Coal Rush

The Built Legacy of the Industrial Revolution and the Rise of the Radical Right *

WORKING PAPER

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Abstract

Historical industrial centers have shifted to the right but have done so at different speeds and intensities. We argue that this variation can be explained by differences in the historical industrialization process. Communities that industrialized later and more intensively realign more toward the radical right today. This is because the built environment shaped by the original industrialization drives demographic persistence and neighborhood disadvantage. To examine our argument, we study the effects of nineteenth-century coal mining in Germany's Ruhr area. We match the geolocation of over 1,000 mining shafts, historical plant-level employment data, and the spread of company housing with contemporary electoral results at the neighborhood level. For identification, we exploit the depth of coal deposits that governed the adoption of deep-shaft mining. The findings demonstrate how the path of economic development influences voting in the long run.

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1 Introduction

Across advanced democracies, former industrial regions, once dominated by left parties, have shifted to the political right (Becker et al. 2017; Dijkstra et al. 2020; Broz et al. 2021). Political scientists often explain this realignment with the economic shocks that have enveloped industrial strongholds over the past half-century. Import competition, automation, and the resulting layoffs and plant closures have been shown to drive support for the radical right (Autor et al. 2020; Colantone and Stanig 2018; Anelli et al. 2021; Greve et al. 2023; Kurer 2020; Baccini and Weymouth 2021; Gazmararian 2025; Bekhtiar 2025), while other studies point to the vulnerability of industrial regions to fiscal cutbacks (Baccini and Sattler 2024; Fetzer 2019).

While most studies focus on the commonalities of deindustrialization trajectories, much less is understood about why some former industrial constituencies have become radical right strongholds whereas others have not. In the U.S., many industrial towns that once formed the New Deal coalition have turned Republican, yet other structurally similar towns continue to support Democrats (Ternullo 2024). In Europe, former textile, coal, steel, and shipbuilding centers have deindustrialized, but the social and political consequences have varied widely (Raphael 2019; Bayerlein et al. 2025; Ejrnæs and Jensen 2024). And even within historical industrial regions where the radical right has found particular success, such as northern France or the German Ruhr area, vast differences in political behavior exist across cities.

We argue that these contemporary differences in voting behavior are rooted not exclusively in the economic shocks of the late twentieth century, but more fundamentally in the historical legacies of industrialization from a century earlier. To develop this argument, we draw inspiration from Alexander Gerschenkron's (1962) analysis of the Industrial Revolution, which posits that early industrialization was gradual and decentralized, whereas late industrialization unfolded rapidly with larger plants and bigger capital requirements.

Applying this logic locally, we contend that late and intensive nineteenth-century industrialization generated larger workforces and forged a distinctive built environment in industrializing cities. When the original industries disappeared, this built environment persisted and continued to shape the demographic and political development of these cities (Rodden 2019). As a result, areas that industrialized later and more intensively remain characterized by worker housing and insufficient infrastructure, reinforcing the concentration of low-income households in places structurally isolated from economic opportunity (Glaeser and Gyourko 2005; Heblich et al. 2021; Gagliardi et al. 2023; Heblich et al. 2025).

We study our theoretical argument in a paradigmatic context of industrial development and decline: coal mining in the German Ruhr area. The Ruhr was Europe's largest industrial region from around 1870 until the late twentieth century. In 1913, its 400,000 miners generated 9 percent of global coal production, which fueled 12 percent of global pig iron production (Steinberg 1985, 72–73; Czierpka 2019, 18). Coal mining powered local economic development and the rise of advanced industries (Fernihough and O'Rourke 2021; Gutberlet 2014). Today, about 3.5 million inhabitants live in the cities we study in this paper.

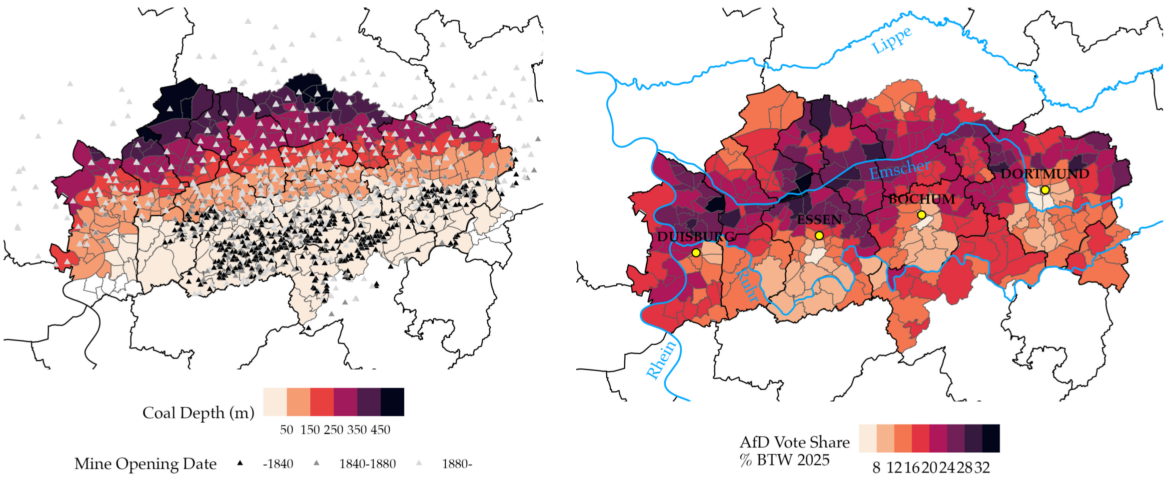
Although the entire region industrialized in the nineteenth century, the timing and pace of this process varied enormously. The region's south engaged in small-scale mining before the Industrial Revolution and gradually transitioned to industrial operations. In contrast, northern Ruhr communities underwent a late but rapid industrial expansion beginning in the mid-nineteenth century, transitioning directly into large-scale deep-shaft coal mining (Tilly and Kopsidis 2020). We refer to this development as the *coal rush*.

We harness the heterogeneous adoption of deep-shaft mining to study the electoral legacy of different industrialization trajectories in the long run. Empirically, we use data on the location and opening dates of over 1,000 historical shafts and adits (Dodenhoff 2022), as well as historical surveys of shaft-level employment. Matching these shafts with contemporary city districts, we capture both the intensity and the timing of coal mining adoption. To ascertain how they shape electoral behavior, we construct a district-level (5,000-20,000 inhabitants) database of federal electoral outcomes in the 2017, 2021, and 2025 elections for 17 Ruhr cities.

For causal identification, we leverage the geological conditions that governed the sequential adoption of coal mining. As panel (a) of Figure 1 shows, the Carboniferous layer lies near the surface in the south but is buried deep beneath younger sediments in the north. As a consequence, mining had been confined to the south, until the introduction of the steam engine in the 1830s enabled industrial pioneers to access northern deposits. This process created spatial variation in the timing and intensity of industrialization: the south experienced an early and gradual transition from proto-industrial mining to bigger operations, whereas the north underwent a later but more rapid industrial expansion characterized by larger sites and workforces. The concentration of workers around northern mines gave rise to entirely new settlements during the late nineteenth and early twentieth centuries. As panel (b) shows, many of these new settlements have become strongholds of the AfD. At its core, our study of the Ruhr's electoral geography is thus a study in electoral geology.

Figure 1: The Electoral Geography and Historical Coal Mines of the Ruhr Area

(a) *Mines and Coal Depth* (b) *AfD Support 2025*



Note: The left-hand panel of this figure shows the depth of coal deposits and the spatial distribution and historical opening dates of coal mines across the Ruhr. The right-hand panel shows electoral support for the *Alternative für Deutschland* (AfD) in the 2025 federal election at the district level (N=348). The black lines indicate modern county boundaries; blue lines indicate rivers.

Our analysis provides causal evidence that the path of industrialization conditions modern electoral alignments. We demonstrate that communities that industrialized later and more intensively exhibit stronger support for the radical right and lower turnout. While social democracy still commands support in these communities, the radical right is increasingly replacing it as the dominant electoral force. Our instrumental variable design, which exploits the absence of close-to-surface coal deposits, demonstrates that the additional presence of 1,000 coal miners (50th percentile) in 1912, the high point of the coal rush, generates an increase in radical right support of up to 7 percentage points. We show that the impact of historical mining employment outweighs the effect of the decline in manufacturing employment since 1970.

Why are places that adopted deep-shaft coal mining later and more intensively electorally distinct from early industrializers? We argue that the historical industrialization experience shapes contemporary politics through the persistence of the industrial built environment. As the mines emerging at the height of the coal rush mostly opened in rural areas, they forged an enduring spatial landscape of worker settlements, transport infrastructure, and industrial premises. We focus on worker settlements, which, by determining who could live where and at what scale, offer the most immediate intertemporal link between historical demographic transformation and contemporary voters. We harness mine-level construction records to show that later-established coal mines invested more in company housing. These mining colonies persist, literally, in the modern built environment.

This legacy of the built environment lives on in the modern geography of neighborhood disadvantage and isolation. Residential areas shaped by worker housing exhibit lower rents, land values, and price-to-rent ratios, reflecting insufficient vertical density and diminished expectations for future development. These neighborhoods also lack access to urban amenities, educational opportunities, and critical infrastructure. As a result of these disadvantages, deprived and less-educated individuals remain concentrated in, and continue to sort into, coal rush communities long after industrial decline. Applying causal mediation methods (Dippel et al. 2022), we establish that this inherited demographic concentration accounts for much of the long-term influence of industrialization on electoral change.

This paper contributes to an established theoretical lineage that links political alignments to industrial timing. As Bartolini (2000) argued, later and more rapid industrial development often strengthened labor parties. Where industrialization occurred earlier, workers instead became inculcated in liberal or confessional coalitions (Luebbert 1991). Our paper complements this argument by suggesting that the demographic profile that once sustained the linkages between industrial communities and social democracy now places these areas on the frontlines of electoral realignment, as the radical right mobilizes disadvantaged urban voters.

This paper also makes several empirical contributions. First, it extends research on the economic roots of electoral change (Colantone and Stanig 2018; Margalit 2019; Kurer 2020; Baccini and Weymouth 2021; Stutzmann 2025; Gazmararian 2025; Cremaschi et al. 2025) by showing how the economic and political development trajectories of historically industrial areas are shaped by the legacies of the first era of large-scale industrialization. Second, it connects work on political persistence with research in urban economics, demonstrating that cities' historical built environments, through their impact on demographic persistence and residential sorting, help explain why historical economic structures have lasting effects on political outcomes (Acharya et al. 2016; Cantoni et al. 2019; Haffert 2022; Heblich et al. 2025; Heblich et al. 2021; Rodden 2019; Glaeser and Gyourko 2005). Third, by focusing on the industrial built environment, we provide micro-level evidence on the long-run costs of industrialization (Fritzsche and Wolf 2023; Esposito and Abramson 2021; Franck and Galor 2021; Berbée et al. 2025).

In the following, we first outline why the timing and intensity of industrialization shape social and political outcomes. Next, we introduce our case of coal mining in the Ruhr and explain our identification strategy. We then present results linking the timing and intensity of coal mining adoption to voting behavior, before we provide evidence for our mechanism: the industrial built environment creating sociodemographic persistence. The final section discusses the implications of our findings for electoral change in postindustrial democracies.

2 How Industrial Timing Shapes Urban Development

In his seminal work, Alexander Gerschenkron (1962) argued that a country's long-run development fundamentally depended on the timing and context of its industrialization. According to Gerschenkron, early industrializers integrated large-scale machinery gradually into existing production systems, whereas countries industrializing in the late nineteenth and early twentieth centuries transitioned abruptly from rural backwardness into heavy industries. This rapid transition entailed larger factories, higher capital requirements, and greater state intervention.[1]

While Gerschenkron (1962) focused on the industrialization trajectories of nations, we argue that the timing of industrialization also influences the economic and political development of cities. We emphasize that, beyond its impact on institutions, the timing of industrialization produced distinct patterns of spatial organization. Specifically, a later and more intensive industrialization created urban built environments that drive demographic persistence, local

1. Mokyr (2010) attributes Britain's early industrialization to the Enlightenment's emphasis on useful knowledge and its production and application by a growing class of inventors and engineers. Germany's later industrial catch-up is often linked to universal banks supporting rapid industrial capital formation (Burhop 2006), while late industrialization in Tsarist Russia depended heavily on state bank loans (Suesse and Grigoriadis 2025). Nonetheless, German growth also relied on decentralized knowledge clusters (cf. Chiopris 2024).

development, and, in turn, electoral outcomes in the long run.[2] In contrast to early industrial manufacturing, which arose within or close to existing towns, the factories of late industrialization demanded more space and a larger labor force than was available in urban centers. These factories emerged in sparsely populated areas in the surrounding countryside, drawing substantial migration flows to meet the soaring labor demands of intensive industrial production.

Compared to early industrializers, which integrated the new economic sectors more gradually into existing urban landscapes, the rapidly expanding workforces in late-industrializing areas, thus, required the development of local infrastructure, transport networks, and, above all, an entirely new housing stock tailored to workers' needs (Rodden 2019, 103). The larger the industrial sites, the less existing housing markets could absorb incoming workers. In response, company towns and worker housing established new settlements, which were detached from urban centers and concentrated workers near the plants (Krämer 2012, 180; Honhart 1990; Fishback and Lauszus 1989, 125; Griskavich 2014, 33).

This has consequences until today: after industrial plants close, the purpose-built settlements that emerged around them persist in the built environment. Crucially, this means that, amid declining economic prospects, these areas retain an extensive housing stock. As demand falls, this persistent housing supply depresses home prices and rents, keeping residents locked into worker neighborhoods while attracting poor households less able to adapt to economic shocks (Glaeser and Gyourko 2005, 362). In this way, worker settlements transmit the demographic legacy of late nineteenth-century industrialization into the present, sustaining large urban populations but leaving behind communities particularly vulnerable to structural change (Rodden 2019, 47; Heblich et al. 2021; Gagliardi et al. 2023; Heblich et al. 2025).

The legacy of the industrial built environment also exacerbates the economic disadvantages of contemporary residents. As late industrialization often concentrated workers in a single industry or even firm, many areas were left unable to reinvent themselves when dominant industries disappeared (Berbée et al. 2025; Glaeser et al. 1992). The literature primarily highlights the lack of access to education and the resulting deficiencies in human capital formation (Esposito and Abramson 2021; Franck and Galor 2021; Gagliardi et al. 2023). This problem is likely

2. With "late industrialization", we refer to the late nineteenth and early twentieth centuries. By intensity, we mean the speed, scope, and scale at which industrialization transforms a place.

to be exacerbated in worker settlements that emerged around industrial plants, often isolated from urban centers, and where local infrastructure was tied to the industry itself.[3] More generally, access to urban infrastructure remained underdeveloped, while the weak integration with central business districts limits the economic benefits of agglomeration and urban diversity (cf. Jacobs 1961; Glaeser 2012; Ahlfeldt et al. 2015). Lastly, the industrial era left behind large industrial premises that disrupt spatial connectivity and remain difficult to repurpose.

Consequently, late and intensive industrialization created a persistent built environment that retains and attracts poorer and less-educated individuals while reinforcing their disadvantages. This dynamic distinguishes the late-industrializing communities of the nineteenth and early twentieth centuries from those that industrialized earlier or in the postwar period. Early industrialization gradually accommodated workforces in existing urban structures within historical cities, where factories originally emerged. Conversely, postwar industrialization was accompanied by rising car ownership and labor-saving technologies, which decoupled industrial expansion from the creation of worker settlements near production sites (Rodden 2019).

We contend that these conditions provide fertile ground for the electoral realignment of former industrial constituencies.[4] Indeed, the adverse socioeconomic conditions we attribute to late and intensive industrialization are widely recognized as drivers of radical right support (Baccini and Weymouth 2021; Becker et al. 2017). The rise of cultural divisions and the transformation of party strategies (Bonomi et al. 2021; Abou-Chadi and Wagner 2019) have enabled the radical right to mobilize voters with lower levels of education and income (Gethin et al. 2022).

As a result, the demographic profile created by late and intensive industrialization, which traditionally sustained the electoral dominance of social democracy, is increasingly conducive to radical right support, in particular where late-industrialized areas attract low-income residents without preexisting attachments to social democracy. The radical right's electoral fortunes are further reinforced by the limited capacity of late-industrial communities to adjust to deindustrialization, due to their historical economic concentration and weak integration with the central urban economy. The endurance of economic decline thereby fuels broader political

3. Company stores in American mining towns exemplify such local monopolies (Fishback 1986).

4. Our aim is not to explain why individuals vote for the radical right, but to account for why the structural conditions that foster radical right support are more prevalent in late-industrializing places.

alienation. As such, greater radical right support should coincide with structurally lower rates of overall political participation (Algan et al. 2017; Guiso et al. 2024).

Thus, our argument suggests that even among communities facing similar declines in industrial employment, the historical built environment of late-industrializing areas has left some with more adverse demographic and economic conditions than others. These conditions, in turn, make such communities increasingly susceptible to radical right appeals.

3 The Empirical Case: Coal Mining in the Ruhr Area

We examine the effects of the timing and intensity of industrial development in the Ruhr area–Europe's largest industrial region from the late nineteenth century to the postwar period. Since it was part of Prussia, and later of North Rhine-Westphalia, the institutional context is held constant. The Ruhr's key advantage for our research design is its geology, which dictated the adoption of coal mining and led to variation in the intensity and timing of industrialization. As the Carboniferous strata lie near the surface in the south, southern communities adopted mining earlier and on a smaller scale. In contrast, northern coal deposits are buried deep underground, which led to a later but much more rapid adoption of deep-shaft mining in the nineteenth century. This allows us to exploit exogenous variation in the timing and intensity of mining, which, we contend, left a lasting imprint on the region's electoral geography.

The Rise and Fall of the Ruhr

In the early nineteenth century, what would become the German Empire's industrial heartland had been an eclectic collection of small towns and villages with diverse confessional affiliations. The largest towns included the Protestant Imperial cities of Dortmund and Duisburg, each with fewer than 5,000 inhabitants in 1818. The modern city of Essen, which was divided into over 30 municipalities in 1871, coalesced around the Catholic Abbeys of Essen and Werden. North of Essen was the village of Gelsenkirchen, home to 511 people after the Congress of Vienna.

For centuries, coal mining had been limited to small-scale shaft and adit operations clustered around the Ruhr basin. The transformation of this mainly rural area into an industrial powerhouse began in earnest in the 1830s with the breaking of the marl cover ("Mergeldecke"), the upper geological layer under which coal was buried in the north. This enabled industrialists to exploit the north's rich coal deposits (Tilly and Kopsidis 2020; Steinberg 1985, 7). From 1840 onward, then, hundreds of mines were established, with over 700 recorded shafts until the late Weimar Republic. This marked the age of the coal rush.[5]

The Ruhr area's population exploded from around 236,000 inhabitants in 1840 to about 655,000 by 1871 and 2.5 million by 1905 (Steinberg 1985). This massive population growth was enabled by large-scale immigration: at first, migration from the Rhenish and Westphalian peripheries catered to the soaring demand for labor (Steinberg 1985, 88; Sperber 1983, 350). Once nearby labor reserves were depleted, Ruhr firms increasingly recruited workers from Prussia's eastern provinces. By 1913, more than one-third of the Ruhr's 410,000 coal miners came from these East Elbian regions (Allgemeiner Knappschafts-Verein 1912).

The unprecedented inflow of immigrants raised the question of housing the new arrivals. The land requirements of deep-shaft mining meant that mines arose in thinly populated rural areas without residential infrastructure (Steinberg 1985, 37). Mining entrepreneurs responded to these shortages by establishing mining colonies. The needs of industry thereby dominated urban development at the expense of planning (Boldt and Gelhar 2008). Colonies not only allowed workers to live within walking distance of the mines but also provided schools, churches, cooperative stores, and garden plots for household production. As a result, the north developed a distinctive settlement structure that coalesced entirely around the mines.

Workers thus became concentrated in mining colonies, with their purpose-built housing, worker-centric infrastructure, and the settlements that developed around them. Already in 1893, more than fifty municipalities had populations fully dependent on mining (Taeglichsbeck 1895). Mining colonies, which provided relatively high-quality housing at low rents (Brüggemeier 2018, 330), also reinforced the intergenerational persistence of mining employment, as sons who entered working age were sometimes compelled to either move out or begin working in the mines themselves (Günther and Prévôt 1905, 48).

As mining communities expanded, they were incorporated into historical towns. In Essen,

5. The Ruhr's industrialization was driven by coal and steel. We focus on coal, since the rise of steel followed different logics, with steel mills often arising near urban centers. This should attenuate our estimates, as some places we code as gradual industrializers through coal were heavily industrialized through steel. By 1939, coal employed 320,000 workers and steel 173,000 (Steinberg 1985, 93).

Bochum, and Dortmund, this united the early industrial south with the intensively industrialized north, whereas other mining towns merged to form new cities. This settlement structure still defines the Ruhr today. Modern planners describe northern colonies as "villages within towns" due to their urban isolation (Netzwerk Siedlungskultur 2017, 23).

After steady expansion until WWI, coal mining in the Ruhr entered a more volatile phase during the interwar period. Coal production again increased during the first decade after WWII until the coal crisis of 1957/58 initiated the decades-long decline of the industry. Although some additional mines opened during the early postwar years, their spatial impact was weaker than that of prewar mines. Miners increasingly commuted by car, while shafts could be connected underground to create compound mines, reducing the need for overground transport infrastructure. Our argument thus centers on the construction of deep-shaft mines before the postwar period, when the impact of industrialization on urbanization began to fade.

Against this background, we expect late and intensive industrialization to generate enduring urban disadvantages for former coal rush communities. Deep-shaft mines and their industrial settlements concentrated workers from diverse regions in areas isolated from urban centers. As in other once-industrial cities (Heblich et al. 2021), this disproportionate presence of disadvantaged households persists over generations, as affordable housing keeps worker families in place even after the mines closed. At the same time, low rents create incentives for low-income migrants to settle in these areas. The industrial built environment thus reinforces urban disparities in education and income through demographic sorting.

The inheritance of the Ruhr's polycentric industrial built environment also constrains urban redevelopment. As entire districts were forged during the coal rush, their historical isolation now translates into limited access to urban amenities and infrastructure. The predominance of low-density housing, paired with large conversion zones left behind by mining sites (Leerkamp and Meißner 2020, 354), makes these communities less residentially diverse and poorly suited for commercial development. Moreover, since workers lived close to the mines, there was little incentive to develop mobility networks to facilitate commuting (Pries and Roos 2020, 26–27). These rigidities hinder the Ruhr's transition out of its historical monosectoralism, despite the creation of several universities (Grabher 1993, 260–264). Reinventing Bottrop, in other words, has proven far more difficult than reinventing Boston (Glaeser 2005). Indeed, measured by GDP per capita, the northern Ruhr area belonged to the wealthiest quartile of West German labor market areas in 1960 and fell to the lowest decile by 2020 (Bartels and Rieger 2025).

Although most mines had closed by the 1990s, with hard coal mining finally ending in Germany and the Ruhr in 2018, the legacy of deep-shaft mining endures in the built environment through low housing costs, limited residential diversity, and poor access to infrastructure. Together, we expect this legacy to catalyze the rise of the radical-right *Alternative für Deutschland* (AfD), founded in 2013, and to lower turnout through the persistence of low human capital and urban disadvantage. Today, the Ruhr is one of the AfD's strongholds in Western Germany, yet its success within the region is highly uneven: in the 2025 federal election, the party's vote share ranged from around 7% in southern Bochum or Essen to more than 30% in parts of Bottrop or Gelsenkirchen. This is the variation our analysis seeks to explain. The electoral gains of the AfD should come at the expense of social democracy (SPD), the region's dominant party since the postwar period (Rohe 1987).[6] While some social democratic support may persist in former industrial communities, the growing appeal of the radical right to deprived voters should increasingly override these historical loyalties.

Empirical Strategy: The Electoral Geology of the Ruhr

To identify the causal effects of late and intensive industrialization on the Ruhr's contemporary political geography, we leverage the region's distinctive geological conditions, which created exogenous variation in both the extensive and intensive margins of coal mining. The Carboniferous strata in the Ruhr are close to the surface layer in the southern part of the region but lie progressively deeper underground toward the north beneath the marl cover (*Mergeldecke*). As a result, until the early nineteenth century, coal mining was confined to the southern Ruhr, where accessible surface deposits supported proto-industrial extraction.

After the introduction of the steam engine, which enabled industrialists to breach the marl cover, coal mining expanded northward (Tilly and Kopsidis 2020, 51). This initiated the coal rush, the second phase of industrial development, in which coal depth dictated the continued

6. Historically, the Ruhr was marked by strong confessional divides in voting between 1871 and 1912. In the interwar period, the Communist Party received substantial support in heavily industrialized areas, with notable heterogeneity across cities (Rohe 1987).

northward relocation (*Nordwanderung*) of coal mining: the deeper the Carboniferous layer, the later a district adopted coal mining. At the beginning of the twentieth century, mining activities reached the north of what now constitutes the urban core of the Ruhr area, where the Carboniferous formations begin at 300 meters below ground.

The later adoption of coal mining in the nineteenth century produced a more intensive industrialization. However, while coal depth drove mining adoption monotonically, the intensive margin depended on whether the marl cover had initially prevented proto-industrial mining. Although southern towns could also engage in deep-shaft mining–since seams that reached the surface continued underground at depths of several hundred meters–their specialization evolved gradually, as deeper shafts replaced earlier sites. By contrast, the north–where coal deposits exclusively existed deep underground–transitioned directly into deep-shaft mining after the steam engine became widely available. This rapid adoption of deep-shaft mining, which required greater capital investments, drove a more intensive industrialization in the north that produced substantially larger workforces (cf. Steinberg 1985, 7). Thus, the (in)accessibility of close-to-surface coal forged two distinct industrialization regimes: early, gradual industrialization in the south and late, intensive industrialization in the north.

We exploit these geological conditions to identify the long-term effects of the timing and intensity of coal mining operations. We first use the depth of coal deposits to examine the general pattern predicted by our argument: later nineteenth-century industrialization underpinning electoral support for the radical right today. Our identification strategy then leverages the geological divide between deep and close-to-surface deposits to trace the legacy of late industrialization through its impact on intensity. In this design, we use the exclusive presence of deep coal in the north as an instrument to estimate how intensive industrialization shapes contemporary electoral outcomes. The target estimand is the local average treatment effect (LATE), identified for districts where deep coal deposits led to more intensive industrialization.

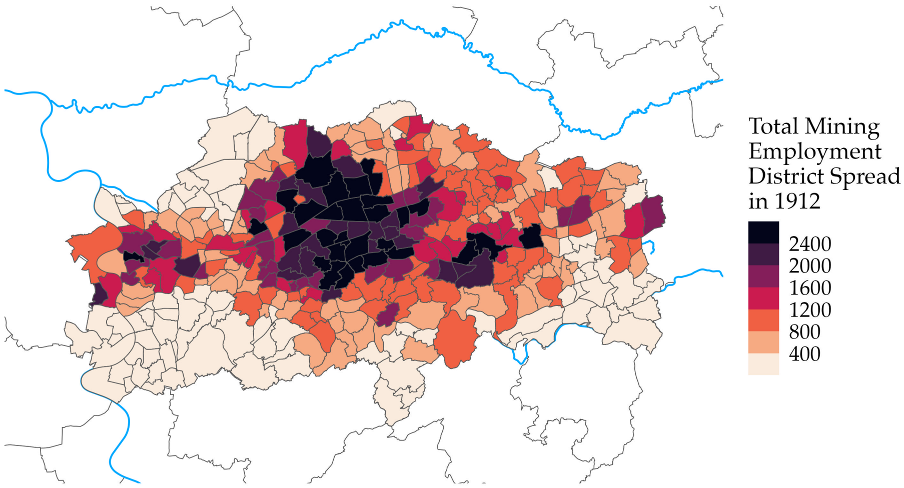
Empirically, we use geological maps of the Ruhr to capture the average depth of coal deposits, normalized by ground-level elevation.[7] However, because of intra-district variation in elevation and coal depth, the average depth does not necessarily indicate whether proto-

7. By average depth, we mean the average depth of the uppermost coal-bearing layer.

industrial extraction was viable. We therefore draw on a granular stratigraphic database of boreholes to identify the presence of close-to-surface Carboniferous strata (Geologischer Dienst NRW 2023, 2025).[8] We link these indicators to a novel dataset of modern city district boundaries (*Stadtteile*; $N = 348$) across seventeen cities, covering the Ruhr's urban heartland.[9]

Next, we draw on an extensive collection of mining sites compiled from several private data projects. Our foundation is the *Zechenkarte* (coal mine map) by Dodenhoff (2022), which geo-references over 1,000 historical shafts and adits, including their opening and closure dates. We augment this dataset with additional sources on proto-industrial mines. To measure the timing of industrialization, we calculate the average opening date of all mines within a contemporary district's boundaries and of the ten nearest sites. The district measure avoids assigning mines to areas never engaged in mining, while the distance-based measure captures districts affected by mining despite lacking a shaft within their boundaries.

Figure 2: Predicted Spread of Coal Miners in 1912 at the City District Level



Note: This figure shows the historical spread of coal miners in 1912 across city districts ($N = 348$).

To capture the intensity of industrialization, we leverage a historical survey of shaft-level employment at the height of the coal rush, offering us a detailed account of the size and composition of the workforce for the universe of operational mining shafts in 1912 (Allgemeiner Knappschafts-Verein 1912). We link this survey to records on the residential distribution of miners across historical municipalities, reporting how many workers from each mine lived

8. See Appendices I and II for details on the instrument and geological data.
9. Of the counties that are today organized in the "Regionalverband Ruhr", this excludes Wesel, Unna, Hamm, northern Recklinghausen, and southern Ennepe-Ruhr.

within defined distances of the shaft (Taeglichsbeck 1895). From these sources, we estimate the historical settlement distribution of coal miners across modern city districts i, denoted $miners_i$ and measured in thousands. As our most direct measure of the intensive margin of mining activity, it captures the concentrated settlement of miners that determined the enduring demographic structure and scale of coal communities. In the Appendix, we also consider alternative measures, including the number of shafts constructed during the coal rush.

We then instrument the scale of mining employment ($miners$) in district i with the exclusive presence of deep coal deposits, $deepcoal_i$. The intuition is that the sedimentary cover over the rich northern coal deposits required the adoption of deep-shaft mining, which expanded the workforce in areas where coal could not be extracted near the surface. Our instrument is coded 0 for districts with close-to-surface access–operationalized as at least two boreholes reaching the Carboniferous within 10 meters of the surface–and 1 for districts with only deep coal deposits. In the full sample, the eleven districts without coal deposits are also coded 0.

$$\text{First Stage}: \quad miners_i = \alpha + \gamma\, deepcoal_i + \delta' X_{i,\text{pre-1840}} + \theta_c + \epsilon_i \tag{1}$$

$$\text{Second Stage}: \quad y_i = \alpha + \beta\, \widehat{miners}_i + \delta' X_{i,\text{pre-1840}} + \theta_c + \epsilon_i, \tag{2}$$

The key identifying assumption is that $deepcoal_i$ is exogenous and affects electoral outcomes y_i solely through its impact on the intensity of industrialization, with no direct effects or alternative pathways. The assumption is plausible in our application, as variation in coal depth affected local conditions primarily through the scale of mining activity. Differences in economic prosperity, migration, or social structure emerged as downstream consequences of intensive industrialization, rather than as independent effects of geological variation. The instrument is further plausibly exogenous to unobserved determinants of prior industrial and political development, as geological variation in coal depth reflects natural processes unrelated to human settlement or economic activity. In additional specifications, we still add city fixed effects θ_c and controls $X_{i,\text{pre-1840}}$, drawing on census data on population, religion, urbanization, and income in the early nineteenth century–before the onset of deep-shaft mining. This enables us to identify the effects of intensive industrialization net of preindustrial economic development.

For our analysis, we collect an original dataset of local electoral behavior in the Ruhr area, compiling city district–level results for the federal elections of 2017, 2021, and 2025. Our analysis focuses on electoral support for the radical right, measured as the AfD vote share, and voter turnout as an indicator of political mobilization. In additional analyses, we also consider support for the Social Democratic Party (SPD), the traditional representative of industrial labor since the postwar period. All vote shares and turnout are measured in percent. In the Appendix, we also present results based on polling districts, which are even more fine-grained but have the disadvantage of excluding mail-in ballots.

To investigate the long-term demographic and economic effects of intensive industrialization, we assemble contemporary and historical census data. From the 2011 and 2022 censuses, we obtain 100m-×-100m grid-cell information on rents, homeownership rates, and the share of foreigners (Zensus 2011, 2022), which we apportion to city districts. We supplement these with a 1km-×-1km dataset on social assistance recipients, high-income earners, and university graduates (Helbig 2023). To measure the effects of contemporary deindustrialization, we incorporate district-level records of industrial employment in 1970 and 2011 (Schräpler et al. 2017).

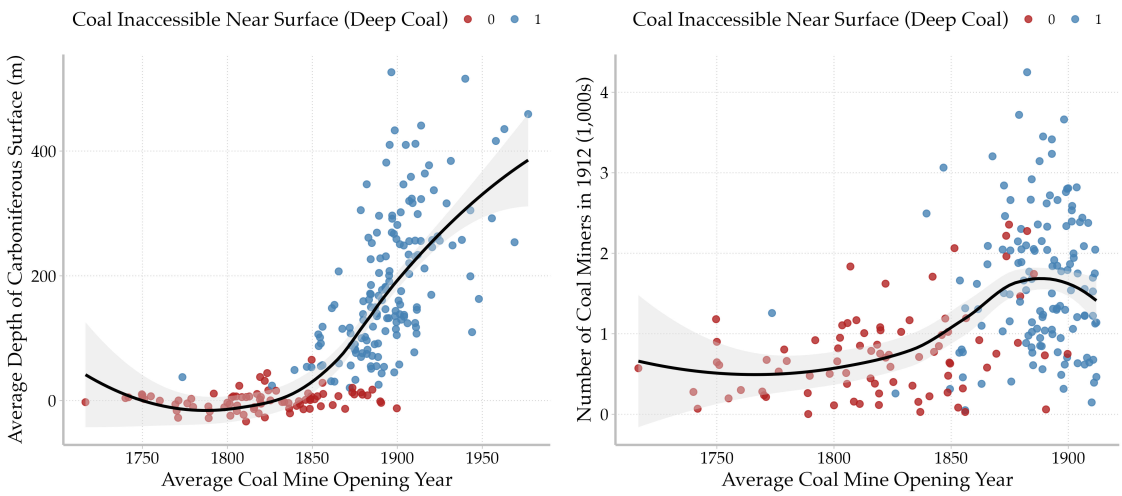
4 Results

We begin our analysis by examining the relationship between coal depth and the timing and intensity of mining adoption. The left-hand panel of Figure 3 shows that mine opening dates closely followed the depth of the Carboniferous surface: the deeper the deposits beneath a district, the later mining began, while proto-industrial mines emerged only where coal lay near the surface. The right-hand panel indicates that late industrialization, in turn, produced the largest workforces. Thus, while coal depth determined the timing of mining adoption, its scale depended, above all, on the presence of deep coal. Among the districts shown in Figure 3, those where coal deposits were inaccessible at the surface contained, on average, about 900 more miners. This surge in employment and population during late nineteenth- and early twentieth-century industrialization remained unmatched in the following decades (Figure A8).

Table 1 shows that the later adoption of coal mining generated lasting effects on electoral outcomes. Consistent with expectations, the radical right performs significantly better in areas that adopted mining relatively late. According to *Panel A*, a ten-year later onset of mining results in 0.38-0.47 percentage points more support for the AfD (Models 1-3). Communities that adopted mining later also exhibit lower voter turnout (Models 4-6). These effects are larger when considering the nearest ten mines instead of those within the district (*Panel B*). Crucially, contemporary radical right support concentrates in communities that industrialized in the late nineteenth and early twentieth centuries, where coal deposits lay 100-200 meters underground and large-scale mining workforces permanently remade the social structure (Figure A9).

Figure 3: Coal Deposits and the Timing and Intensity of Industrialization

(a) *Coal Depth-Industrial Timing* (b) *Industrial Timing-Employment*



Note: This figure shows the relationship between coal depth, the timing of mining adoption, and mining employment in 1912 at the city district level. The sample includes all districts containing at least one mine. *Panel (b)* excludes districts whose average industrialization occurred after 1912. The black lines indicate local regression polynomials, and the bands represent 95% confidence intervals.

Against this background, we propose that the relationship between the adoption period of coal mining and electoral outcomes reflects how timing has historically shaped the intensity of industrial development. We therefore turn to historical mining employment as our measure of the intensity of industrialization. Whether and to what extent coal mining transformed villages into urban areas, after all, depended on the number of workers who settled there. To this end, we exploit our $deepcoal_i$ instrument both in reduced-form regressions and to isolate exogenous variation in mining employment in 1912. Where coal deposits lay near the surface, places moved gradually from proto-industrial mining into moderately scaled industrial operations. Conversely, in the north, where seams lay deep underground, places shifted directly into deep-shaft mining during the coal rush, attracting thousands of workers.

Table 1: The Timing of Industrialization: Coal Mine Opening Dates and District-Level Electoral Outcomes; OLS Estimates

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***District Mines***						
Average Coal Mine Opening Year	0.465***	0.396***	0.375***	-0.593***	-0.482***	-0.527***
	(0.072)	(0.070)	(0.064)	(0.144)	(0.150)	(0.143)
N	720	720	720	720	720	720
Panel B: ***Distance Mines***						
Average Coal Mine Opening Year	0.559***	0.640***	0.613***	-0.768***	-0.896***	-0.990***
	(0.077)	(0.083)	(0.078)	(0.156)	(0.149)	(0.155)
N	1,044	1,044	1,044	1,044	1,044	1,044
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of the average starting year of coal mining operations on electoral outcomes at the city district level in the 2017, 2021, and 2025 federal elections. We normalize the opening year by subtracting 1839 and dividing by 10, so that a one-unit increase corresponds to industrialization occurring ten years later. *Panel A* reports regressions of electoral outcomes on the average starting year of all mines located within the boundaries of a district. *Panel B* reports regressions of electoral outcomes on the average opening year of the nearest ten coal mine shafts relative to each city district. Historical controls include log population, the Protestant share, population per building (all measured around 1819), and per capita income tax revenues around 1860. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Panel A in Table 2 first presents reduced-form evidence of the relationship between deep coal deposits, radical right support, and voter turnout. These estimates indicate that the AfD receives around 5 percentage points more support in communities where coal seams are buried deep beneath younger sediments (Models 1-3). As the party obtained, on average, 13.2% of the vote per district across the three elections in our pooled sample ($SD = 5.96$), this effect is substantial. Our estimates indicate that, once we account for preindustrial levels of development, voter turnout is nearly 10 percentage points lower in deep-coal districts (Models 4-6). These turnout gaps are not uncommon even within Ruhr cities: Altenessen and Rüttenscheid border Essen's historical core to the north and south, yet turnout in Rüttenscheid (south, 86.4%) was more than 17 percentage points higher than in Altenessen (north, 69.2%) in 2025.

