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The Capitalization of Coal Phase-Outs into Residential Property Values

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Abstract

How do residential real estate markets value large-scale climate policies? We study how Germany's coal phase-out affects residential property values near decommissioned coal-fired power plants. Combining detailed residential property listing data from 2007 to 2023 with the staggered timing of plant closures, we estimate dynamic spatial difference-in-differences (DiD) models that account for the geographic proximity. Nearby residential property values decline by 8.2%, implying aggregate homeowner wealth losses of approximately €1.9 billion. To distinguish economic from environmental adjustment, we examine changes in local employment, population, purchasing power, and local air pollution. Declines in population, employment and purchasing power coincide with falling residential property values, whereas improvements in air quality do not seem to offset these losses. Our findings show that residential real estate markets primarily capitalize the deterioration of local economic fundamentals rather than improvements in environmental quality, implying that climate policy generates substantial localized household wealth effects through residential real estate markets – a distributional channel that complements conventional evaluations focused on aggregate environmental benefits and macroeconomic adjustment.

JEL classification

Q40, Q48, R12, R31

Keywords

asset pricing, housing prices, climate policy, wealth effects, real estate

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1 Introduction

Understanding who ultimately bears the economic costs of climate policy has become a central question for both economics and finance. While the environmental benefits of decarbonization are broadly shared across society, its economic costs may be geographically concentrated and capitalized into local asset prices. This question is particularly important for residential real estate because owner-occupied housing constitutes the dominant asset on household balance sheets while simultaneously serving as a consumption good, an investment asset, and the primary collateral for mortgage borrowing. Consequently, changes in residential property values provide a revealed-preference measure of how climate transition policies affect household wealth, borrowing capacity, and the distribution of private wealth.

Germany's coal phase-out provides a unique setting to study these questions. As one of the world's largest industrial economies, Germany has committed to achieving climate neutrality by 2045 (Federal Climate Change Act, 2021). To operationalize this long-term goal, intermediate goals are the reduction in emissions of greenhouse gases by 65% compared to 1990 levels by 2030, and by 88% by 2040. A central component of this strategy is the gradual retirement of coal-fired electricity generation, which remains the largest source of carbon emissions within the energy sector (Oei et al., 2019).[1] Over the past decades, a substantial share of coal-fired power plants have been decommissioned, with 69 coal-fired generation unit closures between 2011 and 2023 reducing coal-based electricity generation by approximately one half.[2] Under current legislation, all remaining hard-coal and lignite-fired generation units will be retired by 2038.[3]

[1]In 2022, the German energy sector was the largest emitter of greenhouse gases among defined sectors in the Federal Climate Change Act (*Bundesklimaschutzgesetz*), releasing 257 million tons of carbon dioxide (CO_2) equivalents, i.e., 34% of the country's total greenhouse gas emissions that year (UBA, 2024).

[2]Including coal-fired generation units larger than 10 MW net installed generation capacity.

[3]Referring to the currently as operating listed electricity generation units in the power plant list of the Bundesnetzagentur (BNetzA, 2026) as of November 2025. The Coal Phase-Out Act (*Kohleausstiegsgesetz*) mandates further gradual closure of coal-fired capacity. For lignite-fired power plants, the act initiated a fixed

As in many countries, Germany's coal phase-out has been politically contested, with environmental and health concerns weighed against the lobbying of the country's largest unions, who emphasize the risk of regional socio-economic decline (Blonz et al., 2026; Brauers et al., 2020). Expected local socio-economic concerns include a decline in employment, population numbers, real wages of affected workers and tax revenues (Haywood et al., 2024; Heinisch et al., 2021; Oei et al., 2019; Reitzenstein et al., 2022).[4] Additionally, the phase-out is associated with improved environmental and health outcomes due to reduced (negative) externalities of fossil infrastructure (Oei et al., 2019). The improvement of environmental quality on a local level occurs primarily due to fewer airborne pollutants, in addition to improving global climate outcomes by reducing carbon emissions (Li & Jin, 2024; Mei et al., 2021; Rivera & Loveridge, 2022). Whether the positive environmental effects outweigh the negative local economic consequences remains an open empirical question. More importantly, little is known about how these opposing forces are reflected in private asset values and, consequently, how the costs of climate policy are distributed between households, firms, and the public sector. This question is central for understanding both the welfare consequences and the political acceptance of the energy transition.

Despite the scope of the coal phase-out – comparable to climate policy measures implemented in many other countries – robust evidence on its effects remains limited. In particular, the individual burdens and benefits, as well as their distribution between private and public actors, are poorly understood. Residential property values are particularly informative in this context because they capitalize households' valuation of both local economic opportunities and environmental amenities into the largest asset

road map to close all units until 2038. For hard-coal plants, the act defines competitive tendering rounds that aim to ensure an economically efficient order of closures by 2027. Afterwards, regulatory policy determines the remaining closures by 2038 at the latest.

[4]The adverse economic effects during the transformation period are addressed by public subsidies supporting coal regions with €41 billion until 2038 through the Coal Regions Structural Strengthening Act of 2020 (*Strukturstärkungsgesetz Kohleregionen*) (Brachert et al., 2023).

held by most households (e.g., Doling & Ronald, 2010). Whether climate transition policies ultimately increase or decrease local residential property values therefore remains theoretically ambiguous.

This ambiguity is naturally captured by the spatial equilibrium framework of Rosen (1979) and Roback (1982). It conceptualizes the relationship between local wages, housing prices, and amenities. In this framework, household utility equalizes across locations through perfectly mobile sorting. Locations with superior levels of amenities inherit lower levels in wages or higher housing prices. The closure of a coal-fired power plant generates two opposing shocks in this setting: Environmental quality improves through lower air pollution, noise, and traffic, i.e. a positive effect on local amenities. At the same time, employment opportunities decline because of negative local labor-demand effects. These two channels imply opposing effects on residential property values, rendering the overall capitalization effect theoretically ambiguous and ultimately an empirical question. Residential property values summarize households' willingness to pay for these competing effects while simultaneously incorporating expectations about future regional development. Consequently, they provide a revealed-preference measure of the localized economic incidence of climate transition policies and their effects on household wealth.

We study whether climate transition policies are capitalized into residential property values using quasi-experimental variation generated by coal-fired power plant closures. Our empirical strategy exploits spatial and temporal variation in plant retirements within a difference-in-differences (DiD) framework comparing houses located close to retiring plants with otherwise similar houses located further away. We estimate dynamic treatment effects using the robust event-study estimator of Sun and Abraham (2021) combined with a hedonic pricing framework. Our analysis combines highly disaggregated housing advertisement data from the RWI-GEO-RED database (RWI & ImmobilienScout24, 2023) with detailed information on coal-fired power plants, neighborhood characteristics, local air pollution, and prevailing wind directions. The data allow us to analyze approximately 160,000 residential properties located within eight kilometers of 18 major coal-fired power plants between 2007 and 2023. Beyond average treatment effects, we investigate heterogeneity across plant and housing characteristics and study effect differences when integrating the average wind direction at plant sites. We further estimate the effects on local air pollution and socio-economic outcomes to examine mechanisms underlying observed price changes.

We find that residential real estate markets respond strongly to coal-fired power plant closures, with residential property values declining by 8.2% within two kilometers of affected plants. A back-of-the-envelope calculation implies aggregate losses of approximately €1.9 billion in privately held housing wealth for homeowners living close to the affected facilities. These results demonstrate that climate transition policies generate economically meaningful valuation effects on household balance sheets, implying that a substantial share of the costs of decarbonization is borne through changes in private asset values rather than solely through labor-market adjustment. While environmental benefits accrue broadly beyond coal regions, the associated wealth losses are geographically concentrated (Dehio et al., 2025). Exploring the mechanisms through which housing prices are affected, we find simultaneous declines in population, employment, and purchasing power following plant closures, while local air pollution levels simultaneously decline. Additionally, we explore various heterogeneities related to power plant characteristics, including plant type, size, and the nature of decommissioning. Notably, we find effects to be concentrated around retired lignite-fired power plants (-14.9%) indicating that the economic shock is more pronounced in former lignite regions characterized by a stronger economic dependence on coal-fired energy production. We also examine housing characteristics, such as size, age, and price of properties.

Our paper contributes to three strands of literature. First, we contribute to the literature studying how public policies are capitalized into asset prices (e.g., Bauer et al., 2017; Caballero et al., 2023; Eichholtz et al., 2023; Fraenkel et al., 2024; Mei et al., 2021; Rivera & Loveridge, 2022). We show that climate transition policies generate economically meaningful revaluations of residential real estate and thereby affect household wealth. We show that residential real estate markets capitalize the interaction of deteriorating local economic fundamentals and improving environmental quality following large-scale climate policy interventions.

Second, we contribute to the literature on the distributional consequences of climate policy and structural transformation. Existing research has primarily focused on labor-market adjustment, firm outcomes, public finances, and regional economic development following the decline of fossil industries, i.e. retired plants or closing mining sites (e.g., Bartram et al., 2022; Blonz et al., 2026; Gathmann et al., 2020; Haywood et al., 2024; Rud et al., 2024; Walker, 2013). We complement this literature by showing that an important share of the costs of decarbonization is borne through changes in privately held housing wealth. Our results therefore identify residential real estate as an important transmission channel through which climate policy affects household wealth.

Third, we contribute to the literature on regional adjustment following industrial transitions by disentangling the competing roles of environmental improvements and local economic shocks (e.g., Andrikogiannopoulou et al., 2025; Bothe, 2024; Currie et al., 2015). Combining detailed housing market data with information on air pollution, neighborhood characteristics, and prevailing wind directions allows us to investigate the mechanisms underlying capitalization effects. We show that although local air quality improves following plant closures, declines in employment, purchasing power, and population dominate households' valuation, particularly around lignite-fired power plants. These findings provide new evidence on how environmental and economic channels jointly shape residential asset values during large-scale structural change.

Our findings have broader implications for finance and climate policy. Because owner-occupied housing represents the dominant asset for most households and serves as the primary collateral for household borrowing, localized changes in residential property values translate directly into changes in household wealth, borrowing capacity, and financial resilience. Residential property values thereby capture a dimension of the private costs of decarbonization that is largely absent from conventional evaluations of climate policy. These concentrated wealth losses may also shape the political economy of the energy transition. When the costs of climate policy are borne visibly by homeowners in affected regions while its benefits accrue diffusely, local opposition to further decarbonization may intensify and contribute to regional political polarization. Understanding these wealth effects is therefore essential for assessing both the economic incidence and the long-run political acceptance of the transition to climate neutrality.

2 The German coal phase-out: institutional background and expected effects

2.1 Institutional background

Germany is still the largest producer of coal-fired electricity in the EU and the ninth largest producer worldwide in 2023 (Wiatros-Motyka et al., 2024).[5] However, the current state of Germany's coal generation infrastructure is comparable to that of other European

[5] Coal remains a widely used source for electricity generation worldwide, with coal-based generation increasing by 1.9% in 2023 (IEA, 2024). However, the growth in global coal use for electricity generation is projected to slow in 2024 and level off by 2025 (IEA, 2024). The recent rise in coal generation was primarily driven by developments in China, India, Vietnam, and Mexico, where low hydro output affected the electricity generation shares that year (Wiatros-Motyka et al., 2024).

countries. Consequently, potential external effects from power plant closures–such as reductions in airborne pollution but also economic effects are likely to be of similar magnitude across these nations. German coal-fired power plants rank high among the most emission-intensive plants across Europe, considering overall carbon emissions and airborne pollutants. Nevertheless, German plants are equipped with comparatively modern filters for SO_2 and NO_X emissions, which lowers emissions per production unit, especially compared to plants in Romania and Bulgaria (Jones et al., 2016). However, due to the large production volume, six German plants rank among the most toxic European coal power plants defined by most associated premature deaths (Jones et al., 2016). In terms of carbon emissions, the same six German coal power plants are among the top ten emitting plants in Europe in 2022 (Fox, 2023).

Figure 1 displays annual developments in the German electricity mix. Until 2009, hard coal and lignite generation levels remained steady, followed by a slight increase until 2013 (Pahle, 2010). Since then, the combined share of hard coal and lignite has dropped by more than half by 2023 and is on a long-term declining trend. Within the EU, coal generation dropped by 25% in 2023, with Germany contributing the largest share to this reduction.[6]

< Include Figure 1 about here >

Germany's coal phase-out is part of–or the result of–a lengthy political process and is governed by various individual laws. The Integrated Energy and Climate Programme (*Integriertes Energie- und Klimaprogramm*) in 2007 has driven the recent reduction in coal capacity by setting the climate goal to a 40% reduction in greenhouse gas emissions

[6] In 2023, the German energy sector achieved a record annual reduction in greenhouse emissions by 20.1% compared to 2022 levels, which was primarily due to the sharp decline in electricity generation from lignite and hard coal (Council of Experts on Climate Change, 2024). Coal-fired power plant closures occur either in response to market forces or as a result of regulatory incentives. Several plants were decommissioned before reaching the end of their technically feasible lifespans. In the case of hard coal plants, these premature shutdowns were often driven by electricity market conditions with low electricity prices (Oei et al., 2019).

compared to 1990 levels by 2020. However, the program still emphasized coal-fired power plants as a viable component of the future energy mix when combined with carbon capture and storage (CCS). Similarly, in 2010 the Energy Concept (*Energiekonzept*) proposed the introduction of coal-fired power plants that could be considered carbon neutral in combination with CCS by around 2050 (Oei et al., 2020). The Climate Action Programme 2020 (*Aktionsprogramm Klimaschutz 2020*), approved in 2014, set an overall emission reduction target for 2020 but did not specify targets for the energy sector. In 2018, the federal government established the Commission on Growth, Structural Change and Employment (*Kommission 'Wachstum, Strukturwandel und Beschäftigung'*) which published its recommendations in 2019 (BMWi, 2019). Following these recommendations, the federal government passed the Act to Reduce and End Coal-fired Power Generation (*Gesetz zur Reduzierung und zur Beendigung der Kohleverstromung*), i.e. the so-called Coal Phase-out Act (*Kohleausstiegsgesetz*) in 2020, which prescribes the coal phase-out by 2038 at the latest.[7] Furthermore, the Coal Regions Structural Strengthening Act of 2020 (*Strukturstärkungsgesetz Kohleregionen*) accompanies the expected negative regional economic effects of the transition (Brachert et al., 2023).

