Für Die H2-Wirtschaft’. Federal Ministry of Education and Research. 26 July 2023.

https://www.bmbf.de/bmbf/de/forschung/energiewende-und-nachhaltiges-wirtschaften/nationale-wasserstoffstrategie/nationale-wasserstoffstrategie_node.html.

———. 2023b. ‘Zum Stand der Deutschen Einheit – Bericht der Bundesregierung 2023’. The Federal Government of Germany. <https://www.bundesregierung.de/resource/blob/975292/2226090/c677074bf753365b61052f2d61dd12bb/zum-stand-der-deutschen-einheit-2023-download-bkamt-data.pdf?download=1>.

Verband der Chemischen Industrie e.V. 2023. ‘Bericht des VCI für das Gesamtjahr 2023’. <https://www.vci.de/ergaenzende-downloads/kennzahlentabelle-pk-2023.pdf>.

Verde, Stefano F. 2020. ‘THE IMPACT OF THE EU EMISSIONS TRADING SYSTEM ON COMPETITIVENESS AND CARBON LEAKAGE: THE ECONOMETRIC EVIDENCE’. *Journal of Economic Surveys* 34 (2): 320–43. <https://doi.org/10.1111/joes.12356>.

Wagner, Ulrich J., Katrin Rehdanz, and Sebastian Petrick. 2014. ‘The Impact Of Carbon Trading On Industry: Evidence From German Manufacturing Firms’. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.2389800>.

8. Annexe

Table 3: Correlations of Indicators

Dimensions		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Share Employees in Food, Beverage, Tobacco Production	1,00	0,05	-0,06	0,15	-0,07	-0,03	-0,01	-0,30	0,08	-0,26	-0,10	0,10	-0,25	-0,27	0,22	-0,19	0,27	-0,12	0,06
2	Share Employees in Paper Production	0,05	1,00	-0,01	0,07	0,09	0,06	-0,07	-0,13	-0,01	-0,11	0,01	0,01	-0,14	-0,15	0,00	-0,13	0,11	-0,05	0,12
3	Share Employees in Chemical Production	-0,06	-0,01	1,00	0,04	0,03	-0,05	-0,03	0,04	-0,01	0,08	-0,01	0,03	0,10	0,05	-0,03	0,07	-0,09	0,03	-0,01
4	Share Employees in Glass, Ceramics, Mineral Production	0,15	0,07	0,04	1,00	-0,09	0,10	-0,22	-0,22	0,20	-0,26	-0,07	0,19	-0,18	-0,12	0,18	-0,13	0,18	-0,08	-0,01
5	Share Employees in Metal Production	-0,07	0,09	0,03	-0,09	1,00	0,06	-0,25	0,03	-0,02	0,08	-0,06	0,18	0,19	-0,14	-0,12	0,04	0,07	0,18	-0,08
6	Share Employees Automotive Production	-0,03	0,06	-0,05	0,10	0,06	1,00	-0,06	-0,25	-0,02	-0,02	-0,31	0,15	-0,25	0,26	0,29	-0,26	0,05	-0,10	-0,03
7	Population Trend	-0,01	-0,07	-0,03	-0,22	-0,25	-0,06	1,00	0,25	-0,78	0,45	-0,24	-0,17	-0,26	0,35	-0,21	-0,39	-0,20	-0,22	0,34
8	Population Density	-0,30	-0,13	0,04	-0,22	0,03	-0,25	0,25	1,00	-0,49	0,70	0,23	-0,07	0,61	0,48	-0,40	0,38	-0,39	0,19	-0,15
9	Average Age	0,08	-0,01	-0,01	0,20	-0,02	-0,02	-0,78	-0,49	1,00	-0,68	0,29	0,04	-0,06	-0,50	0,32	0,26	0,21	0,05	-0,25
10	Foreign Nationals	-0,26	-0,11	0,08	-0,26	0,08	-0,02	0,45	0,70	-0,68	1,00	-0,13	0,01	0,37	0,55	-0,49	0,09	-0,23	0,08	-0,03
11	Care Rate	-0,10	0,01	-0,01	-0,07	-0,06	-0,31	-0,24	0,23	0,29	-0,13	1,00	-0,28	0,31	0,04	0,02	0,48	-0,26	0,07	-0,22
12	School Dropouts	0,10	0,01	0,03	0,19	0,18	0,15	-0,17	-0,07	0,04	0,01	-0,28	1,00	-0,01	-0,25	0,01	-0,06	0,30	0,11	-0,02
13	Children in Families Receiving Unemployment Benefits	-0,25	-0,14	0,10	-0,18	0,19	-0,25	-0,26	0,61	-0,06	0,37	0,31	-0,01	1,00	0,12	-0,34	0,81	-0,12	0,39	-0,41
14	GDP per capita	-0,27	-0,15	0,05	-0,12	-0,14	0,26	0,35	0,48	-0,50	0,55	0,04	-0,25	0,12	1,00	-0,01	-0,06	-0,51	-0,15	-0,07
15	Economic Trend	0,22	0,00	-0,03	0,18	-0,12	0,29	-0,21	-0,40	0,32	-0,49	0,02	0,01	-0,34	-0,01	1,00	-0,12	0,04	-0,19	-0,14
16	Youth Unemployment	-0,19	-0,13	0,07	-0,13	0,04	-0,26	-0,39	0,38	0,26	0,09	0,48	-0,06	0,81	-0,06	-0,12	1,00	-0,07	0,31	-0,59
17	Low-Skilled Employment	0,27	0,11	-0,09	0,18	0,07	0,05	-0,20	-0,39	0,21	-0,23	-0,26	0,30	-0,12	-0,51	0,04	-0,07	1,00	0,14	-0,02
18	Cash Credits	-0,12	-0,05	0,03	-0,08	0,18	-0,10	-0,22	0,19	0,05	0,08	0,07	0,11	0,39	-0,15	-0,19	0,31	0,14	1,00	-0,10
19	Deviation in Voter Turnout	0,06	0,12	-0,01	-0,01	-0,08	-0,03	0,34	-0,15	-0,25	-0,03	-0,22	-0,02	-0,41	-0,07	-0,14	-0,59	-0,02	-0,10	1,00