The effects of historical mining employment underscore that the specialization patterns of the Ruhr have causally contributed to the modern divergence in electoral preferences. Across specifications in *Panel B*, we identify that 1,000 additional coal miners in 1912 are associated with a 2.2-2.9 percentage point increase in radical right support. Our instrumental variable estimates reported in *Panel C* indicate substantially larger effects of coal mining employment on electoral outcomes. Substantively, a one-standard-deviation increase in the historical presence of coal miners generates 6.1-6.6 percentage points more support for the AfD across the three federal elections. Thus, the intensive margin of historical industrialization explains a substantial share of the electoral gap observed within the Ruhr area today.

Table 2: Historical Coal Mining Employment in 1912 and Electoral Outcomes; OLS and 2SLS Estimates

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***Reduced Form***						
Deep Coal	5.040***	5.102***	5.017***	-8.543***	-9.966***	-9.800***
	(0.627)	(0.687)	(0.663)	(1.159)	(1.336)	(1.229)
Panel B: ***1912 & OLS***						
Coal Miners (1,000s)	2.235***	2.903***	2.895***	-4.236***	-6.178***	-5.949***
	(0.380)	(0.351)	(0.389)	(0.757)	(0.804)	(0.705)
Panel C: ***1912 & 2SLS***						
Coal Miners (1,000s)	7.727***	7.345***	7.344***	-13.098***	-14.349***	-14.348***
	(1.949)	(1.423)	(1.386)	(3.369)	(2.566)	(2.487)
F-stat	148.9***	193.9***	187.1***	148.9***	193.9***	187.1***
N	1,044	1,044	1,044	1,044	1,044	1,044
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal mining employment in 1912 on electoral outcomes in 2017, 2021, and 2025. *Panel A* reports reduced-form estimates of the effect of $deepcoal_i$. *Panel B* presents OLS estimates. *Panel C* shows IV estimates using the $deepcoal$ instrument.

Although our results indicate that a later and more intensive historical industrialization has lasting electoral legacies, these effects could be driven by a more intensive *de*industrialization in the postwar period. To examine this, we compute the decline in manufacturing employment between 1970 and 2011, standardize this variable alongside our indicators of timing and intensity, and estimate their effects on AfD support between 2015 and 2017.

Table 3 demonstrates that the original industrialization offers a stronger explanation of electoral change than the district-level decline in manufacturing employment underlined by previous work (Baccini and Weymouth 2021; Bekhtiar 2025). While we find that industrial decline is positively associated with radical right support (Model 1), this effect diminishes and loses its statistical significance at the 5% level once we account for mining employment in 1912 or the timing of mining adoption (Models 4-5). The effects of the historical industrialization path far exceed those of more recent deindustrialization: a one-standard-deviation shift in historical mining employment is associated with nearly eight times the percentage-point increase in AfD support compared to a one-standard-deviation greater industrial decline (Models 2-3).

The evidence thus far indicates that later and more intensive industrialization increases contemporary support for the radical right. However, the intensity of industrialization has been linked to greater support for social democracy. Bartolini (2000) traced labor mobilization to the timing of industrialization, while Rodden (2019, 40) explains support for the Democratic Party in contemporary elections in the United States with the industrial employment share in the 1920s. This suggests that the gains of the radical right in areas with late and intensive industrialization may come at the expense of the Social Democrats.

Table 3: Industrialization vs. Deindustrialization: The Standardized Effects of Industrial Decline and the Historical Industrialization on Radical Right Support

	AfD				
	(1)	(2)	(3)	(4)	(5)
Manufacturing Share (Std.) $\Delta_{1970-2011}$	0.391**			0.214	0.266*
	(0.191)			(0.171)	(0.142)
Average Coal Mine Opening Year (Std.)		2.425***		2.393***	
		(0.220)		(0.222)	
Coal Miners (1,000s) in 1912 (Std.)			2.472***		2.448***
			(0.211)		(0.211)
N	1,044	1,044	1,044	1,044	1,044
R^2	0.133	0.202	0.217	0.203	0.219
City FE	✓	✓	✓	✓	✓
Historical Controls	✓	✓	✓	✓	✓
Std.Errors	District-ID	District-ID	District-ID	District-ID	District-ID

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of deindustrialization, the historical timing of coal mining adoption, and the historical spread of coal miners in 1912 on electoral support for the AfD at the city district level in the federal elections of 2017, 2021, and 2025. Deindustrialization is measured as the change in the share of manufacturing employment between 1970 and 2011, with positive values indicating greater industrial decline. All independent variables are standardized to facilitate effect size comparison. Standard errors are clustered at the unified city districts in the original dataset by Schräpler et al. (2017), from which we source the manufacturing employment estimates.

To examine this more systematically, we estimate the effect of historical mining employment on political realignment between the 2017 federal election, when the AfD first entered parliament, and the 2025 election, when it overtook social democracy nationally. Table 4 shows that districts once intensively engaged in coal mining remain partially attached to social democracy. Yet Models 3-6 demonstrate that this historical dominance is steadily eroding. The higher the number of coal miners in 1912, the greater the SPD's losses and the bigger the AfD's gains between 2017 and 2025. As all but one mine had closed by 2017, these specific shifts cannot be attributed to recent deindustrialization (Stutzmann 2025). Rather, they suggest that the radical right is making inroads into traditional social democratic districts. We find similar evidence when examining the timing of industrialization (Table A9).

Table 4: The Intensity of Industrialization and Electoral Realignment at the Ruhr

	SPD		SPD Δ^{2025}_{2017}		AfD Δ^{2025}_{2017}	
	(1)	(2)	(3)	(4)	(5)	(6)
*Panel A: **1912 & OLS***						
Coal Miners (1,000s)	1.444***	1.913***	-1.606***	-1.857***	0.869**	1.383***
	(0.407)	(0.444)	(0.428)	(0.436)	(0.379)	(0.290)
*Panel B: **1912 & 2SLS***						
Coal Miners (1,000s)	6.130***	5.683***	-6.581***	-5.587***	4.718***	3.826***
	(1.858)	(1.374)	(1.870)	(1.195)	(1.561)	(0.954)
F-stat	148.9***	187.1***	49.4***	59.7***	49.4***	59.7***
N	1,044	1,044	348	348	348	348
City FE	✗	✓	✗	✓	✗	✓
Historical Controls	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of the historical spread of coal miners (1,000s) in 1912 on levels of SPD support in the federal elections of 2017-2025 and the change in AfD and SPD support between the federal elections of 2025 and 2017.

Robustness

We conduct a series of robustness checks and supplementary analyses to ensure the validity of our findings. To strengthen the credibility of our instrument, we first show that deep-coal and non-deep-coal communities did not differ in preindustrial levels of economic development, although the former tended to be less populous (Table A10). As discussed previously, our results also remain robust when explicitly accounting for preindustrial heterogeneity. We also verify that our findings are not driven by pooling multiple elections, the specification of standard errors, or reliance on a single election year in the sample (Table A15-Table A17). Lastly, we replicate our results using polling-district returns for the 2021 federal election (Table A23).

We also employ an alternative design that mirrors Gerschenkron's (1962) classic distinction between early and late industrialization. Specifically, we restrict the sample to districts where deep-shaft mines were constructed at some point. Then, we compare districts that transitioned gradually from proto-industrial operations into deep-shaft mining with those where mining only began as deep-shaft mining during the coal rush. The results show that districts that industrialized late and rapidly are significantly more supportive of the radical right when compared to deep-shaft mining districts with proto-industrial roots (Table A18–Table A20).

To test the robustness of our findings on the intensity of industrial development, we corroborate them with municipal-level employment data from 1893, linked to modern city districts via administrative correspondences rather than spatial matching, and by considering the number of coal rush-shafts within a district (Table A24–Table A26). Moreover, when we limit our analysis to districts north of the marl boundary (i.e., districts with exclusive deep coal deposits), we show that variation in the intensity of industrialization also predicts radical right voting within this sample of late industrializers (Table A27). A divided-cities design, which restricts the analysis to municipalities split by the marl boundary, yields consistent effects (Table A28).

Mechanism: The Industrial Built Environment

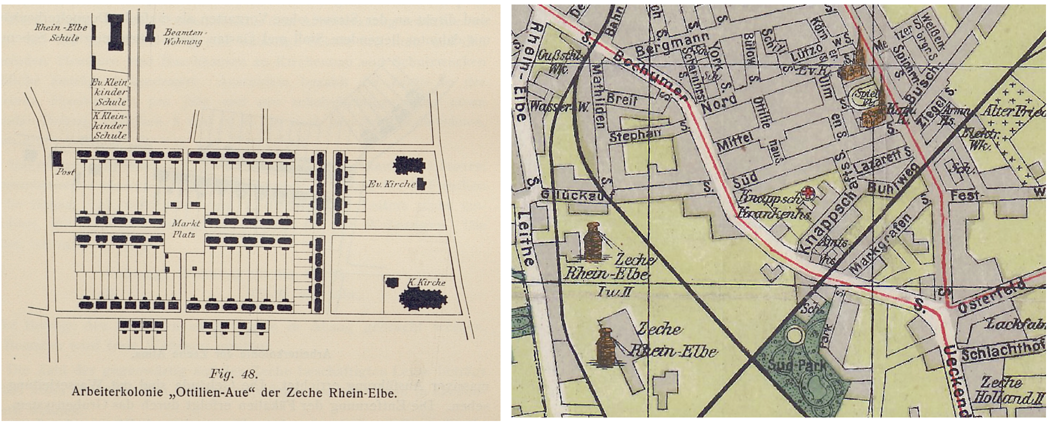
So far, we have demonstrated that differences in the historical intensity of industrialization influence radical right voting today. Arguments about long-term persistence have become increasingly common in explanations of contemporary voting behavior. However, they raise the challenge of explaining how the effects of historical shocks can unfold and endure across long periods of time (Cirone and Pepinsky 2022; Charnysh and Peisakhin 2022; Acharya et al. 2023; Conley and Kelly 2025). In our case, the central question is how the trajectory of nineteenth-century industrialization is connected to contemporary electoral outcomes in the Ruhr.

We argue that the electoral divergence between city districts with differential industrialization timelines is a path-dependent effect of the built environment constructed at the height of the coal rush. As coal rush mines often emerged in rural areas without housing infrastructure, mining entrepreneurs built company-owned colonies. Already in 1900, 21% of the region's 225,000 miners lived in company-provided housing (Verein für die Bergbaulichen Interessen 1901, 210). In 1914, this share had risen to 33%, amounting to nearly 140,000 miners (Landesarchiv Nordrhein-Westfalen, n.d.).

The construction of mining colonies created a built environment specifically tailored to worker and company needs. Colony housing typically consisted of small, multi-family homes with garden plots for household production. Since companies prioritized easy access to their own mines, but not to those of their competitors, they did little to ensure the integration of these settlements into towns and public transportation networks. Thus, the spatially isolated settlements developed as self-contained communities with worker-centric infrastructure.

The early colony of *Ottilienaue* illustrates this dynamic (Figure 4). Converging on a central plaza, its 68 housing units were flanked by a post office, Catholic and Protestant churches, schools, and separate residences for clerks. As these colonies also influenced where new residential areas would emerge, their impact extended beyond their original boundaries. They forged city districts that, by design, remained poorly integrated with urban centers.

Figure 4: Mining Colonies in the Emscher Zone: The Example of *Ottilienaue*



Note: This figure shows a conceptual drawing and a historical map of *Ottilienaue*, today known as *Floez Dickebank*, an early mining colony (*Zechenkolonie*) in Ueckendorf in the south of Gelsenkirchen. The left-hand map is from Verein für die Bergbaulichen Interessen (1901); the right-hand map is an excerpt of a historical city plan of 1905 from Stadt Gelsenkirchen (2018). The colony is visible in the central upper half of the map. Also note the two shafts of the mine to which the colony belonged ("Zeche Rhein-Elbe"), on the lower left. Finally, the map also shows the different railway lines that were built around the mine.

Mining colonies created an enduring settlement structure that contributes to demographic persistence and neighborhood disadvantage in the long run. After coal mining declined, these areas were left with a vast housing stock but declining economic prospects, leading to persistently low rents and home prices. These diminished housing costs encouraged former workers to stay and attracted low-income newcomers. This built environment has also cemented disadvantages for long-term residents, as colony settlements remained spatially disconnected from urban infrastructure, including schools, amenities, and transport networks.

We begin our analysis by examining how late industrialization drove the construction of mining colonies. For this purpose, we draw on three mine-level surveys of the presence of colony residents and company housing stock in 1893, 1900, and 1912 (Taeglichsbeck 1895; Verein für die Bergbaulichen Interessen 1901; Landesarchiv Nordrhein-Westfalen, n.d.). Table 5 shows that mines established later housed a larger share of their workforce in colony settlements in 1893. The effect of industrial timing is markedly stronger in 1912, following the massive expansion of company housing. A mine opened ten years later accommodated around 2.5 percentage points more of its workers in colonies (Models 1–2). Later-opening mines also provided more flats to miners, and every third flat built by 1900 was located within a purpose-built mining colony, underscoring that mine owners invested in entirely new settlements (Models 3-4). Finally, the 1900 survey (Models 5-6) reveals that later-opening mines spent more on company housing both in total and per flat, illustrating a shift from provisional barracks to higher-quality, multi-family homes (Figure A18).

Table 5: The Timing of Mine Openings and the Historical Construction of Colony Housing; Mine-Level Evidence

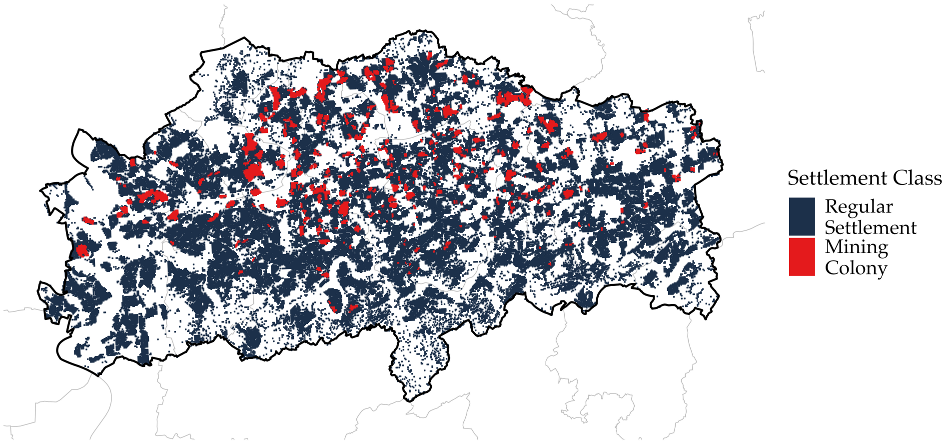
	Colony Miner Share		Company Flats per Mine		Costs	Cost per Flat
	(1)	(2)	(3)	(4)	(5)	(6)
Coal Mine Opening Year	0.467***	2.502***	27.461***	83.245***	112.815***	85.669**
	(0.119)	(0.451)	(8.552)	(22.186)	(36.707)	(39.963)
N	146	133	105	133	105	104
Year of Survey	1893	1912	1900	1912	1900	1900
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table reports OLS estimates of the effects of the normalized coal mine opening year on the historical development of colony housing. Models (1)-(2) examine the share of workers housed in mining colonies in 1893 and 1912. Models (3)-(4) focus on the number of company-owned flats rented to coal miners in 1900 and 1912. Models (5)-(6) examine the financial dimension of company housing in 1900, using the costs of company housing (1,000 RM) and the cost per flat (RM).

To examine how colony housing influences demographic persistence and urban diversity today, we draw on historical aerial imagery and extensive contemporary sources to identify over 300 settlements that were originally constructed as mining colonies. We georeference these colonies and spatially link them to the 100-×-100 meter census grid covering the Ruhr area. Figure 5 illustrates how colony settlements shaped the region's built environment. Across the northern cities, we can link more than 20% of settled grids to historical mining colonies. Next, we collect census and cadastral records on rents, land prices, railway infrastructure, and present-day land use to test our hypotheses concerning housing costs, limited neighborhood diversity, weaker mobility integration, and reduced access to educational institutions.

Table 6 demonstrates that the settlements constructed during the coal rush persist in the modern built environment and continue to influence its economic trajectory. Model (1) indicates that the share of residential buildings built before 1919 is nearly 20 percentage points higher in grids that contain colony settlements than in other areas. This enduring built environment is associated with significantly lower rents and land prices (Models 2-3). Rents within historical colony grids are lower by 0.33 to 0.47 €/m² compared to other areas ($SD = 1.11$). Thus, settlements that originated as colony housing reinforce residential sorting into disadvantaged areas. Notably, the lower price-to-rent ratios in colony grids also indicate especially weak demand for ownership, signaling negative expectations about future development (Model 4).

Figure 5: The Historical Spread of Mining Colonies in the Built Environment



Note: This figure shows the spread of mining colonies at the 100-×-100 meter grid cell level. Settlements are extracted from Zensus (2022). We classify building blocks and settlements using historical aerial images, city plans, and topographic maps. For more information, see Appendix.

These patterns of neighborhood disadvantage align with the dynamics of durable housing and urban decline described by Glaeser and Gyourko (2005). Economic decline diminishes rents and property values, which attracts low-income residents to these areas and constrains homeowners' ability to sell without incurring significant losses, thereby preventing them from leaving deindustrialized areas despite aggravating economic prospects. Consequently, residents who became homeowners following the privatization of company housing may remain locked into these communities, contributing to demographic persistence. This is consistent with the higher homeowner share in former colonies (Model 5).

Settlements that emerged around colony housing also exhibit several adverse contextual conditions, which both deepen demographic sorting and constrain the economic opportunities of incumbent residents. Model (6) reveals that access to education remains more limited in former mining colonies. Colony settlements are located more than 300 meters farther from the nearest Gymnasium (the highest track of secondary school) compared to other settlements (SD = 1,027m). While this distance premium may only marginally affect attendance, it underscores the insulation of these neighborhoods from the diffusion of advanced educational infrastructure. Industrialization thus not only caused long-term differences in access to education between industrial and non-industrial regions, but also within industrial regions.

Table 6: The Effects of Historical Colony Housing on Neighborhood Disadvantage

	Pre-1919 Buildings	Rent €/m^2 (monthly)	Land Prices €/m^2	Price-to-Rent Ratio	Homeowner Share	Distance: High Schools	Urban Amenities	Distance: Rail Stations
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: ***Baseline***								
Mining Colony	0.190***	-0.473***	-95.271***	-0.826***	0.039**	352.122***	-0.007***	171.140**
	(0.014)	(0.056)	(18.752)	(0.222)	(0.016)	(105.043)	(0.002)	(84.299)
Panel B: ***With Controls***								
Mining Colony	0.195***	-0.330***	-63.624***	-0.521***	0.035***	305.551***	-0.006**	34.801
	(0.014)	(0.041)	(9.666)	(0.100)	(0.012)	(85.476)	(0.003)	(58.419)
N	44,319	44,319	44,319	44,319	44,319	44,319	44,319	44,319
Std.Errors	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the relationship between mining colony housing and the economic conditions of modern residential neighborhoods. The units of analysis are 100 -×-100 meter grid cells. The analysis only includes settled grid cells ($pop_{2022} > 0$). The controls in *Panel B* include population in 2022, distance to the nearest central business district (CBD), and city fixed effects.

Another structural determinant of neighborhood disadvantage is access to residential externalities in the spirit of Jacobs (1961). Compared to other residential areas, colony settlements devote marginally less land to urban amenities such as sports facilities and cultural institutions (Model 7). Appendix Table A35 also shows that they are less likely to host nonindustrial business space and exhibit a 10 percentage point higher share of low-density housing (buildings restricted to three stories). Thus, mining colonies have left a settlement structure that provides lower agglomeration benefits. The transport infrastructure does not offset these disadvantages: colony settlements are more isolated from rail-based public transport, including both light and heavy rail, although this effect disappears once controls are added (Model 8). Nevertheless, they remain less integrated into the main street network (Table A35).

As mining colonies were among the earliest housing structures that emerged in mining areas, they embedded path dependencies in urban development. During postwar reconstruction, modern housing for low-income households was frequently built in the vicinity of colonies. Worker settlements were thus the nucleus for the development of disadvantaged districts that extend beyond historical colony boundaries. Against this background, we examine whether the disadvantages associated with colony housing extend into adjacent residential areas. Appendix Figure A23 illustrates that while historical buildings remain confined to colony boundaries, the trajectories of the surrounding urban landscape have been conditioned by its coalescence around worker settlements. Colony rents are €0.74 lower than in areas located at least 2 kilometers from the nearest colony. Yet, non-colony settlements within 500 meters of a colony still exhibit rents €0.59 below those in the control group. The effect decays but remains discernible in areas 1.5-2 kilometers away. The deficits in urban diversity and commuting access are more concentrated within the colony environment itself.

Table 7: The Effect of Historical Mining Colony Presence on Sociodemographic Outcomes at the District Level; OLS Estimates

	University Graduates		High-Income Earners		Social Assistance Recipients		Foreign Residents	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mining Colony Presence (District-Level)	-0.068***	-0.055***	-0.046***	-0.042***	0.035***	0.032***	0.027**	0.033***
	(0.013)	(0.012)	(0.009)	(0.009)	(0.010)	(0.011)	(0.013)	(0.011)
N	328	328	328	328	328	328	348	348
City FE	✗	✓	✗	✓	✗	✓	✗	✓
Historical Controls	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports the effects of historical mining colony presence on district-level sociodemographic outcomes in 2021. Outcomes include the share of university graduates, high-income earners (monthly income > €4,800), recipients of social assistance (SGB-II), and foreign residents (2022). Colony presence is a binary variable equal to 1 if at least 10% of a district's settled grids emerged through colony housing (32% of districts).

The legacy of industrial settlements therefore drives neighborhood disadvantage. To examine how colony housing influences the contemporary concentration of disadvantaged households, we next return to the district level and estimate the effect of colony housing presence on demographic outcomes. Table 7 shows that the residential environment created by colony housing produces demographic persistence. Districts with mining colony origins have significantly fewer university graduates and high-income earners, but higher shares of foreigners and social assistance recipients. Substantively, we estimate a 6 percentage point gap in graduates between colony and non-colony districts–an effect equivalent to three-quarters of a standard deviation (Models 1-2). Settlements historically built around colony housing also exhibit a large deficit in high-income earners, amounting to 0.63 standard deviations (Models 3–4). Notably, despite their economic decline, these districts remain demographically dynamic, exhibiting a lower share of elderly residents than districts without colony legacies (Table A41).

A concern with our analysis is that we may not capture all mining colonies due to the absence of centralized records. In the Appendix, we address this by returning to our mine-level data. Specifically, we match the historical scope of colony housing at the mine level with demographic records of their adjacent districts, comparing former mining communities with extensive colony housing to those without. This confirms that a higher prevalence of colony housing is associated with the persistence of sociodemographic disadvantages, reflected in lower educational attainment and greater reliance on social assistance, while we find less evidence of a systematic concentration of foreigners (Figure A24).

We also show that areas with a stronger presence of colony housing continue to exhibit substantial sorting dynamics. City districts that historically developed around colony housing have become more heavily populated by social assistance recipients and residents without tertiary education than other districts in the past decade (Figure A25). Therefore, the emergence, endurance, and spillovers of worker settlements, which remain characterized by lower rents, reduced urban diversity, and weaker infrastructure access, explain why communities that industrialized later and more intensively continue to concentrate disadvantaged residents.

Demographic Persistence and Electoral Realignment

Lastly, we examine how the demographic concentration of disadvantaged households mediates the impact of late and intensive industrialization on contemporary electoral outcomes. We apply the causal mediation framework of Dippel et al. (2022) to formally decompose this relationship in the presence of endogeneity in both our historical industrialization indicators and the mediator, sociodemographic persistence. This method allows us to use deep coal deposits as a single instrument to identify both the direct effect of the historical mining intensity on the electoral outcomes and the indirect effect operating through the contemporary demographic structure, measured as the first principal component (PCA) of the dependent variables in Table 7 (cf. Berbée et al. 2025, 325; Dippel et al. 2022, 211).

For this approach, we estimate two instrumental variable regressions. The first identifies the impact of mining intensity on demographic structure, and the second estimates the effects of both mining intensity and demographics on voting. The indirect effect is then calculated as the product of the effect of mining on demographics and the effect of demographics on voting. The identifying assumption is that there are no unobserved confounders that drive both mining intensity and electoral outcomes other than through the demographic mediator.[10]

10. We formally describe the approach and its application to our case in Appendix V.

Table 8: The Direct and Indirect Effects of Historical Coal Mining Indicators on AfD Support; Causal Mediation Results

	Historical Employment		*Mining Colony Presence*	
	(1)	(2)	(3)	(4)
Direct Effect of Mining	-0.337	0.776	2.055	2.095
Indirect Effect via Demographic Structure	9.523	6.916	11.197	12.231
Total Effect of Mining	9.186	7.692	13.252	14.326
% Explained by Indirect Effect	103.7	89.9	84.5	85.4
City FE	✗	✓	✗	✓
Controls	✗	✓	✗	✓
N	984	984	984	984

Notes: This table reports the direct and indirect effects of mining employment in 1912 (1,000s) and the district-level presence of mining colonies on the AfD vote share. The mediator is the first principal component of the shares of university graduates, high-income earners, social assistance recipients, and foreign residents. The controls include (log) population and the Protestant share between 1819 and 1834, the population per building and the share born outside the municipality in 1871, and per capita income tax revenue around 1860. The full results are available in Table A48.

The causal mediation results Table 8 show that the electoral legacy of intensive industrialization and its built environment is transmitted almost entirely through an enduring demographic structure. According to our baseline specification, an additional 1,000 miners per district raises AfD support by about 6.9–9.5 percentage points via demographic persistence, while the direct effect is close to zero (Models 1-2). When historical control variables are included, the indirect effect accounts for around 90 percent of the total impact of historical mining employment on electoral outcomes. Alternatively, we use colony housing as an explanatory indicator in our mediation framework.[11] We find that the district-level presence of colony housing increases radical right support by 13.3 to 14.3 percentage points, with 85 percent of this effect mediated through its impact on demographic persistence (Models 3-4).

In the Appendix, we document analogous patterns for voter turnout (Table A50). As a robustness check, we also estimate the effects of historical employment and colony housing on electoral outcomes with controls for each community's endogenous sociodemographic characteristics, which yields consistent results (Figure A26). Although our argument emphasizes the entire demographic structure forged by historical industrialization, one might alternatively suggest that industrialization affects electoral outcomes only through more recent exposure to

11. Mining colonies, which turned the scale of mining employment into enduring built-up structures, were established long before the demographic structures and electoral outcomes we observe. We therefore employ them as an alternative treatment rather than as a mediator in our framework.

foreigners. We demonstrate that neither immigration flows nor the presence of foreigners or dual citizens, which are partially endogenous to historical mining, account for our main effects (Table A51). We further show that the impact of intensive industrialization is not absorbed by heterogeneity in the historical composition of migrants (Table A52).

Overall, our analysis substantiates that the sociodemographic impact of late and intensive industrialization, transmitted through an enduring built environment, accounts for why some former industrial communities have realigned to the radical right more than others.

5 Conclusion

Coal mining in the Ruhr area ended in 2018, when Zeche Prosper-Haniel, located in the far north of our study region, closed its last shafts built during the postwar period. This marked the final step in a decades-long process of mine closures, with its symbolic importance underscored by the attendance of the German President at the closing ceremony. Yet the surrounding area has not become an AfD stronghold. In the 2025 election, the AfD received a middling 15 percent of the vote in Bottrop-Kirchhellen. By contrast, the party's vote share exceeded 30 percent in parts of Bottrop where the mine had founded its shafts in the late nineteenth century–sites that had been closed more than three decades earlier.

In this paper, we make sense of this pattern by arguing that differences in the initial industrialization process are central for understanding the political evolution of industrial areas once industrial jobs disappear. The radical right thrives not in areas with the most recent industrialization experience, but in those that underwent particularly intensive industrialization in the late nineteenth century, regardless of whether their mines closed in the 1960s, 1980s, or the 2000s. This historical industrialization episode created the persistent urban built environment that drives demographic persistence and structural disadvantage today.

The Ruhr's geological conditions have allowed us to study this argument in great empirical detail, but it should apply more generally to other industrialized countries. Cities often specialized in the same industries but at different times, due to geographic factors such as port accessibility to larger vessels (e.g., Rotterdam vs. Amsterdam), the opening of waterways (e.g., the Erie, Suez, or Panama canals), or the discovery of raw material deposits (cf. Scheve et al. 2024). This heterogeneity in the timing of industrialization within the same sector, we submit, may have produced lasting disparities in human capital, economic performance, and voting behavior. The disadvantages of late and intensive industrialization thereby explain why some once-industrial cities shift to the radical right much more strongly than others.

The timing of industrialization also often determined whether cities became heavily reliant on a single sector. While diversified cities like Boston reinvented themselves as advanced service hubs, single-sector cities like Detroit experienced economic decline (Glaeser 2005, 2012). Yet the most encompassing legacy of intensive industrialization unfolds in places that, as the Ruhr's coal rush communities, emerged entirely around a single plant. These settlements arose from the massive labor demands of nineteenth-century industrialization, exemplified by English districts like Saltaire, a textile colony near Bradford, or steel and mining towns in the Midwest and Appalachia (Fishback 1986; Griskavich 2014). Several of these communities have since experienced economic decline and electoral realignment.

Industrial towns took their most extreme form in late Imperial Russia and the Soviet Union, the hallmark of late industrialization (Gerschenkron 1962). In this context, hundreds of so-called monotowns arose from the Ukrainian Donbas to Russia's far east. Places such as Magnitogorsk, "a city attached to a factory" (Kotkin 1995, 144), still concentrate large populations, yet many plants have become economically unviable (Crowley 2016). In Soviet monotowns, the national and local legacies of late industrialization converge.

We believe that translating Gerschenkron's argument to the local level offers valuable insights for regions in economic transition. Our findings may also carry implications for policies aimed at revitalizing industrial communities. While U.S. public policy provided only modest support to Rustbelt areas, Germany subsidized hard coal with more than €200 billion since WWII (Brüggemeier 2018, 382) and established three public universities. Whether these policies had an aggregate political effect is uncertain. Radical right support in the Ruhr remains lower than in British or French coal regions, but we show that policy interventions have not overcome historical path dependencies. As knowledge-intensive production increasingly concentrates in dense urban centers, the industrialization from over a century ago should become more relevant to the economic and political trajectories of cities in the West and beyond.

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Supporting Materials for:

Coal Rush:

The Built Legacy of the Industrial Revolution and the Rise of the Radical Right

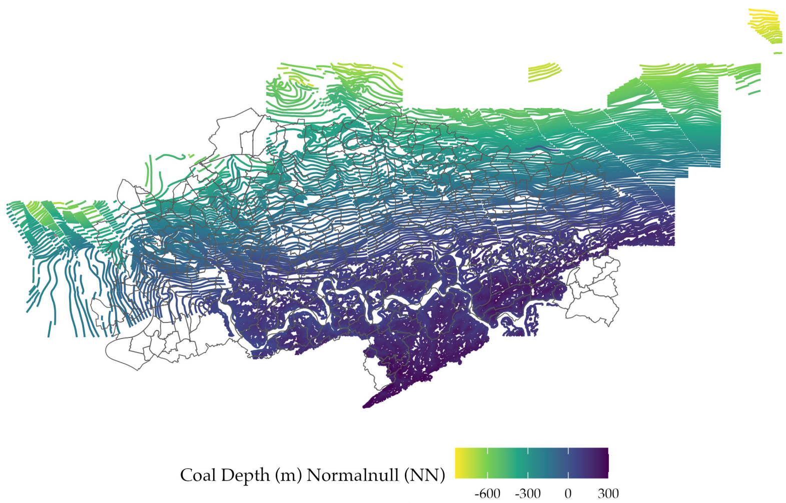
Appendix Contents

Contents

I The Geology of the Ruhr

We exploit the Ruhr area's geological conditions to extract exogenous variation in the timing and intensity of mining adoption. For this purpose, we need information on the existence and depth of coal deposits across the Ruhr area. To measure coal depth, we use the Geological Map of the Rhenish-Westphalian Hard Coal Area provided by Geologischer Dienst NRW (2023). This map, illustrated in Figure A1, contains rich tectonic information on the depth of the Carboniferous surface and individual coal seams.

Figure A1: Geological Map of the Rhenish-Westphalian Hard Coal Area

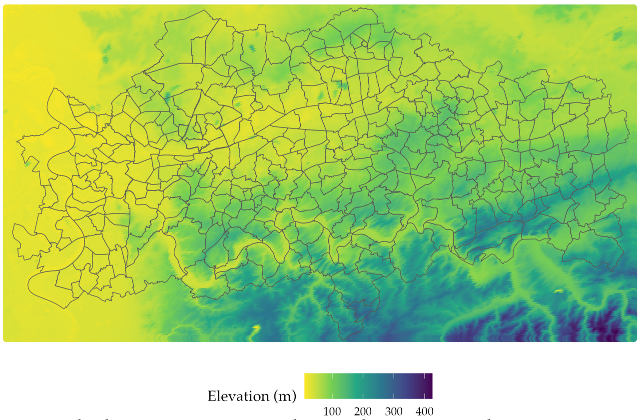


Note: This figure shows the distribution and depth of hard coal deposits, measured in meters relative to *Normalnull* (standard sea level), together with district boundaries (Geologischer Dienst NRW 2023).

We conduct a spatial join and compute the average depth of all intersecting coal seams within each city and polling district. However, this does not enable us to identify the actual depth of coal deposits *relative to surface*, because coal depth is measured in *Normalnull* (NN) and there is substantial heterogeneity in elevation across the Ruhr area. For this reason, we link this map with a database of elevation points at the 200m×200m grid cell level, provided by Bundesamt für Kartographie und Geodäsie (2021), to compute the average elevation at the district level. We then normalize sea-level coal depth with each district's average elevation to obtain our instrument of average coal depth, $coaldepth_i$, relative to local surface elevation.

In the Appendix, we use this measure as an instrument for the timing of industrialization, measured with the average opening date of coal mines located in or near each district. For example, in a district like Katernberg, the average depth of coal seams relative to sea level is approximately 70 meters, while the district's average elevation (10th percentile) is around 45 meters. This implies a coal depth of roughly 115 meters below the local surface. By contrast, in a southern district such as Herbede (Witten), where the terrain is more elevated and rugged, the average elevation is about 150 meters, and coal seams lie approximately 174 meters above sea level. This results in a relative coal depth of -24 meters. While this may look counterintuitive at first, it means that coal is mainly found under hilltops but not in valleys. Crucially, this means that coal is accessible near the surface or by horizontal shafts that can be driven into the hillside and do not need complicated water management. Such conditions are characteristic of adit-based mining practices typical of the proto-industrial period in the hilly southern Ruhr, particularly around southern Essen, Bochum, and Witten.

Figure A2: Ground Elevation Across the Ruhr Area

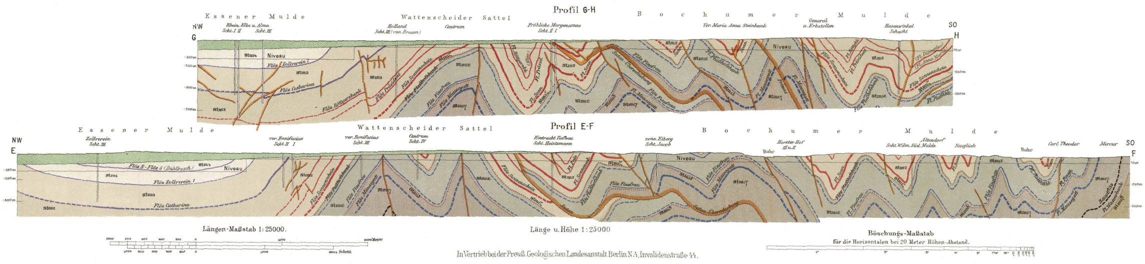


Note: This figure shows ground elevation across the Ruhr area at the 200×200 grid cell level, along with district boundaries ($N = 348$). Elevation data is from Bundesamt für Kartographie und Geodäsie (2021).

To construct our core instrument, we must distinguish between areas where coal could be extracted at or near the surface and those where it could not. The feasibility of proto-industrial coal mining was shaped by the presence of sedimentary layers that overlay the richer coal seams in the northern part of the region, often referred to as the marl cover (*Mergelschicht*). Unlike in the southern Ruhr, where coal seams outcropped and could be reached through shallow adits, mining in the north required deep vertical shafts to reach the buried seams. Crucially, these deeper operations faced persistent groundwater inflow, but the marl's dense, water-resistant sediments meant that traditional drainage methods were ineffective. As a result, until the advent of steam-powered pumps in the nineteenth century, sustained coal extraction in the marl-covered northern Ruhr was technologically unviable. Figure A3 shows geological profiles of Bochum, Essen, and Gelsenkirchen, highlighting the younger sedimentary layers that impeded early mining in the north.

We aim to isolate geological conditions that restricted coal extraction to heavy industrial mining, specifically, the presence of deep coal deposits inaccessible to proto-industrial technologies. One approach to proxy this constraint is to impute the location of the marl boundary (*Mergelgrenze*) using our average coal depth indicator. A simple classification would define coal as "surface-accessible" when the local topography (elevation) exceeds the district's average coal depth, implying that seams could outcrop in hillsides or shallow valleys. However, even districts where coal seams lie below average elevation levels may have encompassed areas where extraction near the surface was technologically feasible. At the same time, in areas north of the marl boundary, thin marl layers or favorable hydrological conditions may have made early mining viable through manual drainage techniques before the advent of steam-powered pumping. The district of Essen-Altendorf, for example, lies north of the marl boundary, but mining activities on *Zeche Vereinigte Sälzer & Neuack* began even before the eighteenth century.

Figure A3: The Geology of Coal: The Mergel Cover in the Emscher Zone



Note: This figure illustrates the geological layers of parts of the Emscher Zone (Essen, Bochum, Gelsenkirchen). The green layer illustrates the marl cover (*Mergelschicht*) of the younger sediments covering the Carboniferous strata. Lighter Carboniferous layers indicate gas and fat coal deposits (*Gas- und Fettkohle*); darker Carboniferous layers indicate lean coal (*Magerkohle*) deposits. Analoges Kartenwerk der Geologischen Karte von Preussen (NRW-Abdeckung) 1:25.000 GK25PR-4508-Essen.

To identify areas characterized by the exclusive presence of deep coal deposits–conditions we argue led to a more intensive adoption of deep-shaft mining—we rely on a granular geological database of boreholes provided by Geologischer Dienst NRW (2025). This dataset includes over 50,000 drilling records across our sample area and measures drilling depth relative to ground level, thereby removing local variation in surface elevation. Each record specifies the stratigraphic layer encountered at the final depth, such as Quaternary, Cretaceous, or Carboniferous. For our purposes, we isolate boreholes that reach the Carboniferous layer, which contains the coal-bearing strata central to Ruhr mining, as illustrated in Figure A4. We then further restrict our sample to drillings that hit the Carboniferous within 10 meters of the surface. This threshold captures areas where coal seams were likely accessible without large-scale industrial machinery, either through surface outcrops or through earlier drainage methods. We interpret such areas as geologically compatible with proto-industrial mining, in contrast to locations where deeper Carboniferous layers necessitated industrial technology for extraction.