By the end of 2023, 37 countries worldwide had established a coal phase-out timeline in their national plans. Most of them are advanced economies in Europe (IEA, 2023). Among the 23 European countries with established coal phase-out plans, Germany has set the second-latest deadline to end coal generation (Beyond Fossil Fuels, 2024). The long tradition of coal mining and the historic importance of the coal and steel sector in Germany shape the transition process away from coal. Technological challenges, like the mono-industrial reliance in former coal regions, along with cultural factors such as regional identity, hamper a rapid phase-out which took place for example in the UK

[7]Between 2011 and 2016, 51 hard coal units were taken offline, resulting in a total capacity reduction of 10.6 GW, while three lignite units were transferred to the security reserve, corresponding to an additional 0.9 GW decrease in capacity (BMWi, 2018).

(Brauers et al., 2020). The longstanding association of coal with economic growth and strong ties between trade unions, employers associations, companies, and various levels of government have contributed to a slower transition away from coal (Reitzenstein et al., 2022).

While phase-out strategies heavily depend on local circumstances and market structures, Germany's historical reliance on coal in its energy mix is comparable to the UK for example, which implemented a much faster phase-out and closed the last coal-fired power plant in 2024 (Brauers et al., 2020). A major difference between the German and UK coal phase-outs is the direct and indirect subsidies supporting domestic mining in Germany. These subsidies, which remained in place until EU legislation banned them in 2018, helped prevent the steep production decline experienced in the UK. Currently, two major components of Germany's strategy are a regional support program and a tendering mechanism that compensates workers, companies, and plant owners alike (IEA, 2021).

2.2 Expected effects

Residential property values reflect the discounted value of future housing services and location-specific benefits. Within the spatial equilibrium framework of Rosen (1979) and Roback (1982), any persistent change in local environmental quality or economic opportunities is capitalized into residential real estate values. The closure of coal-fired power plants simultaneously improves environmental amenities while weakening local economic fundamentals through employment losses, lower expected incomes, population decline, and reduced municipal fiscal capacity. These opposing forces affect the expected future value of residential locations and are therefore reflected in housing prices. Whether residential property values ultimately increase or decrease is theoretically ambiguous and constitutes an empirical question.

Coal-fired power plants impose substantial environmental externalities on surrounding communities. Besides greenhouse gas emissions, they emit nitrogen oxides, sulfur dioxide, mercury, and particulate matter, all of which are associated with adverse health outcomes and environmental degradation (Oei et al., 2019).[8] They also generate noise, heavy traffic, and visual disamenities (Davis, 2011). Decommissioning plants is therefore expected to improve local environmental quality and public health, increasing the attractiveness of nearby residential locations. Since households value cleaner air and healthier living conditions, these improvements should be capitalized into higher residential property values.

At the same time, coal plant closures represent major negative local economic shocks. Coal-fired power plants and their supply chains provide relatively well-paid employment, particularly in lignite regions where mining and electricity generation are spatially concentrated (Brachert et al., 2023).[9] Plant closures therefore reduce labor demand directly through employment losses at power plants and indirectly through supplier linkages and lower local consumption (Oei et al., 2019). Beyond employment, affected workers are also likely to experience persistent wage declines because coal-sector jobs typically offer above-average earnings (Heinisch et al., 2021; Oei et al., 2020). Lower expected local incomes reduce housing demand and, consequently, residential property values.

[8]The overall environmental costs of emitting greenhouse gases in coal-fired electricity generation were estimated to be 46 billion Euros in 2016 in Germany alone (Drosihn et al., 2017). Air pollutants do not only represent a problem locally, but are also carried over longer distances and are associated with health implications across borders. Associated health outcomes are aggravated respiratory illness, cardiovascular illness, and chronic effects on the nervous system. There are further negative effects on soils and bodies of water impeding biodiversity. These external costs are many times higher than the current electricity wholesale price (Oei et al., 2019). However, most externalities from coal-fired power plants remain unaddressed by current environmental policies. For example, ultra-fine particulate matter, mercury emissions, and sulfur dioxide emissions are not part of the emissions trading system or the energy tax.

[9]In 2018, about 18,500 people worked in open-cast lignite mines and power plants nationwide, and about 4,000 to 8,000 people worked in hard coal-fired power plants, which run on imported coal exclusively (Oei et al., 2019). Corresponding estimates for the same year placed the total number of indirectly associated and induced jobs between 38,100 and 42,900. Indirectly associated jobs refer to suppliers to the coal industry, while induced jobs are those created in businesses that benefit from coal industry workers spending their earnings. Although the employment effects of renewable energies are expected to more than offset the losses at the national level, there are still significant local negative effects due to spatial concentration.

Economic adjustment may further amplify these effects. Lower employment opportunities can induce out-migration, reducing local population and housing demand (Heinisch et al., 2021; Oei et al., 2020). Declining economic activity may also weaken municipal finances through lower tax revenues and reduced dividend payments from municipally owned energy companies. Reduced fiscal capacity can constrain public investment in schools, transport infrastructure, recreational facilities, and cultural amenities, thereby lowering the attractiveness of affected municipalities (Reitzenstein et al., 2022).[10] These developments reduce the expected future stream of local amenities and economic opportunities that households capitalize into residential property values.

The magnitude of these economic effects is likely to differ across coal regions. Lignite-fired power plants are closely tied to nearby mining operations because lignite is uneconomical to transport over long distances. As a result, employment losses tend to be geographically concentrated and local economies are often highly specialized. Former hard coal regions, by contrast, generally exhibit more diversified industrial structures and may therefore adapt more easily to structural change (Reitzenstein et al., 2022). Consequently, the negative capitalization of economic adjustment costs into residential property values is expected to be stronger in lignite regions than in hard coal regions.

Overall, coal plant closures simultaneously improve local environmental quality while reducing local economic prospects. Residential property values capitalize both sets of expectations. Whether property prices increase or decrease is therefore an empirical question that depends on the relative importance of environmental improvements and local economic decline.

[10] Regional compensation of losses through renewable energy uptake is unlikely since their spatial allocation is less regionally concentrated. The federal government of Germany enacted the so-called Coal Regions Structural Strengthening Act of 2020 (*Strukturstärkungsgesetz Kohleregionen*) to support coal regions with €41 billion by 2038 at the federal level Brachert et al. (2023). The resulting policy mix consists of a diverse set of measures addressing areas that range from education to health and culture. For example, it includes compensation payments for laid-off workers above the age of 58 years and the balancing of their pensions.

3 Data

3.1 Power plants

We combine data on fossil electricity generation infrastructure from the Core Energy Market Data Register (*Marktstammdatenregister*) and the List of Power Plants by the Federal Network Agency (*Kraftwerksliste der Bundesnetzagentur*) (BNetzA, 2023, 2024). The level of the initial data set is the electricity generation unit (EGU), containing individual blocks of coal-fired power plants. In the first step, we restrict the sample to fossil units (oil, natural gas, hard coal, and lignite) that were active at one point between 2007 and 2023, have a given geographical location, and comprise a net installed capacity of more than 10 MW. Most power plants contain multiple EGUs. To perform the analysis at the power plant level, we define all EGUs located within a one-kilometer distance from each other as belonging to the same power plant. We use the point coordinate of the geographical center of all grouped EGUs to calculate distances relative to power plants. The resulting sample includes 57 plants. See Figure 2 for an overview of their spatial allocation.

< Include Figure 2 about here >

In addition to precise geographical coordinates, the data contain the installed net capacity and number of EGUs by fuel type for each period, the age of the power plant, and of each associated EGU. The power plants left in our sample use natural gas and oil alongside hard coal or lignite as input fuels. On average, power plants commissioned their first associated EGU 42 years ago relative to the end of the sample period and have an average net installed capacity of 720 MW. We present three types of coal-fired power plants concerning changes in installed electricity-generating capacity over the sample period. First, full closure power plants permanently decommission all associated EGUs between

2007 and 2023. Second, partially closed power plants decommission some but not all EGUs. Lastly, non-closing power plants have no decrease in net installed capacity over the sample period. We present individual power plant characteristics in Table 1. Panels A and B present fully and partially closing power plants, which enter our main regressions. Panel C presents additional coal-fired power plants that have not decreased their installed capacity.

< Include Table 1 about here >

3.2 Houses for sale

We use the data set *RWI-GEO-RED* by the Research Data Center Ruhr, which contains private real estate advertisements in Germany from 2007 to 2023 (RWI & Immobilien-Scout24, 2023).[11] The data set is based on advertisements from *ImmobilienScout24*, the leading online marketplace for real estate in Germany (Schaffner & Thiel, 2023). It includes detailed housing characteristics and the geographical location of 1-square-kilometer grid cells. We focus on properties of the 'houses for sale' type.[12]

We restrict the data set to houses around the treated coal-fired power plants.[13] Here, we use the centroid of the houses' grid cell and the point locations of coal-fired power plants to approximate the Euclidean distance. We remove observations with missing geographical information and special property types such as castles and mansions. Additionally, we remove houses with extraordinary characteristics. We drop observations with listing prices below €1,000 and above €10 million. We do not consider observations with less than 25 and more than 500 m^2 of living space, and houses with less than 50 m^2 of plot area.[14] We exclude houses with more than 11 rooms and houses older than 200 years. In the

[11] We use version 9 of the data set, which was published in 2023.

[12] Several applications utilize this data set for localized housing price analyses and argue for its representativeness and only moderate upward bias compared to transaction prices (e.g., Bauer et al., 2017; Brausewetter et al., 2024; Frondel et al., 2020; Micheli et al., 2019).

[13] For our main specification, this area refers to treatment areas between 0 and 2 km of treated power plants and control areas between 3 and 8 km.

[14] The original censoring threshold for the maximum plot area in the data is 5,000 m^2 (Schaffner & Thiel, 2023).

case of repeated advertisements for the same house without major quality changes, we use the latest observation only. Here, we assume this last listed price to be closest to transaction prices and aim to minimize a potential upward bias. Finally, to account for potential changes in housing composition following treatment, our main regressions include key housing characteristics: age, living space, number of rooms, plot area, and dummies for under construction, detached, and multi-family homes. We omit observations with missings in these characteristics. The restrictions result in an estimation sample of 163,125 individual housing observations covering an area of 1,742 km^2.

3.3 Information on socio-economics, wind direction, and emissions

We integrate the regionally disaggregated socio-economic data *RWI-GEO-GRID* by the Research Data Center Ruhr (RWI & microm, 2023).[15] This data set provides household-based information, including total employment, population, and purchasing power (Breidenbach & Heinze, 2025). The data are provided annually for 2005 and 2009–2021 at the 1-km^2 grid-cell level, which is identical to the geographical unit of our housing data. We use a number of characteristics as additional outcomes to explore the channels through which the closure of coal-fired power plants affects housing prices.

We augment the data by the average wind direction at power plant locations using sub-daily (three times a day), station-level data of wind speed and wind direction (DWD, 2023). The German National Meteorological Service (DWD) operates 204 weather stations throughout the sample period between 2007 and 2023.[16] For our measure of average wind direction at each power plant location, we first allocate each plant to its closest weather station. The average distance between power plants and the closest weather stations is 16.8 km, while the maximum distance is 39.9 km. We apply vector averaging

[15] We use version 13 of this data set, which was published in 2023.
[16] See Figure A.1 in the appendix for their spatial distribution.

to calculate the average wind direction for each weather station and allocate the resulting values to matched power plants.[17]

Moreover, we merge annual facility-level emissions data reported to the European Environment Agency (EEA) to the estimation sample (EEA, 2024). We include emissions reported for all German European Pollutant Release and Transfer Register (EPRTR) facilities under the label *thermal power stations and other combustion installations*. Similar to Rivera and Loveridge (2022) we present nitrogen oxide (NO_x) levels following the shutdown of coal EGUs as one of the most detrimental airborne pollutants that is a direct externality of coal-fired electricity generation. Figure 3 shows that annual average NO_x emissions declined substantially for treated power plants that decommissioned at least part of their coal-fired EGUs. For power plants that operate at unchanged net installed capacity, emission levels remain roughly constant. The graphs, furthermore, suggest that treated power plants generated relatively higher emission levels at the beginning of the sample.

< Include Figure 3 about here >

We add regional air quality measures to facility-level data by including ground-level particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2) concentration estimates at a similar geographical unit as housing and socio-economic data (Cooper, 2022; Shen et al., 2024). While Shen et al. (2024) use monitored $PM_{2.5}$ concentrations as their basis and improves local estimates using satellite, simulation-, and monitor-based sources, Cooper (2022) bases NO_2 concentration estimates on satellite instruments.[18]

[17] We follow Li and Jin (2024) and first calculate the vector components for each recorded wind direction. The x-component, which corresponds to east-west, results from multiplying the wind speed by −cosine of the wind direction angle. The y-component, which corresponds to north-south, results from multiplying the wind speed by the −sine of the wind direction angle. After aggregating both components separately, we can determine the average wind direction (Grange, 2014).

