Inequalities in Energy Transitions: Insights from Historical Shifts in Fuels for Home Heating

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Abstract

As economies seek to decarbonize, energy transitions are underway across many sectors, including heating and cooling, transportation, and manufacturing. Yet historical transitions in specific sectors and countries remain poorly understood. This paper uses newly digitized census-tract data to document the 1940–1970 urban transition from coal to natural gas and heating oil for home heating. We apply InMAP, an air pollution model, to provide the first tract-level estimates of $PM_{2.5}$ from home heating. The paper has three main findings. First, the transition was remarkably rapid, and $PM_{2.5}$ from home heating fell by about $14\mu g/m^3$ under our headline filterable-primary measure. Second, the pace of the transition and the decline in $PM_{2.5}$ varied substantially across counties, depending on when households adopted natural gas. Declines were largest in counties that adopted in the 1940s. Third, tracts with greater Black shares used coal significantly longer and had higher $PM_{2.5}$, with statistically significant pollution associations in most decades. Tracts with greater renter shares and older housing also used coal longer and had higher $PM_{2.5}$ in some decades.

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1 Introduction

As economies seek to decarbonize, energy transitions are underway across a range of sectors, including heating and cooling, transportation, and manufacturing. Home heating is often seen as one of the harder sectors to transition. It is dispersed across tens of millions of dwellings, tied to long-lived building stock, and embedded in daily routines. Yet history offers a striking counterexample. Over just three decades in the mid-twentieth century, American households almost completely abandoned coal, the fuel that had heated the country for generations. Understanding how that transition unfolded offers lessons for the transitions being sought today: how fast it moved, what drove it, and who was left behind.

This paper uses newly digitized census-tract data to document the 1940–1970 transition from coal to natural gas and heating oil in urban America. We then apply InMAP, a widely used air-transport model, to produce the first tract-level estimates of fine particulate pollution ($PM_{2.5}$) from residential heating. The sample covers about 15,000 urban census tracts, home to 28 percent of the national population and 27 percent of the Black population. Beyond the aggregate transition, we examine heterogeneity by the timing of natural gas adoption, race, renter status, and the age of the housing stock. This lets us ask whether the benefits of the transition were shared evenly.

We have three main findings. First, the transition was remarkably rapid. In our population-weighted sample, coal's share of home heating fell from about 60 percent in 1940 to roughly 10 percent by 1960. It kept falling thereafter, as households switched to natural gas, where distribution networks reached them, and heating oil, otherwise. Several forces made coal increasingly unattractive, notably the national coal strikes of the 1940s and the dust and smoke of its use. Switching, meanwhile, was cheap: a conversion burner let an existing coal furnace burn gas or oil without replacement. Over the same period, $PM_{2.5}$ from home heating fell by about $14 \mu g/m^3$ under our headline filterable-primary measure.

Second, the pace of the transition and the associated pollution declines varied substantially across places, depending on when a county's households adopted natural gas. Natural gas was delivered through fixed pipes, many repurposed from earlier manufactured-gas systems, rather than by truck like coal and heating oil. Availability was therefore uneven,

and households leaving coal without gas access typically turned to heating oil instead. Grouping counties by adoption timing reveals three distinct trajectories. The largest $PM_{2.5}$ reductions occurred in colder, denser, coal-reliant counties that gained gas in the 1940s.

Third, the transition did not reach all communities at the same time. Census tracts with larger Black population shares, more renters, and less recently built housing retained coal longer than otherwise-similar tracts within the same county. Within a county, a one-standard-deviation increase in Black population share is associated with a 2 to 2.5 percentage point higher coal share over 1940–1960, holding household income, heating demand, and population density constant. Renter share and older housing show similar patterns. Under the filterable-primary measure, tracts with larger Black population shares also had significantly higher home-heating $PM_{2.5}$ in 1950–1970; renter share and older housing were associated with higher $PM_{2.5}$ in some decades. Local pollution depends not only on the fuel burned within a tract, but also on fuels burned in nearby tracts.

Taken together, these findings speak to why some heating transitions are fast and others slow. The mid-century U.S. transition was quick because coal was dirty and its supply uncertain, cleaner substitutes had become widely available, and switching was inexpensive. A comparable British transition from coal was also rapid, accelerated in that case by government policy. By contrast, the transition to electric heating has been far slower. The incumbent fuels are relatively clean and reliable, electricity is not always cheaper, and switching often requires new equipment and delivery infrastructure. This contrast suggests the disparities we document may be even more pronounced today. In the current transition, incentives to switch are weaker and switching costs are higher for disadvantaged households.

The paper contributes to three literatures. The first is the literature on transitions in heating. It includes historical studies over long horizons (Barreca, Clay and Tarr, 2014; Fouquet, 2014) and recent work on the transition to electricity (Davis, 2023; Borenstein and Bushnell, 2022; Davis, 2024; Gwee and Tan, 2026). In contrast to Barreca, Clay and Tarr (2014), which uses state-level data, we use census-tract data to measure the transition's speed and to study disparities in fuel adoption. The second is the literature on disparities in home heating. It includes work on racial gaps (Lyubich, 2020; Wang et al., 2021; Baik, Hines and Sim, 2023) and renter-owner differences (Gillingham, Harding

and Rapson, 2012; Melvin, 2018; Aydin et al., 2026), both focused on the contemporary period. We provide historical evidence that both gaps were present during the coal-to-gas transition. The third is the literature on historical air pollution (Beach and Hanlon, 2018; Hanlon, 2024; Clay, Lewis and Severnini, 2018, 2024; Heblich, Trew and Zylberberg, 2021). It has estimated pollution from industry and power plants using models such as ADMS5 and AP3. We extend this work, using InMAP to produce new estimates of historical air pollution from residential heating.