We construct a district-level indicator for the (exclusive) presence of deep coal deposits, $deepcoal_i$, as illustrated in the second equation of the manuscript, by spatially matching each borehole to our district boundaries. All districts are then classified as follows:

1. Districts with coal deposits but without at least two boreholes reaching the Carboniferous layer within 10 meters of the surface are coded as 1. These are interpreted as areas where coal was geologically inaccessible without deep-shaft mining, implying the exclusive presence of deep coal deposits.

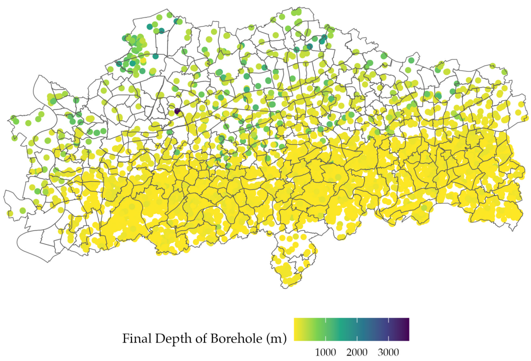
2. Districts with at least two boreholes that reach the Carboniferous within 10 meters of the surface are coded as 0. In these areas, shallow access to coal deposits suggests that proto-industrial or early surface mining was feasible.

3. Districts without coal deposits are also coded as 0.

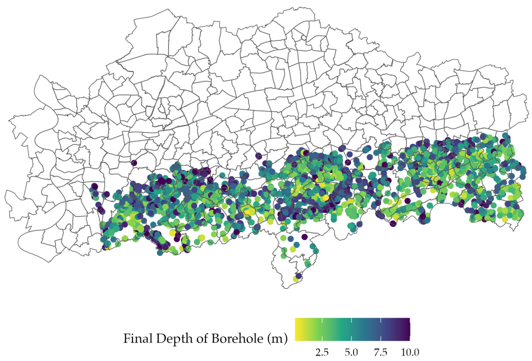
Figure A5 displays the spatial distribution of our $deepcoal_i$ indicator. This illustrates the northern skew of deep coal deposits already demonstrated in the main manuscript. However, it also descriptively matches the geographic frontier of proto-industrial mining in the large cities of Essen, Bochum, and Dortmund. Across these cities, proto-industrial mining reached into the southern city centers, while the expansion of deep-shaft mining took off in areas where extraction was limited to deeper Carboniferous sediments.

Figure A4: Boreholes with Carbon Stratigraphy at Final Depth

(a) *All Boreholes*

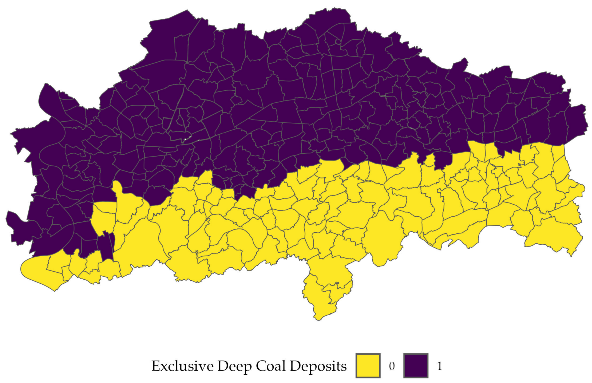


(b) ≤ 10 *Meters*



Note: This figure shows the distribution of boreholes across the Ruhr area and the depth of each drilling. The sample is limited to boreholes that reached the Carboniferous surface at their final depth (*Endteufe*), regardless of whether coal seams were encountered. Source: Geologischer Dienst NRW (2025).

Figure A5: The Spatial Distribution of Deep Coal Deposits



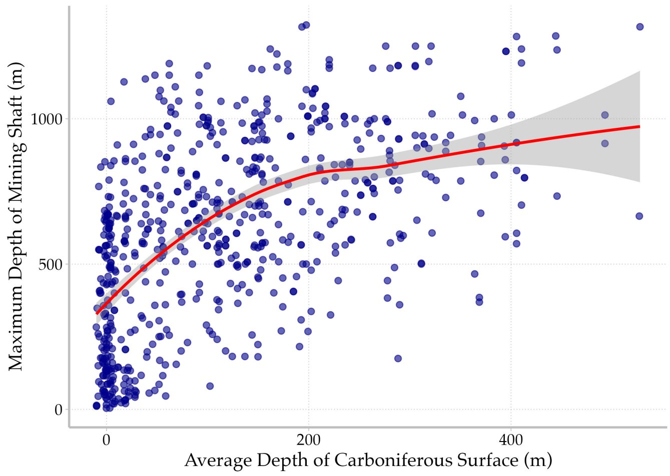
Note: This figure illustrates the (exclusive) presence of deep coal deposits across city districts in the Ruhr area. The deep coal indicator equals 1 if coal seams exist beneath a district's surface but lie at depths inaccessible to proto-industrial extraction technologies. The indicator equals 0 if coal deposits are either absent or located at or near the surface, defined as being reached by boreholes whose stratigraphic endpoint lies within 10 meters of the surface.

II Coal Depth and Deep Coal

We further elaborate on the intuition behind our instrument, specifically regarding the relationship between coal depth and $deepcoal$. As we demonstrated in the paper, the depth of coal deposits influenced when northern communities adopted coal mining, with deeper deposits leading to a later adoption. Conversely, in the south, the existence of close-to-surface deposits enabled an early adoption of mining before the Industrial Revolution on aggregate. The late adoption of mining in the north triggered a more intensive industrialization, which manifested in substantially bigger plants and workforces (Table A7).

Coal depth governed when northern communities adopted mining, but deeper coal did not necessarily imply bigger workforces and hence more intensive industrialization *within* the north. Northern coal mining generated a more intensive industrialization process because (i) the higher capital requirements of deep-shaft mining, and the immediate transition to it, required a more concentrated and mechanized mode of production; (ii) the northern coal seams contained a higher share of fat coal, whose suitability for coking in steel production created powerful cluster effects; (iii) and the flat, uninterrupted structure of northern seams facilitated deep-shaft extraction compared to the geological conditions in the south.[12] These forces, crucially, were at play throughout the north, regardless of the relative depth of coal deposits.

Figure A6: The Depth of Carboniferous Strata (Top Layer) and the Depth of Individual Mining Shafts



Note: This figure illustrates the relationship between the average depth of the top layer of the Carboniferous strata ("average coal depth") and the maximum depth of coal mines in our mining dataset. It is visible that while shaft depth is strongly elastic to coal depth between 0 and 200 meter, this elasticity strongly declines afterwards.

As a result, relative coal depth did not lead to greater employment within the northern coal basin. Instead, areas with exclusively deep coal deposits but proximity to the proto-industrial mining frontier could engage in mining as intensively as those farther north. Large mines such as *Zeche Zollverein* in Essen-Katernberg were able to specialize in deep-shaft mining immediately after the diffusion of the steam engine, achieving unprecedented employment scales. Although mines in Gelsenkirchen entered mining later due to relatively deeper coal seams, they did not sustain proportionally larger workforces. Notably, shafts on Zollverein could reach depths comparable to those farther north and thus access a similar number of seams. While the depth of the Carboniferous top layer determined how soon coal could first be reached, mines could continue to excavate deeper until ventilation and drainage costs became prohibitive. Consequently, Figure A6 shows that shaft depth varied substantially between 0 and 200 meters of top-layer coal depth, but changed little between 200 and 400 meters.

12. See http://www.ruhrkohlenrevier.de/rw13.html.

For this reason, areas with exclusively deep coal deposits experienced a similarly intensive industrialization, regardless of whether they were located near the original mining frontier or farther north. In contrast, some of the far northern areas–such as Bottrop-Kirchhellen, home to the last operating coal mine until 2018, *Zeche Prosper-Haniel*–partly adopted mining in the postwar period and consequently experienced a much lower intensity of industrialization. In this period, technological change and the widespread adoption of automobiles allowed workers to commute to distant mines, reducing the need for large local labor forces and the construction of worker settlements. As a result, in areas where very deep coal seams implied that industrialization partially occurred as late as the postwar period, technological conditions prevented them from reaching the urban growth rates and employment concentrations that had characterized the Ruhr area's northern industrial centers a few decades earlier.

We illustrate the differences between the impact of coal depth and deep coal empirically. Table A1 shows that coal depth and the exclusive presence of deep deposits influenced both the timing and scale of industrialization. Models (1) and (2) indicate that the deeper the coal, the later the districts engaged in mining. Crucially, as we argued above, this effect persists even after distinguishing deep- from close-to-surface coal regions. In the lands of the coal rush, where proto-industrial extraction was impossible, adoption followed coal depth monotonically, such that depth explains variation in timing.

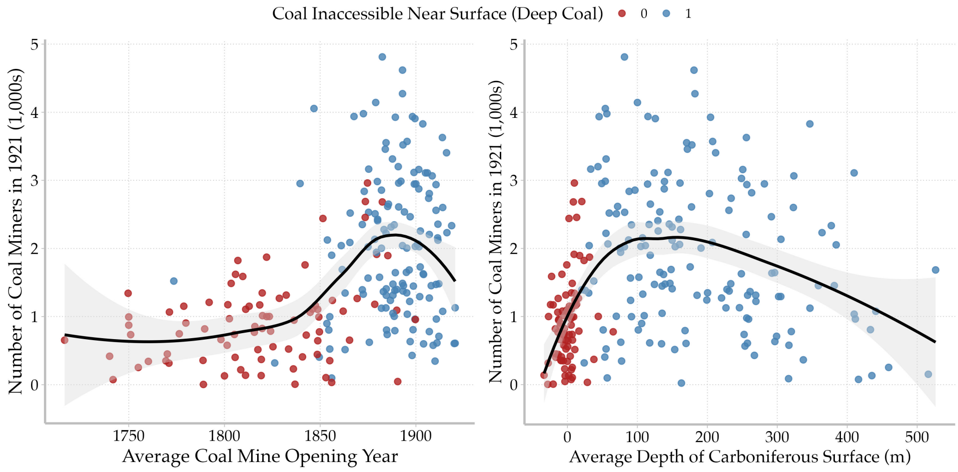
Table A1: Coal Depth, Deep Coal, and the Timing and Intensity of Industrialization

	Coal Start		Miners 1912		Miners 1921		Workers 1970 (%)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Depth of Carboniferous surface (100 meters)	2.001***	1.054***	0.002	-0.018*	0.005	-0.019	0.200***	-0.046
	(0.292)	(0.186)	(0.007)	(0.011)	(0.009)	(0.014)	(0.058)	(0.069)
Deep Coal		45.511***		0.955***		1.136***		11.819***
		(6.526)		(0.335)		(0.408)		(2.025)
N	337	337	337	337	337	337	337	337
City FE	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table reports the effects of Carboniferous surface depth (measured in 100 meters) and the presence of deep coal deposits on the timing and intensity of industrialization. Models (1) and (2) use the average opening date of the nearest 10 coal mines. Models (3) and (4) use the number of coal miners in 1912 (in thousands). Models (5) and (6) use the number of coal miners in 1921. Models (7) and (8) use the share of industrial workers in 1970, measured in percent. All models are estimated with and without city fixed effects. Conley-standard errors with a 5-kilometer cutoff to account for spatial autocorrelation are in parentheses for Models (1) to (6). In Models (7) and (8), we use the original spatial units by Schräpler et al. (2017) to cluster standard errors.

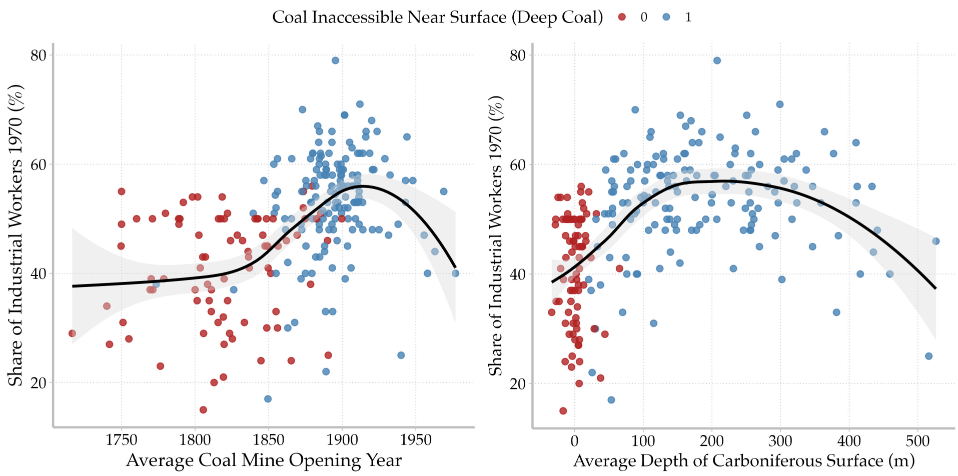
When turning to intensity, however, the regime distinction between early, gradual industrialization in the south and late, intensive industrialization in the north fully explains the scale of employment. Models (3) and (4) underscore that mining employment in 1912 was driven entirely by the presence of deep coal, with deeper areas in fact showing slightly lower employment. One might suspect that this reflects a delayed adoption of northern coal, which would eventually generate similar employment gains. Still, evidence from 1921, at the historical peak of mining employment (Allgemeiner Knappschafts-Verein 1921), confirms that deep coal remained the decisive factor. In 1970, when we measure industrial rather than mining employment, coal depth is positively associated with labor demand. Yet this is fully explained by deep coal. Even then, as several mines in the original coal mining hub of Bochum were already closed, coal depth did not predict higher employment levels within the north.

Figure A7: Coal Deposits and the Timing and Intensity of Industrialization: Employment in 1921



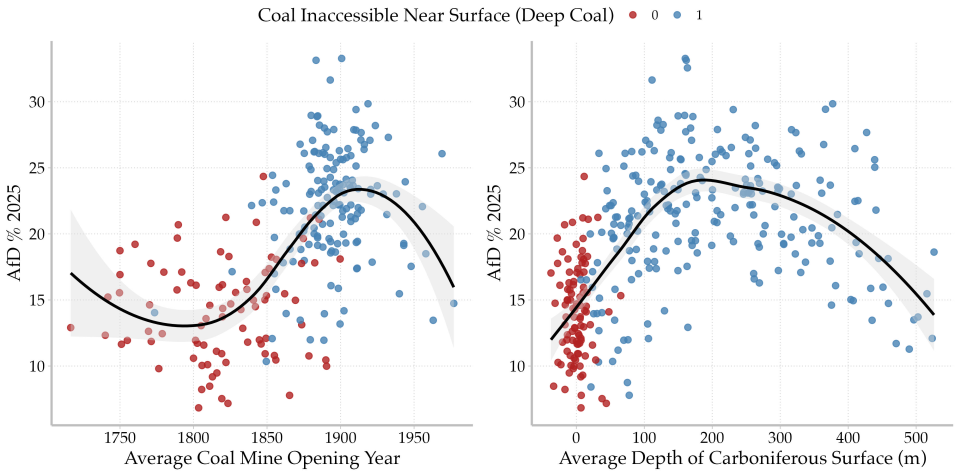
Note: This figure shows the relationship between coal depth, the timing of mining adoption, and mining employment in 1921 at the city district level. The sample comprises all districts with a mine within their boundaries (l.–m.), and the full sample for coal depth and employment (r.). The black lines indicate local regression polynomials, and the ribbons represent 95% confidence intervals.

Figure A8: Coal Deposits and the Timing and Intensity of Industrialization: Share of Industrial Workers in 1970



Note: This figure shows the relationship between coal depth, the timing of mining adoption, and the share of industrial workers in 1970 (Schräpler et al. 2017) at the city district level. The sample comprises all districts with a mine within their boundaries (l.–m.), and the full sample for coal depth and employment (r.). The black lines indicate local regression polynomials, and the ribbons represent 95% confidence intervals.

Figure A9: Coal Deposits, the Timing of Industrialization, and AfD Support



Note: This figure shows the relationship between coal depth, the timing of mining adoption, and electoral support for the AfD in the 2025 federal election. The sample comprises all districts with a mine within their boundaries (l.), and the full sample for coal depth and employment (r.). The black lines indicate local regression polynomials, and the bands represent 95% confidence intervals.

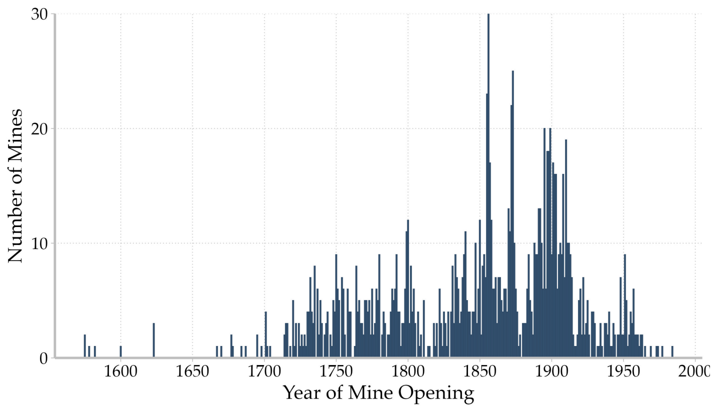
Empirically, we therefore rely on the binary distinction between areas with close-to-surface deposits on the one hand and exclusively deep coal on the other, for this captures variation in intensity in mining that nevertheless results from the differentially sequenced industrialization process. Deep coal areas industrialized later on average, and hence had bigger workforces, while close-to-surface coal enabled a gradual industrialization where workforces remained smaller. What the $deepcoal$ instrument ignores is variation in timing within the north, which, however, was not clearly related to intensity, given the secular changes in technology and the uniform intensification dynamics we discussed previously.

III Coal Mine Data

We compile a comprehensive database of historical coal mines, including both deep shafts and proto-industrial adits, by combining geolocations, opening and closure dates, and, where available, shaft depths from a range of sources. Our primary source is the *Zechenkarte* ("coal mine map") created by Dodenhoff (2022), which georeferences approximately 1,000 mines and includes detailed information on shaft depth and operational timelines. We use this dataset as the foundation of our mine inventory and supplement it by imputing missing opening dates and shaft depths. For this purpose, we rely on *Ruhrzechenaus*, a detailed database compiled by Norbert Rescher (2025), which documents larger mines along with their constituent shafts.

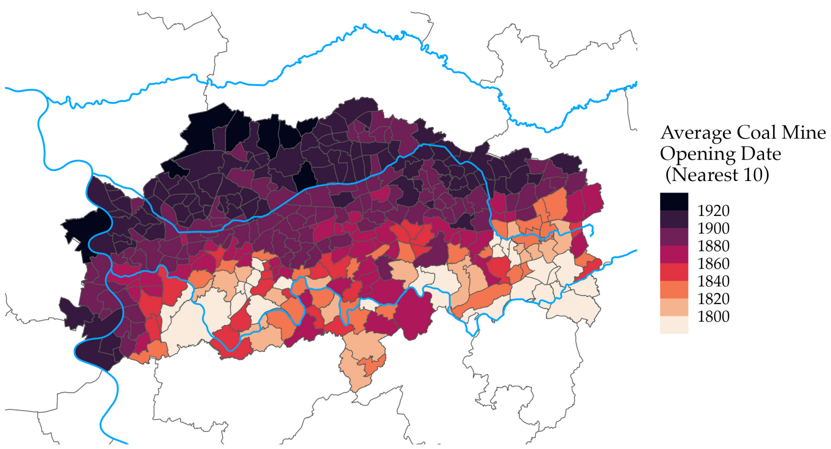
While the *Zechenkarte* provides extensive coverage of industrial-era deep-shaft mining, it underrepresents early, small-scale adits. To address this gap, we incorporate data from a third privately maintained source by Michael Tiedt (2019), which documents numerous proto-industrial adits in cities such as Essen, Bochum, Dortmund, Mülheim, Witten, Hattingen, and Schwerte. This database includes analog maps with approximate georeferencing, which we use, together with information from Wikipedia, to code their locations. For southern Essen, we additionally draw on a dataset compiled by the Historischer Verein Essen (2025), from which we include only those mines with verifiable opening dates. Despite this restriction, the Essen dataset offers broad coverage of early mining activity. In total, our supplementary sources contribute nearly 400 additional entries, primarily adits, to our baseline. The final dataset includes 1,455 distinct mines and adits, of which 1,280 fall within our defined sample area.

Figure A10: The Timing of Coal Mine Openings in the Ruhr Area



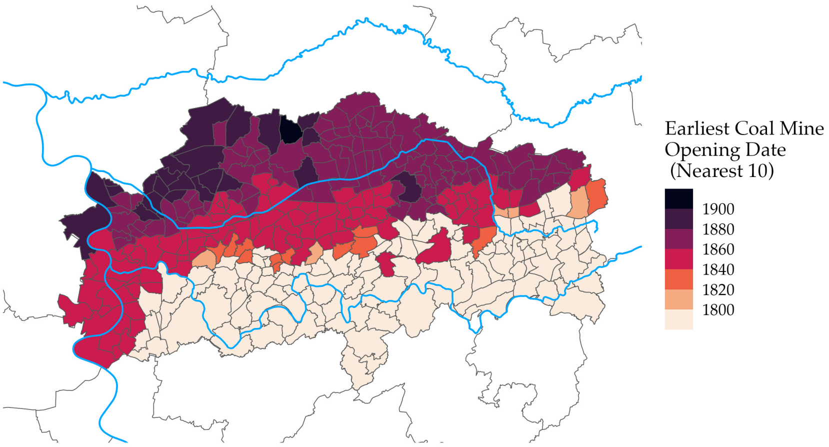
Note: This figure displays the opening dates of 1,276 mines in the sample area of the Ruhr.

Figure A11: The Average Timing of Coal Mine Openings; City Districts



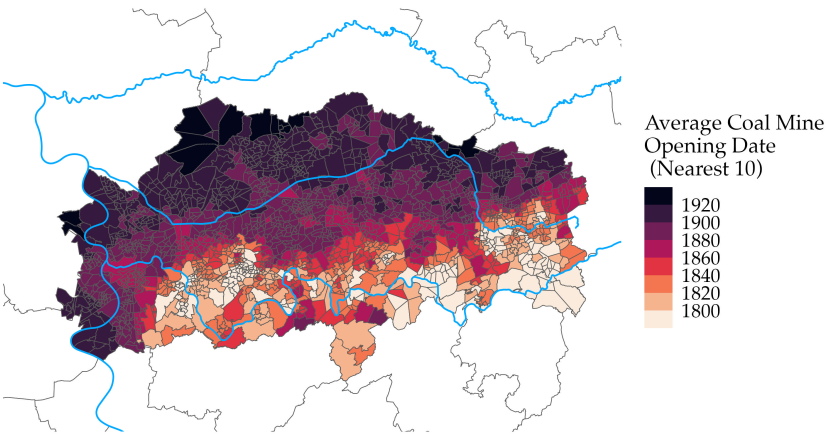
Note: This figure displays the average opening date of the nearest 10 coal mines (shafts or adits) for each city district ($N = 348$).

Figure A12: The Earliest Timing of Coal Mine Openings; City Districts



Note: This figure displays the earliest opening date of the nearest 10 coal mines (shafts or adits) for each city district ($N = 348$).

Figure A13: The Average Timing of Coal Mine Openings; Polling Districts



Note: This figure displays the average opening date of the nearest 10 coal mines (shafts or adits) for each polling district ($N = 1,953$).

IV Supplementary Results A: Timing

Table A2: The Timing of Industrialization: Coal Mine Opening Dates and District-Level Electoral Outcomes; OLS Estimates with Reported Control Variable Coefficients

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***District Mines***						
Average Coal Mine Opening Year	0.465***	0.396***	0.375***	-0.593***	-0.482***	-0.527***
	(0.072)	(0.070)	(0.064)	(0.144)	(0.150)	(0.143)
Population (log) 1819			-0.993**			0.527
			(0.387)			(0.638)
Protestant Share 1819			-0.126			0.449
			(1.015)			(1.603)
Population per Building 1819			-0.032			-0.295***
			(0.035)			(0.054)
Income Tax Revenues p.c. 1860			-0.076			-0.029
			(0.495)			(0.935)
N	720	1720	720	720	720	720
Panel B: ***Distance Mines***						
Average Coal Mine Opening Year	0.559***	0.640***	0.613***	-0.768***	-0.896***	-0.990***
	(0.077)	(0.083)	(0.078)	(0.156)	(0.149)	(0.155)
Population (log) 1819			-0.923***			0.441
			(0.311)			(0.475)
Protestant Share 1819			0.468			-2.492
			(0.986)			(2.037)
Population per Building 1819			-0.046			-0.254***
			(0.031)			(0.047)
Income Tax Revenues p.c. 1860			-0.451			0.252
			(0.363)			(0.734)
N	1,044	1,044	1,044	1,044	1,044	1,044
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of the average starting year of coal mining operations on electoral outcomes at the city district level in the 2017, 2021, and 2025 federal elections, including the coefficients of control variables. We normalize the opening year by subtracting 1839 and dividing by 10, so that a one-unit increase corresponds to industrialization occurring ten years later. *Panel A* reports regressions of electoral outcomes on the average starting year of all mines located within the boundaries of a district. *Panel B* reports regressions of electoral outcomes on the average opening year of the nearest ten coal mine shafts relative to each city district. Historical controls include log population, the Protestant share, population per building (all measured around 1819), and per capita income tax revenues around 1860. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Table A3: The Timing of Industrialization at the City District Level: Coal Mine Opening Dates and Electoral Outcomes; Reduced Form and 2SLS Estimates

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***Reduced Form***						
Depth of Carboniferous Surface (100 meters)	0.994**	1.073**	0.971*	-0.784	-0.650	-1.099
	(0.411)	(0.518)	(0.520)	(0.642)	(0.917)	(0.901)
N	1,011	1,011	1,011	1,011	1,011	1,011
Panel B: ***District Mines, 2SLS***						
Average Coal Mine Opening Year	0.546***	0.510***	0.517***	-0.534**	-0.462	-0.646**
	(0.123)	(0.154)	(0.165)	(0.243)	(0.319)	(0.296)
N	720	720	720	720	720	720
F-stat	751.2***	351.8***	314.5***	351.8***	751.2***	314.5***
Panel C: ***Distance Mines, 2SLS***						
Average Coal Mine Opening Year	0.497***	0.578***	0.536**	-0.392	-0.350	-0.607
	(0.154)	(0.217)	(0.236)	(0.285)	(0.449)	(0.423)
N	1,011	1,011	1,011	1,011	1,011	1,011
F-stat	1,193.6***	470.9***	427.1***	470.9***	1,193.6***	427.1***
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal depth and the average opening year of coal mining operations on electoral outcomes at the city district level in the 2017, 2021, and 2025 federal elections. *Panel A* displays reduced-form evidence of the effect of coal depth (continuous) on electoral outcomes. *Panel B* and *Panel C* report instrumental variable regressions, using the depth of coal deposits to predict the average opening year of all mines located within a district's boundaries or of the nearest ten coal mine shafts relative to each city district. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Table A4: Coal Mine Opening Dates and Electoral Outcomes; Earliest Mine Opening (Distance-Based Measure)

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***OLS***						
Earliest Coal Mine Opening Year	0.280***	0.296***	0.280***	-0.419***	-0.477***	-0.538***
	(0.043)	(0.049)	(0.044)	(0.092)	(0.085)	(0.084)
N	1,044	1,044	1,044	1,044	1,044	1,044
Panel B: ***2SLS***						
Earliest Coal Mine Opening Year	0.273***	0.350***	0.333**	-0.215	-0.212	-0.377
	(0.086)	(0.130)	(0.144)	(0.157)	(0.270)	(0.253)
N	1,011	1,011	1,011	1,011	1,011	1,011
F-stat	931.2***	301.6***	262.4***	931.2***	301.6***	262.4***
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal depth and the *earliest* opening year of coal mining operations on electoral outcomes at the city district level in the 2017, 2021, and 2025 federal elections. *Panel A* reports OLS estimates. *Panel B* reports instrumental variable regressions, using the depth of coal deposits to predict the earliest opening year of the nearest ten coal mine shafts relative to each city district. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Table A5: The Timing of Industrialization: Coal Mine Opening Years and Electoral Outcomes at the Polling-District Level; OLS Estimates

	AfD		Turnout	
	(1)	(2)	(3)	(4)
Panel A:				
Average Coal Mine Opening Year	0.541***	0.585***	-1.044***	-1.118***
	(0.062)	(0.071)	(0.190)	(0.217)
Panel B:				
Earliest Coal Mine Opening Year	0.260***	0.253***	-0.533***	-0.534***
	(0.041)	(0.039)	(0.126)	(0.152)
N	1,953	1,953	1,929	1,929
City FE	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of the average starting date of coal mining operations on electoral outcomes at the polling station level in the 2021 federal election. *Panel A* regresses electoral outcomes on the average starting date (centered around 1839 and divided by 10) of the nearest ten coal mine shafts relative to each polling district. *Panel B* regresses electoral outcomes on the earliest starting date of the nearest ten coal mine shafts relative to each polling district. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Table A6: The Timing of Industrialization: Coal Mine Opening Years and Electoral Outcomes at the Polling-District Level; 2SLS Estimates

	AfD		Turnout	
	(1)	(2)	(3)	(4)
Panel A: ***Reduced Form***				
Depth of Carboniferous Surface (100 meters)	1.322***	1.306***	-1.556*	-1.034
	(0.345)	(0.415)	(0.808)	(1.071)
Panel B: ***Average Opening, 2SLS***				
Average Coal Mine Opening Year	0.567***	0.633***	-0.672**	-0.501
	(0.100)	(0.154)	(0.281)	(0.460)
F-stat	2,177.3***	884.6***	2,119.6***	882.7***
Panel C: ***Earliest Opening, 2SLS***				
Earliest Coal Mine Opening Year	0.318***	0.390***	-0.377**	-0.309
	(0.060)	(0.097)	(0.160)	(0.282)
F-stat	1,570.9***	517.0***	1,522.7***	514.6***
N	1,908	1,908	1,884	1,884
City FE	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table presents the estimated effects of the average starting date of coal mining (centered at 1839, divided by 10) on electoral outcomes at the polling station level in 2021, using instrumental variable estimation. *Panel A* presents reduced-form estimates, regressing electoral outcomes on the depth of the Carboniferous surface measured in 100 meters. *Panel B* regresses electoral outcomes on the average starting date of the nearest ten coal mines relative to each polling district. *Panel C* regresses electoral outcomes on the earliest starting date of the nearest ten coal mines relative to each polling district. All models are estimated with and without city fixed effects. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Table A7: The Timing of Coal Mine Openings and the Expansion of Mining Employment; Mine-Level Analysis

	Total Miners		East Elbia Share		Foreign Share	
	(1)	(2)	(3)	(4)	(5)	(6)
Coal Mine Opening Date	0.088***	0.104***	0.017***	0.018***	0.001	0.006***
	(0.019)	(0.019)	(0.005)	(0.003)	(0.001)	(0.002)
N Coal Mines	157	250	157	250	157	250
Year of Survey	1893	1912	1893	1912	1893	1912
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the association between the opening date of a coal mine and its total employment, the foreign share, and the East Elbian share of miners in 1893 and 1912. We link two surveys of mining employment with our database of mining shafts. Conley-standard errors with a 5-kilometer cutoff to account for spatial autocorrelation are in parentheses.

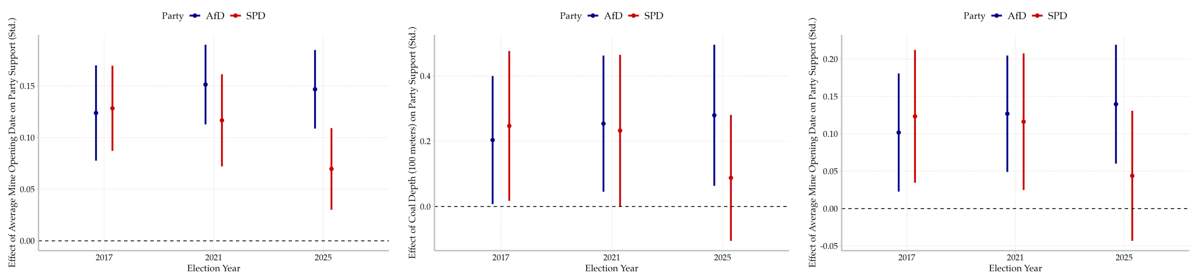
Table A8: The Timing of Coal Mine Openings and the Social Composition of Coal Miners; Mine-Level Analysis

	Westphalia & Rhine	Foreign Language	Mining Father	Protestants	Catholics	Conf. Diversity	Literacy	Perm. Contract
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Coal Mine Opening Date	-0.023***	0.011***	-0.015***	-0.016	0.016	0.032***	-0.002***	-0.008**
	(0.005)	(0.004)	(0.004)	(0.011)	(0.011)	(0.007)	(0.000)	(0.003)
N Coal Mines	157	157	157	157	157	157	157	156
Year of Survey	1893	1893	1893	1893	1893	1893	1893	1893
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the association between the opening date of a coal mine and the social composition of coal miners in 1893. The outcomes are as follows: The share of coal miners from Westphalia and the Rhine Province, foreign language speakers, miners whose father was a coal miner, the share of Protestants and Catholics, confessional diversity (measured as $1-|\text{protestantsh}-\text{catholicsh}|$), the share of literate miners, and the share of miners with permanent contracts. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Figure A14: The Effect of Industrial Timing on Electoral Outcomes: Election Decompositions

(a) *OLS* (b) *Reduced Form* (c) *2SLS*



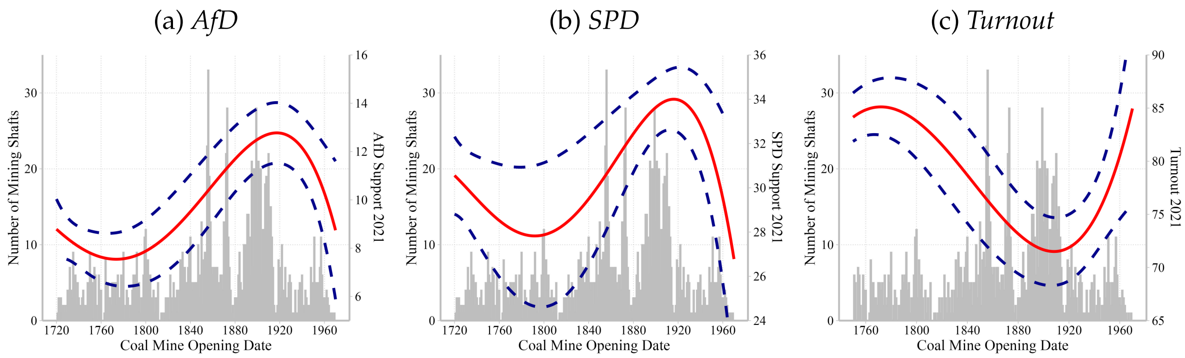
Note: This figure shows the effect of the average adoption date of coal mining (log) and the average depth of coal deposits (reduced form) on electoral outcomes in the 2017, 2021, and 2025 federal elections. The average adoption date is instrumented with average coal depth. Confidence intervals are based on Conley-standard errors with a 5-kilometer cutoff.

Table A9: The Timing of Industrialization and Electoral Realignment at the Ruhr

	SPD		SPD Δ_{2017}^{2025}		AfD Δ_{2017}^{2025}	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***Reduced Form***						
Depth of Carboniferous Surface	0.811*	0.761*	-1.006***	-0.800*	0.842***	0.664*
	(0.429)	(0.438)	(0.385)	(0.415)	(0.325)	(0.341)
N	1,011	1,011	337	337	337	337
Panel B: ***OLS Estimates***						
Average Coal Mine Opening Year	0.433***	0.434***	-0.469***	-0.464***	0.385***	0.371***
	(0.078)	(0.086)	(0.075)	(0.062)	(0.058)	(0.050)
N	1,044	1,044	348	348	348	348
Panel C: ***2SLS Estimates***						
Average Coal Mine Opening Year	0.405**	0.420**	-0.503***	-0.442**	0.421***	0.367**
	(0.170)	(0.198)	(0.147)	(0.191)	(0.125)	(0.164)
F-stat	1,193.6***	427.1***	396.3***	136.1***	396.3***	136.1***
N	1,011	1,011	337	337	337	337
City FE	✗	✓	✗	✓	✗	✓
Historical Controls	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of the average starting date of coal mining operations on the change in AfD and SPD support between the federal elections of 2025 and 2017. *Panel A* presents OLS estimates using the average adoption date of coal mining. *Panel B* presents reduced form estimates, regressing the change in vote shares on the depth of the Carboniferous surface in 100 meters. *Panel C* regresses electoral outcomes on the average opening dates of coal rush mines using coal depth as an instrument. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Figure A15: The Three Waves of Industrialization: Coal Mine Opening Dates and Electoral Outcomes in Adjacent Polling Districts



Note: This figure shows the predicted vote shares of the *Alternative für Deutschland* (AfD), the Social Democratic Party of Germany (SPD), and voter turnout in the federal election of 2021 at the current location of historical coal mines depending on their opening date. We match each coal mine shaft in our dataset ($N = 1,280$) with the polling station at its geolocation and estimate polynomial regressions (k=4) of electoral outcomes on the opening date. We trim opening dates in 1720 and 1970. Dashed lines represent 95% confidence intervals based on Conley-standard errors with a 5-kilometer cutoff.

V Supplementary Results B: Intensity

I. Instrument Plausibility

We assess the plausibility of our instrumental variables strategy by examining how the exclusive presence of deep coal deposits in the northern Ruhr was associated with demographic and economic outcomes before or around the time of the Industrial Revolution. For this purpose, we draw on extensive historical municipal data, described in detail in the Appendix. Our dataset includes information on population size, the number of buildings, and the share of Protestants (all around 1819 or 1871), as well as income tax revenues per capita (around 1860) and literacy rates (1871). Ideally, we would also observe tax revenues and literacy rates for the early nineteenth century, but such data are unavailable at the level of granularity required. To approximate early urban development, we use the population per building as a proxy for urbanization, reflecting the fact that more urbanized areas typically have larger residential structures that house more people. Our most informative outcome is income tax revenues, which capture wealth differences with the greatest precision in the period immediately preceding the rapid expansion of coal mining in the late nineteenth century.