Table 4: Administrative districts with the highest shares of employment associated with food, beverage and tobacco production

Administrative District	Share Employees in Food, Beverage, Tobacco Production	Population Trend	Population Density	Average Age	Foreign Nationals	Care Rate	School Dropouts	Children in Families Receiving Unemployment Benefits	GDP per capita	Economic Trend	Youth Unemployment	Low-Skilled Employment	Cash Credits	Deviation in Voter Turnout
Cloppenburg	16,7%	16,3%	122,49	41,10	13,0%	17,2%	16,5%	7,9%	36533,00	86,0%	3,4%	20,7%	0,00	-1,9%
Burgenlandkreis	13,1%	-20,7%	124,70	49,20	6,5%	79,2%	13,1%	13,7%	27450,00	79,6%	7,9%	17,0%	0,01	-9,6%
Oldenburg (Oldenburg)	10,8%	10,0%	1652,82	42,90	11,6%	47,8%	8,8%	19,9%	50342,00	50,1%	5,3%	16,1%	0,00	1,2%
Ludwigslust-Parchim	9,3%		44,45	47,60	6,0%	69,0%	13,2%	10,0%	27932,00	107,5%	7,3%	19,0%	0,01	-4,4%
Vechta	9,2%	14,5%	177,85	41,20	15,3%	15,6%	12,8%	9,0%	48732,00	90,0%	2,9%	22,9%	0,00	1,3%
Gütersloh	9,0%	6,0%	377,73	43,70	15,0%	50,4%	18,9%	8,6%	52102,00	71,9%	3,1%	21,2%	0,00	1,5%
Bernkastel-Wittlich	8,8%	-0,6%	96,92	45,90	11,6%	64,8%	18,0%	7,0%	33768,00	76,1%	2,9%	20,4%	0,02	0,9%
Straubing-Bogen	8,8%	7,5%	85,22	44,10	8,4%	12,5%	29,9%	2,9%	30752,00	90,7%	2,7%	19,8%	0,00	1,0%
Ammerland	7,8%	14,3%	173,10	45,50	6,9%	26,1%	13,8%	8,9%	34227,00	88,0%	3,2%	17,7%	0,00	1,4%
Lindau (Bodensee)	7,6%	6,8%	254,58	45,50	14,5%	27,8%	16,4%	4,3%	38769,00	69,3%	2,2%	17,2%	0,00	0,6%
St. Wendel	7,2%	-9,7%	180,85	47,90	13,7%	47,8%	19,9%	8,3%	30260,00	55,7%	2,0%	21,6%	0,04	6,0%
Kulmbach	7,1%	-9,5%	108,35	47,20	6,0%	49,5%	23,5%	5,4%	39198,00	95,2%	2,9%	15,4%	0,00	0,9%
Sömmerda	6,9%	-15,4%	85,17	47,50	3,7%	91,2%	13,0%	9,5%	27298,00	101,9%	7,0%	18,4%	0,00	-3,6%
Uelzen	6,8%	-4,5%	63,51	47,40	6,9%	38,4%	16,7%	11,5%	30867,00	81,5%	5,0%	18,6%	0,00	1,0%