In ongoing work, we are extending the analysis in two directions. First, we are digitizing county-level home-heating data for 1940–1960 to trace the transition nationally, including in less urban areas. Second, we are adding a causal analysis of natural gas pipeline arrival, estimating its effects on fuel use, $PM_{2.5}$, carbon emissions, and mortality.

2 Background

Prior to 1940, many households used manufactured gas for lighting, cooking, or both. In urban areas, piped distribution infrastructure had been built to sell it. Manufactured gas was made by heating coal to release gas, often in complex processes involving oil vapor. It was relatively expensive to produce and was generally considered too costly for heating (Barreca, Clay and Tarr, 2014; Castaneda, 2001). Even so, our analysis finds a number of counties reporting manufactured gas for heating above 5 percent, so some households did use it this way. Given its high price, that usage was likely concentrated among wealthier households.

Nationally, in 1940 the vast majority of households heated with coal or wood. Coal heated 55 percent of households, mostly as bituminous coal, though anthracite was common near major anthracite deposits. Wood heated 23 percent, concentrated in the South and, to a lesser degree, the Pacific Northwest. The remaining households had already adopted more modern fuels: utility or bottled gas (11 percent) or fuel oil (10 percent) (U.S. Census Bureau, 2021).

By 1970, this national transition from coal and wood was essentially complete. Only 2.9 percent of households still used coal and 1.3 percent used wood. Utility or bottled gas heated 61 percent of households, fuel oil 26 percent, and electricity 8 percent (U.S. Census Bureau, 1970).

During the 1920s, large amounts of natural gas began to be produced in Texas and California. Initially the gas was used locally, but as Texas volumes grew, pipelines were built to major population centers. A pipeline to Denver was completed in 1928, and one to Chicago around 1930–31. Earlier, shorter pipelines dated to the late nineteenth century, but improved construction technology now allowed larger, longer-distance lines (Castaneda, 2001). After World War II, the pipeline network expanded further. This came both from new construction and from repurposing wartime oil pipelines such as the Big Inch and Little Inch (Barreca, Clay and Tarr, 2014; Castaneda, 2001; Greenspon and Hanson, 2025).

As cities gained access to natural gas, the existing manufactured-gas infrastructure was repurposed to distribute it. Some modifications were needed, because manufactured and natural gas had different properties. Even so, the transition for existing uses was generally straightforward and facilitated by the distribution companies (Barreca, Clay and Tarr, 2014; Castaneda, 2001).

On the heating side, the switch was also relatively cheap, thanks to conversion burners that could be installed in existing coal or wood furnaces (Barreca, Clay and Tarr, 2014; Graham, 1946). A new furnace was not required. Most households instead paid to have a conversion burner installed, letting an existing furnace burn gas or oil directly. The total cost of switching from coal to natural gas after World War II was about $163. For context, average household expenditure in 1950 was $3,925, so the conversion cost less than 5 percent of annual expenditure (Barreca, Clay and Tarr, 2014; Jacobs and Shipp, 1990; Tarr, 1981). Combination furnaces that could burn multiple fuels were also sold during this period as an alternative.

Some parts of the country, predominantly New England, did not receive natural gas pipelines until later, in part because of their distance from major producers. The region had no piped natural gas until interstate pipelines reached it in the early 1950s (Commonwealth of Massachusetts, n.d.). These areas often turned to fuel oil instead. In 1970, New England households used fuel oil at nearly three times the national rate (71 percent vs. 26 percent) and gas at less than half the national rate (23 percent vs. 61 percent) (U.S. Census Bureau, 1970). Fuel oil moved flexibly by ship, rail, or pipeline (Barreca, Clay and Tarr, 2014), but it was typically less clean than natural gas and had to be stored onsite.

It is useful to compare this transition to two others. The first is Great Britain's transition in home heating, which came later but was also rapid, aided by government policy. In 1961, 76 percent of English households used coal (Utley and Shorrock, 2012). Between 1970 and 1990, central heating, predominantly natural gas, rose from 33 to 80 percent of households (Palmer and Cooper, 2011). The second is the ongoing U.S. transition to electric heating, which has been much slower. Nationally, electricity heated 8 percent of households in 1970, 30 percent in 2000, and 40 percent in 2020 (Davis, 2025; U.S. Census Bureau, 2021; U.S. Energy Information Administration, 2025).

The figures above are national. The remainder of the paper focuses on our sample of urban census tracts, described in Section 3. Because the sample is more urban and more coal-reliant than the country as a whole, its coal shares run somewhat higher than the national figures. Coal heated about 60 percent of sample households in 1940 (population-weighted), compared with 55 percent nationally.

3 Data

3.1 Data Sources

Our analysis draws on newly digitized census tract-level data on home heating fuel usage by housing unit for 1940 and 1950.[1] Census tract data are harmonized with existing census data for 1960 and 1970 (Manson et al., 2023). We integrate tract-level tabulations of demographics, population, and housing characteristics, such as renter- versus owner-occupation, and when housing units were built, from decennial censuses. To do so, we harmonize all tract boundaries to 1970 tract boundaries.

Our analysis sample consists of counties which contain census tract data in 1940, 1950, or both and with at least 20 census tracts. Figure 1 shows the locations of these counties. In 1940, tract-level census coverage included 74 counties containing the largest U.S. cities (11,277 tracts under 1970 boundaries). Tracts in 1940 are primarily urban and include 28% of the national population and 27% of the Black population.