Table A10: The Association Between Deep Coal Deposits on Historical Demographic and Economic Outcomes; OLS Estimates

	Population (log)		Protestant Share		Pop. per Building		Income Tax p.c.	Literacy
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: ***All Municipalities***								
Deep Coal	-0.379**	-0.683***	-0.262**	-0.142*	-0.112	-1.194**	0.020	0.010
	(0.146)	(0.220)	(0.103)	(0.085)	(0.344)	(0.535)	(0.056)	(0.006)
N	258	258	258	205	258	258	205	205
Panel B: ***All Municipalities & RB-FE***								
Deep Coal	-0.508***	-0.619***	-0.098	-0.079	-0.309	-0.474	0.031	0.009
	(0.137)	(0.231)	(0.080)	(0.075)	(0.256)	(0.568)	(0.056)	(0.006)
N	258	258	258	205	258	258	205	205
Panel C: ***Excl. RB Münster***								
Deep Coal	-0.464***	-0.545**	-0.132	-0.088	-0.137	-0.632	0.024	0.010
	(0.150)	(0.250)	(0.092)	(0.083)	(0.359)	(0.558)	(0.057)	(0.007)
N	217	217	217	192	217	217	192	192
Panel D: ***Excl. RB Münster & RB-FE***								
Deep Coal	-0.508***	-0.619***	-0.098	-0.079	-0.309	-0.474	0.031	0.009
	(0.137)	(0.231)	(0.080)	(0.075)	(0.255)	(0.568)	(0.056)	(0.006)
N	217	217	217	192	217	217	192	192
Year of Survey	1819	1871	1819	1871	1819	1871	1860	1871
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of *deepcoal* on historical demographic and economic outcomes. We estimate the effects either at the historical municipal level ($N = 205$) or, where available, the sub-municipal level ($N = 258$). For population, buildings, and the preindustrial confessional composition, we have information at the sub-municipal level, enabling a more precise measurement of the demographic structure of the governorate (RB) of Münster. *Panel A* shows the effects of deep coal deposits in the full sample. *Panel B* adds governorate fixed effects. *Panel C* restricts the sample to municipalities in the governorates of Arnsberg and Düsseldorf, as municipalities in Münster were significantly more aggregated. *Panel D* adds governorate fixed effects (for RB Arnsberg and RB Düsseldorf). For RB Düsseldorf, the Protestant share and the number of buildings per population are measured in 1834 instead of the late 1810s. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

We present the results in four different samples. We first use the full sample of historical municipalities or sub-municipal units without additional controls or sample restrictions. Second, to account for the fact that our historical data before 1871 comes from governorate-specific sources, we use fixed effects at this level. Third, we exclude the historical governorate of Münster, the upper north of our modern city district dataset, because its municipal units were highly aggregated. Fourth, we use this restricted sample of the governorates of Arnsberg and Düsseldorf with the aforementioned fixed effects.

Table A10 reports the associations between $deepcoal$ and historical indicators of demographic and economic development. Across all four panels, we find that districts with close-to-surface coal deposits were more populous both in the early nineteenth century and, to an even greater extent, at the time of German unification. The baseline sample further reveals a negative association between deep coal and the share of Protestants in a district. As the additional panels demonstrate, however, this effect is entirely driven by the governorate of Münster, the historical *Vest Recklinghausen*, which was inhabited exclusively by Catholics in the early nineteenth century. While districts with shallow deposits were more populous both before and during early industrialization, this did not translate into higher urbanization rates, as indicated by the insignificant effects on population per building. Instead, the evidence suggests that population density reflected the aggregation of multiple settlements into single districts, rather than genuine urban concentration. Indeed, once governorate fixed effects are included, only population size remains systematically different between deep coal and close-to-surface coal areas.

Importantly, while aggregate population levels differed historically, there is no evidence of an income divergence between northern and southern districts in the mid-nineteenth century, as indicated by our data on historical tax revenues per capita. Nor do we find systematic variation in literacy rates, which were already very high across the region. Together, this suggests that $deepcoal$ did not generate preindustrial variation in economic prosperity, implying that the effects we identify are unlikely to be driven by persistent urban income advantages of the kind documented in earlier work, where preindustrial wealth predicts postindustrial success (Gagliardi et al. 2023; Heblich et al. 2025).

Table A11: The Association Between Deep Coal Deposits and Catholic Presence in 2011; OLS Estimates

	Catholic Share 2011			
	(1)	(2)	(3)	(4)
Deep Coal	0.033	-0.014	0.001	-0.017
	(0.024)	(0.013)	(0.012)	(0.011)
N	348	348	348	348
City FE	✗	✓	✗	✓
Historical Confessional Control	✗	✗	✓	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of $deepcoal$ on the population share of Catholics in 2011. The second and fourth models include city fixed effects. The third and fourth models control for the historical share of Protestants (around 1819), which was nearly the precise inverse of the Catholic share in this time period. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Nevertheless, the historical differences in population size and religious composition documented in *Panel A* could threaten the exclusion restriction if these legacies persisted into the present, regardless of the subsequent rise of coal mining. We argue that this is unlikely for several reasons. One potential concern is that Catholic communities may have exhibited systematically different political preferences over time and space. If such an effect were present, it would most likely bias our estimates downward, as prior research has shown that predominantly Catholic areas, particularly in our context, have been more resistant to radical right appeals (cf. Haffert 2022). Crucially, however, this mechanism relies on the persistence of a disproportionately Catholic population, which no longer holds today: as shown in Table A11, deep coal deposits are no longer associated with greater Catholic population shares. This erosion of historical religious patterns reflects the profound demographic upheavals of late and intensive industrialization, driven by large-scale historical migration waves (see Table A7).

Turning to aggregate population differences, we argue that these would only generate persistent variation in long-term economic fortunes if they translated into greater urban density. Our evidence on population per building, however, shows that this was not the case historically. The larger populations observed in the southern districts also reflected the industrialization process itself and thus already constitute an outcome of the sequential industrialization dynamics we seek to identify. By the 1870s, the south was already engaged in mining, and its higher degree of urbanization was a direct manifestation of the gradual expansion of the Ruhr's mining frontier. Most importantly, as shown in **??**, the coal rush fundamentally reshaped the population balance of the region as a whole, overriding any historical persistence in population differentials that might otherwise have emerged. Finally, we estimate all models with historical controls for these variables, thereby ensuring that our results capture the effects of intensive industrialization while holding constant the documented observable differences.

II. Full Tables

Table A12: Historical Coal Mining Employment in 1912 and Electoral Outcomes; OLS and 2SLS Estimates; Full Table with Reported Conrol Variable Coefficients

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***Reduced Form***						
Deep Coal	5.040***	5.102***	5.017***	-8.543***	-9.966***	-9.800***
	(0.627)	(0.687)	(0.663)	(1.159)	(1.336)	(1.229)
Population (log) 1819			-0.947***			0.437
			(0.228)			(0.344)
Protestant Share 1819			-0.224			-1.515
			(0.799)			(1.262)
Population per Building 1819			-0.071**			-0.212***
			(0.032)			(0.036)
Income Tax Revenue p.c. 1860			-0.541			0.374
			(0.394)			(0.651)
Panel B: ***1912 & OLS***						
Coal Miners (1,000s)	2.235***	2.903***	2.895***	-4.236***	-6.178***	-5.949***
	(0.380)	(0.351)	(0.389)	(0.757)	(0.804)	(0.705)
Population (log) 1819			-0.912***			0.353
			(0.297)			(0.383)
Protestant Share 1819			-0.400			-1.195
			(0.869)			(1.635)
Population per Building 1819			-0.083***			-0.187***
			(0.021)			(0.019)
Income Tax Revenue p.c. 1860			-0.464			0.209
			(0.349)			(0.565)
Panel C: ***1912 & 2SLS***						
Coal Miners (1,000s)	7.727***	7.345***	7.344***	-13.098***	-14.349***	-14.348***
	(1.949)	(1.423)	(1.386)	(3.369)	(2.566)	(2.487)
Population (log) 1819			-0.669***			-0.106
			(0.252)			(0.415)
Protestant Share 1819			-0.032			-1.889
			(1.188)			(2.140)
Population per Building 1819			-0.112***			-0.132**
			(0.029)			(0.057)
Income Tax Revenue p.c. 1860			-0.244			-0.205
			(0.569)			(1.049)
F-stat	148.9***	193.9***	187.1***	148.9***	193.9***	187.1***
N	1,044	1,044	1,044	1,044	1,044	1,044
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal mining employment in 1912 on electoral outcomes in 2017, 2021, and 2025, including control variable coefficients. *Panel A* reports reduced-form estimates of the effect of $deepcoal_i$. *Panel B* presents OLS estimates. *Panel C* shows IV estimates using the $deepcoal$ instrument.

Table A13: Industrialization vs. Deindustrialization: The Standardized Effects of Industrial Decline and the Historical Industrialization on Radical Right Support with Reported Control Variable Coefficients

	AfD				
	(1)	(2)	(3)	(4)	(5)
Manufacturing Share (Std.) $\Delta_{1970-2011}$	0.391**			0.214	0.266*
	(0.191)			(0.171)	(0.142)
Average Coal Mine Opening Year (Std.)		2.425***		2.393***	
		(0.220)		(0.222)	
Coal Miners (1,000s) in 1912 (Std.)			2.472***		2.448***
			(0.211)		(0.211)
Population (log) 1819	-1.058***	-0.923***	-0.912***	-0.919***	-0.905***
	(0.267)	(0.232)	(0.202)	(0.232)	(0.204)
Protestant Share 1819	-0.470	0.468	-0.400	0.546	-0.287
	(0.715)	(0.672)	(0.603)	(0.691)	(0.615)
Population per Building 1819	-0.064***	-0.046**	-0.083***	-0.047**	-0.083***
	(0.022)	(0.022)	(0.017)	(0.022)	(0.017)
Income Tax Revenue p.c. 1860	-0.510	-0.451	-0.464	-0.400	-0.399
	(0.341)	(0.295)	(0.288)	(0.307)	(0.296)
N	1,044	1,044	1,044	1,044	1,044
R^2	0.109	0.185	0.193	0.187	0.195
City FE	✓	✓	✓	✓	✓
Historical Controls	✓	✓	✓	✓	✓
Std.Errors	District-ID	District-ID	District-ID	District-ID	District-ID

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of deindustrialization, the historical timing of coal mining adoption, and the historical spread of coal miners in 1912 on electoral support for the AfD at the city district level in the federal elections of 2017, 2021, and 2025. This table includes control variable coefficients. Deindustrialization is measured as the change in the share of manufacturing employment between 1970 and 2011, with positive values indicating greater industrial decline. All independent variables are standardized to facilitate effect size comparison. Standard errors are clustered at the unified city districts in the original dataset by Schräpler et al. (2017), from which we source the manufacturing employment estimates.

Table A14: The Intensity of Industrialization and Electoral Realignment at the Ruhr; Reported Control Variable Coefficients

	SPD		SPD Δ_{2017}^{2025}		AfD Δ_{2017}^{2025}	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***1912 & OLS***						
Coal Miners (1,000s)	1.444***	1.913***	-1.606***	-1.857***	0.869**	1.383***
	(0.407)	(0.444)	(0.428)	(0.436)	(0.379)	(0.290)
Population (log) 1819		-0.730**		0.489		-0.378
		(0.341)		(0.301)		(0.238)
Protestant Share 1819		-0.058		0.982		-0.616
		(0.706)		(0.769)		(0.713)
Population per Building 1819		-0.080***		0.041**		-0.068***
		(0.023)		(0.019)		(0.022)
Income Tax Revenue p.c. 1860		-0.554		0.507		-0.527**
		(0.567)		(0.403)		(0.250)
Panel B: ***1912 & 2SLS***						
Coal Miners (1,000s)	6.130***	5.683***	-6.581***	-5.587***	4.718***	3.826***
	(1.858)	(1.374)	(1.870)	(1.195)	(1.561)	(0.954)
Population (log) 1819		-0.524		0.285		-0.245
		(0.361)		(0.272)		(0.218)
Protestant Share 1819		0.254		0.674		-0.414
		(1.138)		(1.164)		(0.854)
Population per Building 1819		-0.104***		0.065**		-0.084***
		(0.029)		(0.027)		(0.022)
Income Tax Revenue p.c. 1860		-0.368		0.323		-0.407
		(0.729)		(0.586)		(0.349)
F-stat	148.9***	187.1***	49.4***	59.7***	49.4***	59.7***
N	1,044	1,044	348	348	348	348
City FE	✗	✓	✗	✓	✗	✓
Historical Controls	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of the historical spread of coal miners (1,000s) in 1912 on levels of SPD support in the federal elections of 2017-2025 and the change in AfD and SPD support between the federal elections of 2025 and 2017. This table includes control variable coefficients.

III. Robustness: Data Structure

Our dataset pools federal electoral outcomes from 2017, 2021, and 2025 and regresses them on time-invariant historical indicators of the timing and intensity of coal mining adoption, together with historical control variables. To ensure that pooling multiple elections does not imply that our results are driven by inflating the number of observations at the district level or allow a single election to drive the results, we conduct three robustness checks. First, we re-estimate the models from Table 2 using standard errors clustered at the district level, thereby more directly accounting for unit-level dependence that is otherwise captured by spatial clustering. As shown in Table A15, district-level clustering yields smaller standard errors than the more conservative spatial clustering approach employed in the main analysis.

Table A15: Historical Coal Mining Employment in 1912 and Electoral Outcomes; OLS and 2SLS Estimates with Standard Errors Clustered at the District Level

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***Reduced Form***						
Deep Coal	5.040***	5.102***	5.017***	-8.543***	-9.966***	-9.800***
	(0.304)	(0.429)	(0.393)	(0.603)	(0.766)	(0.750)
Panel B: ***1912 & OLS***						
Coal Miners (1,000s)	2.235***	2.903***	2.895***	-4.236***	-6.178***	-5.949***
	(0.180)	(0.243)	(0.233)	(0.357)	(0.459)	(0.429)
Panel C: ***1912 & 2SLS***						
Coal Miners (1,000s)	7.727***	7.345***	7.344***	-13.098***	-14.349***	-14.348***
	(0.890)	(0.831)	(0.808)	(1.475)	(1.528)	(1.497)
F-stat	148.9***	193.9***	187.1***	148.9***	193.9***	187.1***
N	1,044	1,044	1,044	1,044	1,044	1,044
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	District-ID	District-ID	District-ID	District-ID	District-ID	District-ID

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal mining employment in 1912 on electoral outcomes in 2017, 2021, and 2025. *Panel A* reports reduced-form estimates of the effect of $deepcoal_i$. *Panel B* presents OLS estimates. *Panel C* shows IV estimates using the $deepcoal$ instrument. Standard errors are clustered at the city district level ($N = 348$).

Second, we average electoral outcomes across the three elections and reestimate the models accordingly. As this represents an alternative way of aggregating outcomes at the district level, the coefficient estimates are identical to those in the pooled specification. Only the standard errors increase slightly, without altering the statistical significance of the results (Table A16).

Third, we estimate the models separately for each election (Table A17). The effects on AfD support are largest in 2025 and smallest in 2021, reflecting the overall trajectory of the party's aggregate vote share. Conversely, the negative effect on turnout is weakest in 2025, when political mobilization increased overall. Nevertheless, the effects are statistically significant across all three elections for both AfD support and turnout. Averaging the coefficients across elections (e.g., *Panel A*–*Panel C*) confirms that the pooled analysis captures an equally weighted mean of the single-election estimates. For example, the average of the mining-employment effect on AfD support in Model (3) is $(2.564 + 2.173 + 3.947)/3 = 2.895$, which exactly corresponds to the coefficient estimate reported in the pooled model (Table 2).

Table A16: Historical Coal Mining Employment in 1912 and Electoral Outcomes; OLS and 2SLS Estimates Using Average District-Level Vote Shares, 2017–2025

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***Reduced Form***						
Deep Coal	5.040***	5.102***	5.017***	-8.543***	-9.966***	-9.800***
	(0.628)	(0.698)	(0.677)	(1.161)	(1.359)	(1.256)
Panel B: ***1912 & OLS***						
Coal Miners (1,000s)	2.235***	2.903***	2.895***	-4.236***	-6.178***	-5.949***
	(0.381)	(0.357)	(0.398)	(0.757)	(0.817)	(0.720)
Panel C: ***1912 & 2SLS***						
Coal Miners (1,000s)	7.727***	7.345***	7.344***	-13.098***	-14.349***	-14.348***
	(1.950)	(1.447)	(1.415)	(3.372)	(2.610)	(2.540)
F-stat	49.4***	62.4***	59.7***	49.4***	62.4***	59.7***
N	348	348	348	348	348	348
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal mining employment in 1912 on electoral outcomes in 2017, 2021, and 2025. *Panel A* reports reduced-form estimates of the effect of $deepcoal_i$. *Panel B* presents OLS estimates. *Panel C* shows IV estimates using the $deepcoal$ instrument. We average the vote shares of the AfD and voter turnout for each city district across the federal elections of 2017, 2021, and 2025.

Table A17: Historical Coal Mining Employment in 1912 and Electoral Outcomes; Separate OLS Estimates for Each Federal Election (2017-2025)

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***2017 Election***						
Coal Miners in 1912 (1,000s)	2.009***	2.579***	2.564***	-4.106***	-6.558***	-6.330***
	(0.397)	(0.303)	(0.327)	(0.775)	(0.848)	(0.765)
Panel B: ***2021 Election***						
Coal Miners in 1912 (1,000s)	1.817***	2.191***	2.173***	-4.884***	-6.826***	-6.575***
	(0.301)	(0.279)	(0.304)	(0.883)	(0.911)	(0.793)
Panel B: ***2025 Election***						
Coal Miners in 1912 (1,000s)	2.878***	3.940***	3.947***	-3.717***	-5.150***	-4.944***
	(0.530)	(0.511)	(0.581)	(0.648)	(0.747)	(0.644)
N	348	348	348	348	348	348
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal mining employment in 1912 on electoral outcomes in 2017, 2021, and 2025. *Panel A* shows the effects of historical coal mining employment on electoral outcomes in 2017; *Panel B* uses electoral outcomes in 2021; *Panel C* uses electoral outcomes in 2025.

IV. Coal Rush Mining

We employ a supplementary strategy to measure the intensity of industrialization in the coal sector. Following Gerschenkron (1962), we specifically focus on specialization trajectories, distinguishing between districts that scaled up from proto-industrial to larger industrial operations from those that transitioned directly to large-scale production. For each district, we construct a binary indicator of coal rush mining, equal to 1 for districts with the *exclusive* presence of coal rush shafts and 0 for all remaining districts. Coal rush mines are defined as those established after 1839, with a minimum depth of 100 meters, and operational until at least 1913. The final condition reflects that, even after deep-shaft mining became feasible, numerous small shafts emerged but experienced rapid decline. This allows us to compare communities that adopted coal mining without prior proto-industrial activity to all other districts, and particularly to those that transitioned gradually into deep-shaft operations.

We conduct three empirical analyses to assess the electoral consequences of late and intensive industrialization driven by the extensive adoption of coal rush mining. Table A18 presents the effects of coal rush mining relative to the baseline group of districts that never hosted a coal rush shaft within their boundaries. This broad empirical contrast shows that coal rush districts exhibit between 3.4 and 4.0 percentage points higher support for the AfD in our OLS estimates. The effects more than double in the instrumental variables design, reaching up to 9.3 percentage points. Importantly, such electoral gaps are not abstract but manifest clearly within the Ruhr itself, even across short distances. For instance, in Essen-Altendorf, historically heavily industrialized but through both steel and the gradual adoption of deep-shaft operations after decades of proto-industrial mining, the AfD received around 21% in the 2025 election. A ten-minute drive north in Essen-Vogelheim, where intensive coal mining only arrived in the 1870s, support for the AfD nearly reached 32%.

Table A18: The Incidence of Coal Rush Mining and Electoral Outcomes

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***OLS Estimates***						
Coal Rush Mining	4.043***	3.513***	3.352***	-4.986***	-5.823***	-5.145***
	(0.649)	(0.557)	(0.535)	(1.149)	(1.144)	(1.180)
Panel B: ***2SLS Estimates***						
Coal Rush Mining	9.156***	9.329***	9.141***	-15.520***	-18.224***	-17.858***
	(1.137)	(1.095)	(1.088)	(2.125)	(2.724)	(2.527)
F-stat	379.2***	244.5***	245.1***	379.2***	244.5***	245.1***
N	1,044	1,044	1,044	1,044	1,044	1,044
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal rush mining on electoral outcomes at the city district level in the 2017, 2021, and 2025 elections. Coal rush mines are defined as coal mine shafts constructed since 1840 with a minimum shaft depth of 100 meters and in operation until at least 1913. Coal rush mining is a binary indicator equal to 1 if a district hosted at least one coal rush-era mine and had no earlier mining activity within its boundaries. *Panel A* presents OLS estimates. *Panel B* presents instrumental variable estimates, using the *deepcoal* indicator to predict the exclusive presence of coal rush mining.

However, the initial design contrasts coal rush districts with those that either never engaged in mining or only hosted small-scale, proto-industrial operations. As a second step, we therefore restrict the control group to districts that historically contained at least one mining site, whether an adit or a shaft. The results in Table A19 show that, when using this active mining control, the effects of coal rush mining remain statistically and economically significant. With the improved precision of our instruments, the 2SLS estimates align much more closely with the OLS results, ranging between 6.6 and 7.7 percentage points. This constitutes a sizeable effect, given that the AfD's average vote share in this restricted sample is 13.5%.

Finally, we examine the empirical contrast that most closely reflects Gerschenkron's distinction between early and late industrializers. Here, we compare coal rush districts to those that transitioned gradually from proto-industrial mining to deep-shaft mining. In this specification, all districts were involved in deep-shaft mining, with the key difference being whether they entered through a gradual transition or adopted deep-shaft mining abruptly. The estimates in Table A20 demonstrate that this transition-based control yields strikingly similar results. These findings underscore that late and intensive industrialization had substantial and enduring effects on electoral outcomes in the Ruhr.

Table A19: The Incidence of Coal Rush Mining and Electoral Outcomes; Active Mining District Control

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***OLS Estimates***						
Coal Rush Mining	5.521***	5.535***	5.407***	-7.755***	-8.089***	-8.489***
	(0.754)	(0.723)	(0.749)	(1.344)	(1.544)	(1.508)
Panel B: ***2SLS Estimates***						
Coal Rush Mining	6.582***	7.573***	7.651***	-10.801***	-13.950***	-13.810***
	(0.763)	(0.877)	(0.931)	(1.527)	(2.433)	(2.306)
F-stat	1,654.9***	790.6***	747.6***	1,654.9***	790.6***	747.6***
N	720	720	720	720	720	720
Coal Rush Districts	145	145	145	145	145	145
Coal Control Districts	95	95	95	95	95	95
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal rush mining on electoral outcomes at the city district level in the 2017, 2021, and 2025 elections. Coal rush mines are defined as coal mine shafts constructed since 1840 with a minimum shaft depth of 100 meters and in operation until at least 1913. Coal rush mining is a binary indicator equal to 1 if a district hosted at least one coal rush-era mine and had no earlier mining activity within its boundaries. Coal control districts include all other districts with mining activities, encompassing both early industrial adits and deep-shaft mining. *Panel A* presents OLS estimates. *Panel B* presents instrumental variable estimates, using the *deepcoal* indicator to predict the exclusive presence of coal rush mining.

Table A20: The Incidence of Coal Rush Mining and Electoral Outcomes; Industrial Transition Control

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***OLS Estimates***						
Coal Rush Mining	5.387***	5.178***	4.734***	-7.848***	-8.136***	-8.786***
	(0.804)	(0.815)	(0.837)	(1.449)	(1.830)	(1.775)
Panel B: ***2SLS Estimates***						
Coal Rush Mining	6.347***	6.808***	6.685***	-9.500***	-11.267***	-12.143***
	(0.770)	(0.738)	(0.841)	(1.439)	(2.045)	(2.043)
F-stat	2,288.8***	1,130.9***	1,030.3***	2,288.8***	1,130.9***	1,030.3***
N	606	606	606	606	606	606
Coal Rush Districts	145	145	145	145	145	145
Coal Control Districts	57	57	57	57	57	57
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal rush mining on electoral outcomes at the city district level in the 2017, 2021, and 2025 elections. Coal rush mines are defined as coal mine shafts constructed since 1840 with a minimum shaft depth of 100 meters and in operation until at least 1913. Coal rush mining is a binary indicator equal to 1 if a district hosted at least one coal rush-era mine and had no earlier mining activity within its boundaries. Coal control districts include all districts with both proto-industrial adit mining, defined by adits or shafts opened before 1840, and deep-shaft mining, defined by shafts with a minimum depth of 100 meters. The contrast thus derives from districts historically transitioning from proto-industrial to industrial mining operations. *Panel A* presents OLS estimates. *Panel B* presents instrumental variable estimates, using the *deepcoal* indicator to predict the exclusive presence of coal rush mining.

Table A21: The Incidence of Coal Rush Mining and Electoral Outcomes; Intensive Margin

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***Coal Rush Mines, OLS***						
Coal Rush Mines	0.650***	0.711***	0.692***	-1.096***	-1.164***	-1.145***
	(0.147)	(0.143)	(0.143)	(0.221)	(0.280)	(0.277)
Panel B: ***Coal Rush Mines, 2SLS***						
Coal Rush Mines	5.920**	4.529***	3.493***	4.697**	-8.848***	-8.818***
	(2.322)	(1.204)	(1.061)	(1.914)	(2.250)	(2.275)
F-stat	40.9***	55.2***	53.2***	40.9***	55.2***	53.2***
N	1,044	1,044	1,044	1,044	1,044	1,044
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal rush mining on electoral outcomes at the community level in the 2017, 2021, and 2025 elections. Coal rush mines are defined as coal mine shafts constructed since the 1840s with a minimum shaft depth of 100 meters and in operation until at least 1913. All panels use the total number of coal rush mines within community boundaries as the treatment indicator.

Table A22: Distance to Coal Rush Mines and Electoral Outcomes

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***OLS Estimates***						
Distance to Coal Rush	-0.908***	-1.450***	-1.495***	1.812***	3.200***	3.159***
	(0.293)	(0.307)	(0.270)	(0.493)	(0.468)	(0.416)
Panel B: ***2SLS Estimates***						
Distance to Coal Rush	-4.047***	-3.654***	-2.759***	-3.211**	7.138***	6.967***
	(1.538)	(1.091)	(0.790)	(1.293)	(1.976)	(1.724)
F-stat	173.4***	249.5***	269.4***	173.4***	249.5***	269.4***
N	1,044	1,044	1,044	1,044	1,044	1,044
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of distance to coal rush mining on electoral outcomes at the city district level in the 2017, 2021, and 2025 federal elections. Coal rush mines are defined as coal mine shafts constructed since the 1840s with a minimum shaft depth of 100 meters and in operation until at least 1913. For each district, we compute the average distance to the nearest ten mining shafts. Distance to coal rush mines is instrumented with our binary deep coal indicator, equal to unity if coal deposits are inaccessible at or near the surface. *Panel A* shows the OLS estimates; *Panel B* displays 2SLS estimates, using the *deepcoal* indicator.

V. Alternative Employment Indicators

Table A23: Historical Coal Mining Employment and Electoral Outcomes at the Polling Station Level; OLS and 2SLS Estimates

	AfD		Turnout	
	(1)	(2)	(3)	(4)
Panel A: ***1912 & OLS***				
Coal Miners (1,000s)	9.871***	10.711***	-22.154***	-29.702***
	(1.617)	(1.509)	(4.576)	(5.043)
Panel B: ***1912 & 2SLS***				
Coal Miners (1,000s)	34.444***	33.813***	-83.823***	-90.238***
	(7.736)	(6.350)	(21.741)	(17.940)
F-stat	267.7***	229.3***	259.4***	228.8***
N	1,953	1,953	1,929	1,929
City FE	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of the historical spread of coal miners (1,000s) in 1912 at the polling district level on electoral outcomes in 2021. Historical employment is instrumented with our *deepcoal* indicator, equal to unity if coal deposits are inaccessible at or near the surface. All models are estimated with and without city fixed effects.

Table A24: Coal Mining Employment Shares in Historical Municipalities in 1893 and Electoral Outcomes; OLS Estimates

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***1893 Miners***						
Coal Miner Share 1893	0.114***	0.202***	0.171***	-0.048	-0.118	-0.178***
	(0.030)	(0.028)	(0.030)	(0.057)	(0.076)	(0.046)
Panel B: ***1893 Mining Families***						
Coal Miners & Family Share 1893	0.033***	0.060***	0.051***	-0.010	-0.029	-0.050***
	(0.009)	(0.008)	(0.009)	(0.018)	(0.023)	(0.014)
N	999	999	999	999	999	999
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors Clustered:	ID:1871	ID:1871	ID:1871	ID:1871	ID:1871	ID:1871

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of historical coal mining employment rates in 1893 on electoral outcomes (2017-2025). *Panel A* shows the effect of the population share of coal miners on support for the radical right and voter turnout. *Panel B* shows the effect of the population share of coal miners and their dependants (children, wives, and supported elderly) on electoral outcomes. The historical coal mining employment shares are expressed as percentages. Standard errors in parentheses are clustered at the municipal level in 1871 (N=205).

Table A25: Coal Mining Employment Shares in Historical Municipalities in 1893 and Electoral Outcomes; 2SLS Estimates

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***1893 Miners***						
Coal Miner Share 1893	0.879***	1.423***	1.730***	-1.451***	-2.629**	-3.146**
	(0.238)	(0.454)	(0.615)	(0.444)	(1.113)	(1.244)
F-stat	72.5***	31.1***	23.8***	72.5***	31.1***	23.8***
Panel B: ***1893 Mining Families***						
Coal Miners & Family Share 1893	0.325***	0.428***	0.506***	-0.536***	-0.791**	-0.921**
	(0.103)	(0.151)	(0.190)	(0.188)	(0.362)	(0.383)
F-stat	47.2***	29.2***	24.3***	47.2***	29.2***	24.3***
N	999	999	999	999	999	999
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors Clustered:	ID:1871	ID:1871	ID:1871	ID:1871	ID:1871	ID:1871

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of historical coal mining employment rates in 1893 on electoral outcomes (2017-2025). *Panel A* shows the effect of the population share of coal miners on support for the radical right and voter turnout. *Panel B* shows the effect of the population share of coal miners and their dependants (children, wives, and supported elderly) on electoral outcomes. The historical coal mining employment shares are expressed as percentages. Mining employment is instrumented with our *deepcoal* indicator. Standard errors in parentheses are clustered at the municipal level in 1871 (N=205).

Table A26: Historical Coal Mining Employment in 1921 and Electoral Outcomes; OLS and 2SLS Estimates

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***1921 & OLS***						
Coal Miners (1,000s)	1.808***	2.514***	2.492***	-3.223***	-5.111***	-4.951***
	(0.322)	(0.282)	(0.311)	(0.541)	(0.632)	(0.567)
Panel B: ***1921 & 2SLS***						
Coal Miners (1,000s)	5.979***	5.779***	5.772***	-10.135***	-11.289***	-11.276***
	(1.445)	(1.094)	(1.070)	(2.583)	(2.045)	(1.995)
F-stat	169.0***	232.2***	224.0***	169.0***	232.2***	224.0***
N	1,044	1,044	1,044	1,044	1,044	1,044
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal mining employment in 1921, the historical peak of mining employment (Allgemeiner Knappschafts-Verein 1921), on electoral outcomes in 2017, 2021, and 2025. *Panel B* reports IV estimates using the $deepcoal$ instrument. All models are estimated with and without city fixed effects. Conley-standard errors with a 5-kilometer cutoff to account for spatial autocorrelation are in parentheses.

Table A27: The Intensive Margin of Coal Mining and Electoral Outcomes in Coal Rush Communities; OLS Estimates

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***Coal Rush Mines***						
Coal Rush Mines	0.499***	0.525***	0.487***	-0.751***	-0.728***	-0.752***
	(0.127)	(0.132)	(0.121)	(0.205)	(0.243)	(0.227)
Panel B: ***Miners 1893***						
Coal Miners 1893 (1,000s)	1.450*	1.878***	1.893**	-2.993**	-4.580***	-3.959***
	(0.752)	(0.692)	(0.735)	(1.296)	(1.133)	(0.848)
Panel C: ***Miners 1912***						
Coal Miners 1912 (1,000s)	1.513***	1.941***	1.836***	-2.905***	-4.433***	-4.443***
	(0.353)	(0.412)	(0.388)	(0.776)	(0.775)	(0.733)
N	720	720	720	720	720	720
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal rush mining (number of mining shafts) and historical mining employment at the district level on electoral outcomes (2017-2025). The sample only contains districts where the top geological layer covers coal deposits, $deepcoal_i = 1$. We restrict the analysis to the more homogeneous urban areas where deep-shaft mining became economically dominant. All models are estimated with and without city fixed effects. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

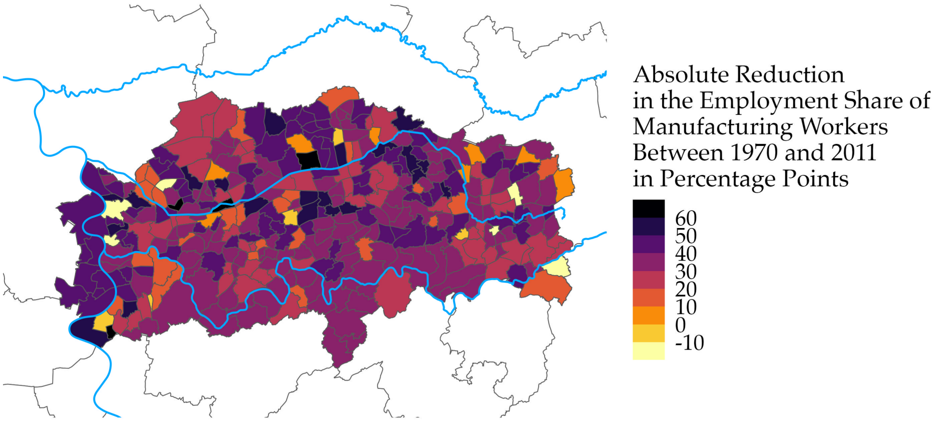
Table A28: Divided Cities Design: Coal Mining Specialization and Electoral Outcomes in Bochum, Dortmund, and Essen; 2SLS Estimates

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: ***OLS & Coal Rush Mining***						
Coal Rush Mining	4.830***	4.952***	4.398***	-7.703***	-7.744***	-7.874***
	(0.804)	(0.773)	(0.767)	(1.493)	(1.476)	(1.524)
Panel B: ***2SLS & Coal Rush Mining***						
Coal Rush Mining	8.714***	8.800***	9.471***	6.997***	-16.449***	-16.733***
	(1.188)	(1.138)	(1.171)	(1.723)	(2.927)	(2.792)
F-stat	240.1***	244.1***	199.4***	240.1***	244.1***	199.4***
Panel C: ***OLS & Miners 1893***						
Coal Miners 1893 (1,000s)	3.185**	4.728***	4.303***	-6.026**	-8.565***	-8.025***
	(1.467)	(1.238)	(1.200)	(2.803)	(2.795)	(2.475)
Panel D: ***2SLS & Miners 1893***						
Coal Miners 1893 (1000s)	35.269	27.000***	31.385**	-66.698	-50.472***	-55.447**
	(29.296)	(10.219)	(13.147)	(55.936)	(19.025)	(23.367)
F-stat	13.8***	34.0***	23.2***	13.8***	34.0***	23.2***
Panel E: ***OLS & Miners 1912***						
Coal Miners 1912 (1,000s)	2.614***	3.416***	3.310***	-5.399***	-6.927***	-6.534***
	(0.701)	(0.504)	(0.568)	(1.245)	(1.271)	(1.164)
Panel F: ***2SLS & Miners 1912***						
Coal Miners 1912 (1,000s)	8.221***	7.300***	7.972***	-15.547***	-13.646***	-14.083***
	(2.751)	(1.627)	(1.548)	(5.188)	(2.830)	(2.700)
F-stat	88.7***	163.8***	124.1***	88.7***	163.8***	124.1***
N	426	426	426	426	426	426
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal rush mining (binary) and the historical spread of coal miners (1000s) (1893 and 1912) at the district level on electoral outcomes (2017-2025). The sample only contains the three cities divided by the marl boundary, namely Bochum, Dortmund, and Essen. All treatment indicators are instrumented with our binary deep coal indicator, equal to unity if coal deposits are inaccessible at or near the surface. All models are estimated with and without city fixed effects. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

VI. Industrialization vs. Deindustrialization

Figure A16: The Local Geography of Deindustrialization in the Ruhr Area



Note: This figure shows the change in the share of manufacturing employment at the district level between 1970 and 2011. Positive values indicate greater industrial decline. The estimates of manufacturing employment in both years come from Schräpler et al. 2017.

Table A29: Industrialization vs. Deindustrialization: The Effects of Industrial Decline and the Historical Timing of Coal Mining Adoption on Radical Right Support

	AfD Support			
	(1)	(2)	(3)	(4)
Manufacturing Share $\Delta_{1970-2011}$	0.036**	0.013	-0.005	-0.011
	(0.015)	(0.012)	(0.013)	(0.012)
Manufacturing Share 1970			0.226***	0.160***
			(0.022)	(0.022)
Average Coal Mine Opening Year		0.553***		0.407***
		(0.046)		(0.051)
N	1,044	1,044	1,044	1,044
R^2	0.008	0.139	0.132	0.192
R^2 Adj.	0.007	0.137	0.130	0.190
Std.Errors	Schräpler ID	Schräpler ID	Schräpler ID	Schräpler ID

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of deindustrialization, intermediate industrialization, and the historical timing of coal mining adoption on electoral support for the AfD at the city district level in the federal elections of 2017, 2021, and 2025. Deindustrialization is measured as the change in the share of manufacturing employment between 1970 and 2011, with positive values indicating greater industrial decline. The manufacturing share is measured in percentages; manufacturing decline is measured as the difference between the manufacturing shares (%) in 1970 and 2011. Standard errors are clustered at the unified city districts in the original dataset by Schräpler et al. (2017), from which we source the manufacturing employment estimates.

VI Supplementary Results C: Mechanism

I. Full Tables

Table A30: The Effects of Historical Colony Housing on Neighborhood Disadvantage with Reported Control Variable Coefficients

	Pre-1919 Buildings	Rent €/m² (monthly)	Land Prices €/m²	Price-to-Rent Ratio	Homeowner Share	Distance: High Schools	Urban Amenities	Distance: Rail Stations
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mining Colony	0.195***	-0.330***	-63.624***	-0.521***	0.035***	305.551***	-0.006**	34.801
	(0.014)	(0.041)	(9.666)	(0.100)	(0.012)	(85.476)	(0.003)	(58.419)
Distance to Nearest CBD	-0.003	-0.012	1.413	0.043	0.013***	80.490***	-0.004***	80.646***
	(0.002)	(0.013)	(3.090)	(0.031)	(0.002)	(27.688)	(0.001)	(17.092)
Population 2022	0.000**	-0.002***	-0.080	0.000	-0.002***	-3.297***	0.000***	-1.820***
	(0.000)	(0.000)	(0.120)	(0.002)	(0.000)	(0.444)	(0.000)	(0.280)
N	44,319	44,319	44,319	44,319	44,319	44,319	44,319	44,319
Std.Errors	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the relationship between mining colony housing and the economic conditions of modern residential neighborhoods, including control variable coefficients (see *Panel B* in Table 6). The units of analysis are 100 -×-100 meter grid cells. The analysis only includes settled grid cells ($pop_{2022} > 0$).

Table A31: The Effect of Historical Mining Colony Presence on Sociodemographic Outcomes at the District Level; OLS Estimates with Reported Control Variable Coefficients

	University Graduates		High-Income Earners		Social Assistance Recipients		Foreign Residents	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mining Colony Presence (District-Level)	-0.068***	-0.055***	-0.046***	-0.042***	0.035***	0.032***	0.027**	0.033***
	(0.013)	(0.012)	(0.009)	(0.009)	(0.010)	(0.011)	(0.013)	(0.011)
Population (log) 1819		0.011*		0.006		-0.005		0.006
		(0.006)		(0.005)		(0.006)		(0.006)
Protestant Share 1819		0.001		-0.017		0.032		0.032*
		(0.021)		(0.019)		(0.024)		(0.019)
Population per Building 1819		0.000		-0.002***		0.003***		0.005***
		(0.000)		(0.000)		(0.000)		(0.001)
Income Tax Revenue p.c. 1860		0.003		-0.007		0.011		0.006
		(0.010)		(0.008)		(0.010)		(0.008)
N	328	328	328	328	328	328	348	348
City FE	✗	✓	✗	✓	✗	✓	✗	✓
Historical Controls	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports the effects of historical mining colony presence on district-level sociodemographic outcomes in 2021, including control variable coefficients. Outcomes include the share of university graduates, high-income earners (monthly income > €4,800), recipients of social assistance (SGB-II), and foreign residents (2022). Colony presence is a binary variable equal to 1 if at least 10% of a district's settled grids emerged through colony housing (32% of districts).