Marburg-Biedenkopf	6,8%	-2,8%	194,95	43,30	12,2%	56,1%	17,1%	10,1%	42529,00	75,3%	3,5%	15,4%	0,00	1,2%
Osnabrück	6,6%	0,6%	1377,58	42,10	15,8%	74,9%	7,7%	18,9%	53267,00	48,4%	5,3%	16,9%	0,01	0,1%
Wittenberg	6,6%	-22,1%	63,80	49,80	4,2%	86,9%	12,0%	13,5%	27821,00	105,7%	8,0%	15,9%	0,03	-7,2%
Median (all administrative districts)	2,0%	1,7%	201,38	45,00	11,5%	42,9%	16,2%	9,6%	36533,00	69,0%	4,3%	17,2%	0,00	0,1%
Average (all administrative districts)	2,5%	0,1%	536,54	45,28	12,3%	45,9%	16,3%	11,2%	40326,29	71,5%	4,7%	17,2%	0,01	-0,5%

Table 5: Administrative districts with the highest shares of employment associated with paper production

Administrative District	Share Employees in Paper Production	Population Trend	Population Density	Average Age	Foreign Nationals	Care Rate	School Dropouts	Children in Families Receiving Unemployment Benefits	GDP per capita	Economic Trend	Youth Unemployment	Low-Skilled Employment	Cash Credits	Deviation in Voter Turnout
Düren	5,4%	-0,7%	283,35	44,60	12,9%	58,2%	18,8%	15,9%	31859,00	52,7%	6,5%	20,1%	0,04	0,9%
Euskirchen	3,1%	2,8%	155,92	45,20	8,3%	29,2%	15,3%	10,9%	29802,00	56,4%	4,6%	19,5%	0,01	0,0%
Spree-Neiße	2,6%	-24,7%	67,57	50,10	6,9%	63,2%	21,1%	9,8%	40905,00	129,2%	5,2%	14,7%	0,02	-3,8%
Mayen-Koblenz	2,4%	2,2%	263,47	45,30	9,5%	51,2%	16,2%	8,3%	32626,00	63,4%	3,3%	19,9%	0,02	0,4%
Neuburg-Schrobenhausen	2,4%	10,4%	133,16	43,40	11,8%	26,0%	20,4%	3,6%	40661,00	81,4%	2,4%	17,2%	0,00	-0,1%
Unterallgäu	2,3%	10,5%	120,19	44,20	11,1%	18,8%	21,9%	2,2%	40840,00	93,5%	1,9%	16,2%	0,00	0,6%
W aldeck-Frankenberg	2,0%	-8,2%	84,66	46,00	9,8%	40,5%	21,3%	8,7%	40868,00	77,2%	3,3%	15,7%	0,00	-0,7%
Median (all administrative districts)	0,1%	1,7%	201,38	45,00	11,5%	42,9%	16,2%	9,6%	36533,00	69,0%	4,3%	17,2%	0,00	0,1%
Average (all administrative districts)	0,5%	0,1%	536,54	45,28	12,3%	45,9%	16,3%	11,2%	40326,29	71,5%	4,7%	17,2%	0,01	-0,5%