[18] Figure A.2 in the appendix shows an exemplary ground-level $PM_{2.5}$ concentration around coal-fired power plants in the German state of North Rhine-Westphalia for the year of 2007. Average concentrations seem to be comparatively higher in the vicinity of plants, but the figure also highlights that coal-fired power plants are only one of many air pollution sources.

4 Empirical strategy

4.1 Identification approach

Our empirical strategy identifies the causal effect of coal-fired power plant closures on residential property values. We focus on properties located in the immediate vicinity of power plants, thereby estimating the capitalization of local rather than global externalities (e.g., CO_2 emissions) into residential real estate values. Exploiting the spatial and temporal variation in German coal-fired power plant closures between 2007 and 2023, we employ a spatial DiD design. To address the potential endogeneity of decommissioning decisions, we compare nearby residential properties around the same treated power plants before and after closure. Restricting the estimation sample to the local surroundings of treated plants minimizes systematic differences in regional characteristics and isolates highly localized capitalization effects. This strategy compares nearby residential properties that are plausibly exposed to similar regional economic conditions and housing market trends while differing in their exposure to plant closures. Such a design mitigates concerns that observed or unobserved regional characteristics – such as land values, economic conditions, or long-run development prospects – that may influence both decommissioning decisions and residential property values bias our estimates (Eichholtz et al., 2023).

In our baseline specification, the treatment group comprises residential properties located within a 2 km linear distance of a treated power plant. This threshold follows Caballero et al. (2023), Davis (2011), Eichholtz et al. (2023), Mei et al. (2021), and Rivera and Loveridge (2022), who document that the external effects of conventional power plants are highly localized. To assess the sensitivity of this definition and characterize the spatial decay of capitalization effects, we additionally estimate treatment effects using 1 km distance increments up to a 5 km radius. We separate treatment and control areas by a 1 km buffer zone to reduce potential spillover effects. The control group is restricted to properties located within an 8 km radius of each plant to ensure comparable local housing market conditions. Panel A of Figure 4 illustrates the resulting treatment and control areas schematically, while Panel B presents an example for the state of North Rhine-Westphalia.

< Include Figure 4 about here >

Power plants are classified as treated once at least one coal-fired generating unit is permanently decommissioned during the sample period. Treatment is absorbing, implying that plants remain treated thereafter and resulting in a staggered DiD design. Figure 5 provides empirical support for our choice of the 2 km treatment radius. It relates facility-level NO_x emissions to average ground-level $PM_{2.5}$ concentrations measured within a 2 km radius of each power plant. The positive association indicates that emissions from coal-fired power plants materially affect local air quality within our treatment area. Consequently, plant closures are expected to generate localized improvements in environmental quality, providing a plausible mechanism through which environmental benefits are capitalized into residential property values.

< Include Figure 5 about here >

To isolate the causal effects of coal-fired power plant closures, we exclude power plants that substitute coal generation with natural gas rather than permanently reducing coal-fired capacity. We classify a plant as fuel-switching if its gas-fired generating capacity increases either before or after the decommissioning of a coal-fired unit. Such investments simultaneously alter local emissions, employment, and economic activity, making it difficult to disentangle the environmental and economic effects of coal-fired power plant closures. Finally, we exclude plants treated after 2021 to ensure that each treated plant contributes at least two years of post-treatment observations.

4.2 Econometric model

We specify an event study model to capture dynamic treatment effects and to investigate pre-treatment trend differences. In our setting, heterogeneous treatment effects may arise due to differences in power plant characteristics and local housing markets. With multiple treatment periods, standard two-way fixed effects (TWFE) estimations could produce biased estimates.[19] For these reasons, we choose the heterogeneity robust estimator by Sun and Abraham (2021), which best fits our setting. The estimator yields separate treatment effects for each cohort and relative time to treatment. Cohorts consist of all coal-fired power plants with the same treatment dates.[20] In our setting, cohorts include between one and three different power plants, depending on whether the first coal unit closures fall into the same year. The obtained dynamic effects are weighted averages of cohort-specific effects, where weights are based on sample shares. Lastly, we pool the overall effects as the simple average of all post-treatment effects as suggested by Sun (2021). Formally, we estimate:

$$Y_{i,j,t} = \sum_{c=2007}^{2021} \sum_{l \neq -1} \theta_{c,l} D_i \times \mathbb{1}[l = t - e_i] \times \mathbb{1}[c = e_i] + X'_{i,j,t}\beta + \alpha_j + \delta_t + \epsilon_{i,j,t}, \qquad (1)$$

where $Y_{i,j,t}$ corresponds to the listing price of an individual house i in municipality j and year t. We present results for both levels (in €) and logs. D_i indicates whether the house is located in the treatment area or control area. $\mathbb{1}[l = t - e_i]$ is a dummy for the relative time to treatment period e_i. We include four annual leads (i.e., from $l <= -5$ to $l = -2$), and five yearly lags (i.e. from $l = 0$ to $l >= 5$), binning periods 5 years before and after the treatment. We argue that effects on housing prices plausibly capitalize in this time frame and assume constant effects within binned periods (Schmidheiny & Siegloch,

[19]See the recent literature on DiD (Borusyak et al., 2024; Callaway & Sant'Anna, 2021; de Chaisemartin & D'Haultfœuille, 2024; Goodman-Bacon, 2021; Sun & Abraham, 2021). We also report the results of a standard TWFE estimation as a robustness check.

[20]We show the annually aggregated number of treatments in Figure A.3 in the appendix.

2023).[21] We normalize the period before treatment. $\mathbb{1}[c = e_i]$ indicates the cohorts based on the treatment period. X'_{ijt} represents housing characteristics including age, age^2, living space, living space^2, number of rooms, plot area, plot area^2, and dummies for being in construction, detached, and multi-family homes, which account for a potentially adapting property composition following the treatment[22]. α_j represents regional fixed effects at the municipality level, δ_t are year fixed effects, and $\epsilon_{i,j,t}$ is an idiosyncratic error term. We cluster the standard errors at the municipality level.

The estimator is a cohort and relative time period-specific ATT, with the control group consisting only of never-treated units that are located further away from power plants. The estimator reports the average ATT for each relative time period as the weighted average of cohort-specific ATTs, where weights are based on sample shares. We furthermore aggregate ATTs following the treatment by taking the simple average of post-treatment effects.

4.3 Plausibility of identification assumptions

Our identification strategy exploits the staggered timing of coal-fired power plant closures to estimate how local environmental and economic shocks are reflected in residential property values. Identification relies primarily on the parallel trends assumption, requiring listing prices in treatment and control areas to have evolved similarly in the absence of plant closures. To make this assumption more plausible, we restrict the control group to properties located in close proximity to treated power plants (3–8 km), thereby comparing neighborhoods exposed to similar regional economic conditions and housing market dynamics.

[21] Figure A.4 in the appendix presents results from our adapted main specification with an expanded effect window of 10 years before and after treatment. First, no pre-treatment differences emerge. Second, the pooled average treatment effect on the treated (ATT) remains remarkably close to our baseline results. Third, persistent negative effects support constant impacts beyond five years post-treatment, although widening confidence bands reflect fewer observations in distant periods. Following Schmidheiny and Siegloch (2023), we select an effect window by checking effect convergence while preserving statistical power.

[22] Our results are robust to omitting housing characteristics from the set of covariates.

Figure 6 provides a first visual assessment of this assumption by plotting average annual listing prices per square meter for properties in the treatment area (0–2 km) and the control area (3–8 km) surrounding treated power plants. Properties in the control area consistently exhibit higher listing prices, consistent with persistent differences in neighborhood desirability associated with the presence of coal-fired power plants. Importantly, however, listing prices in treatment and control areas follow closely parallel trends prior to treatment. The gradual widening of the average price gap over time likely reflects the increasing number of power plants entering treatment during the sample period. Table 2 further documents systematic pre-treatment differences in property characteristics, neighborhood socio-economic conditions, and local air pollution, confirming that treatment and control areas differ in levels but not in their pre-treatment evolution. Beyond this graphical evidence, our event-study specification provides a formal assessment of the parallel trends assumption by estimating dynamic treatment effects prior to plant closures.

< Include Figure 6 and Table 2 about here >

A second identifying assumption is the absence of anticipatory responses prior to plant closures. Such responses appear unlikely in our setting because the exact timing of decommissioning decisions is often determined only shortly before implementation during our sample period, making it difficult for homeowners to anticipate closure dates accurately (Fraenkel et al., 2024). Nevertheless, we assess this possibility in several ways. First, we estimate placebo models assigning random treatment dates. Second, we re-estimate our baseline specification after excluding the two years preceding treatment as well as the treatment year itself. Both exercises yield estimates that are highly consistent with our baseline results. In addition, the event-study estimates reveal no systematic changes in listing prices prior to treatment, providing no evidence of anticipatory responses.

To the extent that some anticipation nevertheless occurred, part of the adjustment in listing prices would occur before plant closure, attenuating the estimated post-treatment effects. Consequently, our estimates should be interpreted as conservative estimates of the underlying effect on residential property values.

5 Empirical results

5.1 Main results

Figure 7 presents our main event-study estimates. We find that residential real estate markets incorporate the consequences of coal-fired power plant closures into significantly lower listing prices for nearby properties. Aggregating the post-treatment coefficients implies an average decline of 8.2% in listing prices. Estimated in levels, this corresponds to an average reduction of €39,378 per property.

< Include Figure 7 about here >

The estimated effects emerge shortly after plant closure and remain remarkably persistent throughout the post-treatment period, indicating a lasting downward revaluation of residential property values rather than a temporary market response. This persistence is consistent with housing markets pricing the expected long-run deterioration in local economic fundamentals. At the same time, we find no evidence of differential pre-treatment trends, lending further support to the credibility of our identification strategy.

5.2 Robustness and sensitivity analyses

Our main findings prove remarkably stable across a wide range of alternative specifications (see Figure A.5 in the appendix). First, we estimate a conventional TWFE model. Although we do not interpret the magnitude of the estimated coefficients because heterogeneous treatment effects may bias TWFE estimators in staggered adoption settings, the estimated effects are quantitatively very similar to our baseline results.

Second, we modify the comparison group by using properties located within 2 km of the last treatment cohort (2022) as the control group, excluding observations from the treatment year onward. This specification compares earlier- with later-treated power plants and therefore relies on the assumption that the timing of plant closures is conditionally exogenous. While this approach yields slight indications of differential pre-treatment trends, the estimated effects remain close to our baseline estimates.

Third, we broaden the estimation sample to include power plants that substitute coal-fired generation with natural gas. Because fuel substitution simultaneously alters local emissions and economic activity, these plants are excluded from our preferred specification to isolate the effects of permanent coal plant closures. Including fuel-switching plants yields economically somewhat smaller effects, corresponding to an average decline of 6.9%, consistent with a weaker revaluation where local economic activity is partly preserved.

We further conduct several exercises to assess the credibility of our identifying assumptions. Assigning random treatment dates produces no systematic post-treatment response (see Figure A.6 in the appendix), providing reassurance that our estimated effects are not driven by spurious time trends. Likewise, excluding the two years preceding treatment as well as the treatment year itself leaves the estimated effects virtually unchanged (see Figure A.7 in the appendix), suggesting that anticipatory responses do not materially affect our results.

To examine the spatial extent of the effects, we estimate treatment effects separately by distance to the power plant. Significant effects are confined to properties located within 2 km of treated plants (see Figure A.8 in the appendix), indicating that the revaluation of residential property values is highly localized.

Finally, we investigate whether regional structural support may already have been incorporated into residential property values. The Coal Regions Structural Strengthening Act (*Strukturstärkungsgesetz Kohleregionen*) came into force in 2020. Restricting the sample to the pre-2020 period yields somewhat larger estimated effects of approximately 11% (see Figure A.9 in the appendix). This pattern is consistent with regional support policies partly mitigating the adverse adjustment of residential property values following plant closures. At the same time, any effects of these policies are likely to remain limited during our observation period, as only 5.5% (€2.2 billion) of the allocated funding had been disbursed by 2024 (Dehio et al., 2025).

5.3 Heterogeneous effects of coal power plant closures

To better understand which local fundamentals residential real estate markets price following coal plant closures, we examine heterogeneity along dimensions related to power plant characteristics, pollution exposure, neighborhood socio-economic conditions, and housing characteristics. Following Sun (2021), we estimate heterogeneous treatment effects by interacting relative-time indicators with the respective characteristics. Compared with estimating separate subsamples, this approach preserves a common comparison group and therefore maintains statistical power. The results are reported in Table 3.

< Include Table 3 about here >

Environmental versus economic channels

Specification (1) of Table 3 interacts treatment effects with the prevailing wind direction. We estimate a small and statistically insignificant effect of −2.2% for properties located downwind of power plants, compared with a highly significant decline of −8.1% for properties located upwind. The substantially weaker response in downwind areas suggests that improvements in local environmental quality partly offset the negative revaluation associated with deteriorating local economic conditions.

Magnitude of local economic adjustment

Across the remaining specifications, a remarkably consistent pattern emerges. The decline in residential property values becomes substantially larger whenever plant closures imply a greater permanent withdrawal of local economic activity. This pattern is most pronounced when distinguishing between full and partial plant closures (Specification (2)). Complete decommissioning results in significantly larger declines (−9.4%) than partial closures, consistent with a larger cumulative reduction in regional employment and economic activity. A similar pattern appears across fuel types (Specification (3)). Lignite-fired power plant closures reduce listing prices by 14.9%, compared with 4.1% for hard-coal plants. This difference is consistent with the greater regional dependence of lignite extraction, which is necessarily co-located with power generation because of high transportation costs. Likewise, closures of high-emission facilities (Specification (4)), which proxy for plant size and the scale of regional adjustment, produce significantly larger declines (−10.6%) than closures of smaller plants, suggesting that residential property markets price the magnitude of the underlying local economic adjustment. The role of economic permanence is further illustrated by fuel-switching plants (Specification (5)). We find no statistically significant response where coal generation is replaced by natural gas, whereas permanent coal plant closures account for essentially the entire estimated decline in residential property values. As an additional mechanism test, we replace listing prices with one-square-kilometer population counts. Areas surrounding permanently closed plants experience significantly stronger population declines, consistent with housing markets pricing the expected out-migration associated with persistent local economic contraction (Brausewetter et al., 2024).