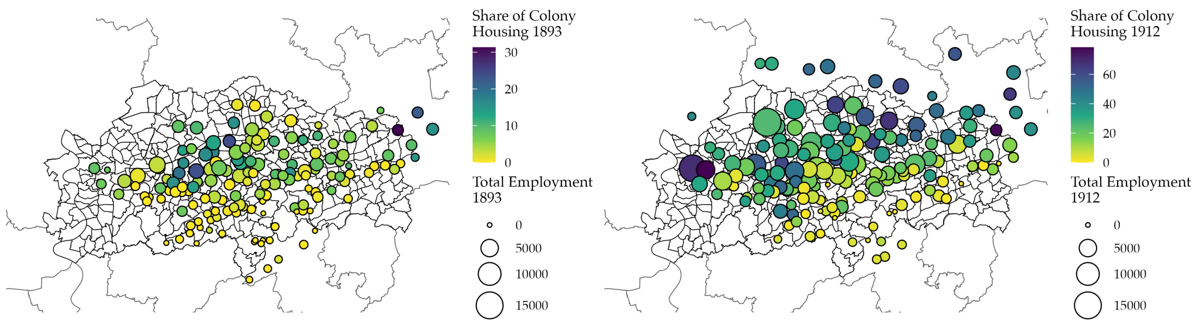
II. Historical Colony Housing Censuses

We draw on three historical sources to measure the spread of worker settlements at the mine level. First, the comprehensive study by Taeglichsbeck (1895) provides data for 1893, including the share of coal miners in company housing and broader information on residential conditions such as tenancy (*Kostgänger*), homeownership, and renting. Second, the survey by the Verein für die Bergbaulichen Interessen (1901) offers a more detailed account of company housing around 1900, reporting not only the number of coal miners in company-owned housing and colonies but also the financial investments and costs incurred by mine owners. Third, archival materials from the *Landesarchiv North Rhine-Westphalia, Department of Westphalia* provide data for 1912 on the number and share of coal miners living in colony housing, as well as the total stock of colony flats (Landesarchiv Nordrhein-Westfalen, n.d.).

Figure A17 illustrates how profoundly colony housing reshaped living conditions in the Ruhr between the late nineteenth and early twentieth centuries. In 1893, only about 7% of the region's roughly 150,000 coal miners—just over 10,000 individuals—lived in mining colonies. By 1912, nearly 118,000 of the 400,000 coal miners in the region lived in colony housing (30%). On the eve of the First World War, by 1914, the number of colony residents had risen further to almost 140,000 (33%).

Figure A17: The Share of Coal Miners in Colony Housing and the Total Scale of Mining Employment: 1893 vs. 1912

(a) *1893* (b) *1912*



Note: This figure illustrates the share of colony housing and the size of total mining employment at the mine level in 1893 and 1912. As the 1893 study reports information at the shaft level, while information in 1912 is confined to coal mine units, we aggregate 1893 records at the mine level as well. To map coal mines with multiple shafts, we use the location of the earliest opened shaft in our database.

Table A32: The Timing of Mine Openings and the Historical Construction of Colony Housing; Mine-Level Evidence with Employment Controls

	Colony Miner Share		Company Flats per Mine		Costs	Cost per Flat
	(1)	(2)	(3)	(4)	(5)	(6)
Coal Mine Opening Year	0.228**	1.794***	22.380**	14.593	104.054**	79.785**
	(0.091)	(0.467)	(9.855)	(16.363)	(45.168)	(37.789)
Plant-Level Employment	0.003***	0.001**	0.071	0.095***	0.130	-0.036
	(0.001)	(0.000)	(0.045)	(0.036)	(0.156)	(0.182)
N	146	133	101	133	101	100
Year of Survey	1893	1912	1900	1912	1900	1900
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table reports OLS estimates of the effects of the coal mine opening year on the historical development of colony housing. We control for total mining employment in 1893 (Models 1, 3, 5-6) and 1912 (Models 2 & 4). Models (1)-(2) examine the share of workers housed in mining colonies in 1893 and 1912. Models (3)-(4) focus on the number of company-owned flats rented to coal miners in 1900 and 1912. Models (5)-(6) examine the financial dimension of company housing in 1900, using the costs of company housing (1,000 RM) and the cost per flat (RM).

Table A33: The Timing of Mine Openings and the Historical Construction of Colony Housing; Mine-Level Evidence; Instrumental Variable Estimates

	Colony Miner Share		Company Flats per Mine		Costs	Cost per Flat
	(1)	(2)	(3)	(4)	(5)	(6)
Coal Mine Opening Year	1.396***	7.686***	73.638***	259.047***	302.291***	161.396
	(0.512)	(1.727)	(22.574)	(51.955)	(98.177)	(99.366)
F-stat	33.8***	36.2***	30.3***	36.2***	30.3***	30.6***
N	146	133	105	133	105	104
Year of Survey	1893	1912	1900	1912	1900	1900
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

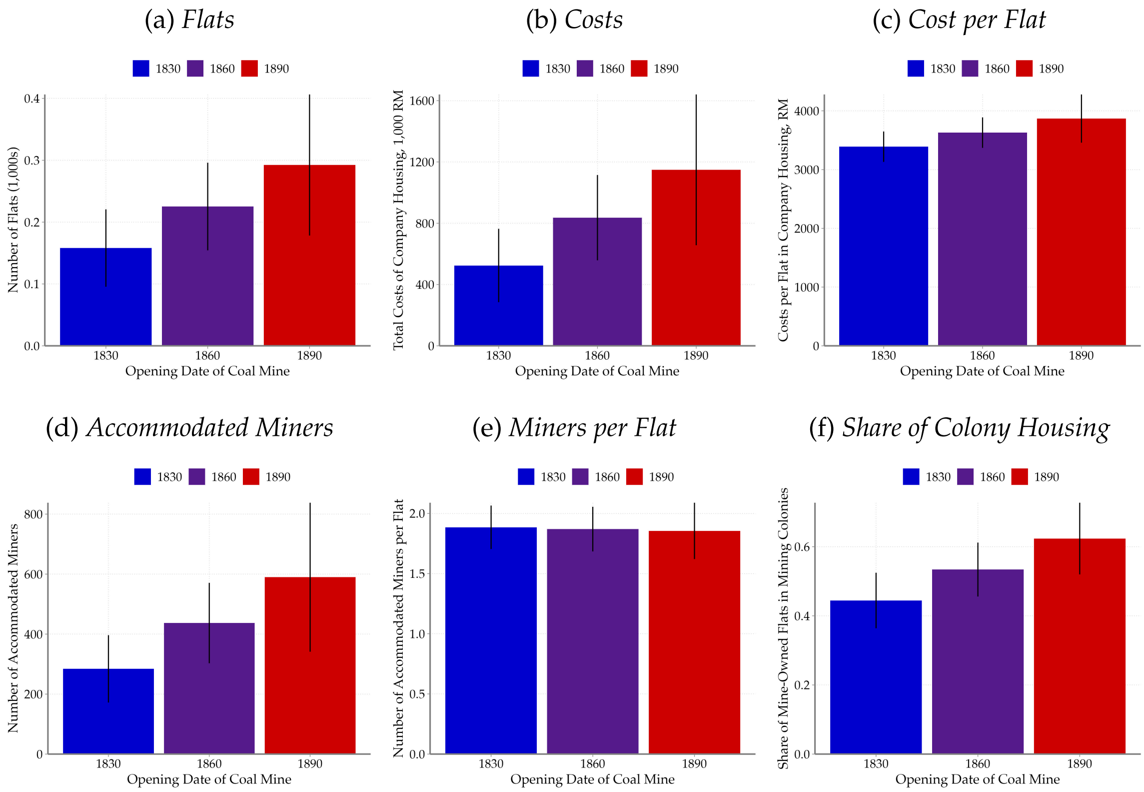
Note: *p<0.1; **p<0.05; ***p<0.01; This table reports 2SLS estimates of the effects of the coal mine opening year on the historical development of colony housing. The normalized coal mine opening year is instrumented with the continuous depth of the Carboniferous surface. Models (1)-(2) examine the share of workers housed in mining colonies in 1893 and 1912. Models (3)-(4) focus on the number of company-owned flats rented to coal miners in 1900 and 1912. Models (5)-(6) examine the costs of company housing (1,000 RM) and the cost per flat (RM).

Table A34: The Timing of Mine Openings and the Other Historical Housing Outcomes

	Tenant Share		Renter Share		Homeowner Share	
	(1)	(2)	(3)	(4)	(5)	(6)
Coal Mine Opening Year	0.011***	0.009***	0.007**	0.005	-0.009***	-0.006**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
N	146	133	105	133	105	104
Year of Survey	1893	1893	1893	1893	1893	1893
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Note: *p<0.1; **p<0.05; ***p<0.01; This table reports OLS estimates of the effects of the normalized coal mine opening year on other historical housing outcomes in 1893. Models (1)-(2) examine the share of workers living as tenants (*Kostgänger*). Models (3)-(4) focus on the share of miners living as regular renters. Models (5)-(6) examine the share of homeowners among coal miners.

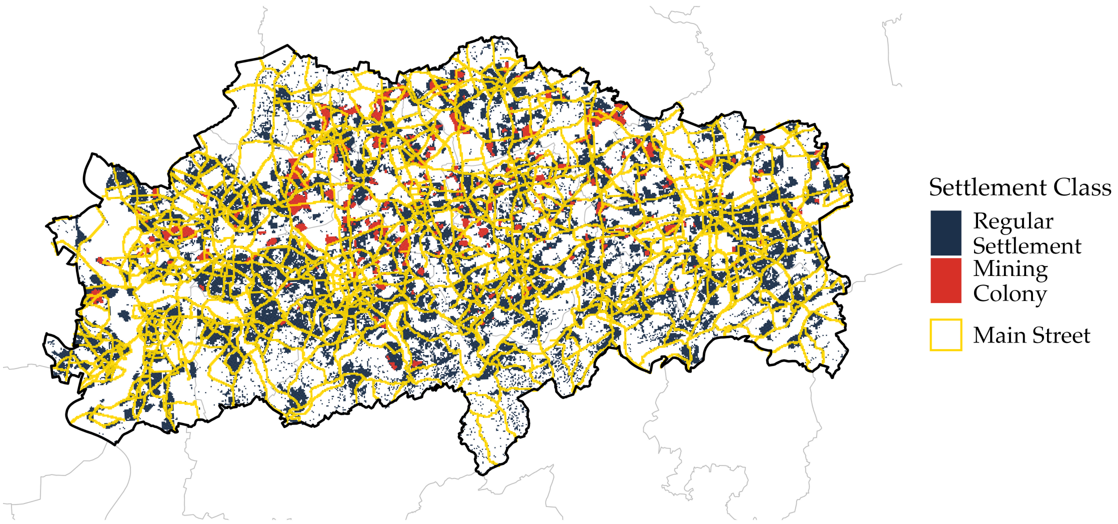
Figure A18: Coal Mine Opening Dates and Housing Conditions; Predicted Values



Note: This figure shows the predicted levels of flats, company housing costs, costs per flat, accommodated miners, miners per flats, and the share of flats belonging to colony housing at different levels of coal mine opening dates. The predictions are based on models including employment controls.

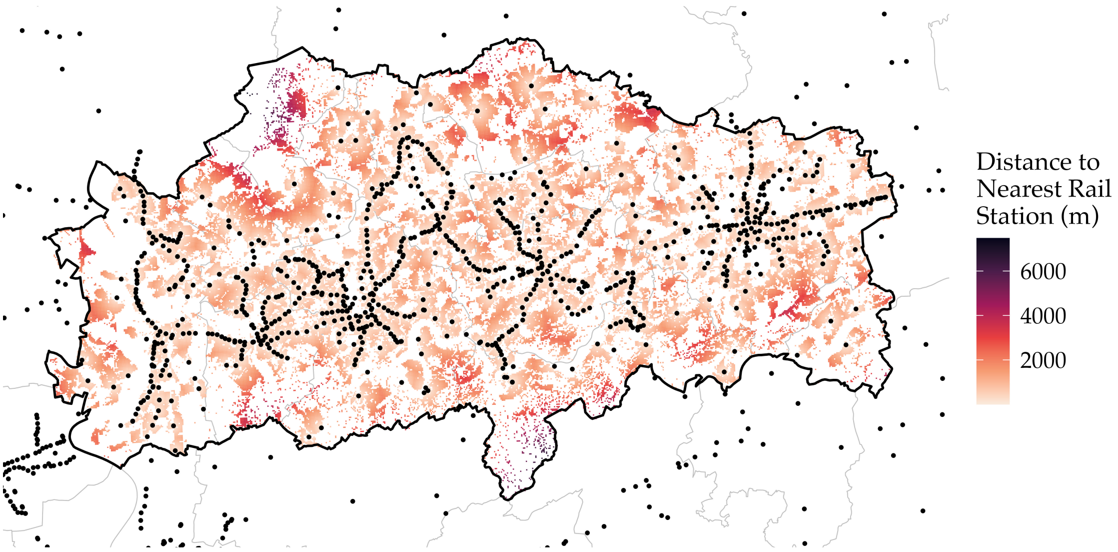
III. Mining Colonies and Modern Neighborhoods

Figure A19: Mining Colonies and the Modern Main Street Network



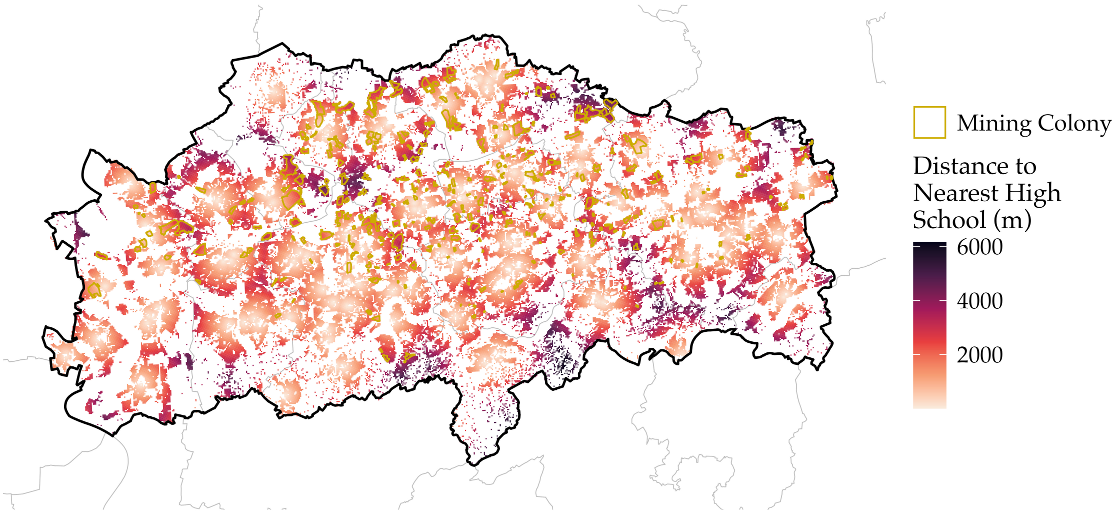
Note: This figure shows the spread of mining colonies at the 100-×-100 meter grid cell level and the modern main street (*Hauptstraße*) network. Settlements are extracted from Zensus (2022).

Figure A20: Mining Colonies and Modern Railways



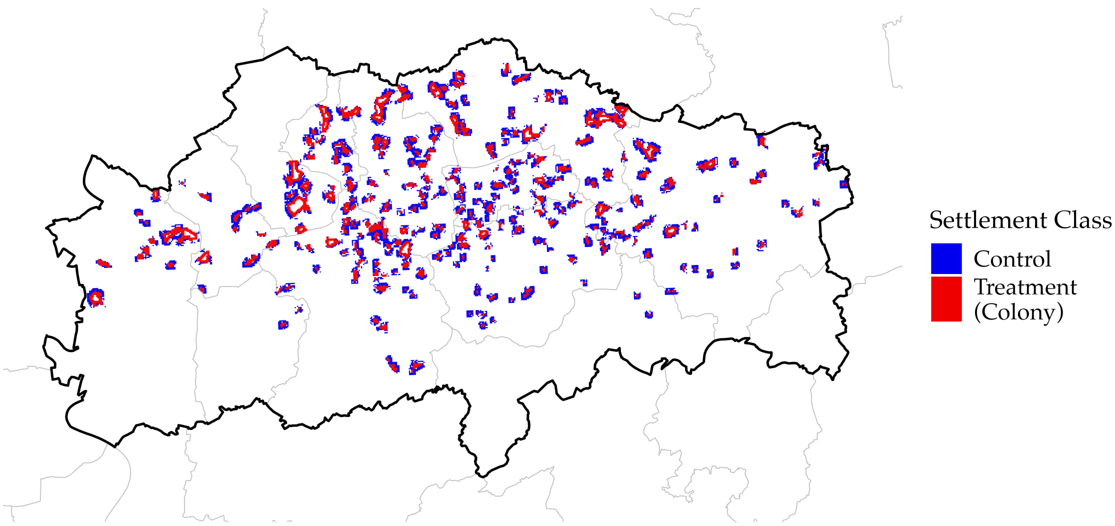
Note: This figure shows the spread of mining colonies at the 100-×-100 meter grid cell level and the modern rail network, including light rail. Settlements are extracted from Zensus (2022).

Figure A21: Mining Colonies and Distance to High Schools



Note: This figure shows the spread of mining colonies at the 100-×-100 meter grid cell level and the distance to the nearest high school. Settlements are extracted from Zensus (2022).

Figure A22: Treatment and Control Group in Geographic Regression Discontinuity Design (RDD)



Note: This figure visualizes the treatment and control group in the geographic regression discontinuity design discussed in the main paper. Treated units are grid cells classified as mining colonies with a maximum adjusted distance of 200 meters to the colony boundary. Control units are non-mining colonies with a maximum distance of 200 meters to the colony boundary.

Variable Descriptions

- **Colony (Treatment)**: A grid cell with at least 5% coverage by a colony settlement polygon.
- **Pre-1919 Buildings**: Share of residential buildings constructed before 1919 (Zensus 2011).

- **Rent**: Monthly rent price (€/m²) (Zensus 2022).
- **Land Prices**: Estimated land value in (€/m²). The *Bodenrichtwert* is an average location value for the land and is determined by expert committees based on actual purchase prices (BORIS-NRW 2024).
- **Price-to-Rent Ratio**: The ratio between land prices and the annualized rent in (€).
- **Homeowner Share**: The share of households living in owner-occupied housing (Zensus 2022).
- **Vacancy Share**: The share of housing units currently vacant (Zensus 2022).
- **Distance to CBD**: The distance in meters to the nearest central business district, namely the city centers of Bochum, Dortmund, Duisburg, or Essen.
- **Low-Density Housing**: Proportion of residential land designated for residential buildings with a maximum of three stories. This measure includes land use codes 10, 27110, and 29110 as defined in the *Nutzungskatalog der Flächennutzungskartierung* (Regionalverband Ruhr 2024a).
- **Business Land Use**: Proportion of all land designated for nonindustrial business buildings. This measure includes land use code 51 as defined in the *Nutzungskatalog der Flächennutzungskartierung*.
- **Urban Amenities**: Proportion of land designated for urban and community-oriented uses. This includes indoor swimming pools, sports facilities, and event venues (codes 71–75); public and private educational institutions, libraries, kindergartens, youth and elderly care homes, postal services, museums, theaters, and other municipal-use facilities (codes 83–85, 87–89); public parks, zoos, and botanical gardens (code 272); as well as outdoor sports facilities, public beaches, golf courses, playgrounds, and other recreational areas (codes 301–309).
- **Pedestrian Zones**: A dummy for whether the grid cell includes space used for pedestrian zones (*Fußgängerzonen*). This indicator is equal to 1 if the space usage share of code 160 exceeds 0.
- **Main Streets**: A dummy for whether the grid cell includes space used for main streets (*Hauptstraßen*). This indicator is equal to 1 if the space usage share of code 140 exceeds 0.
- **Distance to Rail Station**: The distance in meters to the nearest rail station. Rail stations are from Bezirksregierung Köln (2025b).

Table A35: The Effects of Historical Colony Housing; Additional Outcomes

	Vacancy Share		Low-Density Housing		Business Land Use		Main Street Access	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mining Colony	0.000	-0.001	0.116***	0.108***	-0.006***	-0.005***	-0.037**	-0.037**
	(0.001)	(0.001)	(0.026)	(0.015)	(0.001)	(0.001)	(0.015)	(0.015)
N	44,319	44,319	44,319	44,319	44,319	44,319	44,319	44,319
City FE	✗	✓	✗	✓	✗	✓	✗	✓
Controls	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the relationship between mining colony housing and the economic conditions of modern residential neighborhoods. All outcomes are measured at the 100-×-100 meter grid cell level. The analysis only includes settled grid cells ($pop_{2022} > 0$). The controls include population in 2022 and the distance to the nearest central business district (CBD). Conley-standard errors with a 2-kilometer cutoff are in parentheses.

Table A36: The Effects of Historical Colony Housing on Neighborhood Disadvantage; Accounting for Colony Spillovers with Linear Polynomials

	Pre-1919 Buildings		Rent €/m^2 (monthly)		Land Prices €/m^2		Price-to-Rent Ratio		Homeowner Share		Vacancy Share	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mining Colony	0.185***	0.191***	-0.358***	-0.180***	-100.657***	-36.792***	-1.014***	-0.310***	0.062***	0.048***	-0.002	-0.003**
	(0.014)	(0.015)	(0.054)	(0.035)	(18.808)	(7.837)	(0.221)	(0.090)	(0.016)	(0.011)	(0.002)	(0.001)
Distance to Colony	-0.003*	-0.004	0.069***	0.125***	-3.213	22.442***	-0.112*	0.177***	0.014***	0.011***	-0.001***	-0.002***
	(0.002)	(0.003)	(0.022)	(0.016)	(6.414)	(4.901)	(0.065)	(0.046)	(0.004)	(0.003)	(0.000)	(0.000)
N	44,319	44,319	44,319	44,319	44,319	44,319	44,319	44,319	44,319	44,319	44,319	44,319
City FE	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓
Controls	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the relationship between mining colony housing and the economic conditions of modern residential neighborhoods. All outcomes are measured at the 100-×-100 meter grid cell level. The analysis only excludes settled grid cells ($pop_{2022} > 0$). Distance to colony is the distance to the nearest colony grid. The controls include population in 2022 and the distance to the nearest central business district (CBD). Conley-standard errors with a 2-kilometer cutoff are in parentheses.

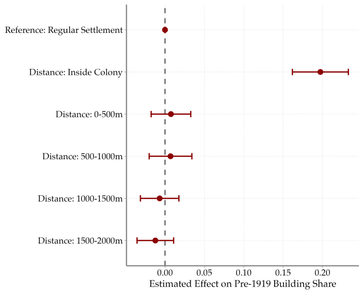
Table A37: The Effects of Historical Colony Housing on Neighborhood Diversity and Commuting Infrastructure; Accounting for Spatial Spillovers with Linear Polynomials

	Low-Density Housing		Business Land Use		Urban Amenities		Main Street Access		Distance: Rail Station		Distance: High School	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mining Colony	0.147***	0.123***	-0.006***	-0.006***	-0.009***	-0.009***	-0.040***	-0.036**	241.379***	91.081	430.929***	350.203***
	(0.027)	(0.015)	(0.001)	(0.001)	(0.003)	(0.003)	(0.015)	(0.015)	(79.970)	(56.740)	(100.138)	(84.094)
Distance to Colony	0.019**	0.013***	0.000	-0.001*	-0.001**	-0.002***	-0.002	0.001	41.897*	47.072*	47.007	37.347
	(0.008)	(0.005)	(0.000)	(0.000)	(0.001)	(0.001)	(0.003)	(0.003)	(23.734)	(27.933)	(34.389)	(39.113)
N	44,319	44,319	44,319	44,319	44,319	44,319	44,319	44,319	44,319	44,319	44,319	44,319
City FE	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓
Controls	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)	Conley (2km)

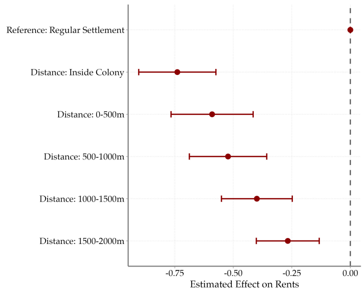
Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the relationship between mining colony housing and the isolation of modern residential neighborhoods. All outcomes are measured at the 100-×-100 meter grid cell level. The analysis only excludes settled grid cells ($pop_{2022} > 0$). Distance to colony is the distance to the nearest colony grid. The controls include population in 2022 and the distance to the nearest central business district (CBD). Conley-standard errors with a 2-kilometer cutoff are in parentheses.

Figure A23: The Effects of Historical Colony Housing on Neighborhood Disadvantage; Accounting for Colony Spillovers with Spatial Zones

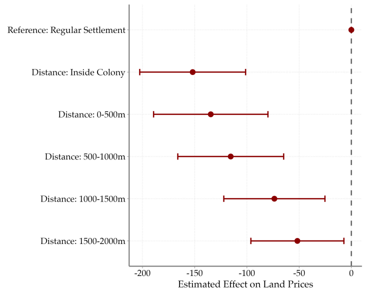
(a) *Pre-1919 Buildings*



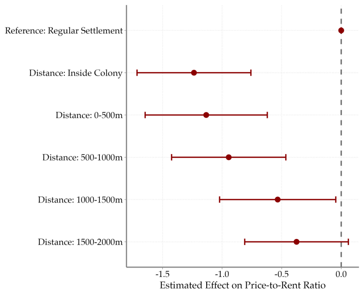
(b) *Rent*



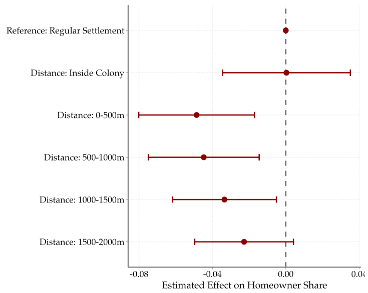
(c) *Land Prices*



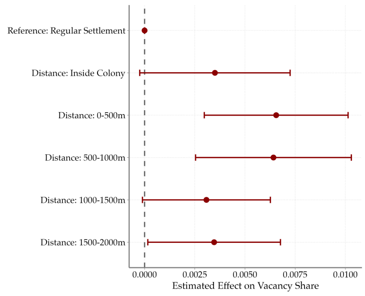
(d) *Price-to-Rent Ratio*



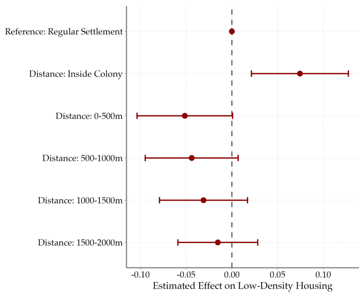
(e) *Homeowner Share*



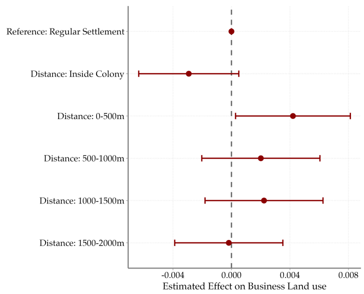
(f) *Vacancy Share*



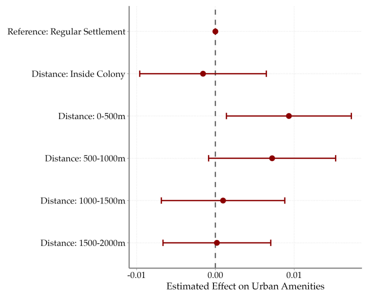
(g) *Low-Density Housing*



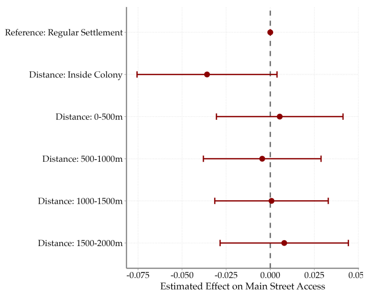
(h) *Business Land Use*



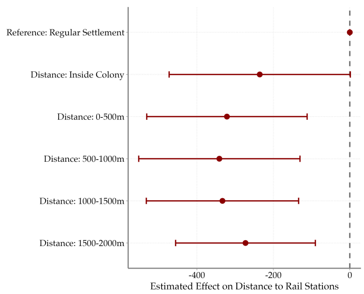
(i) *Urban Amenities*



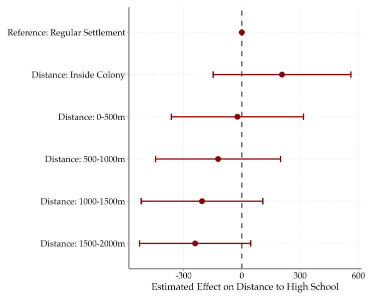
(j) *Main Street Access*



(k) *Distance to Rail Station*



(l) *Distance to High School*



Note: This figure displays the effects of mining colonies and surrounding spillover zones on indicators of neighborhood disadvantage and infrastructure. We differentiate between grid cells located within mining colonies and those within 0–500 meters, 500–1,000 meters, 1,000–1,500 meters, and 1,500–2,000 meters from a colony boundary. The control group consists of grid cells located at least 2,000 meters away from the nearest colony boundary. The coefficients come from models that control for the population in 2022, the distance to the nearest CBD, and fixed effects for municipalities. The error bars represent 95% confidence intervals, based on Conley-standard errors with a 2-kilometer cutoff.

Table A38: Historical Colony Housing and Neighborhood Disadvantage: Sharp RDD Estimates

	Pre-1919 Buildings	Rent	Land Prices	Price-to-Rent	Homeowner Share	Vacancy Share
	(1)	(2)	(3)	(4)	(5)	(6)
Mining Colony	0.153***	-0.118***	-3.083	0.070	0.048***	-0.001
	(0.012)	(0.028)	(2.817)	(0.050)	(0.010)	(0.002)
N	10,819	10,819	10,819	10,819	10,819	10,819
Bandwidth	200	200	200	200	200	200
Triangular Kernel	✗	✗	✗	✗	✗	✗
Colony Segment FE	✓	✓	✓	✓	✓	✓
Std.Errors	ID:Segment	ID:Segment	ID:Segment	ID:Segment	ID:Segment	ID:Segment

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports the estimated effect of mining colony housing at the boundary between colony and non-colony settlements, using a spatial regression discontinuity design. All specifications include a linear polynomial in the running variable interacted with the colony housing indicator, and fixed effects at the colony segment level. Identification is based on comparisons between inner-boundary colony grids and outer-boundary non-colony grids within the same colony segment. Standard errors clustered at the colony segment level are reported in parentheses.

Table A39: Historical Colony Housing and Neighborhood Diversity and Commuting Infrastructure: Sharp RDD Estimates

	Low-Density Housing	Business Land Use	Urban Amenities	Main Street Access	Distance to Rail Station	Distance to High School
	(1)	(2)	(3)	(4)	(5)	(6)
Mining Colony	0.111***	-0.005***	-0.010***	-0.014	11.880*	25.782***
	(0.014)	(0.002)	(0.003)	(0.016)	(7.117)	(9.058)
N	10,819	10,819	10,819	10,819	10,819	10,819
Bandwidth	200	200	200	200	200	200
Triangular Kernel	✗	✓	✗	✓	✗	✓
Colony Segment FE	✓	✓	✓	✓	✓	✓
Std.Errors	ID:Segment	ID:Segment	ID:Segment	ID:Segment	ID:Segment	ID:Segment

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports the estimated effect of mining colony housing at the boundary between colony and non-colony settlements, using a spatial regression discontinuity design. All specifications include a linear polynomial in the running variable interacted with the colony housing indicator, and fixed effects at the colony segment level. Identification is based on comparisons between inner-boundary colony grids and outer-boundary non-colony grids within the same colony segment. Standard errors clustered at the colony segment level are reported in parentheses.

IV. Mining Colonies and Demographic Sorting

Table A40: The Effect of Historical Mining Colony Presence on Sociodemographic Outcomes at the District Level; 2SLS Estimates

	University Graduates		High-Income Earners		Social Assistance Recipients		Foreign Residents	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mining Colony Presence (District-Level)	-0.342***	-0.340***	-0.218***	-0.266***	0.195***	0.279***	0.163***	0.229***
	(0.068)	(0.081)	(0.049)	(0.062)	(0.041)	(0.065)	(0.042)	(0.058)
F-stat	48.7***	30.4***	48.7***	30.4***	48.7***	30.4***	63.0***	32.2***
N	328	328	328	328	328	328	348	348
City FE	✗	✓	✗	✓	✗	✓	✗	✓
Historical Controls	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports 2SLS estimates of the effects of historical mining colony presence on district-level sociodemographic outcomes in 2021. Outcomes include the share of university graduates, high-income earners (monthly income > €4,800), recipients of social assistance (SGB-II), and foreign residents (2022). Colony presence is a binary variable equal to 1 if at least 10% of a district's settled grids emerged through colony housing (32% of districts). Colony presence is instrumented with $deepcoal$.

Table A41: The Effect of Historical Mining Colony Presence on Other Sociodemographic Outcomes at the District Level; OLS and 2SLS Estimates

	Rent		Dual Citizens		Non-Christians		Old-Age	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: ***OLS***								
Mining Colony Presence	-0.441***	-0.316***	0.018***	0.015**	0.011	0.029**	-0.017***	-0.020***
	(0.086)	(0.064)	(0.006)	(0.007)	(0.014)	(0.012)	(0.006)	(0.008)
Panel B: ***2SLS***								
Mining Colony Presence	-1.770***	-1.757***	0.060***	0.090***	0.051	0.093***	-0.085***	-0.113***
	(0.458)	(0.402)	(0.016)	(0.026)	(0.042)	(0.035)	(0.022)	(0.022)
F-stat	63.0***	32.2***	63.0***	32.2***	63.0***	32.2***	63.0***	32.2***
N	348	348	348	348	348	348	348	348
City FE	✗	✓	✗	✓	✗	✓	✗	✓
Historical Controls	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports the effects of historical mining colony presence on district-level sociodemographic outcomes in the census of 2011 and rents in 2022. Outcomes include rent prices in 2022 (€/m²), and the shares of dual citizens, non-Christians (including non-religious and other religions), and the elderly. Colony presence is a binary variable equal to 1 if at least 1% of a district's land area was covered by colony housing (39% of districts). *Panel B* instruments the colony presence with our binary deep coal indicator, equal to unity if coal deposits are inaccessible at or near the surface. All models are estimated with and without city fixed effects. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Table A42: The Effect of Historical Mining Colony (Settlement Share) on Sociodemographic Outcomes at the District Level; OLS and 2SLS Estimates

	University Graduates		Social Assistance Recipients		High-Income Earners		Foreign Residents	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: ***OLS***								
Mining Colony Share	-0.194***	-0.149***	0.075**	0.076**	-0.119***	-0.112***	0.075*	0.097***
	(0.039)	(0.036)	(0.035)	(0.034)	(0.030)	(0.028)	(0.039)	(0.035)
Panel B: ***2SLS***								
Mining Colony Share	-1.096***	-1.228***	0.627***	1.007***	-0.700***	-0.960***	0.519***	0.826***
	(0.221)	(0.269)	(0.145)	(0.214)	(0.164)	(0.210)	(0.145)	(0.202)
F-stat	39.7***	19.5***	39.7***	19.5***	39.7***	19.5***	51.9***	20.6***
N	328	328	328	328	328	328	348	348
City FE	✗	✓	✗	✓	✗	✓	✗	✓
Historical Controls	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports the effects of the share of grid-level settlements originating from colony housing on district-level sociodemographic outcomes in 2021. Outcomes include the share of university graduates, recipients of social assistance (SGB-II), high-income earners (monthly income > €4,800), and foreign residents (2022). This table uses the alternative indicator of colony housing presence, specifically the original share of all settled grids historically covered by colony housing within each district. *Panel B* instruments colony presence with $deepcoal$.