For reference on the natural gas pipeline network, we draw on the Federal Trade Com-

[1] Census data on home heating fuel usage are also currently available at the national and state level for 1940-1970. We are in the process of digitizing the county-level data.

mission's 1940 report on natural gas pipelines, published by the Temporary National Economic Committee (Federal Trade Commission, 1940), which maps the interstate network as of 1940 (Figure 6); we do not currently use the pipeline routes as data in the analysis. To classify county natural gas service where census heating data are unavailable, we use directories of operating gas utilities compiled by the Federal Power Commission for 1942 and by the American Gas Association for 1949 (Section 5).

Heating degree days are constructed from PRISM 800-meter monthly temperature grids, aggregated to census tracts (Section 3.2).

Table 1 provides summary statistics for the sample. On average, tracts had 3,800 people and residents were 12% Black and 11% foreign born. 49% of households were renters and 23% of households lived in housing that had been built in the last decade. Heating fuels were 23% coal, 46% natural gas, and 25% oil. Note that Table 1 reports unweighted tract-level means pooled over the four census years; the headline fuel shares reported in the text are population-weighted and therefore differ somewhat.

3.2 Modeling $PM_{2.5}$ from Home Heating with InMAP

To estimate air pollution from home heating, we convert the census counts of housing units by heating fuel into emissions and pass those emissions through InMAP, a reduced-complexity air transport model (Tessum, Hill and Marshall, 2017). The calculation proceeds in three steps: fuel consumption, emissions, and atmospheric transport.

First, we estimate annual fuel consumption for each tract and decade. Consumption per household scales with local heating demand, measured by heating degree days constructed from PRISM 800-meter temperature grids aggregated to tracts. We multiply the number of housing units using each fuel by tract heating degree days and by per-household-degree-day usage factors from the U.S. Public Health Service's community emissions survey methodology: 0.0012 tons of coal, 0.18 gallons of fuel oil, and 22.5 cubic feet of natural gas per household degree day (Ozolins and Smith, 1966). Units heating with wood, electricity, or other fuels are not modeled.

Second, we convert fuel consumption into emissions of primary particulate matter, sulfur oxides (SO_x), and nitrogen oxides (NO_x) using period-appropriate residential emission factors from the same Public Health Service compilations (Ozolins and Smith, 1966;

Duprey, 1968). For particulates, the residential factors are 25 pounds per ton of coal, 12 pounds per 1,000 gallons of oil, and 9 pounds per million cubic feet of gas. SO_x factors depend on fuel sulfur content ($38S$ pounds per ton of coal and $157S$ pounds per 1,000 gallons of oil, where S is percent sulfur); we apply national era-appropriate sulfur contents of 2.0 percent for coal and 0.24 percent for residential fuel oil. Because these vintage particulate factors measure total suspended particulates (TSP) rather than fine particulates, we convert TSP to primary $PM_{2.5}$ using the fine-particle mass fractions in the EPA's AP-42 compilation for uncontrolled residential combustion: 0.25 for coal (filterable), 0.42 for oil, and 1.00 for gas (U.S. Environmental Protection Agency, 1995). For coal, AP-42 additionally reports that condensable particulate matter—fine particles that form as hot exhaust cools, essentially all smaller than 2.5μm—equals roughly 50 percent of filterable emissions for hand-fired units, implying an effective $PM_{2.5}$ multiplier of 0.75 when condensables are included.[2]

Third, we run the emissions through InMAP, which converts ground-level emissions of primary $PM_{2.5}$ and of the precursor gases SO_x and NO_x into annual-average ambient $PM_{2.5}$ concentrations, including the secondary sulfate and nitrate particles formed from precursors in the atmosphere. Emissions enter the model as diffuse ground-level sources spread over each 1970 census-tract polygon, the standard representation for residential and other non-point sources. We use the InMAP source-receptor matrix (ISRM), which encodes the model's atmospheric chemistry, meteorology, and background concentrations for a 2005 base year (Goodkind et al., 2019). Applying these fixed 2005 source-receptor relationships to 1940–1970 emissions is a maintained assumption of our approach: all variation in modeled $PM_{2.5}$ across tracts and decades comes from the emissions we construct, not from changes in the atmosphere.[3]

We report three measures of $PM_{2.5}$ from home heating that differ only in how primary particulate emissions are treated. The *precursors-only* measure includes secondary $PM_{2.5}$

[2]No vintage residential emission factors exist for ammonia or volatile organic compounds, so these species are omitted and secondary organic particulate matter is not modeled. This omission is conservative: it can only understate $PM_{2.5}$ from home heating.

[3]Two further caveats follow from the model structure. Home-heating emissions are concentrated in winter, whereas InMAP is a steady-state annual-average model, so our estimates should be read as annual averages of a seasonally concentrated source: because annual emission totals are preserved, the annual average itself is not biased by seasonality, but true winter concentrations exceed, and summer concentrations fall below, the annual-average values we report. Seasonal differences in atmospheric chemistry, such as the cold conditions that favor nitrate formation, are likewise not captured. In addition, background concentrations—including the ammonia that governs how much secondary sulfate and nitrate forms—reflect 2005 rather than historical conditions.

formed from SO_x and NO_x but no primary particulates; we treat it as a lower bound. The *filterable* measure adds primary $PM_{2.5}$ using the AP-42 filterable fine fractions (0.25 for coal, 0.42 for oil, and 1.00 for gas). This is our headline measure: it includes direct residential smoke using the standard particle-size scaling available for the vintage TSP factors without adding the less-certain condensable component. The *condensable-inclusive* measure instead applies coal's condensable-inclusive multiplier of 0.75, and we treat it as an upper bound. We report the full ladder when documenting the aggregate decline. The comparison with power plants in Section 5 remains at the precursors-only rung so that it is like-for-like across sources.