Neighborhood and housing heterogeneity

Beyond plant characteristics, we examine whether capitalization effects differ across neighborhood characteristics. Figure 8 presents estimates by quartiles of population density, purchasing power per capita, the share of foreign residents, and unemployment rates. The strongest declines occur in neighborhoods characterized by low population density, low purchasing power, a low share of foreign residents, and high unemployment. These findings suggest that residential property values are particularly sensitive to negative revisions in local economic prospects where regional labor markets are already comparatively weak and alternative economic opportunities are limited.

< Include Figure 8 and 9 about here >

Finally, Figure 9 explores heterogeneity across housing characteristics. We find little variation between detached and non-detached houses or across property age. By contrast, larger homes and properties with larger plot sizes exhibit more pronounced declines. Since these properties represent larger household asset positions, the estimated percentage declines translate into particularly sizable reductions in homeowner wealth.

6 Discussion and mechanisms

Our main results show that coal-fired power plant closures lead to a persistent decline in residential property values in their immediate vicinity. We next investigate the mechanisms underlying this revaluation. Following the spatial equilibrium framework of Rosen (1979) and Roback (1982), plant closures affect residential property values through two opposing channels. On the one hand, they weaken local economic fundamentals by reducing employment, incomes, and population. On the other hand, they improve environmental amenities by reducing local air pollution. We examine both channels to assess their relative importance for the observed adjustment in residential property values.

To capture these broader adjustment processes, we estimate treatment effects for neighborhoods within a 5 km radius of treated power plants. Because labor market effects and pollution dispersion are expected to extend beyond the highly localized effects on residential property values (Kikuchi, 2025), we compare neighborhoods surrounding treated plants with neighborhoods surrounding the last treatment cohort (2022), excluding observations from the treatment year onward. This approach is better suited to identifying broader regional adjustment than the near-versus-far comparison employed in our baseline specification.

6.1 Economic and environmental channels

Figure 10 reports the estimated effects of coal-fired power plant closures on local population, purchasing power, employment, and unemployment. Across these outcomes, a consistent picture emerges. We find persistent declines of approximately 2.9% in purchasing power, 3.4% in total employment, and 3.1% in local population, while unemployment remains largely unaffected. These findings suggest that labor market adjustment primarily occurs through declining employment, lower regional incomes, and subsequent out-migration rather than through persistent increases in local unemployment. Taken together, these results indicate that residential property markets respond primarily to a deterioration in local economic fundamentals following plant closures. Lower expected regional incomes, declining employment opportunities, and population losses reduce local housing demand and provide a natural explanation for the persistent decline in residential property values documented in Section 5.

< Include Figure 10 about here >

We next turn to the environmental amenity channel. Figure 11 presents the estimated effects on annual average $PM_{2.5}$ concentrations. We estimate a reduction of 0.44 $\mu g/m^3$, corresponding to a 2.8% decline relative to the average pre-treatment concentration of 15.8 μg/m^3. Although statistically significant, this improvement is economically modest compared with the observed decline in residential property values. Using the elasticity estimates reported by Chay and Greenstone (2005), the estimated reduction in particulate concentrations would predict an increase in residential property values of only 0.6–1.0% through the air-quality channel. This effect is substantially smaller than the 8.2% decline estimated in our baseline specification.

< Include Figure 11 about here >

These findings suggest that the observed adjustment in residential property values is primarily driven by deteriorating local economic fundamentals rather than improvements in local environmental quality. Nevertheless, the estimated reduction in local air pollution remains economically meaningful and provides direct evidence that plant closures improve environmental conditions in surrounding neighborhoods.

With respect to health outcomes, Deryugina et al. (2019) estimate that a reduction of 1 μg/m^3 in $PM_{2.5}$ is associated with 0.69 fewer deaths over a three-day period per one million elderly individuals, illustrating that even relatively small improvements in air quality may generate important welfare gains beyond those reflected in residential property values. Further evidence supporting the environmental mechanism comes from the heterogeneity analysis. Table 4 shows somewhat larger reductions in $PM_{2.5}$ concentrations for neighborhoods located downwind of power plants. Although these differences are not statistically significant, they mirror the substantially smaller decline in residential property values observed for downwind neighborhoods in Table 3. Taken together, these findings suggest that improvements in environmental quality partly offset, but do not fully compensate for, the negative valuation effects associated with deteriorating local economic conditions.

< Include Table 4 about here >

6.2 Implications for homeowner wealth

To gauge the wealth implications of our estimates, we conduct a simple back-of-the-envelope calculation of the aggregate reduction in homeowner housing wealth associated with coal-fired power plant closures. Using the RWI and microm (2023) data, we identify 47,580 residential houses located within a 2 km radius of treated power plants in 2021. The average listing price of these properties is €382,024. Combining this information with our estimated average reduction of €39,378 per property implies an aggregate decline in homeowner housing wealth of approximately €1.87 billion.

< Include Table 5 about here >

This estimate captures only one component of the regional costs associated with the coal transition. Additional local adjustment costs may arise through lower municipal tax revenues, reduced social security contributions, lower maintenance investment, or tighter local credit conditions. At the same time, a comprehensive welfare assessment would also need to account for the global benefits of avoided greenhouse gas emissions and improvements in environmental quality (Rauner et al., 2020).

Nevertheless, our calculation highlights that climate policy can generate substantial localized wealth effects for incumbent homeowners through the revaluation of residential real estate. These distributional consequences accompany the broader environmental benefits of the energy transition and are likely to arise whenever climate policies induce geographically concentrated economic adjustment. Quantifying such wealth effects therefore complements traditional evaluations of climate policy that focus primarily on aggregate efficiency or environmental outcomes.

7 Conclusion

The transition to a low-carbon economy requires the large-scale retirement of fossil-fuel infrastructure. While the climate benefits of this transition accrue broadly across regions and generations, its economic adjustment costs are often concentrated locally. This paper shows that residential real estate markets rapidly incorporate these localized adjustment costs into residential property values.

Using highly disaggregated listing data from Germany's largest online real estate platform combined with detailed information on the country's coal-fired power plants, we exploit the staggered timing of plant closures between 2007 and 2023 in a spatial DiD framework. We estimate that the closure of a coal-fired power plant reduces nearby residential listing prices by 8.2% on average, corresponding to an average decline of approximately €39,400 per property. Aggregated across affected neighborhoods, this implies an estimated reduction in homeowner housing wealth of around €1.9 billion.

To better understand the sources of this revaluation, we examine both economic and environmental adjustment. Following plant closures, we document persistent declines in local employment, purchasing power, and population alongside comparatively modest improvements in local air quality. Together, these findings indicate that residential property markets respond primarily to the deterioration of local economic fundamentals, while improvements in environmental quality only partly offset these effects in the most exposed neighborhoods.

Our results carry broader implications for policymakers navigating the structural adjustments that accompany energy transitions, speaking to both finance and climate policy. Residential real estate markets provide a revealed-preference measure of the distributional consequences of climate policy, capturing a dimension of the private costs of decarbonization that aggregate welfare measures miss. Because owner-occupied housing constitutes the largest share of household wealth, localized price declines amount to shocks to the financial health of regional communities. Such wealth effects are likely to arise whenever decarbonization induces geographically concentrated structural adjustment. Accounting for them complements conventional evaluations of climate policy, which focus primarily on aggregate environmental benefits and macroeconomic adjustment. The successful implementation of climate policy ultimately hinges on sustained political acceptance, which may be at risk when structural transitions impose unexpected and concentrated wealth losses on homeowners who have little opportunity to insure against or offset them.

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Table 1: Summary statistics: coal-fired power plants

Power plant name	First coal unit commission	First coal unit decommission (2007 to 2023)	Max capacity coal [MW] (2007 to 2023)	Primary input fuel	Change in gas capacity [MW] (2007 to 2023)	Max annual facility NO_x [t]
Panel A. Fully decommissioned power plants.						
KW Shamrock	01/1957	01/2013	132	Hard coal	0	590
Gemeinschaftskraftwerk Kiel	10/1970	01/2019	323	Hard coal	0	1300
KW Gustav Knepper	01/1971	01/2014	345	Hard coal	0	1230
KW Buschhaus	07/1985	10/2020	352	Lignite	0	1660
KW Ensdorf	10/1963	01/2018	389	Hard coal	0	1320
KW Werdohl-Elverlingsen	01/1971	01/2014	186	Hard coal	0	1650
KW Ibbenbüren	06/1985	07/2021	794	Hard coal	0	3280
KW Moorburg	02/2015	07/2021	1600	Hard coal	0	1510
KW Westfalen	01/1963	01/2011	1528.7	Hard coal	0	2780
KW Frimmersdorf	01/1957	01/2011	2008	Lignite	0	13100
KW Gersteinwerk	06/1984	01/2019	614	Hard coal	-9	2230
KW Voerde	01/1971	01/2017	2030	Hard coal	0	6610
Panel B. Partially decommissioned power plants.						
KW Neumünster	11/1974	04/2021	34.47	Hard coal	0	319
KW Frechen	12/1962	12/2022	176	Lignite	0	753
KW Chemnitz	08/1988	12/2023	150.504	Lignite	88	2180
KW Marl	07/1966	01/2017	163.951	Hard coal	148	2050
KW Flensburg	01/1978	01/2016	123.8	Hard coal	176	317
HKW Reuter West	11/1969	10/2019	688	Hard coal	0	2490
KW Herne	01/1963	01/2014	873	Hard coal	657	2180
KW Knapsacker Hügel	02/1992	01/2015	206	Lignite	1326	1878
KW Staudinger	01/1965	01/2012	1064	Hard coal	0	3590
KW Scholven	01/1968	01/2014	2126	Hard coal	0	9260
KW Wilhelmshaven	01/1968	01/2016	2314	Hard coal	0	2754
KW Weisweiler	01/1955	01/2012	2219	Lignite	0	13400
KW Niederaußem	06/1948	01/2012	3671	Lignite	0	19300
Panel C. No net decrease in capacity power plants.						
KW Stuttgart-Münster	01/1982		110	Hard coal	0	273
HKW Hastedt	12/1989		119	Hard coal	56	721
HKW Wolfsburg Süd	09/1998		122	Hard coal	99	1800
HKW West (Frankfurt)	02/1990		123	Hard coal	39	807
HKW Tiefstack	04/1993		154	Hard coal	127	654
KW Walheim	09/1964		244	Hard coal	0	553
HKW Wedel	11/1993		253	Hard coal	0	921
GKW Hannover	01/1989		272	Hard coal	0	1070
HKW Wolfsburg West	01/1985		277	Hard coal	191	924
HKW Nord (München)	12/1991		333	Hard coal	0	1870
KW Farge	01/1969		350	Hard coal	0	952
KW Fenne	08/1982		390	Hard coal	0	2190
KW Zolling	01/1985		472	Hard coal	0	1550
KW Rostock	10/1994		514	Hard coal	0	2250
KW Weiher	09/1976		656	Hard coal	0	1940
KW Mehrum	08/1979		690	Hard coal	0	2540
KW Bergkamen	10/1981		720	Hard coal	0	2760
KW Bexbach	10/1983		726	Hard coal	0	2730
HKW Altbach/Deizisau	06/1985		756	Hard coal	0	1730
KW Heyden	01/1987		875	Hard coal	0	3250
KW Schkopau	01/1995		900	Lignite	0	4240
KW Heilbronn	08/1965		1028	Hard coal	0	2960
KW Datteln 4	01/1964	01/2013	1052	Hard coal	0	1310
KW Lünen	03/1962	01/2018	1219	Hard coal	0	2300
KW Walsum	01/1959	01/2014	1224	Hard coal	0	3640
Rheinhafen-DKW Karlsruhe	06/1985		1351	Hard coal	0	2240
KW Schwarze Pumpe	12/1997		1510	Lignite	0	6290
KW Lippendorf	12/1999		1782	Lignite	0	8740
GKW Mannheim	01/1966	01/2015	1958	Hard coal	0	4060
KW Boxberg	01/1979		2470	Lignite	0	14000
KW Jänschwalde	10/1981		3000	Lignite	0	20500
KW Neurath	06/1972	12/2021	4211	Lignite	0	22800

Note: Table 1 shows summary statistics for coal-fired power plants. *Panel A* and *B* present power plants that close at least one coal-fired generation unit within the given sample. *Panel C* presents plants that maintained their coal-fired net generation capacity between 2007 and 2023. All capacity columns are given in MW and Emissions in t. In the plant names, 'HKW' refers to a combined heat and power plant, 'KW' to a power plant and 'GKW' to cooperative power plant.
Source: BNetzA (2023, 2024) and EEA (2024)