Table A43: The Effect of Historical Mining Colony Presence on Sociodemographic Change at the District Level; OLS and 2SLS Estimates

	University Graduates Δ_{2013}^{2021}		High-Income Earners Δ_{2013}^{2021}		Social Assistance Δ_{2013}^{2021}		Foreign Residents Δ_{2011}^{2022}	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
*Panel A: **OLS***								
Mining Colony Presence	-0.017***	-0.013***	0.003	-0.001	0.001	-0.001	-0.003	-0.004
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)	(0.003)
*Panel B: **2SLS***								
Mining Colony Presence	-0.084***	-0.077***	0.007	0.008	-0.004	-0.008	0.037***	0.071***
	(0.017)	(0.020)	(0.010)	(0.011)	(0.006)	(0.008)	(0.012)	(0.019)
F-stat	48.7***	30.4***	48.7***	30.4***	48.7***	30.4***	63.0***	32.2***
N	328	328	328	328	328	328	348	348
City FE	✗	✓	✗	✓	✗	✓	✗	✓
Historical Controls	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports the effects of historical mining colony presence on district-level changes in sociodemographic outcomes between 2021 and 2013 (2022-2011). Outcomes include changes in the shares of university graduates, social assistance recipients (SGB II), adult SGB-II recipients, and foreign residents. Colony presence is a binary variable equal to 1 if at least 1% of a district's land area was covered by colony housing (39% of districts). *Panel B* instruments the colony presence with our binary deep coal indicator, equal to unity if coal deposits are inaccessible at or near the surface. All models are estimated with and without city fixed effects. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Table A44: The Effect of Historical Coal Mining Employment on Sociodemographic Outcomes at the District Level; OLS and 2SLS Estimates

	University Graduates		Social Assistance Recipients		High-Income Earners		Foreign Residents	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
*Panel A: **1912 & OLS***								
Coal Miners (1,000s)	-0.037***	-0.058***	0.047***	0.058***	-0.037***	-0.050***	0.043***	0.058***
	(0.009)	(0.009)	(0.008)	(0.008)	(0.007)	(0.007)	(0.010)	(0.008)
*Panel B: **1912 & 2SLS***								
Coal Miners (1,000s)	-0.237***	-0.176***	0.135***	0.144***	-0.151***	-0.137***	0.099***	0.118***
	(0.080)	(0.036)	(0.035)	(0.025)	(0.048)	(0.026)	(0.027)	(0.022)
F-stat	29.9***	56.9***	29.9***	56.9***	29.9***	56.9***	49.4***	59.7***
N	328	328	328	328	328	328	348	348
City FE	✗	✓	✗	✓	✗	✓	✗	✓
Historical Controls	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports the effects of historical coal mining employment in 1912 on district-level sociodemographic outcomes in the early 2020s. Outcomes include the share of university graduates, recipients of social assistance benefits (SGB-II), high-income earners (monthly income > €4,800), and foreign residents. Historical employment is instrumented with *deepcoal*, equal to unity if coal deposits are inaccessible at or near the surface. All models are estimated with and without city fixed effects. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Table A45: The Effect of Historical Coal Mining Employment on Other Sociodemographic Outcomes at the District Level; OLS and 2SLS Estimates

	Rent		Dual Citizens		Non-Christians		Old-Age	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
*Panel A: **OLS & 1912***								
Coal Miners (1,000s)	-0.249***	-0.348***	0.020***	0.024***	0.023**	0.041***	-0.012***	-0.022***
	(0.059)	(0.052)	(0.004)	(0.004)	(0.011)	(0.009)	(0.004)	(0.004)
*Panel B: **2SLS & 1912***								
Coal Miners (1,000s)	-1.073***	-0.910***	0.036***	0.047***	0.031	0.048***	-0.051***	-0.059***
	(0.352)	(0.180)	(0.009)	(0.011)	(0.024)	(0.014)	(0.017)	(0.008)
F-stat	49.4***	59.7***	49.4***	59.7***	49.4***	59.7***	49.4***	59.7***
N	348	348	348	348	348	348	348	348
City FE	✗	✓	✗	✓	✗	✓	✗	✓
Historical Controls	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports the effects of historical coal mining employment in 1912 on district-level sociodemographic outcomes in the census of 2011 and rents in 2022. Outcomes include rent prices in 2022 (€/m²), and the shares of dual citizens, non-Christians (including non-religious and other religions), and the elderly. Historical employment is instrumented with $deepcoal$, equal to unity if coal deposits are inaccessible at or near the surface. All models are estimated with and without city fixed effects. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Table A46: The Effect of Historical Coal Mining Employment on Sociodemographic Change at the District Level; OLS and 2SLS Estimates

	University Graduates Δ^{2021}_{2013}		Social Assistance Recipients Δ^{2021}_{2013}		High-Income Earners Δ^{2021}_{2013}		Foreign Residents Δ^{2022}_{2011}	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
*Panel A: **1912 & OLS***								
Coal Miners (1,000s)	-0.010***	-0.015***	0.005*	0.003	0.002	0.001	0.012***	0.013***
	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)
*Panel B: **1912 & 2SLS***								
Coal Miners (1,000s)	-0.058***	-0.040***	0.005	0.004	-0.003	-0.004	0.022***	0.036***
	(0.020)	(0.009)	(0.006)	(0.006)	(0.004)	(0.004)	(0.008)	(0.008)
F-stat	29.9***	56.9***	29.9***	56.9***	29.9***	56.9***	49.4***	59.7***
N	328	328	328	328	328	328	348	348
City FE	✗	✓	✗	✓	✗	✓	✗	✓
Historical Controls	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports the effects of historical coal mining employment in 1912 on district-level changes in sociodemographic outcomes between 2021 and 2013 (2022-2011). Outcomes include changes in the shares of university graduates, social assistance recipients (SGB II), adult SGB-II recipients, and foreign residents. Historical employment is instrumented with $deepcoal$, equal to unity if coal deposits are inaccessible at or near the surface. All models are estimated with and without city fixed effects. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

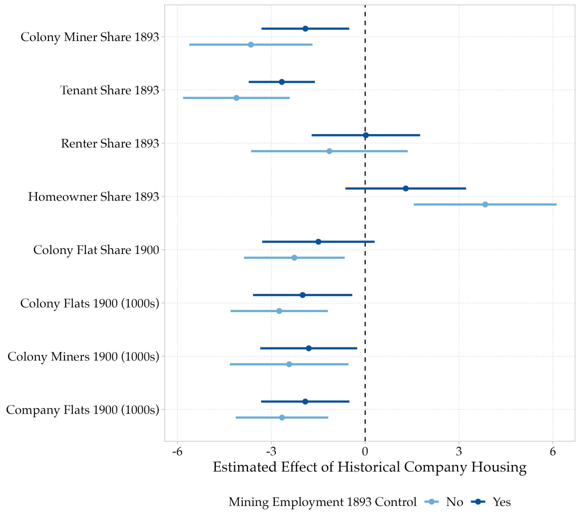
Table A47: The Effects of Coal Mining on Intermediate Socioeconomic Outcomes in the Postwar Period; OLS and 2SLS Estimates

	Workers 1970		Manufacturing 1970		Unemployment 1987		Foreigners 1970	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: ***Intensity & OLS***								
Coal Miners (1,000s)	0.051***	0.073***	0.024***	0.039***	0.016***	0.022***	0.003	0.007***
	(0.007)	(0.008)	(0.007)	(0.007)	(0.002)	(0.003)	(0.002)	(0.002)
Panel B: ***Intensity & 2SLS***								
Coal Miners (1,000s)	0.158***	0.178***	0.081***	0.076***	0.052***	0.050***	0.012***	0.014***
	(0.031)	(0.026)	(0.027)	(0.021)	(0.008)	(0.008)	(0.004)	(0.004)
F-stat	49.4***	59.7***	49.4***	59.7***	49.4***	59.7***	49.4***	59.7***
Panel C: ***Timing & OLS***								
Average Coal Mine Opening Year	0.014***	0.019***	0.010***	0.013***	0.003***	0.004***	0.001**	0.001***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.000)	(0.000)
Panel D: ***Timing & 2SLS***								
Average Coal Mine Opening Year	0.010***	0.015***	0.009***	0.014***	0.001	0.001	0.000	0.000
	(0.003)	(0.004)	(0.003)	(0.004)	(0.001)	(0.001)	(0.000)	(0.001)
F-stat	396.3***	136.0***	396.3***	136.0***	396.3***	136.0***	396.3***	136.0***
N	348	348	348	348	348	348	348	348
City FE	✗	✓	✗	✓	✗	✓	✗	✓
Historical Controls	✗	✓	✗	✓	✗	✓	✗	✓
Std.Errors	Schräpler ID	Schräpler ID	Schräpler ID	Schräpler ID	Schräpler ID	Schräpler ID	Schräpler ID	Schräpler ID

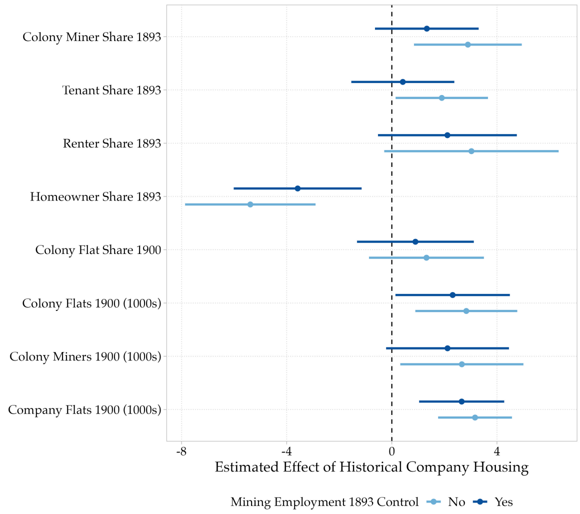
Note: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of the historical spread of coal miners in 1912 and the average timing of mining operations on socioeconomic outcomes in 1970 and 1987 at the community level. The data comes from Schräpler et al. (2017), who harmonized census data in 1970, 1987, and 2011 at the community level. We instrument the intensity of coal mining operations with *deepcoal*; average timing is instrumented with the continuous depth of coal deposits. All models are estimated with and without city fixed effects. *Panel D* uses 336 instead of 348 observations due to the lack of coal deposits in twelve districts of Schwerte and Duisburg. Standard errors are clustered at the census-id level, based on Schräpler's intertemporal harmonization of district boundaries.

Figure A24: Historical Housing Conditions and Sociodemographic Persistence in Modern Communities

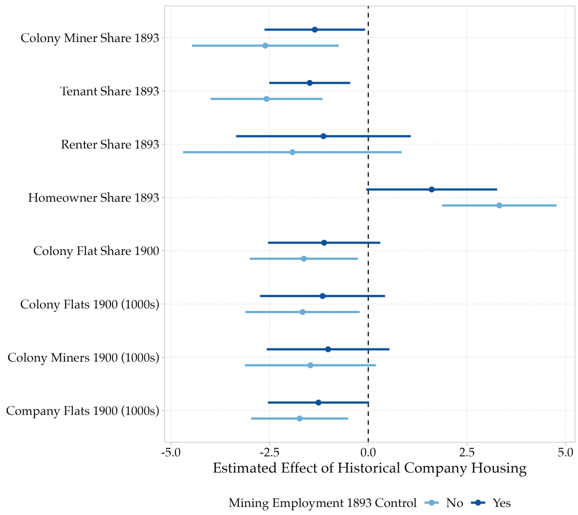
(a) *University Graduates*



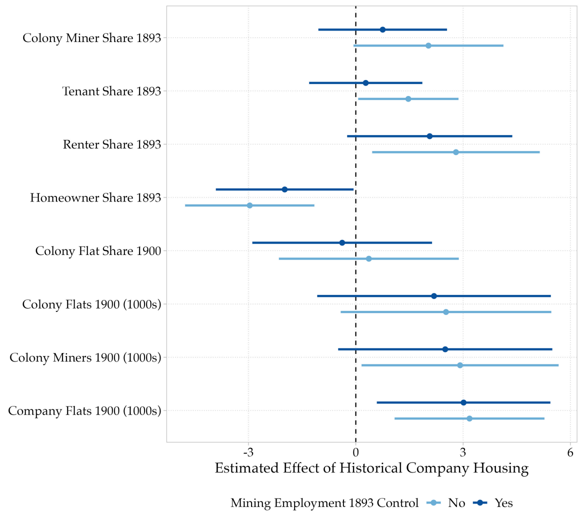
(b) *Social Assistance Recipients*



(c) *High-Income Earners*

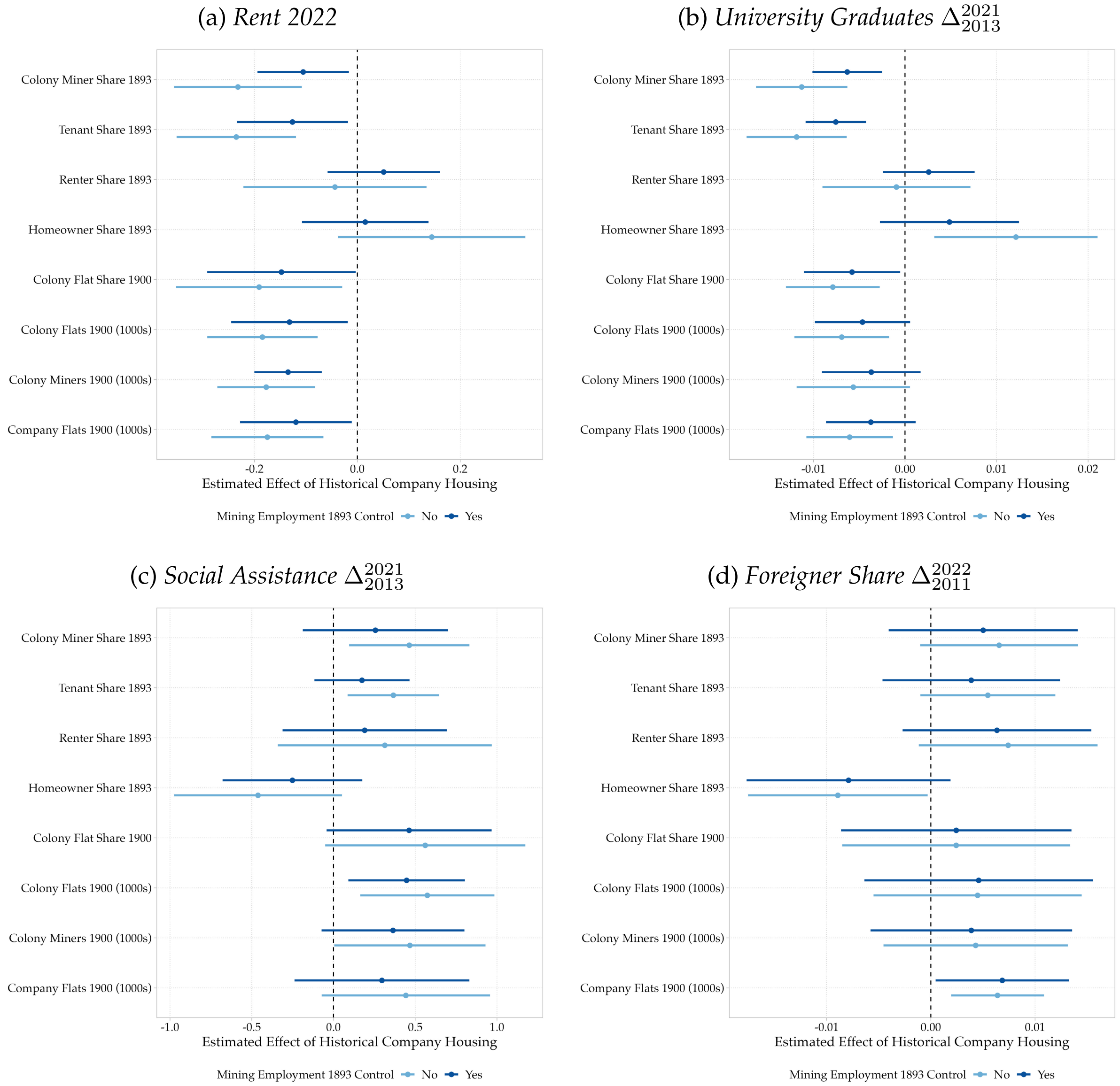


(d) *Foreigners*



Note: This figure shows the effects of housing conditions on the population shares of university graduates, social assistance recipients, high-income earners (all 2021), and foreigners (2022) in the mines' intersecting polling districts. We match each mine with the demography in its adjacent polling district. All independent variables are standardized before estimation. We distinguish between tenants (*Kostgänger*), homeowners, regular renters, and residents in colony housing, all measured in 1893. We also focus on the share of flats belonging to colony housing, the number of colony flats, the number of miners living in colony flats, and the total number of company flats taken from the 1900 survey of miners' housing conditions. We run two models with and without controls for the employment intensity (miners, 1000s) in the polling district in 1893. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Figure A25: Historical Housing Conditions and Sociodemographic Change in Modern Communities



Note: This figure shows the effects of housing conditions on average rent prices in 2022 (€/m²) and the change in the population shares of university graduates, social assistance recipients (2013-2021), and foreign residents (2011-2022) in the mines' intersecting polling districts. All independent variables are standardized before estimation. We distinguish between tenants (*Kostgänger*), homeowners, regular renters, and residents in colony housing, all measured in 1893. We also focus on the share of flats belonging to colony housing, the number of colony flats, the number of miners living in colony flats, and the total number of company flats taken from the 1900 survey of miners' housing conditions. We run two models with and without controls for the employment intensity (miners, 1000s) in the polling district in 1893. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

V. Demographic Sorting and Voting Behavior

We apply the causal mediation framework of Dippel et al. (2022) to formally decompose this relationship in the presence of endogeneity in both the treatment T and the mediator M. This method allows us to use deep coal deposits as a single instrument Z to identify both the direct effect of T on the outcome Y (voting) and the indirect effect operating through M, measured as the first principal component (PCA) of the sociodemographic indicators listed in Table 7. In the presence of unobserved variables that affect both T and M, such as historical economic fundamentals not captured by our controls, we first instrument our historical industrialization indicators with deep coal deposits to estimate the causal effect on contemporary demographic structures with the following two-stage regression.

$$\begin{aligned} \text{First stage:} \quad & T_i = \beta_T^Z \cdot Z_i + (\beta_T^C \mathbf{C}_i) + \eta_i \\ \text{Second stage:} \quad & M_i = \beta_M^T \cdot \widehat{T}_i + (\beta_M^C \mathbf{C}_i) + \epsilon_i. \end{aligned} \tag{3}$$

The identifying assumption is that there are no unobserved confounders that simultaneously shift T and Y independent of the mediator M and observed covariates $\mathbf{C}$, expressed as $\varepsilon_T \perp\!\!\!\perp \varepsilon_Y \mid \varepsilon_M, \mathbf{C}$. Thus, while the model allows for endogeneity in the relationship between T and M *and* between M and Y, it rules out a common unobserved shock that affects T, M, and Y jointly, because such a shock would induce correlation between ε_T and ε_Y that cannot be absorbed by ε_M. For example, if unobserved historical institutions in a region directly influenced both the adoption of mining (T) and contemporary political preferences (Y), while also influencing modern sociodemographic structures (M), the key assumption would be violated. Importantly, the approach still allows for other causal paths from the treatment to the outcome that run through the mediator or other observed components, thereby helping to isolate the direct effect of T and the indirect effect mediated by M.

The key addition to obtain this decomposition in the framework developed by Dippel et al. (2022) is a second instrumental variable regression, in which the mediator M is instrumented by Z while controlling for T and $\mathbf{C}$. In the first stage, M is regressed on Z, T, and $\mathbf{C}$ to obtain the fitted values $\widehat{M}_i$, thereby isolating the component of M that can be predicted by the instrument once T and observed covariates are held constant. In the second stage, Y is regressed on $\widehat{M}_i$, T, and $\mathbf{C}$, which yields consistent estimates of β_Y^M and β_Y^T.

$$\begin{aligned} \text{First stage:} \quad & M_i = \gamma_M^Z \cdot Z_i + \gamma_M^T \cdot T_i + (\gamma_M^C \mathbf{C}_i) + \mu_i \\ \text{Second stage:} \quad & Y_i = \beta_Y^M \cdot \widehat{M}_i + \beta_Y^T \cdot T_i + (\beta_Y^C \mathbf{C}_i) + \epsilon_i. \end{aligned} \tag{4}$$

The intuition behind this approach is that the instrument Z is used not to generate exogenous variation in M independently of T, but to expose the endogenous component of M. This reveals the part of M that is correlated with unobserved factors affecting the outcome, which can be viewed as an alternative pathway from the treatment to the outcome. In the first stage, M is regressed on Z, T, and $\mathbf{C}$, which delivers fitted values $\widehat{M}_i$ and thereby recovers the part of M that can be explained by the instrument conditional on treatment and covariates. This step is equivalent to reconstructing the mediator disturbance ε_M, the source of endogeneity in the link between M and Y. In the second stage, Y is regressed on $\widehat{M_i}$, T, and $\mathbf{C}$, so that the variation in M entering the outcome equation is purged of its endogenous component. Under the orthogonality condition $\varepsilon_T \perp\!\!\!\perp \varepsilon_Y \mid \varepsilon_M, \mathbf{C}$, this procedure allows consistent estimation of both β_Y^M and β_Y^T, and thus a decomposition of the total effect into its direct and mediated parts. After estimating these two instrumental variable regressions, multiplying the estimates of β_Y^M and β_M^T allows us to isolate the effect of historical mining employment and colony housing on voting behavior that runs through long-term demographic dynamics.

Table A48: The Direct and Indirect Effects of Historical Coal Mining Indicators on AfD Support; Instrumental Variable Mediation Estimates

Treatment Variable:	*Historical Employment*		*Mining Colony Presence*	
	(1)	(2)	(3)	(4)
Panel A: Mediator: Demographic Structure PC1				
β_Y^M	2.327***	1.808***	1.896***	1.716***
	(0.336)	(0.250)	(0.273)	(0.188)
DE: β_Y^T	-0.337	0.776*	2.055***	2.095***
	(0.534)	(0.447)	(0.662)	(0.353)
Panel B: Model Parameters				
β_M^T	4.093***	3.826***	5.904***	7.126***
	(1.216)	(0.680)	(1.189)	(1.697)
IE: $\beta_M^T \cdot \beta_Y^M$	9.523	6.916	11.197	12.231
TE: $\beta_M^T \cdot \beta_Y^M + \beta_Y^T$	9.186	7.692	13.252	14.326
IE/TE: $\beta_M^T \cdot \beta_Y^M / (\beta_M^T \cdot \beta_Y^M + \beta_Y^T)$	1.037	0.899	0.845	0.854
City FE & Controls	✗	✓	✗	✓
N	984	984	984	984
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports the direct and indirect effects of historical mining employment in 1912 (1,000s) and the historical presence of mining colonies on the AfD vote share. The mediator is the first principal component of the shares of university graduates, high-income earners, social assistance recipients, and foreign residents. *Panel A* shows the instrumented effect of the mediator and the direct treatment effect (DE); *Panel B* shows the instrumented effect of the treatment on the mediator, the indirect effect (IE) on the outcome, the total effect (TE), and the effect ratio. The controls include (log) population and the Protestant share between 1819 and 1834, the population per building and the share born outside the municipality in 1871, and per capita income tax revenue around 1860.

Table A49: The Direct and Indirect Effects of Historical Coal Mining Employment on *SPD Support*; Instrumental Variable Mediation Estimates

Treatment Variable:	*Historical Employment*		*Mining Colony Presence*	
	(1)	(2)	(3)	(4)
Panel A: Mediator: Demographic Sorting PC1				
β_Y^M	2.000***	1.579***	1.540***	1.349***
	(0.313)	(0.296)	(0.306)	(0.241)
DE: β_Y^T	-0.749	-0.086	1.638**	1.503***
	(0.578)	(0.613)	(0.655)	(0.509)
Panel B: Model Parameters				
β_M^T	4.093***	3.907***	5.904***	7.234***
	(1.216)	(0.703)	(1.189)	(1.691)
IE: $\beta_M^T \cdot \beta_Y^M$	8.187	6.168	9.091	9.757
TE: $\beta_M^T \cdot \beta_Y^M + \beta_Y^T$	7.437	6.081	10.729	11.259
IE/TE: $\beta_M^T \cdot \beta_Y^M / (\beta_M^T \cdot \beta_Y^M + \beta_Y^T)$	1.101	1.014	0.847	0.867
City FE & Controls	✗	✓	✗	✓
N	984	984	984	984
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports the direct and indirect effects of historical coal-mining employment in 1912 (miners in 1,000 s) and the historical presence of mining colonies on the SPD vote share, using causal mediation methods for instrumental variables (Dippel et al. 2022). The mediator is the first principal component of the shares of university graduates, high-income earners (monthly income > €4,800), social assistance recipients (SGB-II), and foreign residents. *Panel A* shows the instrumented effect of the mediator and the direct treatment effect; *Panel B* shows the instrumented effect of the treatment on the mediator, the indirect effect on the outcome, the total effect, and the indirect-to-total ratio. The controls include the preindustrial and intermediate industrial indicators listed in Figure A26. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

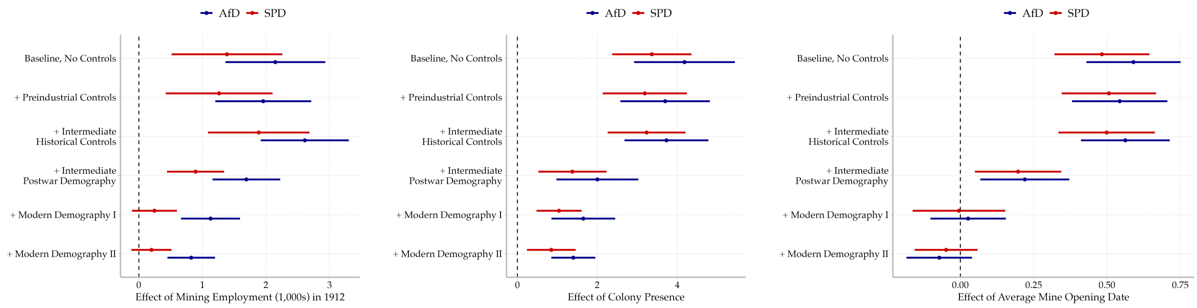
Table A50: The Direct and Indirect Effects of Historical Coal Mining Employment on *Voter Turnout*; Instrumental Variable Mediation Estimates

Treatment Variable:	*Historical Employment*		*Mining Colony Presence*	
	(1)	(2)	(3)	(4)
Panel A: Mediator: Demographic Sorting PC1				
β_Y^M	-3.779***	-3.584***	-3.740***	-3.704***
	(0.236)	(0.210)	(0.193)	(0.152)
DE: β_Y^T	-0.076	-0.821**	-0.334	-0.648**
	(0.429)	(0.406)	(0.335)	(0.328)
Panel B: Model Parameters				
β_M^T	4.093***	3.907***	5.904***	7.234***
	(1.216)	(0.703)	(1.189)	(1.691)
IE: $\beta_M^T \cdot \beta_Y^M$	-15.465	-14.002	-22.084	-26.797
TE: $\beta_M^T \cdot \beta_Y^M + \beta_Y^T$	-15.541	-14.823	-22.418	-27.445
IE/TE: $\beta_M^T \cdot \beta_Y^M / (\beta_M^T \cdot \beta_Y^M + \beta_Y^T)$	0.995	0.945	0.985	0.976
City FE & Controls	✗	✓	✗	✓
N	984	984	984	984
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table reports the direct and indirect effects of historical coal-mining employment in 1912 (miners in 1,000 s) and the historical presence of mining colonies on voter turnout, using causal mediation methods for instrumental variables (Dippel et al. 2022). The mediator is the first principal component of the shares of university graduates, high-income earners (monthly income > €4,800), social assistance recipients (SGB-II), and foreign residents. *Panel A* shows the instrumented effect of the mediator and the direct treatment effect; *Panel B* shows the instrumented effect of the treatment on the mediator, the indirect effect on the outcome, the total effect, and the indirect-to-total ratio. The controls include the preindustrial and intermediate industrial indicators listed in Figure A26. Conley-standard errors with a 5-kilometer cutoff are in parentheses.

Figure A26: The Effects of Historical Mining Indicators on Party Support: Accounting for Sociodemographic Sorting

(a) *Historical Employment* (b) *Colony Housing* (c) *Colony Housing*



Note: This plot shows the effects of mining employment in 1912 (1,000s), the presence of mining colonies, and the timing of coal mining adoption on support for the AfD and SPD ($N = 984$). Preindustrial controls include (log) population and the Protestant share around 1819 (1834 for RB Düsseldorf). Intermediate historical controls include population per building, the population share born outside the municipality in 1871, and per capita income tax revenue around 1860. Intermediate postwar demography includes the manufacturing share, the foreigner share (1970), and the unemployment rate in 1987. Modern Demography I includes average rents and the foreigner share (2022); Modern Demography II includes the share of university graduates, high-income earners (monthly income > €4,800), and social assistance recipients (SGB-II), all from 2021. Error bars indicate 95% confidence intervals based on Conley-standard errors with a 5-kilometer cutoff.

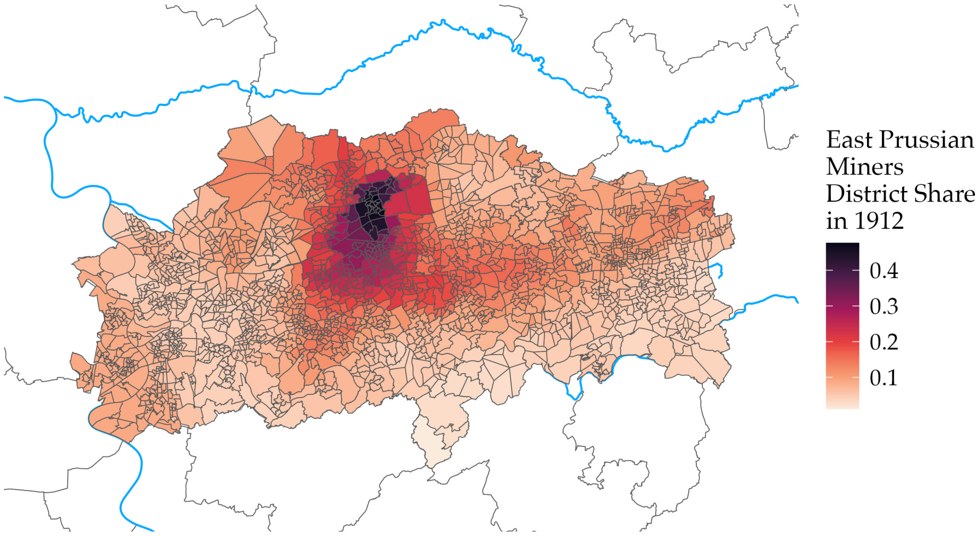
VI. Alternative Explanation: Migration

Table A51: Historical Coal Mining Employment, Migrant Exposure, and Electoral Outcomes; OLS Estimates

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Coal Miners 1912 (1,000s)	1.672***	2.559***	2.429***	-1.567***	-2.633***	-2.549***
	(0.300)	(0.284)	(0.295)	(0.288)	(0.337)	(0.346)
Foreigner Share 2011	-0.023	-0.146***	-0.131***	-0.468***	-0.340***	-0.350***
	(0.056)	(0.038)	(0.030)	(0.041)	(0.039)	(0.035)
Dual Citizen Share 2011	0.428***	0.475***	0.453***	-0.437***	-0.554***	-0.537***
	(0.102)	(0.069)	(0.068)	(0.115)	(0.094)	(0.100)
Δ_{2011}^{2022} Foreigner Share	-0.166*	-0.090*	-0.067	-0.313***	-0.406***	-0.425***
	(0.092)	(0.055)	(0.055)	(0.088)	(0.069)	(0.072)
N	1,044	1,044	1,044	1,044	1,044	1,044
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

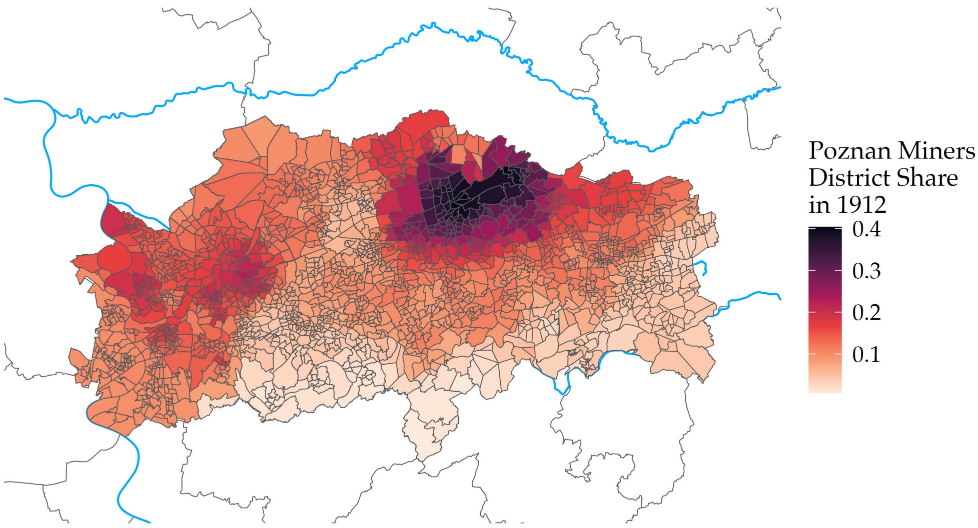
Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal mining employment in 1912 and migration exposure on electoral outcomes in 2017, 2021, and 2025. All models control for the population share of foreigners in 2011, the share of dual citizenship holders, and the change in the foreigner share between 2011 and 2022.

Figure A27: Historical Spread of East Prussian Coal Miners in the Ruhr Area, 1912



Note: This figure shows the share of coal miners in 1912 originating from East Prussia at the polling station level. Historical employment data is from Allgemeiner Knappschafts-Verein (1912). Miners are apportioned to each polling district according to the spatial distribution of coal miner settlements in 1893. For more information, see Appendix VIII..

Figure A28: Historical Spread of Poznań Coal Miners in the Ruhr Area, 1912



Note: This figure shows the share of coal miners in 1912 originating from Poznań at the polling station level. Historical employment data is from Allgemeiner Knappschafts-Verein (1912). Miners are apportioned to each polling district according to the spatial distribution of coal miner settlements in 1893. For more information, see Appendix VIII..

Table A52: Historical Coal Mining Employment, Historical Eastern Migration, and Electoral Outcomes in Deep-Coal Areas; OLS Estimates

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Coal Miners 1912 (1,000s)	1.138***	1.392***	1.491***	-2.618***	-3.859***	-3.528***
	(0.334)	(0.375)	(0.370)	(0.741)	(0.680)	(0.462)
Eastern Coal Miner Share 1912	0.143***	0.210***	0.175***	-0.109	-0.219***	-0.235***
	(0.040)	(0.034)	(0.031)	(0.075)	(0.051)	(0.051)
N	720	720	720	720	720	720
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

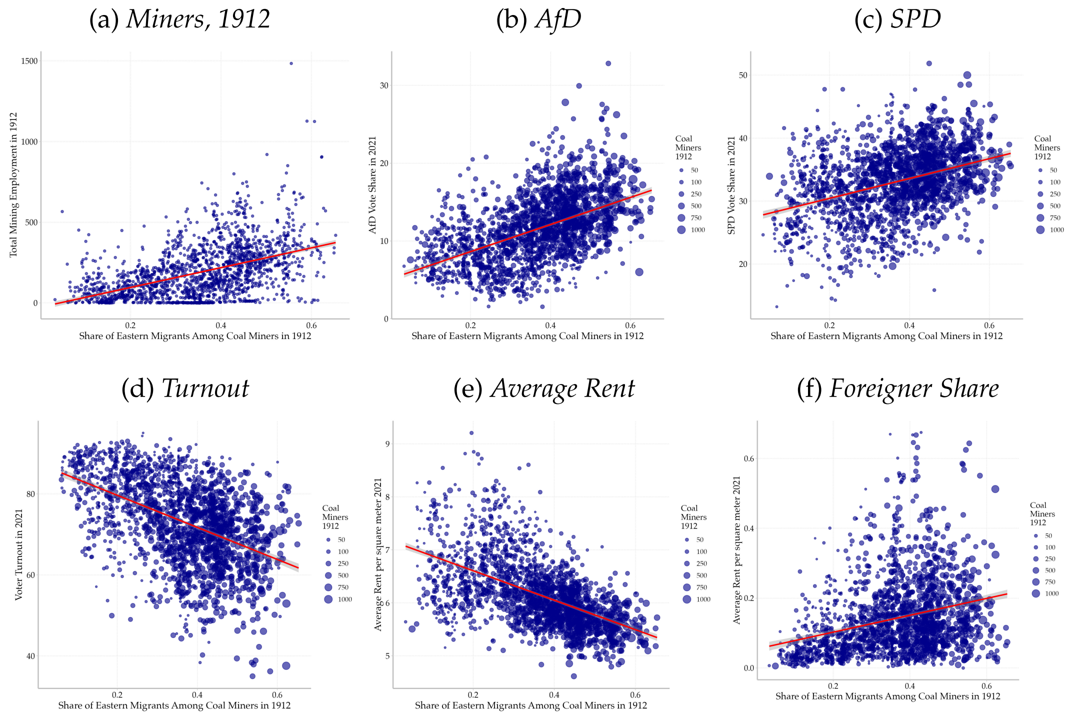
Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal mining employment and the historical share of Eastern coal miners (both in 1912) on electoral outcomes in 2017, 2021, and 2025. The sample is restricted to districts with deep coal deposits.

Table A53: Historical Coal Mining Employment, Historical Migrant Groups, and Electoral Outcomes in Deep-Coal Areas; OLS Estimates

	AfD			Turnout		
	(1)	(2)	(3)	(4)	(5)	(6)
Coal Miners 1912 (1,000s)	1.336***	1.442***	1.520***	-3.640***	-3.750***	-3.462***
	(0.384)	(0.382)	(0.379)	(0.855)	(0.751)	(0.529)
Miner Share: East Prussia	0.145**	0.252***	0.214***	0.144	-0.090	-0.118
	(0.070)	(0.088)	(0.073)	(0.095)	(0.071)	(0.084)
Miner Share: West Prussia	0.008	-0.192	-0.106	-1.045***	-1.065***	-0.773***
	(0.245)	(0.235)	(0.163)	(0.268)	(0.260)	(0.178)
Miner Share: Poznań	0.048	0.223***	0.199***	-0.048	-0.290***	-0.228***
	(0.035)	(0.043)	(0.040)	(0.080)	(0.077)	(0.082)
Miner Share: Silesian	0.246***	0.321***	0.257***	-0.012	-0.146	-0.211*
	(0.043)	(0.044)	(0.047)	(0.092)	(0.159)	(0.111)
Miner Share: Austria-Hungary	0.254***	0.189***	0.147***	-0.334***	-0.096	-0.218**
	(0.051)	(0.052)	(0.042)	(0.095)	(0.108)	(0.091)
N	720	720	720	720	720	720
City FE	✗	✓	✓	✗	✓	✓
Historical Controls	✗	✗	✓	✗	✗	✓
Std.Errors	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)	Conley (5km)

Notes: *p<0.1; **p<0.05; ***p<0.01; This table shows the effects of coal mining employment and the historical shares of different coal miner migrant groups (both in 1912) on electoral outcomes in 2017, 2021, and 2025. The sample is restricted to districts with deep coal deposits.

Figure A29: East Elbian Coal Miners and the Politico-Economic Geography of Ruhr Communities; 2021 Polling Districts

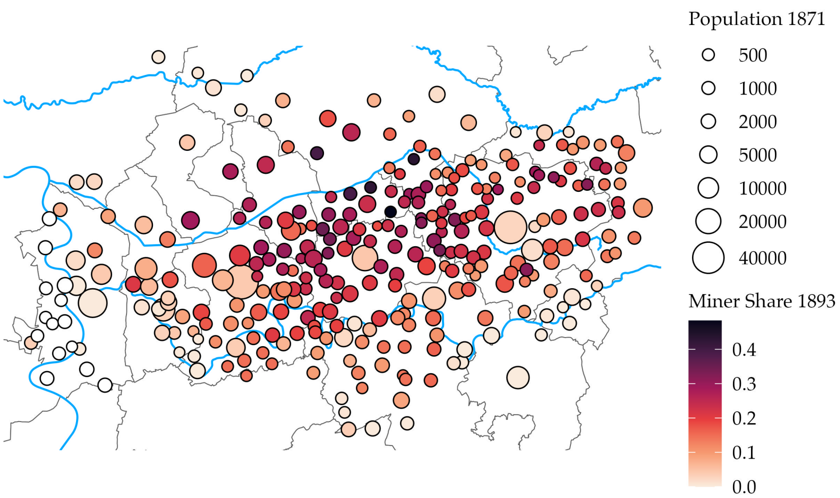


Note: This figure shows the relationship between economic and electoral outcomes in the contemporary Ruhr and the historical share of Eastern coal miners at the level of polling districts. The point size displays the total predicted number of miners in 1912, apportioned to each polling district. We then calculate the share of East Prussians, Poznańs, Silesians, and Austro-Hungarians for each polling district's mining population ($N = 1,953$).

VII. Mapping Historical Municipalities

The modern urban core of the contemporary Ruhr area has been historically divided into several independent rural municipalities, which were clustered around the towns we know today. Around the end of the nineteenth century, these rural municipalities were progressively absorbed into the towns of Duisburg, Essen, Bochum, Dortmund, or Gelsenkirchen. This created many of the city districts that today are deeply interlinked with one specific coal mine, such as Zeche Zollverein in Essen-Katernberg (which became part of Essen in 1929) or Zeche Consolidation in Gelsenkirchen-Schalke (merged with Gelsenkirchen in 1903).

Figure A30: Coal Miners and the Historical Municipalities in the Ruhr Area, 1871



Note: This figure shows the population share of coal miners in 1893 in the historical municipalities of the Ruhr Area. Each spatial point indicates the center of the historical municipality.