4 Empirical Strategy

To explore disparities in the use of coal and in exposure to the resulting pollution, we estimate cross-sectional regressions separately for each census year. The cross-sectional equation is:

$$Y_i = \beta_b BlackShare_i + \beta_r RenterShare_i + \beta_a BuiltRecent_i + X_i'\gamma + \mu_c + \epsilon_i \qquad (1)$$

where i is a census tract; $BlackShare_i$ is the Black population share of the census tract; $RenterShare_i$ is the share of renters in a census tract; $BuiltRecent_i$ is the share of homes in the census tract built in the last decade; and μ_c is a county fixed effect. The vector X_i contains three controls that plausibly confound the relationships of interest: median household income, which lets us separate race- and tenure-based disparities from income-based ones; heating degree days, which capture within-county differences in heating demand; and population density, which is associated with both fuel availability and pollution concentrations.[4] We estimate the equation with two dependent variables Y_i: the share of households heating with coal, and modeled $PM_{2.5}$ from home heating under the headline filterable-primary measure defined in Section 3.2. Standard errors are clustered by county, the level at which the fixed effects are defined and at which gas availability varied. The estimates are descriptive associations, not causal effects.

[4]Income enters as the tract's median household income in current dollars. The 1950 census reports tract medians directly; the 1960 and 1970 medians are interpolated from published family-income bins; and no tract-level income data exist for 1940, so the 1940 regressions use 1950 income as a proxy while we await 1940 census microdata from which to construct tract-level income.

5 Results

5.1 Speed and Nature of the Transition

Coal use for heating declined rapidly from 1940-1960. Figure 2 shows the national declines in coal use and expansion in use of natural gas and fuel oil. Coal use and thus decline varied by census region. Figure 3 shows that baseline coal use in 1940 was highest in the Midwest and lowest in the West. By 1970, natural gas was dominant everywhere except the Northeast, which had limited pipeline coverage.

The use of coal was driven in part by proximity to the major coal basins, especially the Illinois and Appalachian basins (Figure 4). Use of natural gas was driven by proximity to natural gas deposits and the pipelines that moved gas to markets (Figure 5 and Figure 6). Use of heating oil was less dictated by location, because it reached a location by a variety of modes: ship, pipeline, or rail. From there it was transported by truck to individual households. That said, the primary mode of transportation before World War II was ship, during World War II was pipeline and rail, and after World War II was a mix of modes.

Figure 7 shows the share of households using gas by county and decade. To classify counties by the timing of natural gas access, we begin with an adoption proxy: a county is classified as having gas in the first decade in which at least 5 percent of its households heat with it. Where a county's census heating data are unobserved in the decades needed to date its crossing of the 5 percent threshold, we instead classify it using directories of operating natural gas utilities compiled by the Federal Power Commission for 1942 and the American Gas Association for 1949; the directories fill in 16 of the 97 sample counties.[5] Under this classification, 39 of the 97 sample counties (40 percent) had natural gas access by 1940, 46 counties (47 percent) first gained access in the 1940s, and 12 counties (12 percent) first gained access in the 1950s.

Figure 8 shows trends in natural gas use by gas-access cohort. In counties with natural gas access by 1940, 30 percent of households already heated with gas in 1940, rising to about 80 percent by 1960 and 85 percent by 1970. In counties that first gained access in

[5]The 5 percent proxy can misclassify counties whose households heated with manufactured rather than natural gas. Spot checks against utility directories suggest this affects some counties; we are digitizing Brown's directories of gas utilities to verify natural gas service nationally.

the 1940s or 1950s, gas heating reached only about 25–30 percent of households by 1960 and 40–47 percent by 1970, with most of the rest being heating oil.

Heating oil displaced coal if natural gas was not available. Figure 9 shows fuel use by natural gas cohorts. In the pre-1940 gas access locations, very little heating oil was used. In the locations that gained access in the 1940s and 1950s, some heating oil was used. This likely reflects the fact that many households did not have access to natural gas infrastructure and companies only wanted to extend distribution pipelines in high density areas.

Figure 10 shows that $PM_{2.5}$ from home heating declined sharply over time under all three measures defined in Section 3.2. Under the headline filterable-primary measure, population-weighted exposure fell from 16.3μg/m^3 in 1940 to 2.3μg/m^3 in 1970, a decline of about 14μg/m^3. The precursors-only lower bound fell from 3.7 to 0.85μg/m^3. For comparison, national exposure to $PM_{2.5}$ from power plants, estimated under the same precursors-only convention, increased from 0.75μg/m^3 in 1940 to about 3μg/m^3 in 1970. Under this like-for-like precursors-only comparison, the decline in air pollution from home heating was similar in magnitude to the increase from power plants; under the headline filterable-primary measure, the home-heating decline was substantially larger. In later graphs, we report the headline filterable-primary measure.

Figure 11 shows that the declines in $PM_{2.5}$ were very different across the three groups of counties. This is driven by heating degree days and population density. Figure 12 shows that counties that had access by 1940 tended to be in warmer areas, had somewhat lower population density, and used less coal than the other groups, so their exposure fell from about 5.4 to 0.5μg/m^3. Counties that gained access in the 1940s were colder, had higher population density, and used more coal, so their decline was largest, from about 26 to 4μg/m^3. Finally, counties that gained access in the 1950s were in warmer areas, had lower population density, and switched in part to heating oil, which was more polluting than natural gas; their exposure fell from about 10.5 to 1.6μg/m^3.