Table 2: Pre-treatment means

	Estimation Sample			Out-of-Sample
	Means (SE)		Δ	Mean (SE)
	Treatment	Control	in Means	
Panel A. Housing characteristics.				
Price (€)	216,024.4	244,643.3	–28,618.9***	241,167.9
	(1,703.4)	(676.5)		(133.6)
Age	38.3	30.5	7.8***	27.8
	(0.5)	(0.1)		(0.0)
Living space (m^2)	146.7	145.9	0.9	150.8
	(0.8)	(0.2)		(0.0)
# rooms	5.5	5.3	0.2***	5.4
	(0.0)	(0.0)		(0.0)
Base area (m^2)	526.0	546.7	–20.7***	662.8
	(6.2)	(1.9)		(0.4)
Share in construction (%)	6.2	7.8	–1.6***	8.3
	(0.4)	(0.1)		(0.0)
Share detached house (%)	25.8	30.5	–4.7***	42.7
	(0.7)	(0.2)		(0.0)
Share multi-family home (%)	23.0	18.1	4.9***	12.9
	(0.7)	(0.2)		(0.0)
N	4,149	47,830		1,322,760
Panel B. Socio economics.				
Unemployment rate (%)	10.3	8.4	2.0***	6.4
	(0.3)	(0.1)		(0.0)
Population	1,965.8	2,238.0	–272.2*	424.5
	(105.2)	(50.6)		(1.4)
Purchasing power per capita (€)	18,274.8	20,085.6	–1,810.8***	18,162.0
	(186.8)	(63.5)		(6.1)
Foreigners (%)	9.5	8.4	1.1**	3.9
	(0.4)	(0.1)		(0.0)
# households	1,002.6	1,151.7	–149.0*	245.3
	(55.7)	(27.6)		(0.9)
# commercial enterprises	106.2	147.4	–41.2**	20.9
	(7.8)	(5.7)		(0.1)
# residential buildings	348.7	384.2	–35.5**	80.3
	(15.2)	(5.3)		(0.2)
N	338	2,909		619,825
Panel C. Local air pollution.				
$PM_{2.5}$ [$\mu g/m^3$]	15.8	15.2	0.6***	14.1
	(0.0)	(0.0)		(0.0)
N	2,170	24,850		464,870

Note: Table 2 only considers observations before the first treatment in 2011. *Panel A* refers to individual houses for sale observations. *Panel B* presents total values at the annual-km^2-grid-level. Treatment refers to the area between 0 and 2 km of treated power plants, and Control to the area between 3 and 8 km. Out-of-sample observations refer to areas with a distance beyond 8 km from treated power plants. * p<0.10, ** p<0.05, *** p<0.01.
Source: BNetzA (2023, 2024), RWI and ImmobilienScout24 (2023), and RWI and microm (2023)

Table 3: Aggregated effects of coal plant closures on housing prices by subgroups

	(1) Wind direction			(2) Closure type			(3) Power plant type		
	Downwind	Upwind	Δ	Full	Partial	Δ	Hard coal	Lignite	Δ
ATT	–0.022	–0.081***	0.059**	–0.094***	–0.053**	–0.041*	–0.041**	–0.149***	0.108***
(SE)	(0.026)	(0.017)	(0.023)	(0.022)	(0.022)	(0.024)	(0.017)	(0.018)	(0.019)
R^2		0.698			0.698			0.698	
N		209,599			209,599			209,599	
	(4) Air pollution (NO_x)			(5) Fuel-switching			(6) Fuel-switching (population)		
	High emitters	Low emitters	Δ	Fuel-switching	No Fuel-switching	Δ	Fuel-switching	No Fuel-switching	Δ
ATT	–0.106***	–0.044**	–0.062***	–0.041	–0.077***	0.036	–23.4***	–32.5***	9.1
(SE)	(0.016)	(0.019)	(0.016)	(0.027)	(0.018)	(0.023)	(7.4)	(10.7)	(11.9)
R^2		0.698			0.698			0.998	
N		209,599			209,599			3,685	

Note: Table 3 presents aggregated ATT estimated via the robust event study method by Sun and Abraham (2021), with relative time indicators interacted across sample subgroups, as proposed by Sun (2021). Treatment areas are between 0 and 2 km of treated power plants, and Control are between 3 and 8 km. Outcomes in all but the final model are the logarithm of housing prices. Interactions distinguish effects by: (1) upwind vs. downwind areas; (2) power plants fully decommissioning coal capacity (2007–2023) vs. partial shutdowns; (3) lignite vs. hard coal plants; (4) highest vs. lowest emission intensity plants; and (5) fuel-switching plants—defined as those increasing gas-fired capacity at least once during the sample period—vs. non-fuel-switching plants. The last specification examines heterogeneous effects on population density (per km^2) between fuel-switching and non-fuel-switching plants. Here, we define the last treated cohort as the control group and examine the effects up to a five km distance to treated power plants. The aggregated ATT estimate and its standard error pool the effects from years zero to five following the treatment. All but the last (6) specifications control for individual housing characteristics (e.g., age, age^2, living space, living $space^2$, number of rooms, plot area, plot $area^2$, and dummies for in construction, detached, and multi-family homes). All specifications include municipality and yearly fixed effects. Standard errors are clustered at the municipality. Significance levels: * p<0.10, ** p<0.05, *** p<0.01.

Table 4: Aggregated effects of coal plant closures on local air pollution

$PM_{2.5}$		Wind direction		
	Overall	Downwind	Upwind	Δ
ATT	–0.44***	–0.510***	–0.420***	–0.089
(SE)	(0.13)	(0.161)	(0.124)	(0.094)
R^2	0.956		0.956	
N	4,230		4,230	

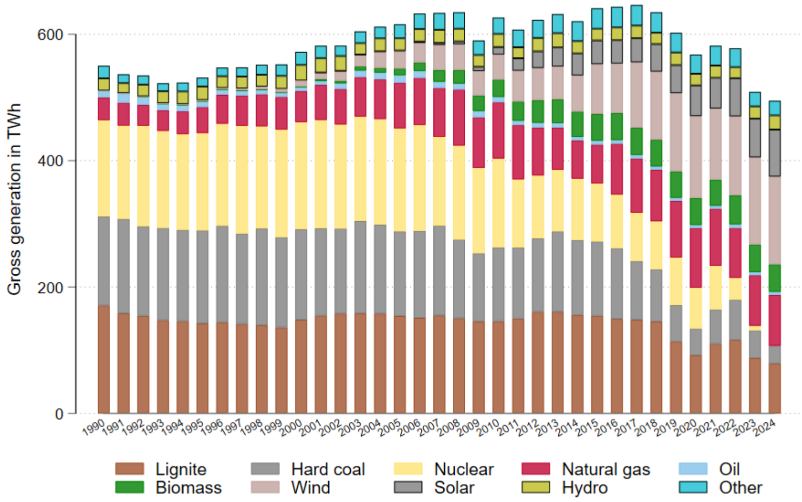
Note: Table 4 shows the aggregated event study point estimates and 95% confidence intervals for the effect of coal-fired power plant closures on local air pollution levels (up to a 2 km distance). Across estimations, we include 1 km^2 grid cell and yearly fixed effects. Standard errors are clustered at the municipality level. The estimator from Sun and Abraham (2021) uses areas around power plants that belong to the last treated cohorts in the sample (2022) as the control group. The table also presents air pollution effects interacted with an indicator for the average wind direction. Significance levels: * p<0.10, ** p<0.05, *** p<0.01.

Table 5: Back-of-the-envelope calculation

Sample	Number of houses	Mean price (€) (observed)	Individual price difference (€)	Overall price difference (€)
All houses within 2 km distance	47,580	382,024	–39,378	–1,873,616,512

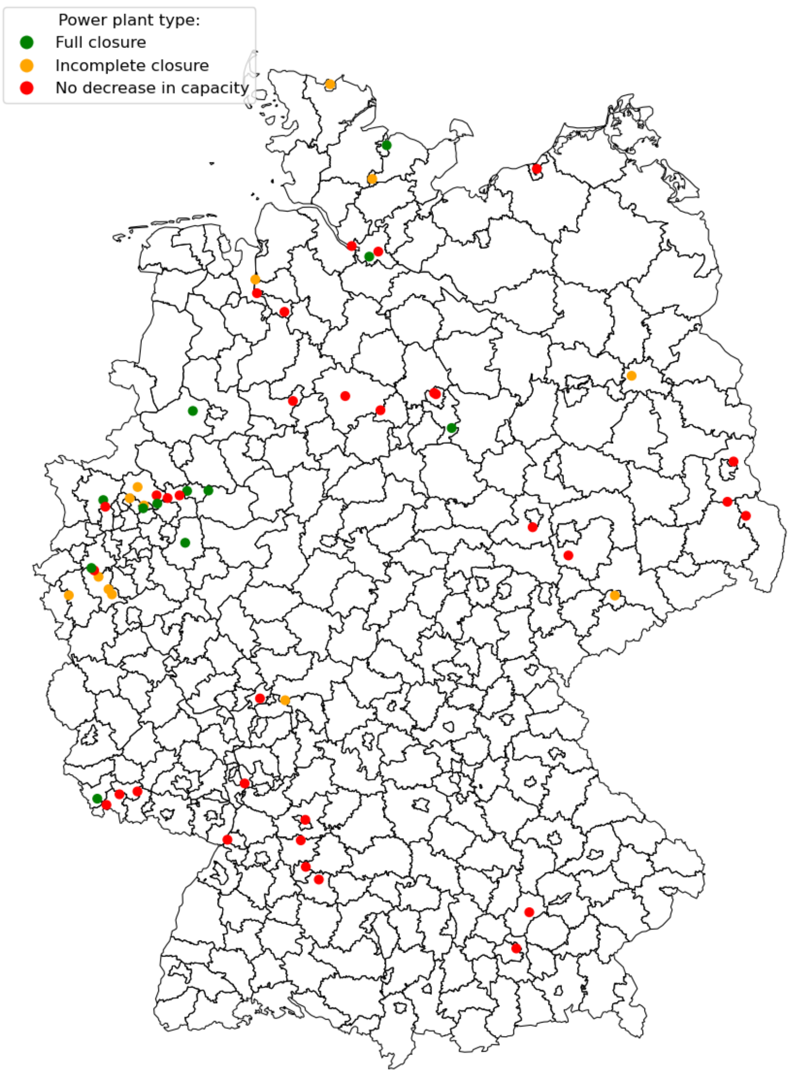
Note: Table 5 uses prices and the number of houses obtained from 2021 observations–the last year of observation in RWI and microm (2023). We use the number of houses two kilometers of coal-fired power plants that were treated between 2007 and 2021. We calculate the mean price of individual houses in these areas in terms of 2021 prices. The individual price difference is taken from our estimation in panel (b) of Figure 7.
Source: RWI and ImmobilienScout24 (2023) and RWI and microm (2023)

Figure 1: Evolution of electricity generation by generation type



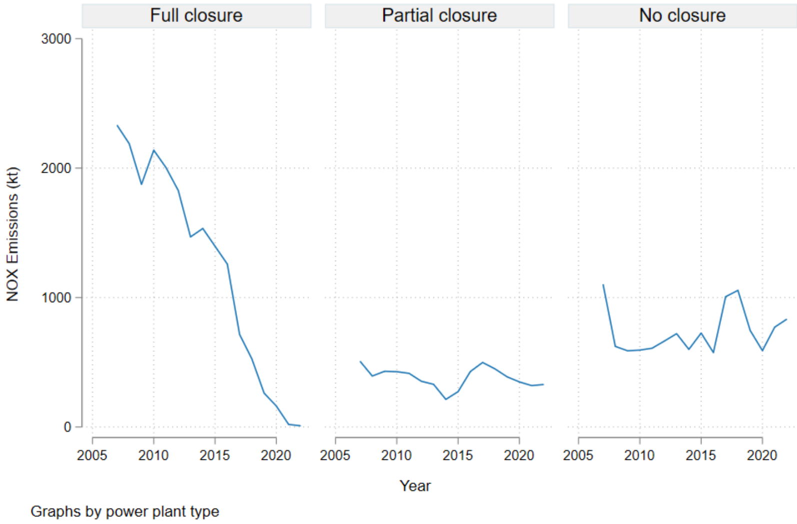
Note: Figure 1 shows the annual gross electricity generation in TWh by generation type in Germany since 1990.
Source: Destatis (2026)

Figure 2: Coal-fired power plant locations



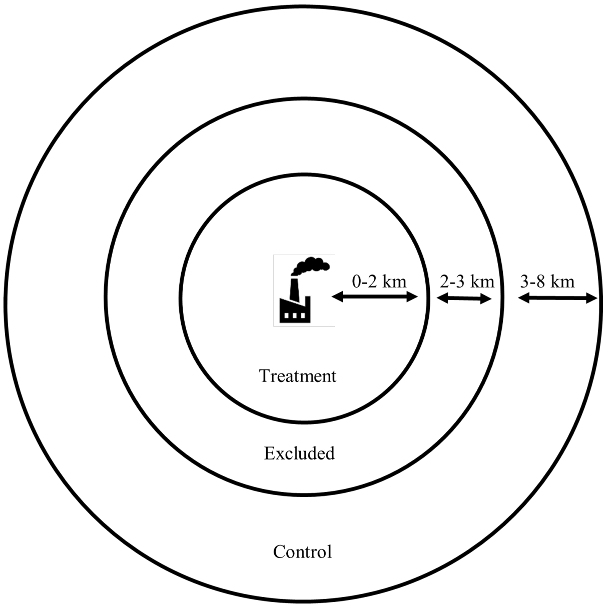
Note: Figure 2 displays the geographical distribution of German coal-fired power plants as of 2023. It distinguishes between fully decommissioned plants, partially decommissioned plants, and those that have maintained their coal-fired net generation capacity between 2007 and 2023.
Source: BNetzA (2023, 2024)