Our study leverages this scattered history of municipal development to capture the level of economic and sociodemographic development across the Ruhr before and during the coal rush. We first digitize the historical census records stored in the municipal encyclopedia of the Rhine Province[13] and the province of Westphalia[14] in 1871, preceding the early waves of municipal reform (particularly in Essen) (Königliches Statistisches Bureau 1874a, 1874b). Second, we harness detailed historical maps of the Prussian state in the early and late nineteenth century (Geobasis NRW 2024; Bezirksregierung Köln, n.d.) to manually georeference the approximate center of each historical municipality. We thereby record the location of 300 municipalities, 244 of which lie within the boundaries of our modern-day city district database. Third, we create an exhaustive correspondence file to map each historical municipality to the modern city district that it eventually became part of.

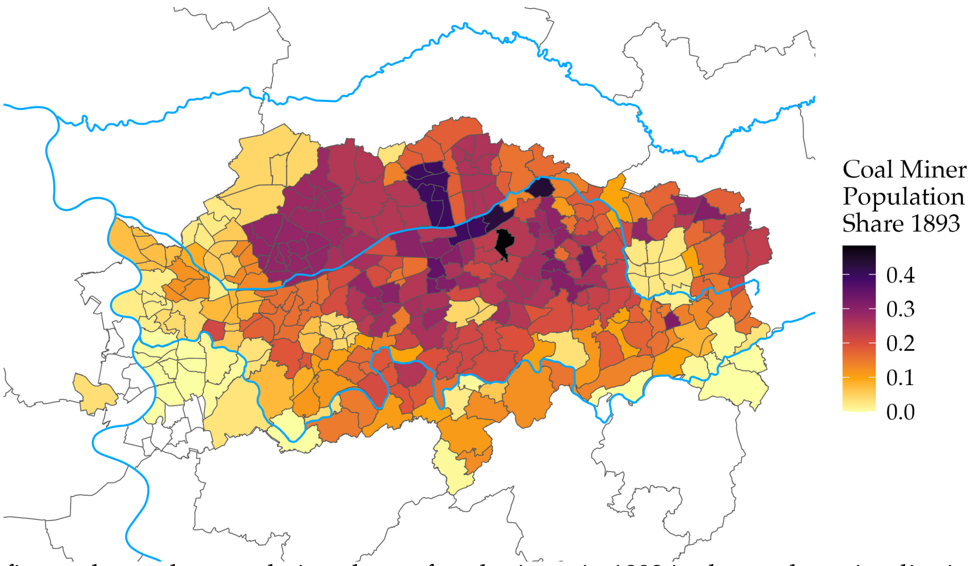
The 1871 census allows us to record the size of the local population (in 1871 and 1867), the number of households and buildings, the share of the population born in the locality, the confessional and religious landscape, the number of young residents, and the rate of (il)literacy. By

13. Essen, Duisburg, Mülheim an der Ruhr, Oberhausen.
14. Bottrop, Gladbeck, Herten, Gelsenkirchen, Bochum, Hattingen, Witten, Herdecke, Schwerte, Dortmund, Herne, Castrop-Rauxel, and Recklinghausen.

1871, the coal rush had fully begun, although it markedly accelerated in the subsequent three decades with the rise of internal migration from the Prussian East. One issue with historical municipal records is that several historical municipalities are split into multiple city districts today. The historical municipality of Borbeck in the northwest of Essen, for instance, historically encompassed ten of Essen's contemporary city districts.[15] The highest number of matches pertains to the city of Bottrop, whose thirteen southern city districts were historically part of the single municipality of Bottrop. Thus, municipal records do not allow us to precisely capture the historical population distribution in these city districts.

This problem is significantly more severe in the historical Vest Recklinghausen, the governorate Münster, which encompassed less than twenty municipalities on the modern lands of the Ruhr cities in our dataset. Conversely, some historical municipalities today constitute a single city community: Essen's richest southern district, Bredeney, was historically divided into Baldeney and Bredeney. The district of Derne in northern Dortmund belonged to Altenderne-Niederbecker and Altenderne-Oberbecker in the nineteenth century.

Figure A31: Historical Population Share of Coal Miners Apportioned to Modern City Districts



Note: This figure shows the population share of coal miners in 1893 in the modern city districts (N=348) of the Ruhr Area. The figures are based on the administrative correspondence between historical and contemporary municipalities. Large rural municipalities in the late nineteenth century, particularly in the northern Ruhr area, have several succeeding city districts.

To maximize observable variation in historical demographic outcomes, we also draw on sub-municipal decompositions of population size and building counts available in both the 1871 census and our preindustrial census records, discussed in more detail below. These sub-municipal units correspond to small rural parishes nested within larger municipalities. The historical district of Buer, for example, comprised the modern city districts of Erle and Hassel as separate localities. We use these finer-grained records for Borbeck and the entire governorate of Münster, where large municipal aggregations would otherwise obscure genuine local

15. Specifically: Bedingrade Bergeborbeck, Bochold, Borbeck, Borbeck-Mitte, Dellwig, Frintrop, Gerschede, Schönebeck, and Vogelheim.

development. Ultimately, this procedure yields 205 unique matches between municipalities (or municipality pairs) and modern city districts, and 258 unique matches between municipal and sub-municipal units and modern city districts.

Nevertheless, the census data do not allow us to capture the level of preindustrial development. Against this background, we harness six editions of the historical statistical records of the three governorates (*Regierungsbezirke*) present in the Ruhr area. The first governorate is Düsseldorf in the western Ruhr, spanning Duisburg, Oberhausen, Essen, and Mülheim. The second governorate is Arnsberg, located in the central, eastern, and southern Ruhr, covering the cities of Bochum, Dortmund, Herne, Witten, Hattingen, Schwerte, Herdecke, and the south of Gelsenkirchen and Castrop-Rauxel. The third governorate is Münster, covering the north of Gelsenkirchen (historical Buer), Bottrop, Gladbeck, Herten, Recklinghausen, and the north of Castrop-Rauxel. The key advantage of these independent statistical volumes is that they report sociodemographic indicators at a sufficiently fine-grained level, including sub-municipal units. This enables us to map the preindustrial data onto the historical municipalities of 1871, which we link with our modern district boundaries. A critical drawback of the administrative division, however, is that the years of reporting differ, as we discuss below.

We use three editions of these sub-provincial statistical volumes to measure population size, confessional composition, and the number of buildings in the early nineteenth century, and hence before the advent of deep-shaft mining. We use the number of people per building as a readily available proxy for urbanization, as more people inhabiting a building signifies higher urban density. This indicator is primarily chosen because the number of habitable buildings is consistently recorded over the nineteenth century. Our statistical editions for Münster and Recklinghausen both come from 1819, measuring these three indicators shortly after the Congress of Vienna (Regierungsbezirk Arnsberg 1819; Sigismund 1819). Notably, in this period, the governorate of Münster did not decompose the population by denomination. We assume, given the historical dominance of Catholics, that its municipalities were (almost) entirely populated by Catholics.

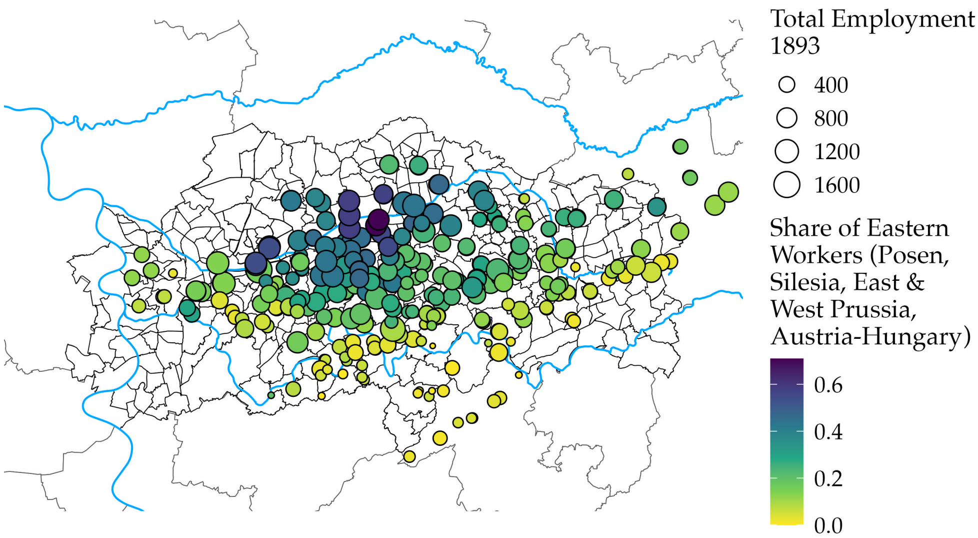
Unfortunately, the documentation for this period is considerably more scattered for the governorate of Düsseldorf, which did not exist in its later territorial boundaries at this stage. For this reason, we are forced to rely upon a statistical volume from 1836 (reporting on 1834) (Von Viebahn 1836). This still falls before the coal rush, but it nevertheless introduces an unobserved degree of distortion for the number of buildings and the share of Protestants or Catholics. Fortunately, this edition still reports the population size in 1819, allowing us to congruently measure the historical population size across the Ruhr area. We link population size, the number of buildings, and the confessional composition to our dataset at the sub-municipal level.

Measuring historical income is significantly more difficult, and we could not uncover statistical information on the preindustrial tax returns of the Ruhr's municipalities strictly before the coal rush. However, three statistical volumes in the late 1850s and early 1860s report the sum of class tax and income tax revenues (*Einkommensteuer* and *Klassifizierte Einkommensteuer*) at the municipal level (Von Mülmann 1865; Regierungsbezirk Arnsberg 1859; Regierungsrath König 1865). Here, too, the reporting dates and population references differ slightly: Düsseldorf reported taxes in 1861 and the population in 1864, Arnsberg reported taxes in 1859 and the population in 1859, and Münster reported taxes in 1861 and the population in 1861. Nevertheless, we use this information to proxy for historical income levels by computing an indicator of tax revenues per capita. As the early 1860s at least preceded most of the intensive industrialization period, we contend that the income differences in this stage of development were only minimally shaped by deep-shaft mining. To address the differences in reporting years across the historical governorates, we estimate several models with historical governorate fixed effects, thereby comparing only those historical municipalities where we can be sure that the differences are not driven by temporal effects of development.

VIII. The Historical Spread of Coal Miners

Understanding how historical specialization in coal mining shaped the contemporary sociodemographic structure of the Ruhr requires examining the patterns of mining employment in the late nineteenth and early twentieth centuries. Coal mining employment in the Upper Mining District of Dortmund (*Oberbergamtsbezirk*) rose significantly in the late nineteenth century. From 31,455 miners in 1858 (Verein für die bergbaulichen Interessen 1882), the workforce doubled by 1871 and reached 81,000 in 1876 before declining during the 1870s economic crisis. Employment rebounded to its 1876 level by 1883 and surged to 154,000 by 1893 (Taeglichsbeck 1895), eventually exceeding 400,000 on the eve of WWI (Allgemeiner Knappschafts-Verein 1912).

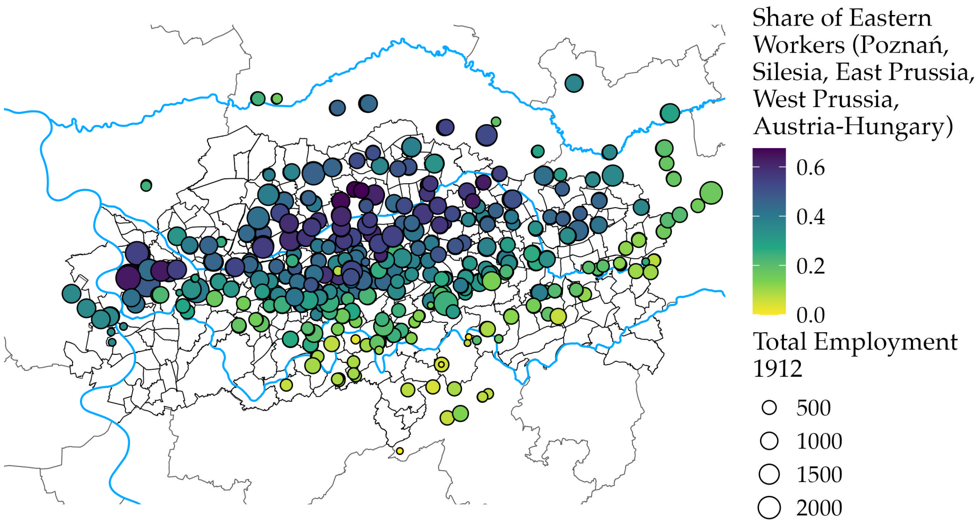
Figure A32: Historical Coal Mine Shaft Employment and the Share of Eastern Workers in 1893



Note: This figure illustrates the employment size of coal mines in 1893 and the share of workers from Prussia's Eastern provinces, which dominated the migration inflow to the Ruhr area.

Our principal aim is to capture the scope of mining employment at the high point of the coal rush, around the turn of the twentieth century. As described in the main paper, we therefore rely on two comprehensive surveys of mine- and shaft-level employment from 1893 and 1912/13. The first survey, provided by the *Oberbergamtsbezirk Dortmund*, is particularly encompassing because it not only reports the size of the workforce for each mine but also includes detailed sociodemographic information on coal miners and their residential spread across the Ruhr's scattered municipal landscape (Taeglichsbeck 1895). For the 158 mines in the dataset, we obtain information on spoken language, province and country of origin, religious denomination, homeownership, contract status, cattle ownership, military service, and the father's occupation. The records of the General Miners' Insurance Association in Bochum (*Allgemeiner Knappschafts-Verein*), which are published from the late nineteenth century to the early 1920s, do not provide a comparable statistical sweep. Most importantly, however, a selection of studies between 1910 and 1913 provides detailed records of shaft-level employment, including a decomposition of the workforce into the province and country of origin (Allgemeiner Knappschafts-Verein 1912). Specifically, we leverage the study recording mining employment on January 1st, 1913, which we denote as mining employment in 1912.[16]

Figure A33: Historical Coal Mine Shaft Employment and the Share of Eastern Workers in 1912



Note: This figure illustrates the employment size of coal mines in 1912 and the share of workers from Prussia's Eastern provinces, which dominated the migration inflow to the Ruhr area.

We digitize these historical records and link them with our georeferenced map of mining shafts from Dodenhoff (2022). The corresponding figures illustrate the size and composition of the workforce in 1893 and 1912. First, they underscore the northward relocation of coal mining operations over time, with a significant northward concentration of mining employment–and a substantial surge overall–unfolding between 1893 and 1912. Coal mines beyond the marl boundary also became significantly more diverse in terms of the origins of the workforce. Ev-

16. The mine-level surveys we obtain focus exclusively on the *Oberbergamt Dortmund*. This district historically encompassed nearly all of the large coal mines at the Ruhr. However, one large coal mine–Zeche Rheinpreußen–on the western side of the river Rhine in contemporary Duisburg and Moers was organized in the *Oberbergamt Bonn*. Thus, we impute an employment figure for 1912. Specifically, we use the *Hamborner Zeitung* from March 12, which, as part of its strike documentation, lists the early- and late-shift employment on *Rheinpreußen* 2230 and 3983 miners, respectively. We distribute the aggregated figure of 6213 miners across the five shafts that have been in operation at the time. The aggregate employment figures, however, do not give us information about the composition of these workers. For this reason, we impute the migrant composition using the nearby *Zeche Diergardt*.

ery third miner in 1912 had migrated from one of Prussia's eastern provinces or the Silesian districts of Austria-Hungary. In some mining districts (*Reviere*), such as Recklinghausen-West or Gelsenkirchen, a majority of miners had eastern origins.

Against this background, our critical empirical challenge is to link the historical employment intensity at the shaft level with our contemporary city and polling districts. This is essential for our empirical design to identify how the initial settlement concentration of coal rush communities contributes to modern demographic sorting within and across city boundaries, thereby shaping the electoral geography of the Ruhr along its geological fault lines.

Our first approach is to harness the rich documentation of the distribution of coal miners across the historical municipalities of the Ruhr area collected by Taeglichsbeck (1895) for 1893. This documentation enables us to apportion coal miners, including their dependent family members, to the historical municipal level in 1871, which we match with contemporary city districts. However, as is portrayed in the subsection above, apportioning the population share of coal miners at the historical municipal level generates a significant reduction in the number of independent contemporary city districts, especially north of the Emscher in the historical Vest Recklinghausen. The entire north of Gelsenkirchen, with the exception of Horst, was originally part of Buer. Similarly, the city of Gladbeck had constituted an independent municipality already in the nineteenth century. A related drawback of this approach is that we are thereby unable to predict the residential concentration of coal miners at the more granular level of polling districts. Finally, linking mining employment with the historical municipal level is only possible for 1893, as this documentation does not reappear in the later surveys.[17]

Figure A34: Settlement Distribution of Coal Miners on *Zeche Consolidation* in Gelsenkirchen, 1893

3.) Consolidation, Schacht I bei Heßler, Schacht II bei Schalke, Schacht III bei Braubauerschaft.

1	2	3	4	5	6	7
Namen der Gemeinden	Schacht I (Gertrud).		Schacht II (Wilhelm).		Schacht III (Minna).	
	Zahl der beschäftigten Arbeiter	Kürzester Landweg vom Wohnorte nach diesem Anfahrpunkte km	Zahl der beschäftigten Arbeiter	Kürzester Landweg vom Wohnorte nach diesem Anfahrpunkte km	Zahl der beschäftigten Arbeiter	Kürzester Landweg vom Wohnorte nach diesem Anfahrpunkte km
Schalke	928	1,2	620	1,7	283	3,2
Gelsenkirchen	229	1,7	249	1,8	159	3,3
Braubauerschaft	97	2,6	216	1,8	707	0,8
Heßler	40	2,5	9	3,4	2	4,9
Bulmke	39	3,0	106	2,1	159	2,3
Katernberg	7	5,4	1	6,2	—	—
Rotthausen	4	4,4	9	4,3	1	5,0
Hüllen	3	3,7	8	2,9	12	2,6
Erle	3	5,3	—	—	1	6,2
Ueckendorf	2	4,5	5	4,4	5	5,1
Buer	1	7,4	4	7,6	2	7,8
Wattenscheid	1	7,0	—	—	4	6,6
Bickern	1	6,7	—	—	—	—
Altenessen	1	6,8	—	—	—	—
Horst	—	—	3	5,2	1	6,7
Westerholt	—	—	—	—	1	8,6
Schonnebeck	—	—	—	—	1	6,5
Summe	1356		1230		1338	

Note: This table is extracted from Taeglichsbeck (1895).

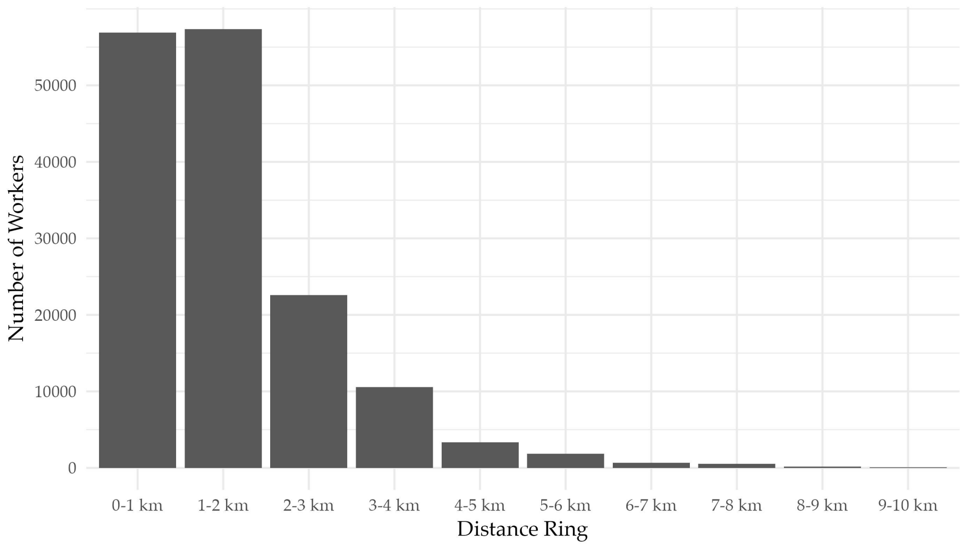
Our main approach, which we display in the paper, harnesses the geocoded location of coal mine shafts paired with detailed information on what we refer to as the spread of coal miners around the shaft itself. The 1893 study contains, for each coal mine and its correspond-

17. The successive incorporation of coal rush communities would also make this endeavor somewhat futile after 1900. In southern Gelsenkirchen, for example, most contemporary city communities had by then become part of the emergent city county.

ing shafts, a detailed documentation of the settlements of its workforce. This is illustrated for *Zeche Consolidation*, possibly Gelsenkirchen's most memorable coal mine. Divided into three shafts, Gertrud, Wilhelm, and Minna, its coal miners primarily clustered in the three municipalities of Schalke, Gelsenkirchen, and Braubauernschaft (later renamed to Bismarck). Thus, we know for each mining shaft the distribution of workers across municipalities–our first piece of information. Our next piece of information is provided in the right-hand column, indicating the distance between the respective municipality and the shaft. We combine these pieces of information to compute the residential distribution of coal miners around each mining shaft, allowing us to extend our analysis beyond historically fixed municipal boundaries.

We proceed in the following steps. First, we create a correspondence file, which links our georeferenced coal mine map to the historical employment surveys of 1893 and 1912. This enables us to spatially connect the employment of coal miners to the specific location of each shaft. For mines lacking sufficiently detailed information on employment distribution across shafts, we divide total employment evenly across the available matches, thereby holding constant the overall number of workers. Second, we load our shaft–distance correspondence file, which lists for each shaft in the 1893 dataset the total number of workers, the municipalities in which they resided, and the distance from those municipalities to the shaft. However, a critical challenge is that the distance to municipal centers generates heterogeneous measurement error across the Ruhr. As the northern Ruhr was historically organized into larger municipalities, the average distance to the shaft indicated in the 1893 survey is artificially inflated.

Figure A35: Distance of Coal Miner Settlements to Mining Shafts in 1893



Note: This figure shows the total number of workers in the *Oberbergamtsbezirk Dortmund* in 1893 by living distance to their respective coal mine shafts (Taeglichsbeck 1895).

We therefore perform an adjustment using our shapefile of historical municipal centers. Specifically, we calculate each shaft's distance to the nearest municipal center. If this distance is below 1 kilometer, we simply assign a correction factor of unity, leaving the distances to municipalities unchanged. However, if the distance exceeds one kilometer, we use the distance as a correction factor to divide all distances to the respective municipalities. For example, for a shaft whose nearest municipality is 1.5 kilometers distant, we divide each distance in the municipal correspondence file by 1.5. After performing this adjustment, we trim these distances into one-kilometer rings, beginning with a 0–1 kilometer ring for municipalities with miners living within one kilometer of a shaft. We extend this procedure up to 9–10 kilometers and finally aggregate the number of coal miners per shaft living in each distance ring. Figure A35 illustrates the resulting distribution, showing that most miners lived close to their shafts. Lastly, we merge this distance-ring file with our baseline georeferenced dataset, such that we capture the spatial distribution of workers distributed around the shafts.

Third, for the coal mines in our 1912 survey, we impute the residential distribution of their miners by using the average residential spread identified for our 1893 sample. For additional shafts created for the same coal mine, we use the mine's specific distance correspondence. For example, for shaft IV-V of *König Ludwig* in Recklinghausen, which was opened in the early twentieth century, we use the distance matrix of the original shaft I-III. After this operation, we have the aggregated residential distribution of each coal mine shaft in 1893 and 1912 across normalized kilometer rings.

$$\text{coverage\_share}_{r,j,z} = \frac{\text{area\_of\_intersection}_{r,j,z}}{\text{total\_district\_area}_z} \tag{5}$$

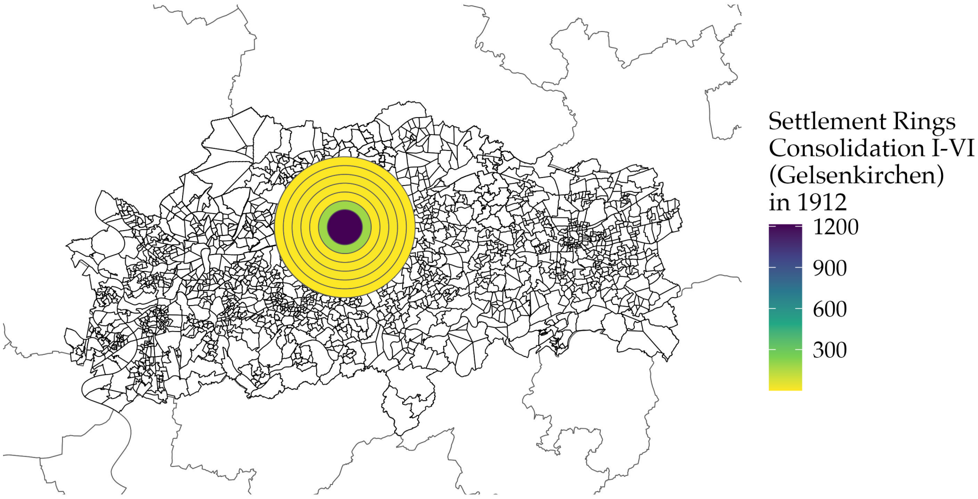
$$\text{initial\_workers}_{r,j,z} = \text{coverage\_share}_{r,j} \times \frac{\text{workers\_per\_ring}_{r,j}}{\text{n\_match}_{r,j}} \tag{6}$$

$$\text{scale\_factor\_workers}_{r,j} = \frac{\text{workers\_per\_ring}_{r,j,z}}{\sum \text{initial\_workers}_{r,j}} \tag{7}$$

$$\text{apportioned\_workers}_z = \sum_z \text{initial\_workers}_{r,j,z} \times \text{scale\_factor\_workers}_{r,j} \tag{8}$$

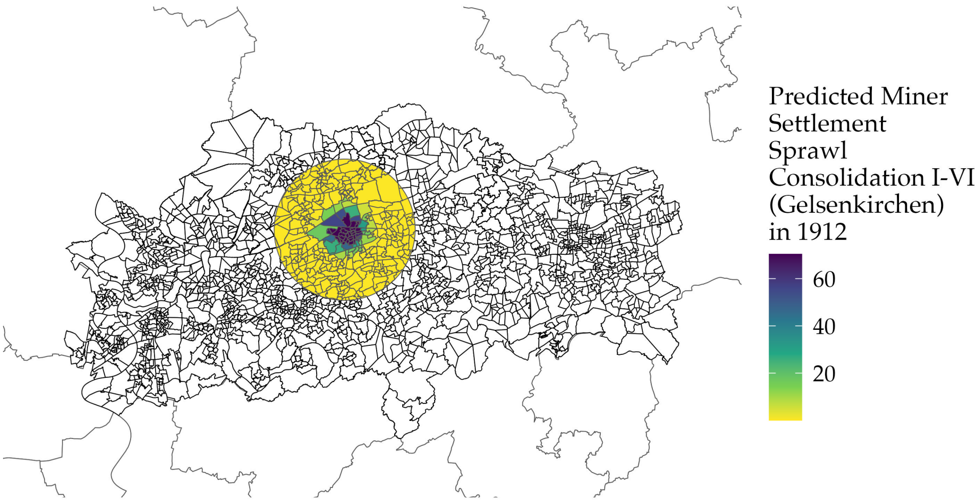
Fourth, we perform a spatial intersection between our district polygons z and the spatial rings r of each mining shaft j. Thus, we observe for each coal mine shaft's ring the share of total area it covers for a respective district, which we denote coverage_share. We then calculate the total number of matches $\text{n\_match}_{r,j}$ of each mine's ring, reflecting that most rings overlap multiple city districts. Using this indicator, we multiply the coverage share by the total number of workers in each shaft's ring $\text{workers\_per\_ring}_{r,j}$, divided by the adjustment factor that captures the number of matches. Then, to adjust this initial workers indicator so that it matches the total number of miners in each shaft, we compute a $\text{scale\_factor\_workers}_{r,j}$, which is defined as the share of each shaft's workers per ring divided by the sum of initial workers. Lastly, we use the scaled sum of initial workers to aggregate predicted employment for each district j.

Figure A36: Settlement Rings of Coal Miners on *Zeche Consolidation, Shaft I (I-VI)*; Polling Districts in 2021



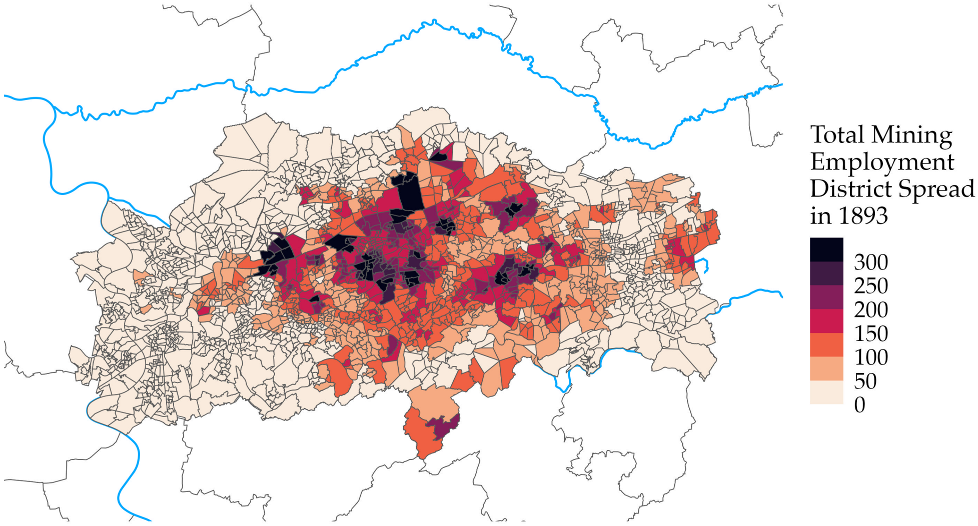
Note: Historical mine-level employment data is from Allgemeiner Knappschafts-Verein (1912).

Figure A37: Predicted Spread of Coal Miners on *Zeche Consolidation, Shaft I (I-VI)* in Gelsenkirchen, 1912; Polling Districts in 2021



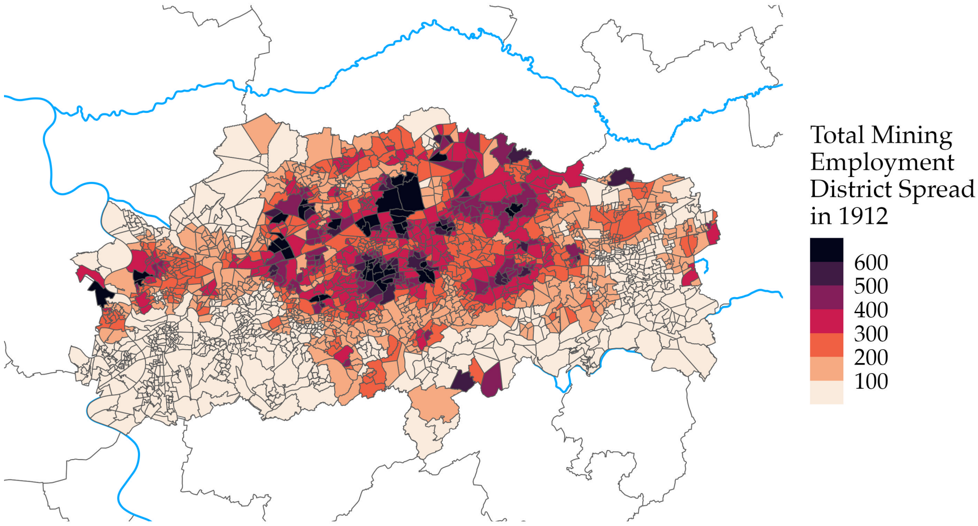
Note: Historical mine-level employment data is from Allgemeiner Knappschafts-Verein (1912).

Figure A38: Predicted Spread of Coal Miners in 1893 at the 2021 Polling Station Level



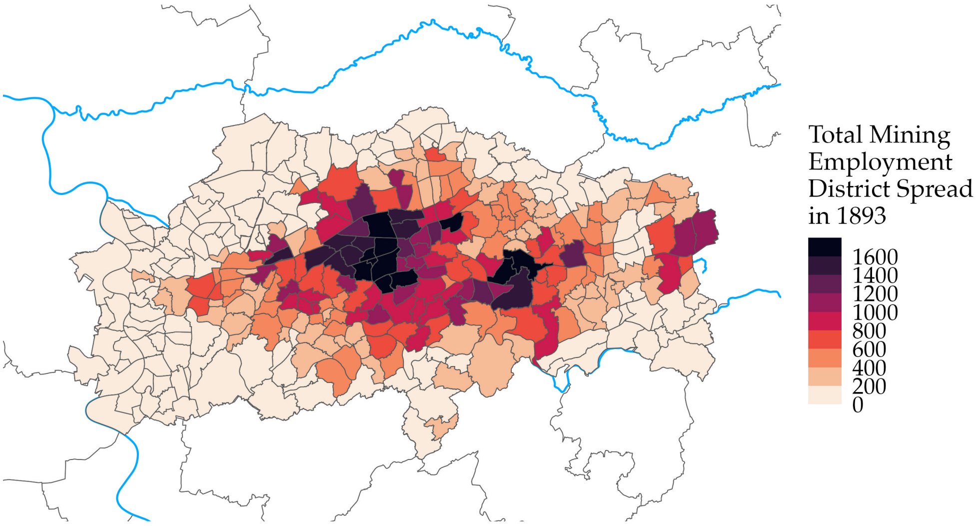
Note: Historical spread of coal miners in 1893 in the Ruhr area across 1953 polling districts. Employment data is from Taeglichsbeck (1895).

Figure A39: Predicted Spread of Coal Miners in 1912 at the 2021 Polling Station Level



Note: Historical spread of coal miners in 1912 in the Ruhr area across 1953 polling districts. Employment data is from Allgemeiner Knappschafts-Verein (1912).

Figure A40: Predicted Spread of Coal Miners in 1893 at the 2021 District Level



Note: Historical spread of coal miners in 1893 in the Ruhr area across 348 districts. Employment data is from Taeglichsbeck (1895).

VII Identifying Historical Mining Colonies

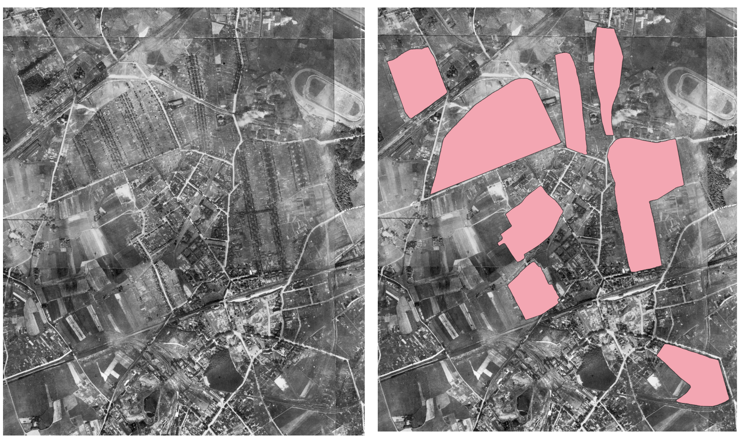
We argue that the electoral legacy of late and intensive industrialization is transmitted into the present through the endurance of the industrial built environment. Worker settlements occupy a special role in this process: because they historically concentrated working-class constituencies close to the original coal mines, they create path dependencies of demographic persistence and residential sorting. However, while Soviet planners built purpose-built worker settlements through political fiat, the construction of mining towns in the nineteenth- and early twentieth-century Ruhr area was driven by private initiative. As such, although the Royal Mining District's administration conducted occasional surveys of company housing (Taeglichsbeck 1895; Verein für die Bergbaulichen Interessen 1901), systematic information on the universe of housing units and settlements that originally emerged through company constructions is missing.

We, at least partially, fill this gap in this paper. Specifically, we are able to identify around 360 historical colony settlements in the Ruhr's contemporary residential landscape. We collect this information from a wide range of sources, including historical aerial images, topographic maps, various contemporary documents, and historical address books, which contain rich information on the ownership structure of residential buildings. Crucially, we limit our attention to private settlements constructed before the end of World War II. Although we made substantial efforts to capture even small worker settlements, our dataset is inevitably limited by the absence of centralized records. As a result, some smaller colonies may be missing, introducing a degree of measurement error. The visual heterogeneity of colony housing, as well as the necessary administrative information on its private origins, prevents us from using a classification algorithm. We therefore georeference them manually using QGIS. In the following, we describe this dataset and the resulting distribution of colony housing across the Ruhr.

I. Aerial Images

Figure A41: Historical Aerial Image of Essen-Katernberg and Georeferenced Colonies

(a) *Aerial Image* (b) *Colony Polygons*

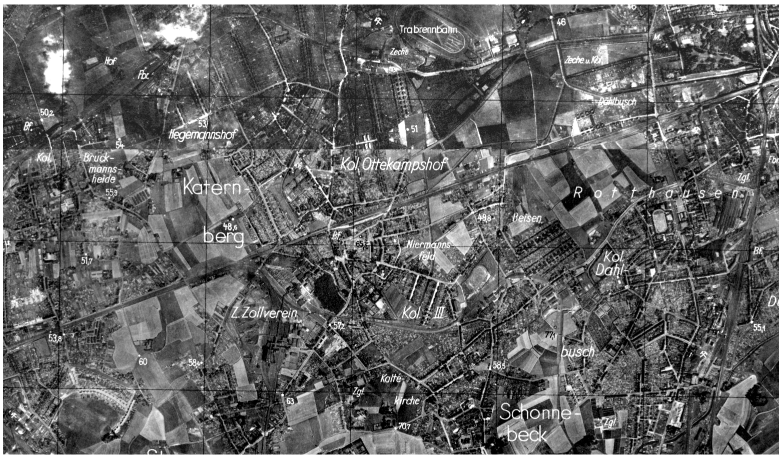


Note: This figure shows an excerpt of a historical aerial image of Essen-Katernberg and its residential areas taken between 1926 and 1930 (Regionalverband Ruhr 2025a).

Our first sources are historical aerial images of the Ruhr, which were first produced in the 1920s (Regionalverband Ruhr 2025a, 2025b). These images have two advantages: first, the physical outlook of historical settlements, especially when located in proximity to large mining sites, often provides clues about the location of mining colonies. The earlier colony settlements typically consisted of symmetrically aligned row block buildings (*Zeilenbau*) with only one story. Figure A41 shows two images of the settlements near *Zeche Zollverein* in Essen-Katernberg, which conformed to this earlier image of colony construction. Later colonies, in turn, were often two stories tall and built as more complex garden cities. Here, the main challenge is distinguishing these later settlements from those that emerged through municipal constructions.