5.2 Race, Renter Status, and Recently Built

Higher Black-share census tracts were more likely to use coal or other/none (often wood) and less likely to use gas or heating oil than lower Black-share census tracts. High Black-

share census tracts are defined as having 20% Black population or more. The number of high Black-share census tracts increased over time from 11 percent of tracts in 1940 to 24 percent in 1970. Figure 13 shows the trajectories for coal, gas, oil, and other/none. Differences were generally small by 1970.

Figure 14 shows that higher Black-share census tracts had higher $PM_{2.5}$ from home heating over 1940–1970 than lower Black-share census tracts. Both types of census tracts experienced substantial declines in $PM_{2.5}$ over time. Lower Black-share census tracts experienced particularly rapid decreases from 1940–1950.

Figures 15 and 16 plot the coefficients on Black population share, renter share, and recently built share from the cross-sectional regressions in equation (1), which control for median household income, heating degree days, and population density; Table 2 reports the full estimates. Within a county, a one-standard-deviation (25 percentage point) increase in Black population share was associated with a 2 to 2.5 percentage point higher coal share in 1940–1960, falling to 0.7 percentage points by 1970. A one-standard-deviation (27 percentage point) increase in renter share was associated with a small and statistically insignificant difference in coal share in 1940, a 1.9 percentage point higher coal share in 1950, and a 3.0 percentage point higher coal share in 1960. Recently built housing worked in the opposite direction: a one-standard-deviation (25 percentage point) increase in the share of housing built in the last decade was associated with a 4.2 percentage point lower coal share in 1940 and a 3.7 percentage point lower coal share in 1950, with the association shrinking mechanically as coal use itself disappeared.

The filterable-primary $PM_{2.5}$ coefficients have the same signs as the coal-share coefficients and are more precisely estimated than their precursors-only counterparts. The coefficient on Black population share is marginally significant in 1940 and statistically significant in 1950–1970. The renter-share coefficient is marginally significant in 1940 and 1950, while the recent-built coefficient is marginally significant in 1950 and statistically significant in 1970. Spatial spillovers remain important for interpretation: pollution in a tract depends on the fuels burned within it and in nearby tracts, which smooths modeled exposure across neighboring tracts.

6 Conclusion

This paper uses newly digitized census-tract data and the InMAP air pollution model to document the transition from coal to natural gas and heating oil in urban America between 1940 and 1970, and to provide new estimates of its consequences for fine particulate pollution. We find that the transition was remarkably rapid. Coal's share of home heating in our sample fell from about 60 percent in 1940 to roughly 10 percent by 1960, and continued to decline thereafter. Households moved toward heating oil and, where pipelines reached them, natural gas. Over this period, $PM_{2.5}$ from home heating fell by about $14 \mu g/m^3$ under our headline filterable-primary measure. The precursors-only measure provides a lower bound and the condensable-inclusive measure an upper bound. The pace and pollution benefits of the shift were far from uniform, however, depending heavily on when a county gained access to the natural gas network, with the largest reductions concentrated in counties connected in the 1940s.

The transition also unfolded unevenly across communities. Census tracts with larger Black population shares, more renters, and less recently built housing retained coal longer. Under the headline filterable-primary measure, tracts with larger Black population shares also experienced significantly higher home-heating $PM_{2.5}$ in 1950–1970, while renter share and older housing were associated with higher $PM_{2.5}$ in some decades. Pollution in a tract depends on fuels burned in nearby tracts as well as its own. These patterns show that even a rapid, welfare-improving energy transition can leave disadvantaged groups exposed to elevated pollution for longer, providing a historical parallel to contemporary concerns about racial and renter-owner disparities in energy use and about ensuring an equitable, or "just," transition.

This transition and the British transition from coal to modern heating fuels proceeded quickly. In the US, this was because coal was dirty and its availability was uncertain, other fuels had become widely available, and switching was relatively cheap because a conversion burner could be installed in an existing coal furnace. In the UK, government policy sped the switch from coal to natural gas.

Why then has the switch to electric heating been so much slower thus far? In contrast to coal, existing fuels (natural gas and heating oil) are reasonably clean and have fairly certain availability. Electric heating has the disadvantage of more frequent outages than

existing fuels. Further, depending on local fuel and electricity prices, electric heating is not necessarily cheaper and even if it is cheaper, switching can be costly. For consumers switching from other fuels, electric heat requires new heating equipment and in some cases changes to heating delivery (e.g., heating ducts). Like the previous transition, the transition to electricity appears to be occurring unevenly. Given the lower incentives to switch and the higher switching costs, the disparities may be larger and last for longer.