Figure 3: NO_x emissions by power plant type

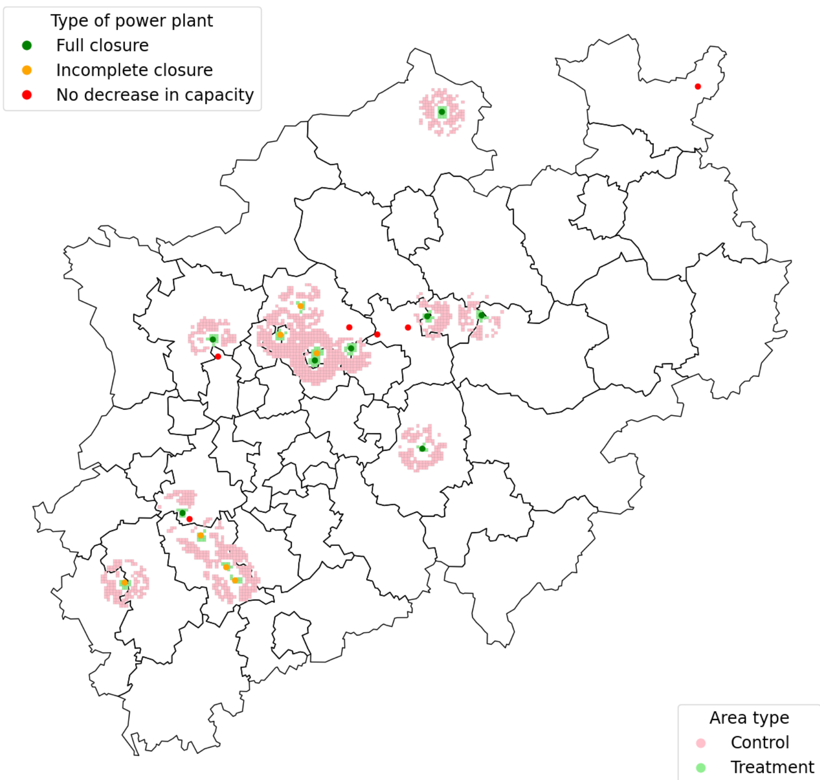


Note: Figure 3 presents annual NO_x emissions (in kt) measured in the one-square-kilometer grid cells containing the matched coal-fired power plants between 2007 and 2023. The figure aggregates emissions by power plant type, distinguishing between fully decommissioned plants, partially decommissioned plants, and those that maintained their coal-fired net generation capacity between 2007 and 2023.
Source: BNetzA (2023, 2024) and EEA (2024)

Figure 4: Treatment and control areas



(a) Schematic representation of treatment and control areas



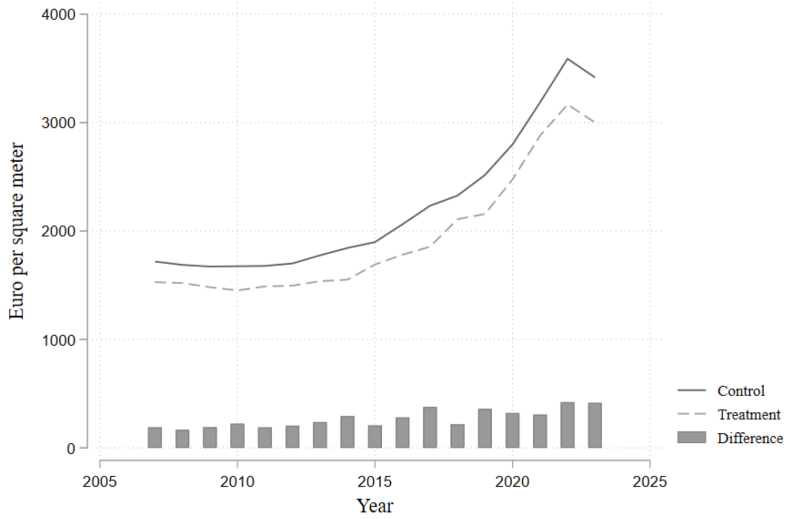
(b) Exemplary illustration: treatment and control areas in NRW

Note: Figure 4 Panel (a) schematically depicts the treatment and control areas in our main specification. Panel (b) illustrates these areas for the example of North Rhine-Westphalia – the German state with the highest concentration of coal-fired power plants – distinguishing between fully decommissioned plants, partially decommissioned plants, and those that maintained their coal-fired net generation capacity between 2007 and 2023. The first two categories represent treated power plants.
Source: BNetzA (2023, 2024)

Figure 5: Facility- and neighborhood-level emissions for highest-emitting treated plants

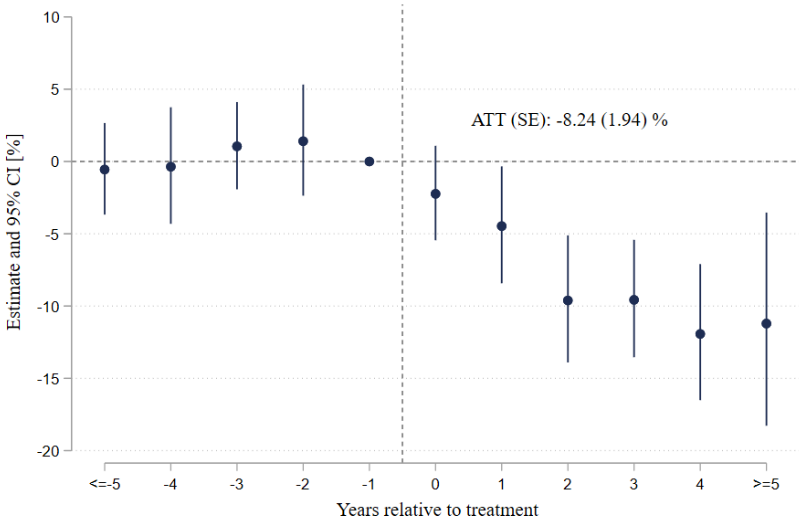
Note: Figure 5 presents annual facility-level NO_x emissions (in kt) alongside annual average neighborhood $PM_{2.5}$ concentrations (in $\mu g/m^3$) for the eight most emission-intensive and treated coal-fired power plants since 2005. The neighborhood level refers to annual average concentrations from all one-square-kilometer grid cells within a 2 km radius of each power plant. Dotted vertical lines indicate the treatment dates of the respective plants (i.e., the year of the first coal unit closure). The labels above the individual plots denote plant names, where 'Heizkraftwerk' refers to a combined heat and power plant and 'Kraftwerk' to a power plant.
Source: EEA (2024) and Shen et al. (2024)

Figure 6: Trends in average housing prices/m^2

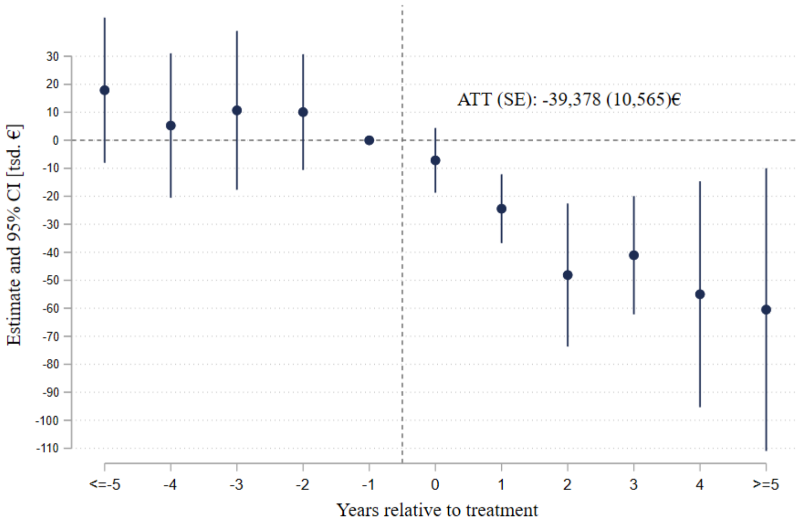


Note: Figure 6 presents average annual housing prices (in €) per square meter across all treatment and control areas. Treatment areas are defined as locations within 0–2 km of treated power plants, while control areas lie between 3 and 8 km. The bars represent differences between the two.
Source: RWI and ImmobilienScout24 (2023)

Figure 7: Effects of coal plant closures on housing prices



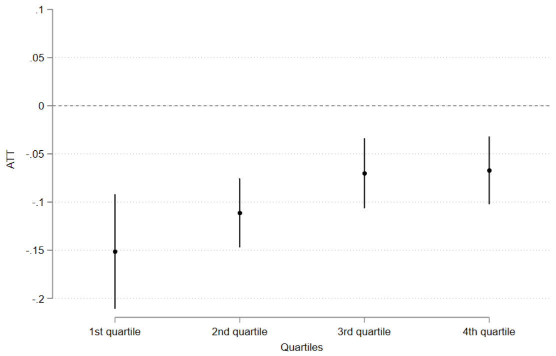
(a) Effects on log housing prices [%]



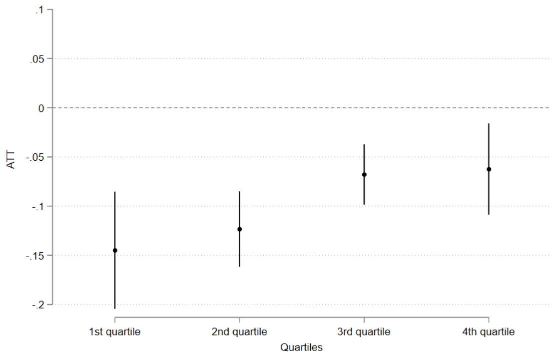
(b) Effects on housing prices [tsd. €]

Note: Figure 7 presents the aggregated ATT from the robust event study estimator of Sun and Abraham (2021), along with event study point estimates and 95% confidence intervals. The outcomes are individual housing prices in logs and levels. The aggregated ATT pools effects from post-treatment years 0 to 5, using the specification in Equation 1 with municipality and year fixed effects, controls for housing characteristics, and standard errors clustered at the municipality level.

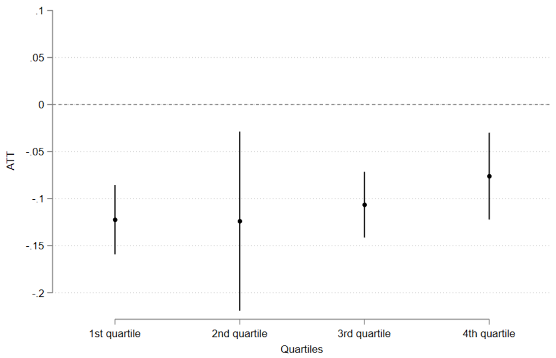
Figure 8: Aggregated effects of coal plant closures on housing prices by socio-economic subgroups



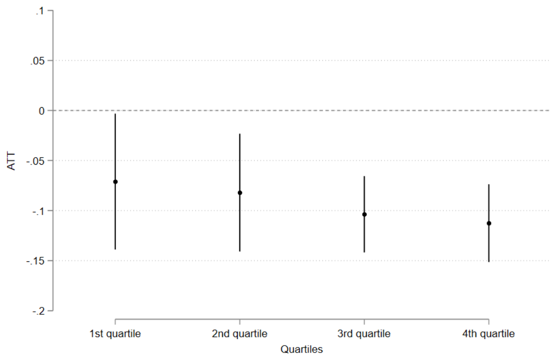
(a) Population



(b) Purchasing power per capita



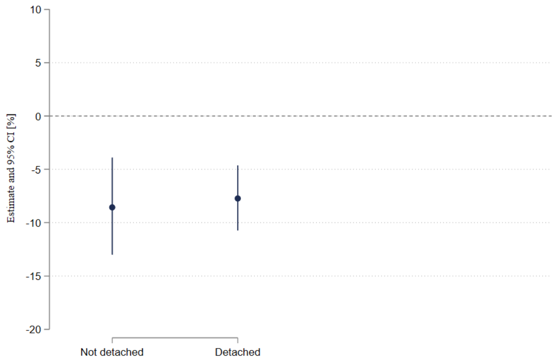
(c) Share foreigners (%)



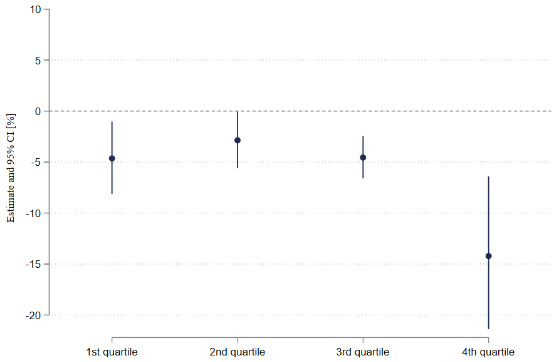
(d) Unemployment rate

Note: Figure 8 shows the aggregated ATT and 95% confidence intervals of the robust event study estimator from Sun and Abraham (2021), where we interact relative time indicators with socio-economic subgroups, as proposed by Sun (2021). The outcome for all specifications is the log of housing price. The four interactions utilize quartiles of average population, purchasing power per capita, share of foreigners, and the unemployment rate at the annual grid cell level between 2007 and 2023. The aggregated ATT estimate and its standard error pool the effects from years zero to five following the treatment. All specifications control for individual housing characteristics (e.g., age, age^2, living space, living space^2, number of rooms, plot area, plot area^2, and dummies for in construction, detached, and multi-family homes). Furthermore, we include municipality and yearly fixed effects. Standard errors are clustered at the municipality level.