Table 6: Administrative districts with the highest shares of employment in professions associated with chemical production

Administrative District	Share Employees Chemical Production	Population Trend	Population Density	Average Age	Foreign Nationals	Care Rate	School Dropouts	Children in Families Receiving Unemployment Benefits	GDP per capita	Economic Trend	Youth Unemployment	Low-Skilled Employment	Cash Credits	Deviation in Voter Turnout
Altötting	17,4%	3,6%	196,94	44,70	13,5%	19,6%	17,5%	5,6%	60222,00	79,2%	2,6%	13,3%	0,00	-2,1%
Leverkusen	10,0%	1,7%	2077,48	44,60	18,0%	61,2%	18,3%	20,6%	51375,00	19,8%	6,3%	12,5%	0,03	0,0%
Holzminden	7,1%	-14,2%	100,63	47,50	6,8%	30,2%	17,3%	14,0%	34611,00	73,6%	5,8%	20,8%	0,02	0,8%
Ludwigshafen am Rhein	7,0%	6,1%	2223,23	42,20	29,9%	35,4%	18,0%	22,9%	76182,00	25,5%	7,6%	12,2%	0,03	-4,3%
Saalekreis	5,1%	-15,9%	127,46	47,80	4,3%	83,6%	12,0%	12,1%	39312,00	100,5%	9,2%	16,1%	0,00	-7,8%
Worms	4,6%	4,3%	771,18	43,50	21,9%	41,2%	22,1%	19,0%	41419,00	71,0%	6,9%	23,6%	0,07	-4,0%
Goslar	4,3%	-14,2%	138,67	48,40	10,4%	40,4%	12,3%	17,4%	29583,00	54,8%	6,2%	18,1%	0,00	-0,6%
Schwalm-Eder-Kreis	4,1%	-6,9%	116,99	46,20	8,5%	36,8%	16,1%	9,1%	33934,00	78,6%	3,8%	21,7%	0,00	2,8%
Anhalt-Bitterfeld	4,0%	-24,8%	107,14	49,40	4,2%	81,4%	11,0%	15,0%	34267,00	134,1%	8,5%	18,5%	0,02	-10,6%
Krefeld	4,0%	-5,4%	1647,92	44,70	19,8%	55,3%	19,3%	23,0%	43194,00	39,0%	7,0%	15,7%	0,03	-3,0%
Darmstadt	3,8%	15,5%	1307,70	41,00	22,4%	57,8%	10,3%	19,1%	88497,00	63,3%	4,8%	10,0%	0,00	1,8%
Miltenberg	3,8%	-1,9%	179,97	45,30	11,8%	25,0%	23,6%	5,5%	38408,00	89,0%	3,1%	19,3%	0,00	2,2%
Median (all administrative districts)	0,6%	1,7%	201,38	45,00	11,5%	42,9%	16,2%	9,6%	36533,00	69,0%	4,3%	17,2%	0,00	0,1%
Average (all administrative districts)	0,9%	0,1%	536,54	45,28	12,3%	45,9%	16,3%	11,2%	40326,29	71,5%	4,7%	17,2%	0,01	-0,5%

Table 7: Administrative districts with the highest shares of employment associated with glass, ceramics, and mineral production