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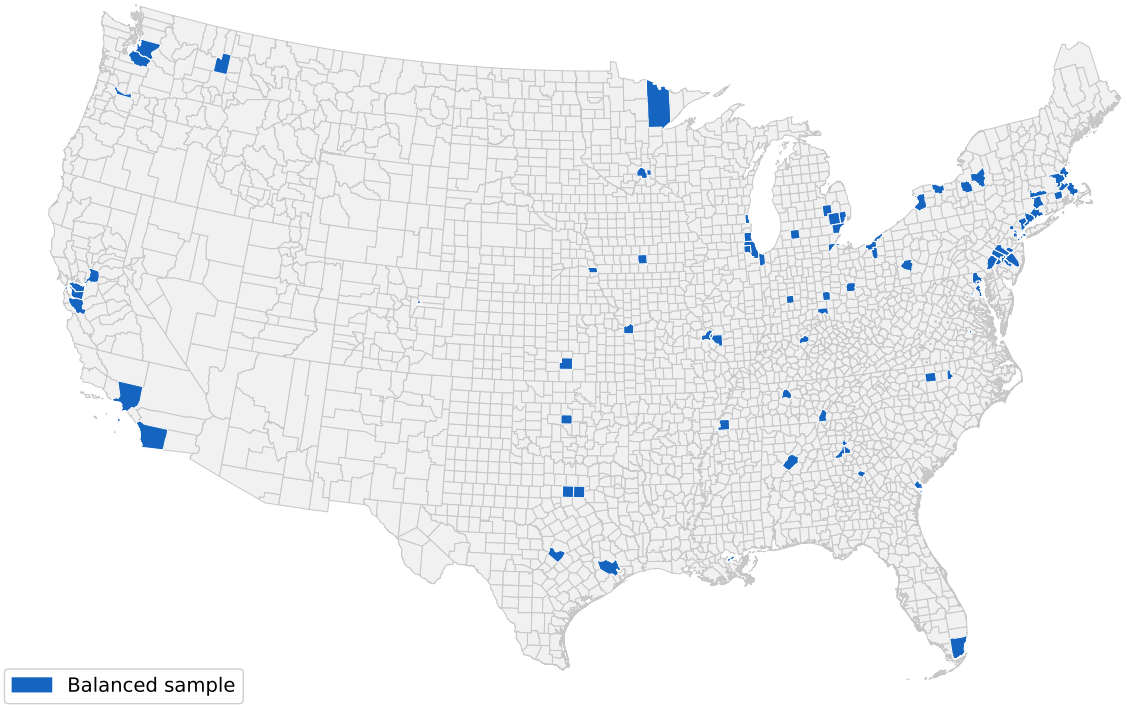
Tables and Figures

Table 1: Summary Statistics

	N	Mean	SD	Min	Max
Total Population	55,273	3,822.23	2,506.98	0.00	38,720.00
Black Population (%)	55,273	11.71	25.18	0.00	100.00
Coal Share	55,273	23.06	30.23	0.00	100.00
Gas Share	55,273	45.57	36.63	0.00	100.00
Oil Share	55,273	24.67	27.23	0.00	100.00
Renter-Occupied (%)	55,271	48.55	27.25	0.00	100.00
Median HH Income	54,899	6,117.97	4,053.92	0.00	57,045.45
Foreign-Born (%)	55,273	10.50	9.12	0.00	100.00
Built Last Decade (%)	54,762	23.07	25.40	0.00	100.00
Heating Degree Days	55,273	24,974.00	9,751.23	19.14	54,852.32
Mean Winter Temp.	55,273	4.50	5.28	-8.45	21.53
Total Housing Units	55,273	1,189.53	819.20	1.36	9,091.55

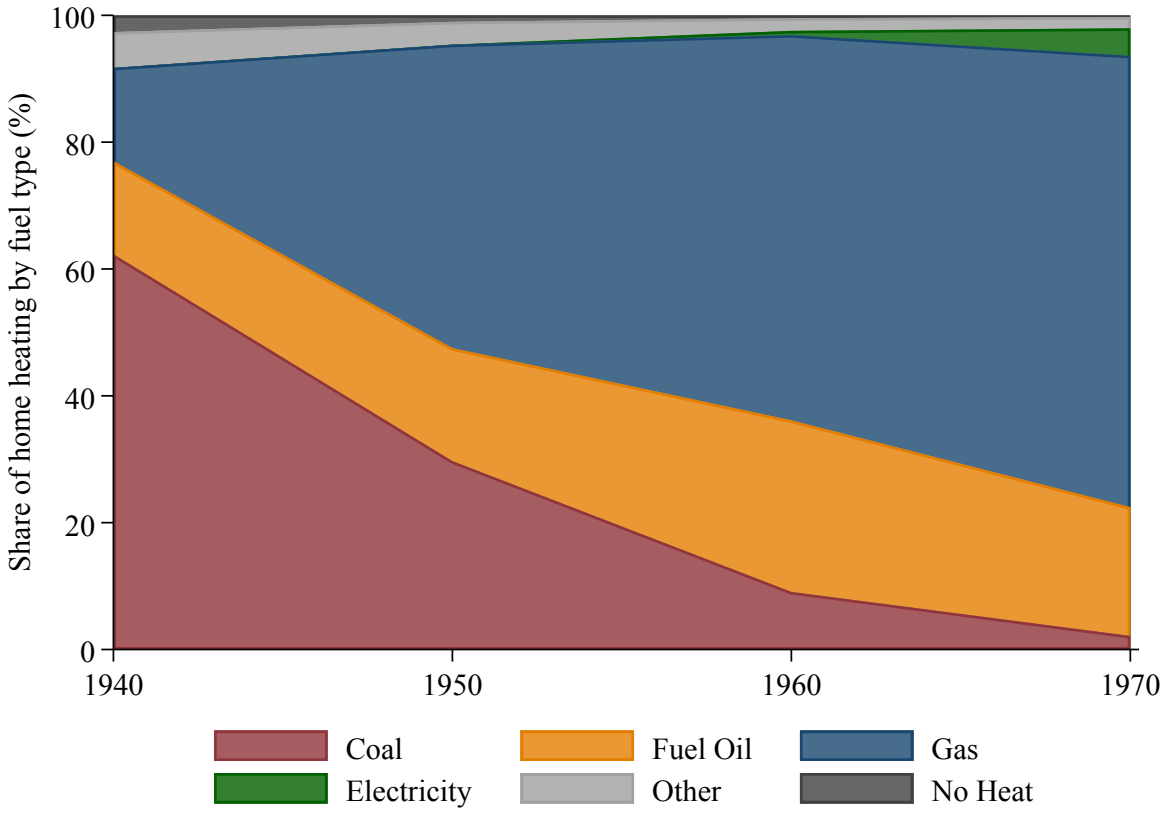
Notes: Unweighted tract-level means pooled over the four census years 1940–1970 for the balanced sample of tracts harmonized to 1970 boundaries (55,273 tract-year observations after dropping observations with missing population, housing-unit, or heating data and tracts with zero population). The population-weighted fuel shares referenced in the text differ from the unweighted means shown here. Fuel shares are percentages of occupied housing units. Median household income is in current (nominal) dollars of each census year: 1950 reports median income of families and unrelated individuals; 1960 and 1970 medians are interpolated from family-income bins (1959 and 1969 incomes); no income data exist for 1940, so 1940 observations use 1950 values. Row counts differ because the income and year-built tabulations are unavailable for a small number of tracts (N = 54,899 and 54,762, respectively).