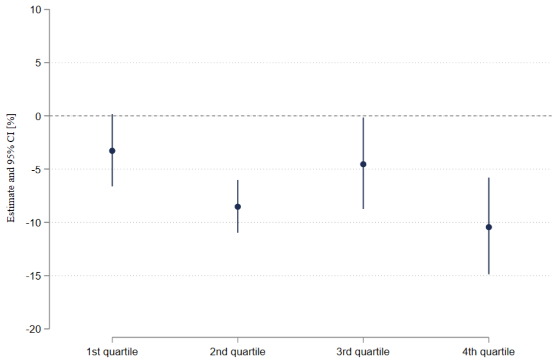
Figure 9: Aggregated effects of coal plant closures on housing prices by housing characteristics



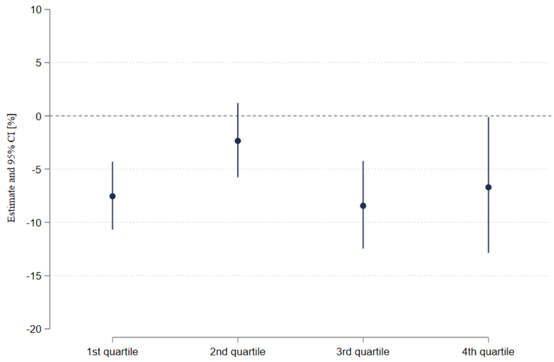
(a) Detached



(b) Living space



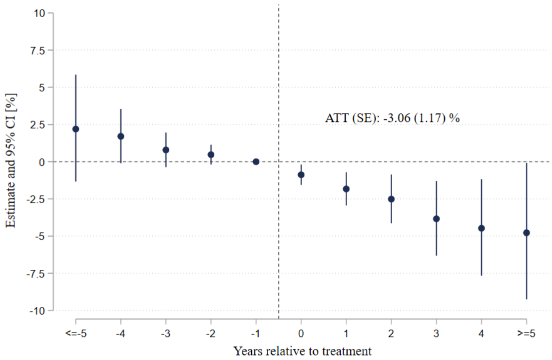
(c) Base area



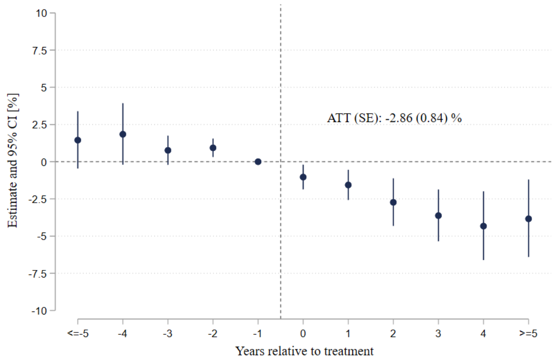
(d) Age

Note: Figure 9 shows the aggregated ATT and 95% confidence intervals of the robust event study estimator from Sun and Abraham (2021), where we interact relative time indicators with housing characteristics subgroups, as proposed by Sun (2021). The outcome for all specifications is the log of housing price. The four interactions utilize the dummy for detached houses and quartiles of living space, base area, and age of individual housing advertisements between 2007 and 2023. The aggregated ATT estimate and its standard error pool the effects from years 0 to 5 following the treatment. All specifications control for individual housing characteristics (e.g., age, age^2, living space, living space^2, number of rooms, plot area, plot area^2, and dummies for in construction, detached, and multi-family homes). Furthermore, we include municipality and yearly fixed effects. Standard errors are clustered at the municipality level.

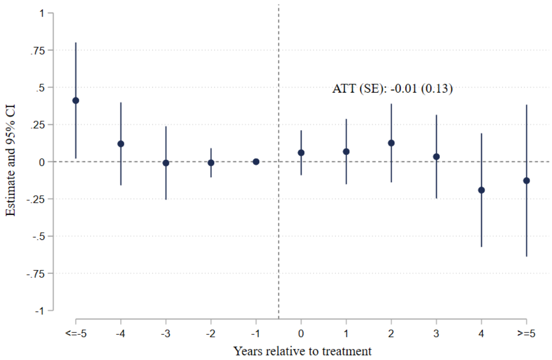
Figure 10: Effects of coal plant closures on socio-economic outcomes



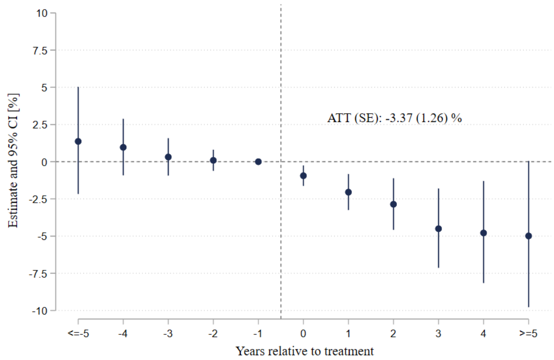
(a) Log population



(b) Log purchasing power



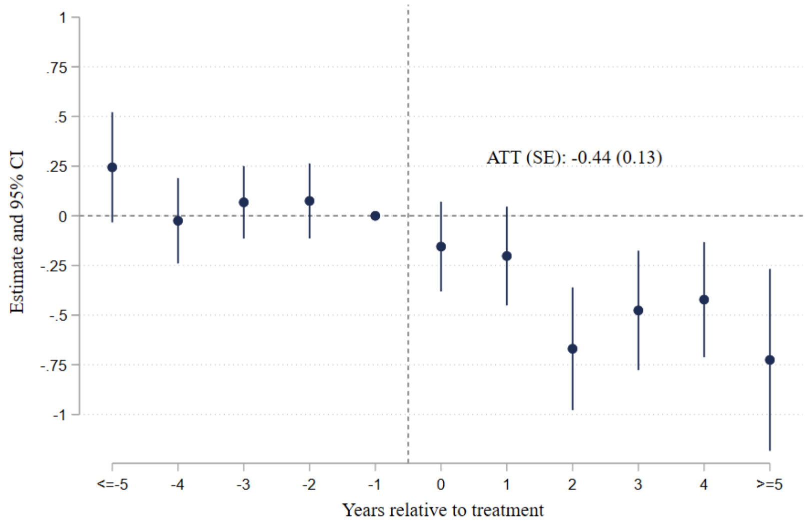
(c) Unemployment rate



(d) Log employment

Note: Figure 10 shows the aggregated ATT and the event study point estimates and 95% confidence intervals for the effect of coal-fired power plant closures on socio-economic outcomes. Across estimations, we include km^2-grid-cell and yearly fixed effects. Standard errors are clustered at the municipality level. We implement the estimator from Sun and Abraham (2021) that uses areas around power plants that belong to the last treated cohort in the sample (2022) as the control group and considers areas up to 5 km from power plants. We exclude power plants that increase their gas-fired capacity.

Figure 11: Effects of coal plant closures on local air pollution ($PM_{2.5}$ [$\mu g/m^3$])



Note: Figure 11 shows aggregated ATT and the event study point estimates and 95% confidence intervals of the effect of coal-fired power plant closures on local $PM_{2.5}$ levels (in μg/m^3). We include km^2-grid-cell and yearly fixed effects. Standard errors are clustered at the municipality level. We use the estimator of Sun and Abraham (2021) and define the control group as the last treated cohort in the sample (2022). We include areas up to 2 km around treated power plants and exclude fuel-switching power plants.

A Appendix

A.1 Tables

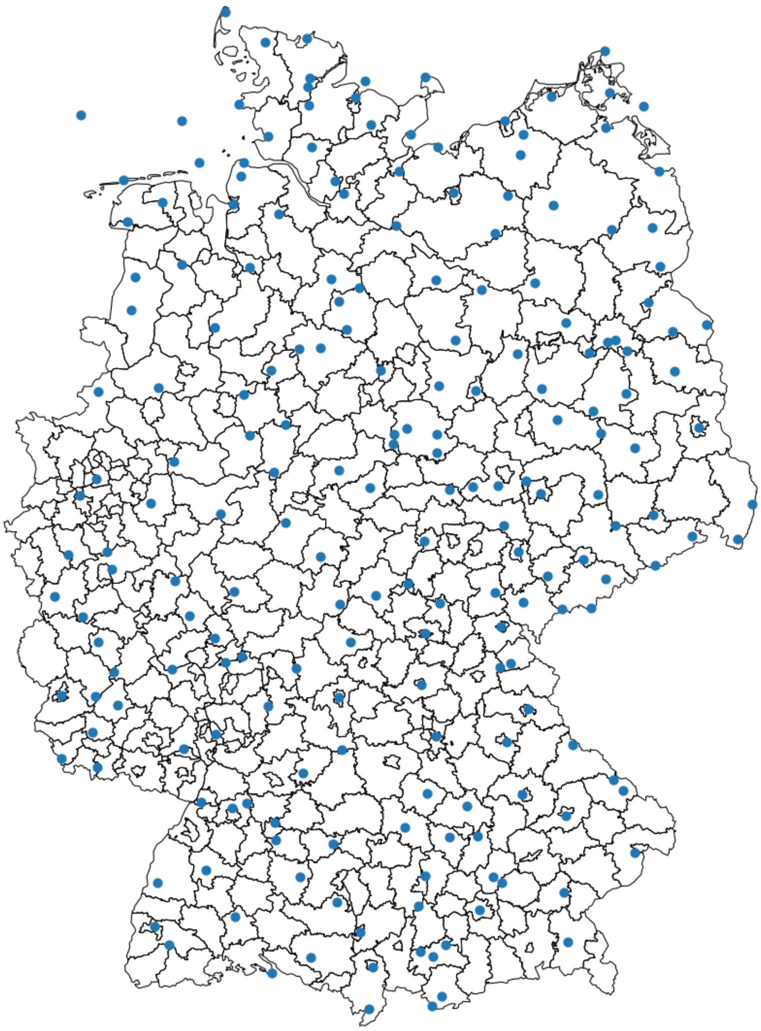
Table A.1: Effects of coal power plants on housing prices - full output

	Log house prices	House prices [€]
<=-5	-0.0056	1.79e+04
	(0.0162)	(1.32e+04)
-4	-0.0036	5261.8016
	(0.0206)	(1.32e+04)
-3	0.0104	1.07e+04
	(0.0152)	(1.45e+04)
-2	0.0139	1.01e+04
	(0.0193)	(1.05e+04)
0	-0.0226	-7.17e+03
	(0.0171)	(5897.5162)
1	-0.0457**	-2.44e+04***
	(0.0216)	(6276.1697)
2	-0.1011***	-4.81e+04***
	(0.0248)	(1.30e+04)
3	-0.1006***	-4.11e+04***
	(0.0229)	(1.08e+04)
4	-0.1270***	-5.50e+04***
	(0.0272)	(2.06e+04)
>=5	-0.1189***	-6.05e+04**
	(0.0423)	(2.58e+04)
Age	-0.0068***	-2.49e+03***
	(0.0009)	(285.8593)
Age^2	0.0000**	9.4654***
	(0.0000)	(2.8024)
Living space	0.0073***	-734.4772
	(0.0005)	(1373.5781)
Living $space^2$	-0.0000***	6.7697
	(0.0000)	(4.8825)
Number of rooms	-0.0117***	-4.16e+03**
	(0.0036)	(1624.6560)
Base area	0.0003***	129.0709***
	(0.0000)	(13.8802)
Base $area^2$	-0.0000***	-0.0214***
	(0.0000)	(0.0041)
In construction	-0.0752***	-2.11e+04***
	(0.0197)	(7694.8033)
Detached	0.1091***	4.05e+04***
	(0.0125)	(5400.3247)
Multi-family	0.0142	-1.02e+04
	(0.0167)	(1.18e+04)
N	163,125	163,125
R^2	0.699	0.438

Note: Table A.1 presents the point estimates from the robust event study estimator of Sun and Abraham (2021). The outcomes are individual housing prices in logs and levels. The specification corresponds to Equation 1 with municipality and year fixed effects, controls for housing characteristics, and cluster standard errors at the municipality level. Significance levels: * p<0.10, ** p<0.05, *** p<0.01.

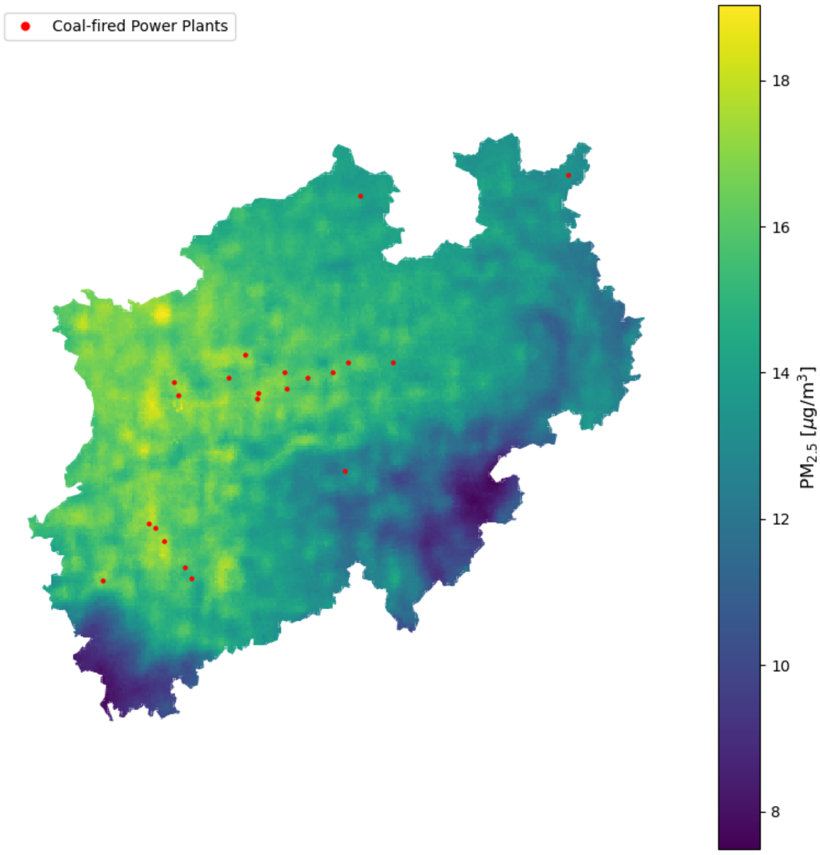
A.2 Figures

Figure A.1: Weather station locations



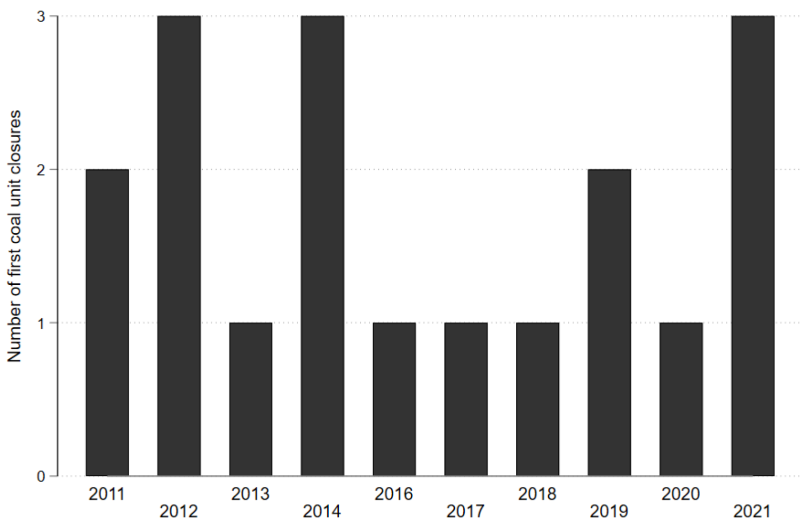
Note: Figure A.1 displays the spatial distribution of the DWD weather stations that record wind speed and direction as of 2023.
Source: DWD (2023)