Administrative District	Share Employees in Glass, Ceramics, and Mineral Production	Population Trend	Population Density	Average Age	Foreign Nationals	Care Rate	School Dropouts	Children in Families Receiving Unemployment Benefits	GDP per capita	Economic Trend	Youth Unemployment	Low-Skilled Employment	Cash Credits	Deviation in Voter Turnout
Kronach	11,6%	-12,6%	101,45	47,80	5,7%	45,6%	19,6%	5,0%	35295,00	60,9%	3,5%	16,7%	0,00	1,1%
Sonneberg	11,0%	-16,7%	122,61	49,60	5,7%	92,9%	17,2%	7,9%	29278,00	143,1%	5,6%	22,5%	0,00	-5,9%
Holzminden	10,8%	-14,2%	100,63	47,50	6,8%	30,2%	17,3%	14,0%	34611,00	73,6%	5,8%	20,8%	0,02	0,8%
Wunsiedel i.Fichtelgebirge	10,4%	-16,9%	117,89	47,90	9,7%	39,4%	20,4%	9,0%	37875,00	81,2%	4,0%	20,7%	0,01	-1,7%
Merzig-Wadern	8,0%	-2,4%	186,14	46,50	13,7%	60,0%	26,6%	9,8%	28344,00	49,4%	3,9%	16,8%	0,02	2,6%
Kitzingen	6,3%	3,4%	134,45	44,60	10,3%	42,9%	15,2%	3,5%	37952,00	82,8%	2,3%	19,0%	0,00	1,7%
Rottal-Inn	6,3%	3,5%	95,42	44,80	11,5%	15,9%	22,5%	5,8%	36745,00	73,9%	2,9%	18,7%	0,00	-4,1%
Westerwaldkreis	4,8%	1,0%	206,09	45,00	10,0%	55,0%	17,6%	6,4%	37356,00	79,2%	2,6%	20,3%	0,00	1,7%
Tirschenreuth	4,6%	-10,4%	66,08	46,10	5,1%	21,0%	20,3%	4,4%	46501,00	142,7%	2,6%	18,6%	0,00	2,2%
Bayreuth	4,5%	-5,0%	81,38	46,10	4,2%	29,2%	30,3%	3,2%	24605,00	50,9%	2,0%	18,5%	0,00	2,6%
Schwandorf	4,3%	4,1%	102,33	44,60	9,9%	21,0%	20,8%	4,6%	39695,00	75,0%	2,8%	19,2%	0,00	-1,4%
Median (all administrative districts)	0,5%	1,7%	201,38	45,00	11,5%	42,9%	16,2%	9,6%	36533,00	69,0%	4,3%	17,2%	0,00	0,1%
Average (all administrative districts)	1,0%	0,1%	536,54	45,28	12,3%	45,9%	16,3%	11,2%	40326,29	71,5%	4,7%	17,2%	0,01	-0,5%

Table 8: Administrative districts with the highest shares of employment associated with metal production

Administrative District	Share Employees in Metal Production	Population Trend	Population Density	Average Age	Foreign Nationals	Care Rate	School Dropouts	Children in Families Receiving Unemployment Benefits	GDP per capita	Economic Trend	Youth Unemployment	Low-Skilled Employment	Cash Credits	Deviation in Voter Turnout
Duisburg	10,8%	-3,8%	2127,03	43,50	24,1%	27,3%	21,6%	30,7%	37053,00	50,5%	8,6%	15,5%	0,05	-4,7%
Märkischer Kreis	6,9%	-11,1%	383,37	45,30	14,7%	31,0%	19,2%	14,6%	38619,00	56,4%	5,3%	19,0%	0,03	-1,8%
Olpe	5,6%	-5,7%	186,94	44,60	10,6%	54,7%	17,0%	7,0%	43932,00	83,7%	2,9%	21,1%	0,00	2,2%
Hagen	5,3%	-7,1%	1176,15	44,10	22,5%	32,5%	20,2%	29,9%	35665,00	42,7%	9,9%	18,6%	0,12	-3,7%
Lahn-Dill-Kreis	4,6%	-3,6%	237,61	45,20	12,0%	35,6%	17,5%	13,4%	35802,00	54,5%	4,1%	18,6%	0,00	-2,3%
Siegen-Wittgenstein	4,6%	-7,4%	242,16	44,50	12,7%	45,5%	16,4%	12,8%	40750,00	59,2%	4,8%	14,9%	0,03	1,2%
Marburg-Biedenkopf	4,5%	-2,8%	194,95	43,30	12,2%	56,1%	17,1%	10,1%	42529,00	75,3%	3,5%	15,4%	0,00	1,2%
Neu-Ulm	4,5%	11,1%	343,77	43,60	16,3%	44,3%	19,9%	4,5%	38284,00	57,2%	2,4%	16,2%	0,00	-0,3%
Konstanz	4,2%	8,2%	352,21	44,00	16,8%	24,6%	15,2%	8,6%	38640,00	64,9%	2,8%	16,6%	0,00	0,4%
Median (all administrative districts)	0,5%	1,7%	201,38	45,00	11,5%	42,9%	16,2%	9,6%	36533,00	69,0%	4,3%	17,2%	0,00	0,1%
Average (all administrative districts)	1,1%	0,1%	536,54	45,28	12,3%	45,9%	16,3%	11,2%	40326,29	71,5%	4,7%	17,2%	0,01	-0,5%