Figure 1: Map of Census Tract Counties in Sample



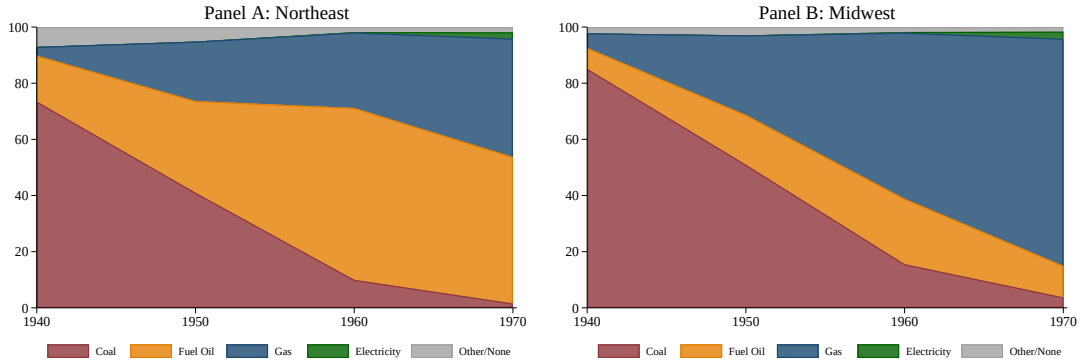
Notes: This map shows the 97 counties in the analysis sample: counties with census-tract data in 1940, 1950, or both, containing at least 20 census tracts. County boundaries are as of 1970, the target geography to which all tract data are harmonized.

Figure 2: Trends in Home-heating Energy Source: 1940 – 1970



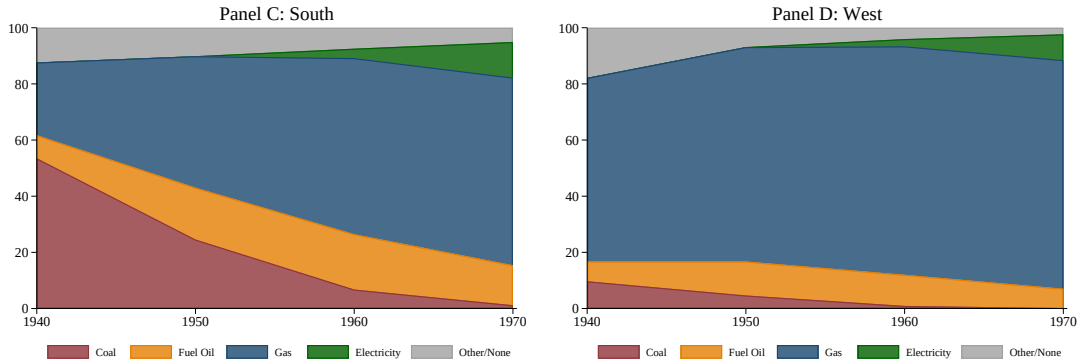
Notes: This figure reports the population-weighted shares of each fuel type used for home heating in our balanced sample of census tracts.