Second, some large colonies, such as Colony Dahlbusch in southwest Gelsenkirchen, are inscribed on the aerial images of 1934, as shown in Figure A42. Although the spatial landscape of areas immediately surrounding historical coal mines is frequently suggestive of the existence of colony housing, we always seek to anchor our geocodes with factual information to confirm the company origins of these settlements. As discussed previously, we use QGIS to manually geocode the areas of these historical settlements

Figure A42: Historical Aerial Image of Essen-Katernberg and Southwest Gelsenkirchen with Colony Names

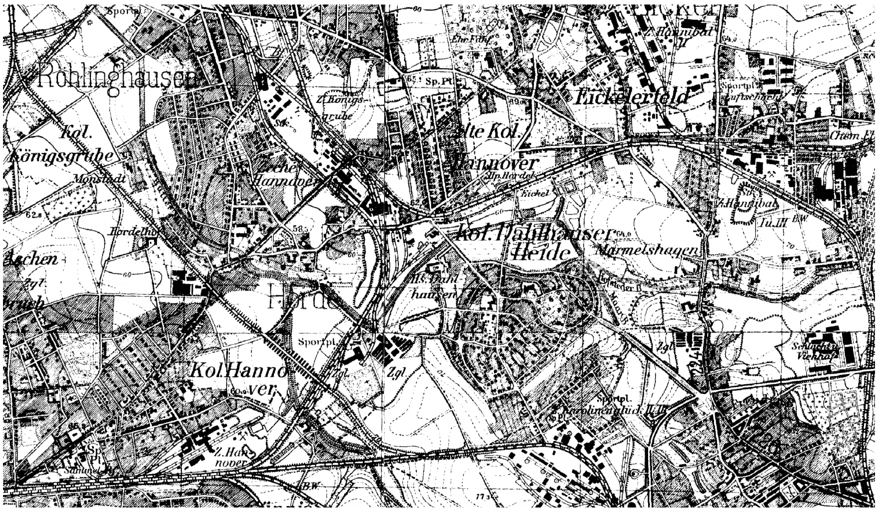


Note: This figure shows an excerpt of a historical aerial image of Essen-Katernberg and Gelsenkirchen-Rotthausen taken between 1934 and 1939 (Regionalverband Ruhr 2025b).

II. Historical Topographic Maps

Next, we turn to historical topographic maps of the Ruhr area, specifically to a map from 1936, which provides names for several colony settlements within the residential built environment. Figure A43 illustrates this for the case of northern Bochum. This map includes the colonies of coal mine *Hannover*, colonies Dahlhauser Heide and Karolinenglück, and a colony of coal mine *Königsgrube*. As was discussed before, the settlements of *Hannover* are more congruent with the earlier model of colony development, consisting of several row blocks. By contrast, which was constructed between 1906 and 1915, was a garden city, and thus departs from the spatial symmetry of earlier worker settlements. Combining aerial imagery with this historical topographic map allows us to capture a significant fraction of the large colonies in the Ruhr area's urban core and northern frontier.

Figure A43: Historical Topographic Map of Bochum with Colony Names



Note: This figure depicts an excerpt of a topographic map of the German Empire, showing northern Bochum and several colonies of *Zeche Hannover* and *Zeche Carolinenglück* (Bezirksregierung Köln 2025a).

III. Contemporary Sources

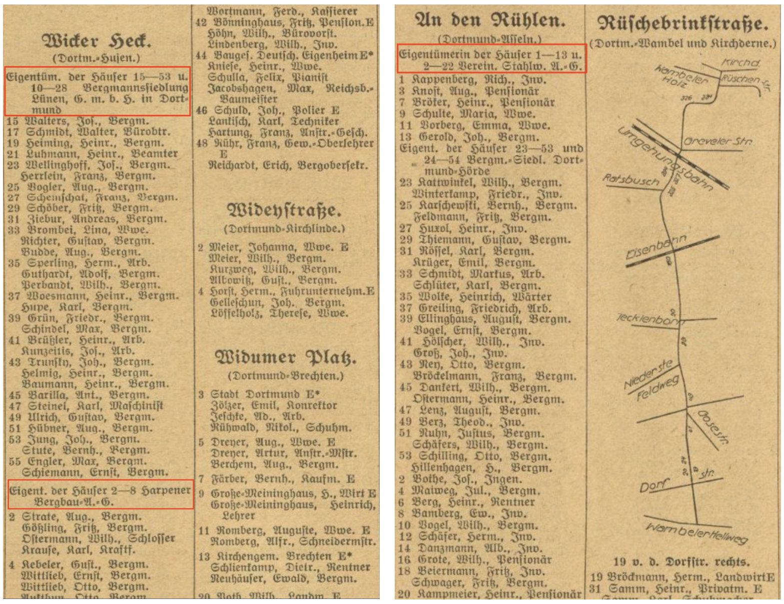
Although historical aerial images and topographic maps allow us to identify large colony settlements, they are much less well-equipped to capture smaller residential units, which nevertheless amount to substantial worker settlements on aggregate. For this reason, we turn to a series of contemporary sources. Especially for Bochum, Herne, Essen, and Gelsenkirchen, these sources allow us to capture smaller colony settlements. As such, we first draw on secondary volumes, including books or dissertations (Pirke 2006; Günter 2000) or publications by specific cities, including reports and monument lists (Bollerey and Hartmann 1980; Stadt Bochum 2010, 2025a; Stadt Gelsenkirchen 2010). Second, we use webpages with detailed information on historical settlements, most notably *Ruhrbauten*, which provides detailed information about Bochum (Ruhr-Bauten). We use a similar web-based collection for Herne, provided by its historical association (Historischer Verein Herne / Wanne-Eickel e. V. 2025). Then, particularly for Essen, we use a webpage with information on worker settlements (Gelhar 2016). Lastly, we use multiple issues from *Netzwerk Siedlungskultur*, which elaborate on several residential areas of the modern-day Ruhr area (Regionalverband Ruhr).

IV. Historical Address Books

Lastly, to identify worker settlements that are neither covered by modern-day sources nor discernible from the built-up structure on historical maps, we use several historical address books, which provide insights into the ownership structure of historical residential buildings. This also has the advantage that we, at least partially, identify colony buildings that have since disappeared from the urban landscape. These address books list the owners of every residential building, through which we make inferences about buildings created by mining entrepreneurs and large-scale companies. To be sure, this generates the risk that we partially code buildings that were acquired by mining entrepreneurs but not originally built by them. However, given the vast dominance of company constructions we document using our historical shaft-level evidence, this bias is arguably negligible. Specifically, we use address books for Bochum, Essen, Dortmund, Gelsenkirchen, Recklinghausen, Witten, and Herne, from varying years, depending on availability (Stadt Bochum 1938; Stadt Essen 1932, 1937; Stadt Dortmund 1932; Stadt Gelsenkirchen 1927; Stadt Recklinghausen 1934, 1934; Stadt Witten 1930; Stadt Herne 1938).

Figure A44: Historical Address Books of Dortmund: Identifying Worker Housing

(a) *Worker Settlement* (b) *Company Ownership*



Wicker Heck.
(Dortm.-Husen.)
Eigentüm. der Häuser 15—53 u. 10—28 Bergmannssiedlung Lünen, G. m. b. H. in Dortmund
15 Walters, Jos., Bergm.
17 Schmidt, Walter, Bürobtr.
19 Heiming, Heinr., Bergm.
21 Luhmann, Heinr., Beamter
23 Wellinghoff, Jos., Bergm.
Herrlein, Franz, Bergm.
25 Vogler, Aug., Bergm.
27 Schemschat, Franz, Bergm.
29 Schöber, Fritz, Bergm.
31 Ziebur, Andreas, Bergm.
33 Brombei, Lina, Wwe.
Richter, Gustav, Bergm.
Budde, Aug., Bergm.
35 Sperling, Herm., Arb.
Guthardt, Adolf, Bergm.
Perbandt, Wilh., Bergm.
37 Woesmann, Heinr., Bergm.
Hupe, Karl, Bergm.
39 Grün, Friedr., Bergm.
Schindel, Max, Bergm.
41 Brüßler, Heinr., Arb.
Kunzeitis, Jos., Arb.
43 Trunsky, Joh., Bergm.
Helmig, Heinr., Bergm.
Baumann, Heinr., Bergm.
45 Barilla, Ant., Bergm.
47 Steinel, Karl, Maschinist
49 Ulrich, Gustav, Bergm.
51 Hübner, Aug., Bergm.
53 Jung, Joh., Bergm.
Stute, Bernh., Bergm.
55 Engler, Max, Bergm.
Schiemann, Ernst, Bergm.
Eigent. der Häuser 2—8 Harpener Bergbau-A.-G.
2 Strate, Aug., Bergm.
Gößling, Fritz, Bergm.
Ostermann, Wilh., Schlosser
Krause, Karl, Kraftf.
4 Kebeler, Gust., Bergm.
Wittlieb, Ernst, Bergm.
Wittlieb, Otto, Bergm.

Wortmann, Ferd., Kassierer
42 Bönninghaus, Fritz, Pension. E
Höhn, Wilh., Bürovorst.
Lindenberg, Wilh., Inv.
44 Baugel. Deutsch. Eigenheim E*
Kniese, Heinr., Wwe.
Schulla, Felix, Pianist
Jacobshagen, Max, Reichsb.-Baumeister
46 Schuld, Joh., Polier E
Lantisch, Karl, Techniker
Hartung, Franz, Anstr.-Gesch.
48 Rühr, Franz, Gew.-Oberlehrer E
Reichardt, Erich, Bergobersekr.

Wideystraße.
(Dortmund-Kirchlinde.)
2 Meier, Johanna, Wwe. E
Meier, Wilh., Bergm.
Kurzweg, Wilh., Bergm.
Albowitz, Gust., Bergm.
4 Horst, Herm., Fuhrunternehm. E
Gelleschun, Joh., Bergm.
Löffelholz, Therese, Wwe.

Widumer Platz.
(Dortmund-Brechten.)
3 Stadt Dortmund E*
Zölzer, Emil, Konrektor
Jeschke, Ad., Arb.
Rühwald, Nikol., Schuhm.
5 Dreyer, Aug., Wwe. E
Dreyer, Artur, Anstr.-Mstr.
Berchem, Aug., Bergm.
7 Färber, Bernh., Kaufm. E
9 Große-Meininghaus, H., Wirt E
Große-Meininghaus, Heinrich, Lehrer
11 Romberg, Auguste, Wwe. E
Romberg, Alfr., Schneidermstr.
13 Kirchengem. Brechten E*
Schlienkamp, Dietr., Rentner
Neuhäuser, Ewald, Bergm.

An den Kühlen.
(Dortmund-Asseln.)
Eigentümerin der Häuser 1—13 u. 2—22 Verein. Stahlw. A.-G.
1 Kappenberg, Rich., Inv.
3 Knost, Aug., Pensionär
7 Bröker, Heinr., Pensionär
9 Schulte, Maria, Wwe.
11 Vorberg, Emma, Wwe.
13 Gerold, Joh., Bergm.
Eigent. der Häuser 23—53 und 24—54 Bergm.-Siedl. Dortmund-Hörde
23 Kattwinkel, Wilh., Bergm.
Winterkamp, Friedr., Inv.
25 Karschewski, Bernh., Bergm.
Feldmann, Fritz, Bergm.
27 Huxol, Heinr., Inv.
29 Thiemann, Gustav, Bergm.
31 Rössel, Karl, Bergm.
Krüger, Emil, Bergm.
33 Schmidt, Markus, Arb.
Schlüter, Karl, Bergm.
35 Wolke, Heinrich, Wärter
37 Greiling, Friedrich, Arb.
39 Ellinghaus, August, Bergm.
Vogel, Ernst, Bergm.
41 Hölscher, Wilh., Inv.
Groß, Joh., Inv.
43 Ney, Otto, Bergm.
Bröckelmann, Franz, Bergm.
45 Dankert, Wilh., Bergm.
Ostermann, Heinr., Bergm.
47 Lenz, August, Bergm.
49 Berz, Theod., Inv.
51 Ruhn, Justus, Bergm.
Schäfers, Wilh., Bergm.
53 Schilling, Otto, Bergm.
Hillenhagen, H., Bergm.
2 Bothe, Jos., Ingen.
4 Maiweg, Jul., Bergm.
6 Berg, Heinr., Rentner
8 Bamberg, Ew., Inv.
10 Vogel, Wilh., Bergm.
12 Schäfer, Herm., Inv.
14 Danzmann, Alb., Inv.
16 Grote, Wilh., Pensionär
18 Beiermann, Fritz, Inv.
Schwager, Fritz, Bergm.
20 Kampmeier, Heinr., Pensionär

Rüschebrinkstraße.
(Dortm.-Wambel und Kirchderne.)

19 v. d. Dorfstr. rechts.
19 Bröckmann, Herm., Landwirt E
31 Samm, Heinr., Privatm. E

Note: This figure displays excerpts from historical address books of Dortmund, showing the ownership structure of specific residential buildings. This ownership structure allows us to observe settlements owned by mining companies.

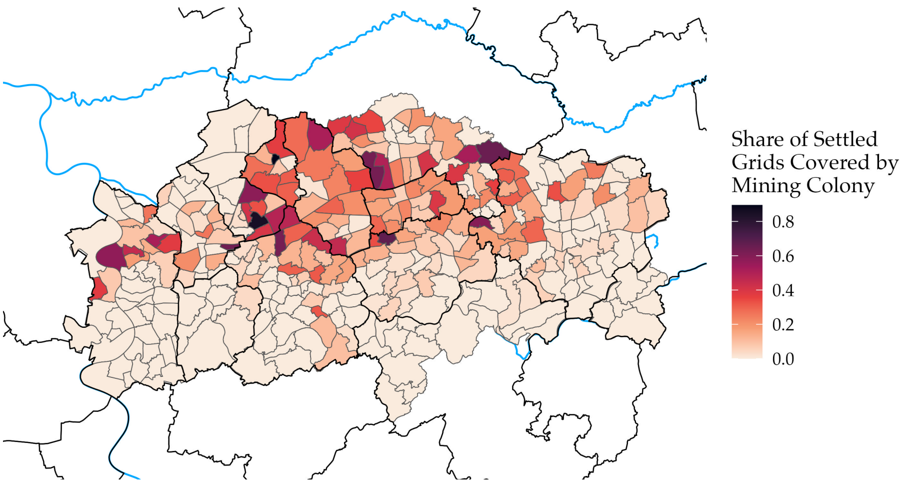
We ideally use a version from the early 1930s, before the seizure of power by the NSDAP. Address books from the 1920s might still be missing settlements constructed during this period or shortly thereafter, while address books from the later 1930s often feature street names that strikingly diverge from their modern equivalents. This impairs our ability to identify these historical streets in the modern-day road network. We also highlight that, due to the vast variation in naming practices of company housing, we likely do not capture the universe of company housing that could be gleaned from these documents. We also deliberately exclude single houses that were company-owned but did not exist as part of a broader network of company housing, because these houses cannot be understood as actual settlements. These single-place constructions cannot be interpreted as actual settlements, which is the unit of interest.

Figure A44 presents two excerpts from Dortmund's historical address books that illustrate our coding procedure. The left-hand panel shows addresses from a mining settlement in Dortmund-Husen. At the beginning of the street section, the book explicitly identifies a series of houses as belonging to a mining settlement. We classify all housing blocks designated in this way as mining settlements. The right-hand panel depicts a settlement owned by Vereinigte Stahlwerke, which also operated several coal mines. In such cases, we verify whether the residents were predominantly miners to distinguish between company-owned settlements in general and those actually inhabited by coal miners, the latter being the only ones we record.

V. Final Output

Finally, to construct indicators of colony housing at the city-district level, we proceed in four steps. First, we merge the manually digitized colony polygons back onto the grid-cell database, identifying settled grids with at least 5% coverage by colony housing. Second, we spatially link this restricted sample of settled grids to the city-district dataset. Third, we calculate for each district the share of settled grids historically covered by colony housing, as shown in Figure A45. Fourth, we classify districts as colony districts (coded 1) if at least 10% of their settled grids fall within colony housing; all other districts are coded 0.

Figure A45: The Share of District Territory Covered by Colony Settlements

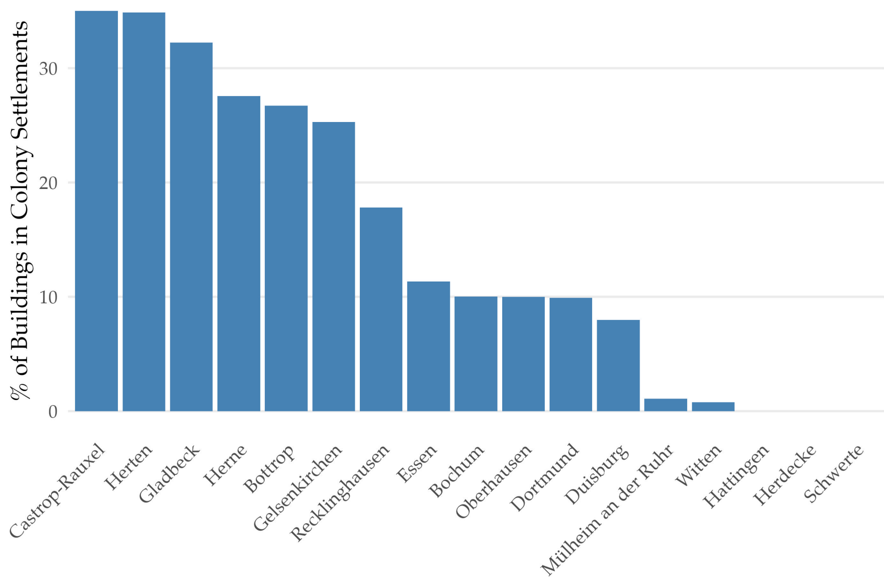


Note: This figure illustrates the share of district territory covered by mining colony polygons. The colony polygons are based on our data collection and geocoding of historical settlements. We apportion these polygons to our 348 city districts and define those with at least 10% of settled grids emerging through colony housing as colony districts and those below as districts without colonies.

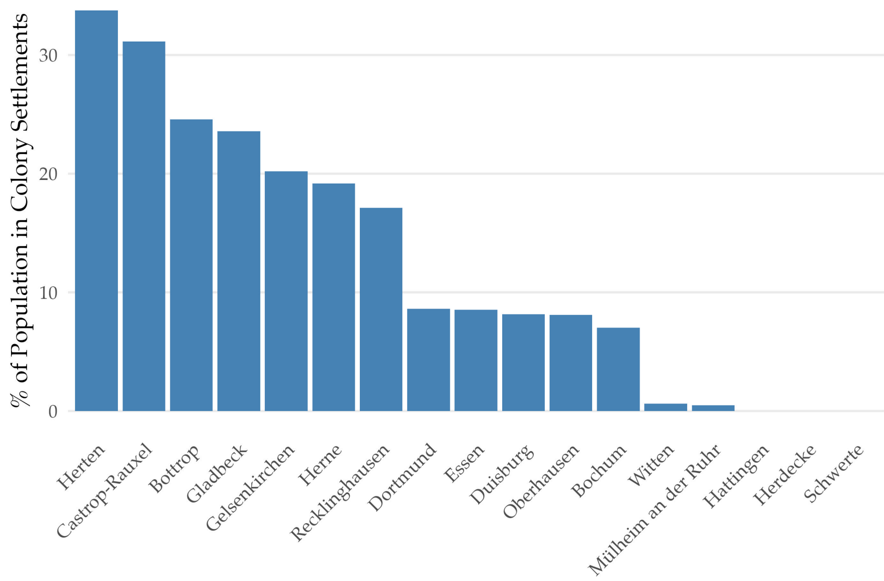
The distribution of colony housing in the Ruhr closely mirrors the region's north–south divide in industrialization intensity. The highest concentrations are found in Herten and Castrop-Rauxel, where more than 30% of buildings and population in the grid fall within historical mining colonies. Shares remain high–above 20% for both indicators–in Gladbeck, Bottrop, Herne, and Gelsenkirchen. Recklinghausen occupies a middle position, reflecting both its northern location and its historical growth around an established urban core. By contrast, despite the heavy industrialization of northern Essen, Dortmund, Bochum, and Duisburg, only about 10% of buildings and an even smaller share of residents are located in colony settlements today. This pattern underscores the stark differences in urban density: larger historical centers dominate these cities, making them, in aggregate, far less shaped by mining colonies than the northern towns. In the southern Ruhr, colony housing plays only a marginal role, either because industrialization proceeded more gradually or, as in Schwerte, because mining was largely absent.

Figure A46: The Built-Up Scale and Population of Historical Colony Housing Across Ruhr Cities

(a) *Buildings*



(b) *Population*



Note: This figure shows the share of all buildings (2011) and of the population (2022) located in historical colony settlements. Settlements are identified at the grid-cell level based on company housing, after which we calculate total population and building counts for colony and non-colony grids.

VIII Constructing Our Election Database

Our paper builds on two self-collected election databases at the city district level (*Stadtteile*) and the polling station level (*Stimmbezirke*). The city community database allows us to track the full breadth of voting behavior, including mail-in ballot results, at a relatively granular level. Another crucial advantage of this level of aggregation is the historical connection of the city district to historical municipalities in the Ruhr. Across the Ruhr area, with the important exception of the governorate of Münster, several city districts are immediate successors of historically independent rural municipal units. Therefore, analyzing at the city district level enables us to link historical census data at the municipal level with contemporary socioeconomic and political indicators while maintaining a reasonable level of dimensionality. This also enables us to measure the number of shafts within district boundaries with minimal bias, given that modern city districts often correspond to historical municipal units.

A potential limitation of using the city district level is the relatively small sample size, with only 348 city districts per election. Collecting data for the 2017, 2021, and 2025 elections provides a total of 1,044 observations (348 for each election). To enable more granular analyses of sociostructural sorting and voting behavior, we also compile a database of election returns at the polling station level for the seventeen core cities of the Ruhr. This approach offers greater detail but comes with a significant drawback: the exclusion of mail-in ballots. Mail-in ballot districts (*Briefwahlbezirke*) substantially reduce the number of available units and are poorly documented in most cities. Although we rely on data from a variety of sources, often the open data portals of the cities themselves, two primary repositories are particularly valuable: The *votemanager*[18] website, where several cities store granular election data, and the *Wahlarchiv*.[19]

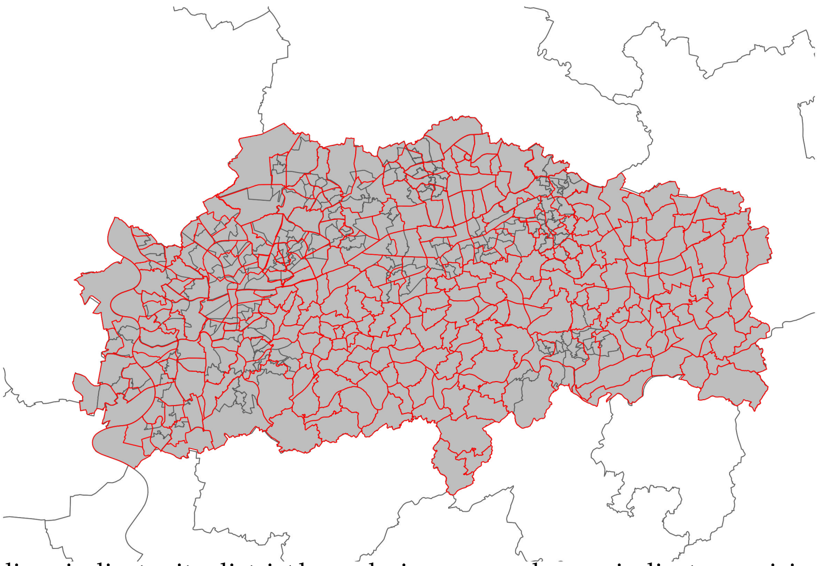
Our general approach is the following: We first build a unified shapefile of city communities in the seventeen cities in our dataset. As most cities also report federal election results at the level of municipal voting districts (*Kommunalwahlbezirke*), we compile a shapefile of these districts as well. At least in the mid-sized Ruhr cities, municipal voting districts tend to outnumber city districts. To fully exploit the advantages of city district data, we spatially apportion election results in 2017, 2021, and 2025, the three federal elections in our database, from the level of municipal voting districts to the city district level. For large cities, particularly Dortmund and Bochum, we leverage the detailed spatial documentation of mail-in ballot districts to aggregate results at the city district level, thereby reducing measurement errors. Other cities, like Essen, provide election results at the city district level itself.

Spatial information on polling district boundaries is considerably harder to obtain compared to the boundaries of city communities. The largest cities of the Ruhr (Dortmund, Essen, Duisburg, Bochum, and Gelsenkirchen) freely provide shapefiles of polling station boundaries. However, for around half of the cities in our dataset, information on the exact spatial extent of polling districts is unavailable. We, therefore, approximate the boundaries of these polling districts by creating Voronoi diagrams around the geolocation of the polling station. Crucially, we draw diagrams only within a city district, which yields more plausible results that take

18. https://wahlen.votemanager.de/
19. https://wahlarchiv.krzn.de/.

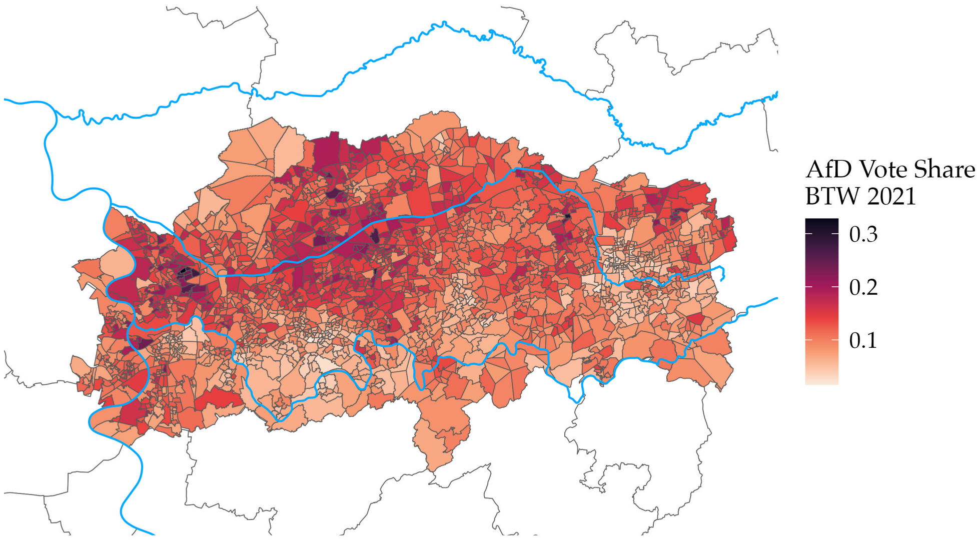
into account the natural district boundaries within cities. Our approach is similar to Dörr et al. (2023), who use precise street lists to approximate the boundaries of urban polling districts. However, due to the reliance on polling stations, our districts are less precise and more prone to measurement error.

Figure A47: City District and Municipal Voting District Correspondence in 2021 Dataset



Note: Red spatial lines indicate city district boundaries; grey polygons indicate municipal voting districts (*Kommunalwahlbezirke*). For some cities, we use the city district level to begin with.

Figure A48: AfD Support at the Polling Station Level



Note: This figure shows the vote share of the *Alternative für Deutschland* at the polling district level in the federal election of 2021.

I. Dortmund (Census 2022 Population: 598,246)

We source election data for Dortmund from the city's independent open data portal. The primary geospatial basis of our dataset is the shapefile of Dortmund's 62 statistical districts (*Statistische Bezirke*) (Stadt Dortmund 2019). We collect data at the polling district level for 2017, 2021, and 2025, and aggregate polling station and mail-in ballot results at the level of mail-in ballot districts (Open Data Dortmund 2017a, 2021a, 2023b, 2023a, 2017b, 2021b, 2025b, 2025a). For our polling station dataset, we simply use the polling station results and the corresponding shapefile for 2021. For our city community dataset, we spatially apportion election results measured at the mail-in ballot districts at the city district level.

II. Essen (571,039)

We source election data for Essen from the https://wahlen.votemanager.de/ website, where the city deposits election results at the city community level and the polling district level (Stadt Essen 2017, 2021, 2025). We, therefore, observe election results in the city community itself. We use the standard shapefile of Essen's city districts, which is sourced from Stadt Essen (2024). Finally, we link results at the polling station level with the shapefile from Stadt Essen (2022).

III. Duisburg (501,415)

Our election data for Duisburg comes from two sources: First, we use data from votemanager.de for election results for the city's municipal voting districts and polling districts for the federal elections of 2017, 2021, and 2025 (Stadt Duisburg 2017, 2021, 2025). We then link polling station returns with the shapefile provided by Open Data Duisburg (2022). We then spatially apportion the election results at the municipal voting district (N=36), including mail-in ballots, at the level of city districts (N=46) for the federal elections of 2017 and 2021. Duisburg is the only case in our dataset where the number of city districts exceeds the number of municipal voting districts. We conduct these spatial operations with three shapefiles, specifically the boundaries of municipal voting districts in the respective election (Open Data Duisburg 2019, 2020) and the shapefile of city communities (Open Data Duisburg 2024).

IV. Bochum (354,288)

Our construction of a local election database for Bochum differs between the federal elections of 2017 and 2021/5. For 2021 and 2025, we proceed as we did in Dortmund and aggregate electoral returns at the polling station level at the level of mail-in ballot districts. We source both election datasets from votemanager.de (Stadt Bochum 2017, 2021, 2025b), extract mail-in ballot and polling district boundaries from Open Data Bochum (Open Data Stadt Bochum 2024). We then apportion the results at the mail-in ballot district at the level of Bochum's 30 city districts. This shapefile comes from BOStatIS Bochum (1980). The polling station results in Bochum confront us with a challenge: The most recent available shapefile of Bochum's polling districts is from the European elections of 2019. By comparing the spatial identification numbers, the total number of districts, and the names of the polling stations, we can confirm that the 2019 and 2021 boundaries align relatively well. However, although Bochum had 186 polling stations in both 2019 and 2021, four identification numbers in each year lack a corresponding match in the other dataset. Based on the location of polling stations, we apportion the results of four polling stations in 2021 to the boundaries of 2019. Specifically, polling district 3307 is apportioned to 3201, 5307 to 5105, 5308 to 5105, and 6105 to 6202. For the 2019 shapefile, we aggregate districts 3206 with 3207, 5106 with 5107, 5406 with 5407, and 6305 with 6306.

V. Gelsenkirchen (264,130)

Election data from Gelsenkirchen is sourced from the city's online documentation, which is interlinked with votemanager.de (Stadt Gelsenkirchen 2017, 2021, 2025). We collect data for the federal elections of 2017, 2021, and 2025 at the municipal voting district (N=33) and aggregate these results at the level of city districts (N=18). To this end, we use the shapefile provided by Stadt Gelsenkirchen (2024). We also use this shapefile and the corresponding election data to capture voting behavior at the level of polling stations in 2021 (N=156).

VI. Oberhausen (212,127)

Our election data for Oberhausen is drawn from votemanager.de, where we collect the results of the 2017, 2021, and 2025 elections at the municipal voting district and the results of the 2021 election at the polling station level (Stadt Oberhausen 2017, 2021, 2025). We aggregate the results at the level of city districts. We use a shapefile from Regionalverband Ruhr (2022), which contains the city districts of several Ruhr cities. However, we could not identify digitized shapefiles of municipal voting districts and polling districts. For this reason, we first use a static map of municipal voting districts (Stadt Oberhausen 2020) to create the corresponding shapefile in QGIS. Finally, to approximate the boundaries of polling stations, we use Open Street Maps (OSM) to georeference the polling stations extracted from the documents stored online. We then use these locations as the centroids of Voronoi diagrams.

VII. Mülheim an der Ruhr (171,435)

We source election data for Mülheim from votemanager.de at the municipal voting district in the federal elections of 2017, 2021, and 2025 (Stadt Mülheim an der Ruhr 2017, 2021, 2025). We also use this repository to collect election data in 2021 at the polling station level. We then use data from the city's Open Data Portal to get shapefiles of municipal voting districts, city districts, and polling districts (Stadt Mülheim an der Ruhr 2019b, 2019b, 2019a). We then follow the usual procedure and aggregate the election returns at the level of city districts, while linking returns at the polling station level with the corresponding boundaries.

VIII. Herne (155,446)

Election data for Herne is sourced from the Wahlarchiv, which contains the electoral returns for the federal elections of 2021 and 2025 at the municipal voting district level (*Ratswahlbezirke*) and the polling district level (Stadt Herne 2021, 2025). We aggregate these results at the city district level and link polling returns with the corresponding shapefile. The shapefiles of municipal voting districts, city districts, and polling districts are sourced from the Regionalverband Ruhr (2020) and the city's Open Data Portal (Open Data Stadt Herne 2020b, 2020a). A critical drawback for the city of Herne is that the city does not report community-level election results for the federal election of 2017. For this reason, we impute the levels of party support in 2017 by taking the relative distribution of party support from 2021 and adjusting the levels with the aggregate city-level returns. We thereby assume that the distribution of voter support across political parties did not change within Herne between the two elections, while we keep the level of party support at its true value.

IX. Bottrop (117,921)

We collect election data for Bottrop's municipal voting districts (*Ratswahlbezirke*) and polling districts from the Wahlarchiv (Stadt Bottrop 2017, 2021, 2025). We have the election results for the federal elections of 2017 and 2021. We link them with the shapefile of municipal voting districts, which is sourced from Stadt Bottrop (2024), and then aggregate these results at the level of city districts (Regionalverband Ruhr 2024b). Bottrop does not offer a shapefile of its polling districts, so we use the geolocation of polling stations in 2021 from Wahlarchiv to recreate a shapefile based on Voronoi polygons within Bottrop's statistical districts.

X. Recklinghausen (115,216)

We source election data for Recklinghausen from votemanager.de. Specifically, we use election data measured at the city district level for the federal elections of 2021 and 2025 (Stadt Recklinghausen 2021, 2025) and election results at the municipal voting district in 2017 (Stadt Recklinghausen 2017). We then use the city's shapefile of city districts, which is taken from Stadt Recklinghausen (2024), to apportion the results at the municipal voting district. Crucially, because Recklinghausen does not provide a shapefile of municipal voting districts, we manually reconstruct this shapefile in QGIS based on the boundaries in a static document (Stadt Recklinghausen 2020). Polling district returns in 2021 are also sourced from votemanager.de, but a shapefile is unavailable. For this reason, we create Voronoi diagrams around the geolocation of the polling station within the city's district boundaries.

XI. Witten (91,735)

Election data for Witten is taken from votemanager.de for the three federal elections in our dataset (Stadt Witten 2017, 2021, 2025). We link this information with district boundaries by scraping the shapefile stored on the votemanager.de website. To aggregate the election results at the level of city districts, we use a shapefile of the city districts in the Ennepe-Ruhr county Ennepe-Ruhr-Kreis (2024). Finally, we use the geolocation of polling stations in 2021, also extracted from votemanager.de, to create Voronoi diagrams as approximations of polling districts.

XII. Gladbeck (75,515)

We collect election data for Gladbeck from votemanager.de, encompassing results at the municipal voting district for 2017, 2021, and 2025 and polling district results in 2021 (Stadt Gladbeck 2017, 2021, 2025). Unfortunately, Gladbeck does not provide shapefiles for either municipal voting districts or polling districts, but the city's online geoportal contains vector data showing their boundaries (Stadt Gladbeck 2022). We use these boundaries to generate shapefiles in QGIS, which we then use to aggregate the election results at the level of city districts. The city district shapefile is from Regionalverband Ruhr (2022).

XIII. Castrop-Rauxel (72,839)

Castrop-Rauxel represents the most complicated endeavor of collecting election data at the community level. The results of the 2021 and 2025 federal elections are available at the level of municipal voting districts on votemanager.de (Stadt Castrop-Rauxel 2021, 2025), but election results for 2017 are only available at the level of polling stations – thus excluding mail-in ballots. As a result, we pursue the imputation approach adopted in Herne, where we impute the levels of party support in 2017 by taking the relative distribution of party support from 2021 and adjusting the levels with the aggregate city-level returns. We thereby assume that the distribution of voter support across political parties did not change within Castrop-Rauxel between the two elections, while we keep the level of party support at its actual value in the 2017 election. Another challenge emanates from the lack of spatial data. First, we use a static image of city district boundaries to create a shapefile in QGIS (Kreis Recklinghausen 2018). Second, we also recreate the boundaries of Castrop-Rauxel's municipal voting districts using a dynamic image on the website of the city's Green Party (Stadtverband Castrop-Rauxel Bündnis 90/Die Grünen 2020). Finally, we aggregate the election results (measured at the municipal voting district) at the level of city districts. Collecting data at the polling station level is equally challenging, as the city does not provide information on polling district boundaries. What is more, several polling districts share a polling station and are linked to a specific municipal voting district. For example, municipal voting district 21 is divided into two polling districts, 21.1 and 21.2, while both vote at Elisabethschule. We thus simply use our shapefile of municipal voting districts and aggregate polling station returns at this somewhat less granular level. For Castrop-Rauxel, therefore, polling districts and municipal voting district boundaries are identical.

XIV. Herten (61,062)

Election data for Herten is almost as scattered as for Castrop-Rauxel. We have the complete results at the level of municipal voting districts for the federal election of 2021 and 2025 from votemanager.de (Stadt Herten 2021, 2025). Crucially, Herten's municipal voting districts are identical to its polling districts. However, for 2017, we only have results without mail-in ballots from Wahlarchiv, which is why we use the imputation method described for Herne and Castrop-Rauxel. The Wahlarchiv, however, gives us a static shapefile of the municipal voting districts (and hence its polling districts) (Stadt Herten 2017), which we digitize as a shapefile in QGIS. Finally, we aggregate the election results for our community-level dataset at the level of city districts. As for other Ruhr cities, we use the shapefile from Regionalverband Ruhr (2022).

XV. Hattingen (52,758)

We source election data for Hattingen from votemanager.de (Stadt Hattingen 2017, 2021, 2025). Specifically, we use election results at the polling station level for 2021 in combination with the relatively detailed documentation of mail-in ballot districts to measure electoral outcomes directly at the level of city districts (N=11). However, the documentation is significantly less comprehensive for 2017, which is why we apportion results only at the level of polling stations. As a result, we need to approximate turnout as the sum of station-level and registered mail-in voters divided by the total eligible electorate. We link these results at the city district with the shapefile for the Ennepe-Ruhr county (Ennepe-Ruhr-Kreis 2024). Finally, we adopt the usual procedure of drawing Voronoi diagrams around the polling station to approximate Hattingen's polling districts within city district boundaries.

XVI. Schwerte (45,954)

Election data for Schwerte is from votemanager.de (Stadt Schwerte 2017, 2021, 2025). The city of Schwerte does not publish results at the level of municipal voting districts, and there is no information available on the correspondence between mail-in ballot districts and polling districts. As a result, we assign polling stations based on their location to a city district, with city district boundaries extracted from Regionalverband Ruhr (2022). We adjust party support at the polling district level by accounting for support levels in mail-in ballot districts, acknowledging substantial differences between mail and in-person voters. Turnout is approximated as the sum of polling station-level and registered mail-in voters, divided by the total eligible electorate. As in several other cities, we use the geolocation of the polling station to approximate polling district boundaries using Voronoi diagrams.

XVII. Herdecke (23,158)

We collect election data for Herdecke, the smallest city in our dataset, from votemanager.de (Stadt Herdecke 2017, 2021, 2025). Unlike several other cities, Herdecke offers a shapefile of polling districts and links polling stations with mail-in ballot districts. The shapefile is taken from Ennepe-Ruhr-Kreis (2022). We then aggregate the results at the mail-in ballot districts by spatially uniting polling districts belonging to the six (2021, 2025) or four (2017) mail-in ballot districts. Finally, we apportion the election results at the level of city districts from Regionalverband Ruhr (2022). For polling station results, we simply use the existing shapefile.

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