Table 9: Administrative districts with the highest shares of employment in professions associated with automotive production

Administrative District	Share Employees Automotive Production	Population Trend	Population Density	Average Age	Foreign Nationals	Care Rate	School Dropouts	Children in Families Receiving Unemployment Benefits	GDP per capita	Economic Trend	Youth Unemployment	Low-Skilled Employment	Cash Credits	Deviation in Voter Turnout
Wolfsburg	33,8%	1,8%	605,75	44,50	16,9%	68,5%	7,4%	14,4%	158749,00	88,5%	6,2%	9,3%	0,00	-1,1%
Dingolfing-Landau	31,4%	8,3%	111,72	43,70	13,6%	19,4%	26,8%	3,3%	69339,00	128,9%	2,5%	16,2%	0,00	-4,1%
Emden	25,6%	-2,8%	440,83	44,00	12,3%	25,5%	10,7%	22,7%	66872,00	61,1%	6,6%	17,5%	0,00	-4,0%
Salzgitter	24,5%	-7,7%	461,91	44,20	20,9%	42,8%	17,9%	26,5%	51738,00	66,9%	8,9%	14,1%	0,04	-2,8%
Kassel	23,2%	-3,5%	183,46	46,80	14,1%	30,5%	18,5%	8,9%	29469,00	47,6%	4,2%	18,8%	0,00	3,8%
Rastatt	22,1%	4,0%	314,58	45,20	15,5%	18,0%	15,9%	7,3%	43570,00	65,0%	3,2%	18,1%	0,00	-0,4%
Ingolstadt	21,7%	19,3%	1034,99	42,20	24,2%	45,0%	12,1%	9,5%	130509,00	153,2%	3,9%	10,1%	0,00	-6,5%
Germersheim	21,4%	4,8%	279,10	44,30	13,9%	53,8%	17,7%	8,7%	37765,00	96,2%	3,8%	24,8%	0,03	1,9%
Schweinfurt	20,5%	-1,4%	1500,98	44,80	21,4%	31,3%	18,3%	17,1%	99130,00	72,1%	4,5%	15,5%	0,00	-6,7%
Böblingen	18,1%	7,7%	636,49	43,60	19,7%	19,7%	12,9%	6,8%	67350,00	74,6%	2,3%	14,9%	0,00	4,1%
Ludwigshafen am Rhein	17,7%	6,1%	2223,23	42,20	29,9%	35,4%	18,0%	22,9%	76182,00	25,5%	7,6%	12,2%	0,03	-4,3%
Wartburgkreis	16,6%	9,8%	115,89	48,00	5,4%	91,0%	13,9%	8,7%	29031,00	107,0%	6,1%	15,9%	0,00	-2,6%
Median (all administrative districts)	8,5%	1,7%	201,38	45,00	11,5%	42,9%	16,2%	9,6%	36533,00	69,0%	4,3%	17,2%	0,00	0,1%
Average (all administrative districts)	9,1%	0,1%	536,54	45,28	12,3%	45,9%	16,3%	11,2%	40326,29	71,5%	4,7%	17,2%	0,01	-0,5%