Figure A.2: Exemplary illustration: Ground level $PM_{2.5}$ emissions and coal power plant locations



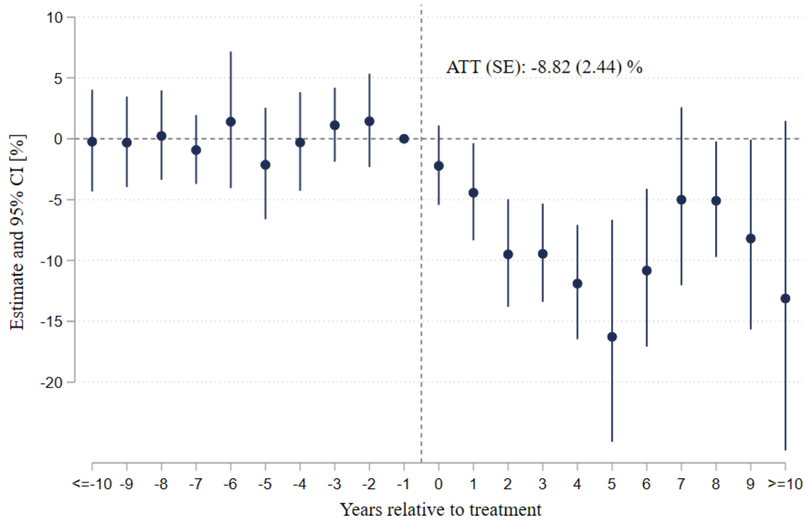
Note: Figure A.2 presents annual average $PM_{2.5}$ emission levels (in μg/m^3) per one-square-kilometer grid cell for the example of the German state of North Rhine-Westphalia. The depicted levels refer to 2007, the first year of the estimation sample.
Source: BNetzA (2023, 2024) and Shen et al. (2024)

Figure A.3: Number of treatments by year



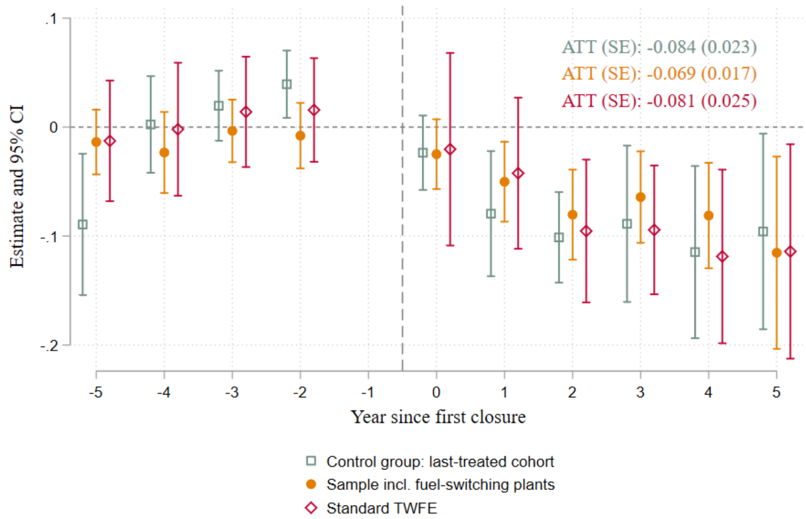
Note: Figure A.3 presents the annual number of first coal unit closures across all power plants in the sample (i.e., the number of treatments).
Source: BNetzA (2023, 2024)

Figure A.4: Effects of coal plant closures on housing prices [%] with increased effect window



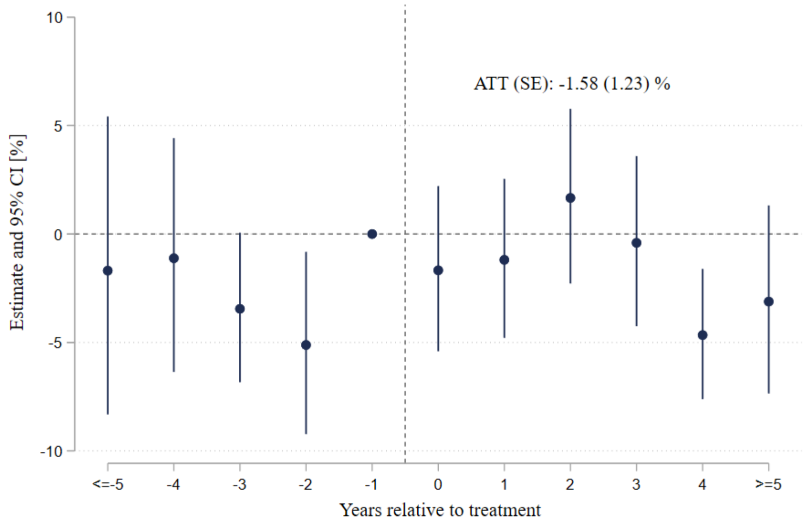
Note: Figure A.4 presents the aggregated ATT from the robust event study estimator of Sun and Abraham (2021), along with event study point estimates and 95% confidence intervals. The outcomes are individual housing prices in logs. The aggregated ATT pools effects from post-treatment years 0 to 5, using the specification in Equation 1 with municipality and year fixed effects, controls for housing characteristics, and standard errors clustered at the municipality level. Compared to the main specification, Figure A.4 increases the effect window, binning periods 10 years before and after the treatment.

Figure A.5: Effects of coal plant closures on housing prices – alternative specifications



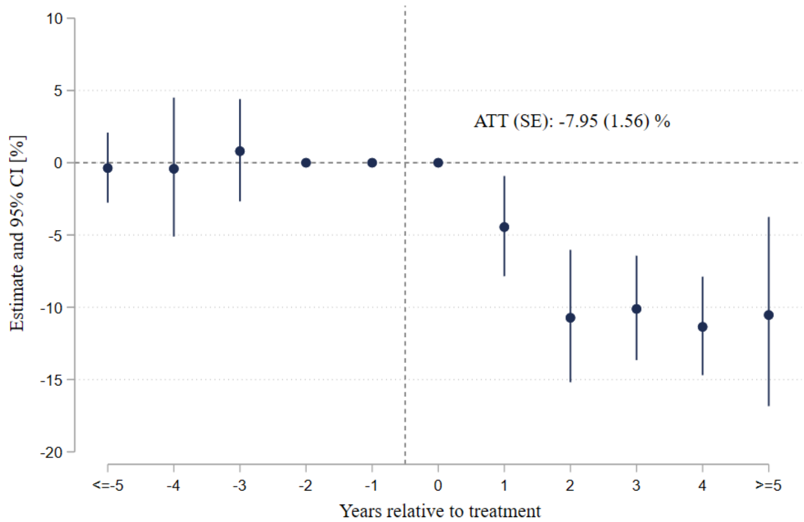
Note: Figure A.5 presents the aggregated ATT from the robust event study estimator of Sun and Abraham (2021), along with event study point estimates and 95% confidence intervals for alternative specifications. The outcome is individual housing prices in logs for all three specifications. The aggregated ATT estimate and its standard error pool the effects from years zero to five following the treatment. The first specification defines the last treated cohort, which is treated in 2022, as the control group and includes only observations before 2022. Thus, we only consider areas up to a 2 km distance of treated power plants instead of a near-far comparison. The second specification expands the main specification of Equation 1 by including fuel-switching power plants. The third specification uses a standard TWFE estimator instead of the estimator by Sun and Abraham (2021). All specifications include municipality and year fixed effects and control for the individual housing characteristics. Standard errors are clustered at the municipality level.

Figure A.6: Effects of coal plant closures on housing prices – placebo treatment dates



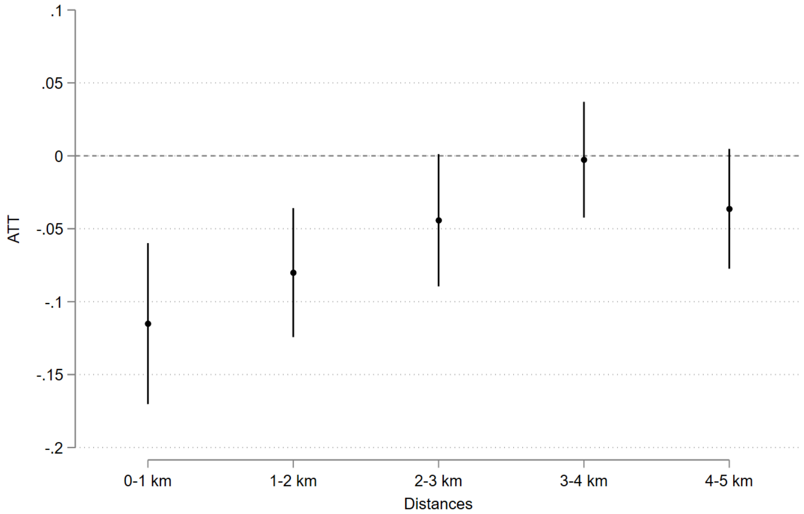
Note: Figure A.6 presents the aggregated ATT from the robust event study estimator of Sun and Abraham (2021), along with event study point estimates and 95% confidence intervals for our main specification of Equation 1, but with randomized treatment dates. It includes municipality and year fixed effects and controls for individual housing characteristics. The outcome is individual housing prices in logs. Standard errors are clustered at the municipality level. The aggregated ATT estimate and its standard error pool the effects from years zero to five following the treatment.

Figure A.7: Effects of coal plant closures on housing prices [%] omitting two years before treatment



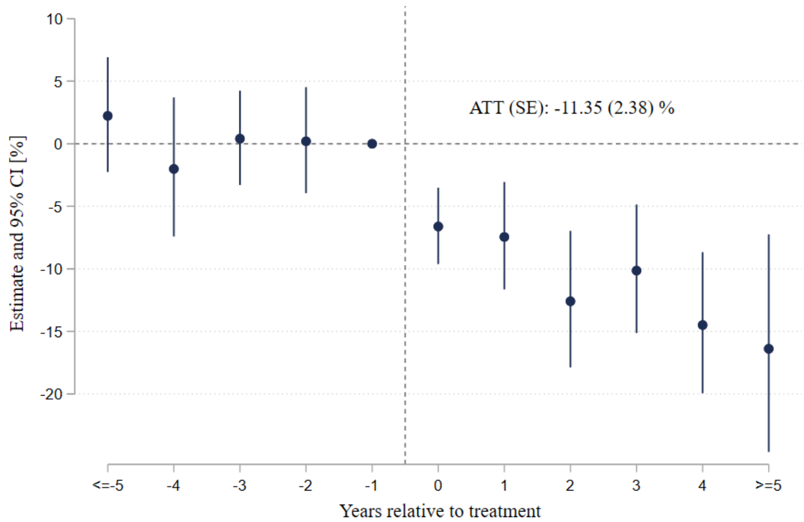
Note: Figure A.7 presents the aggregated ATT from the robust event study estimator of Sun and Abraham (2021), along with event study point estimates and 95% confidence intervals. The outcomes are individual housing prices in logs. The aggregated ATT pools effects from post-treatment years 0 to 5, using the specification in Equation 1 with municipality and year fixed effects, controls for housing characteristics, and standard errors clustered at the municipality level. Compared to the main specification, Figure A.7 omits observations in the year of the treatment and the two years before the treatment.

Figure A.8: Effects coal plant closures on housing prices at increasing distances



Notes: Figure A.8 shows the aggregated event study estimates interacted with increasing distance indicators, as proposed by Sun (2021). The control group is specified as houses within a 6 to 8 km distance to treated power plants. Confidence intervals are given at 95 % level. The specification includes municipality and year fixed effects and controls for the individual housing characteristics. Standard errors are clustered at the municipality level.

Figure A.9: Effects of coal plant closures on housing prices [%] omitting years after 2019



Note: Figure A.9 presents the aggregated ATT from the robust event study estimator of Sun and Abraham (2021), along with event study point estimates and 95% confidence intervals. The outcomes are individual housing prices in logs and levels. The aggregated ATT pools effects from post-treatment years 0 to 5, using the specification in Equation 1 with municipality and year fixed effects, controls for housing characteristics, and standard errors clustered at the municipality level. Compared to the main specification, Figure A.9 omits years after 2019 to account for a potentially compensatory impact of structural support measures starting in 2020.