Figure 3: Trends in Home-heating Energy Source: 1940 – 1970, by Census Region



(a) Northeast

(b) Midwest

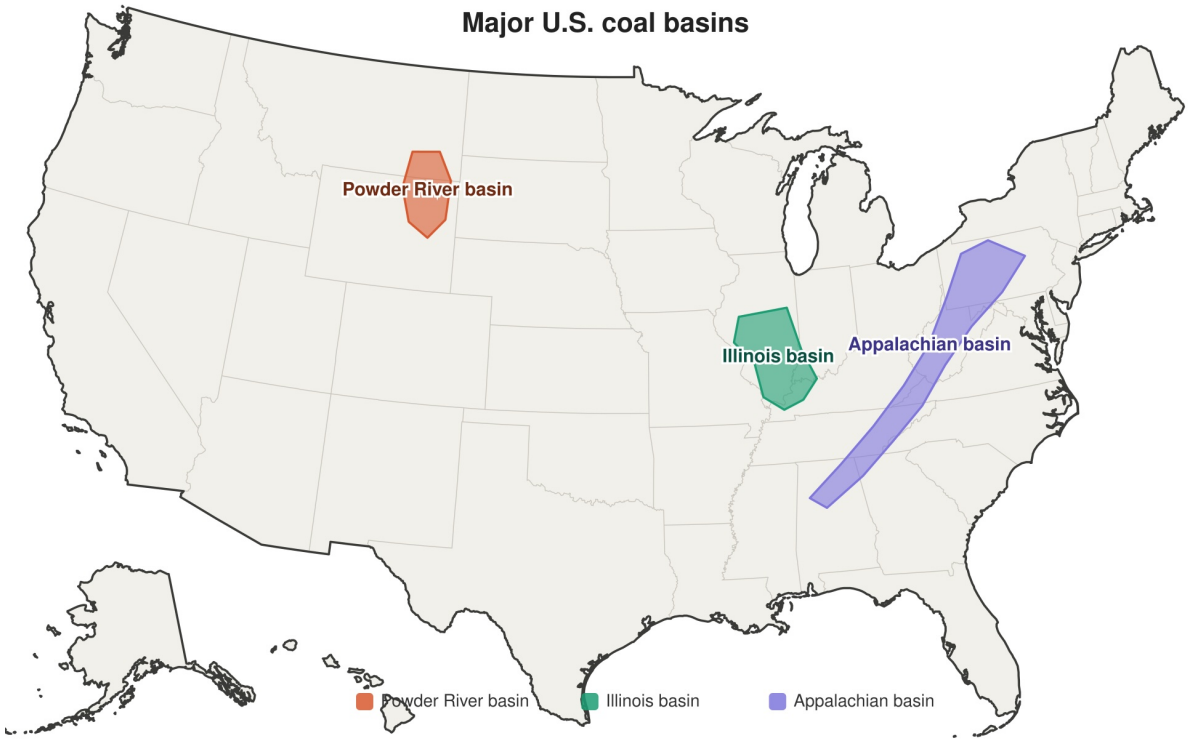


(c) South

(d) West

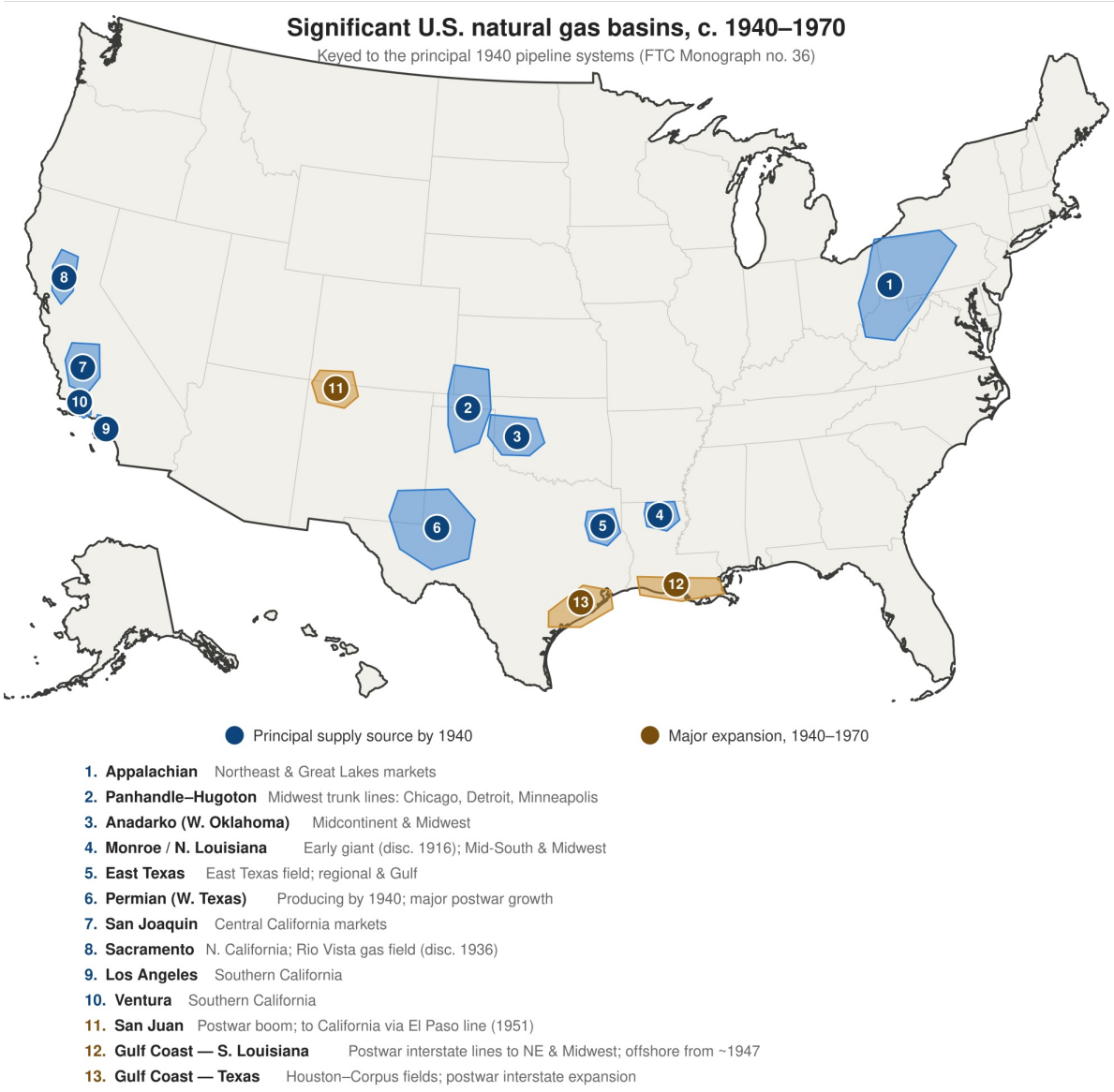
Notes: This figure reports, separately by census region, the population-weighted shares of each fuel type used for home heating in our balanced sample of census tracts.

Figure 4: Map of Coal Basins



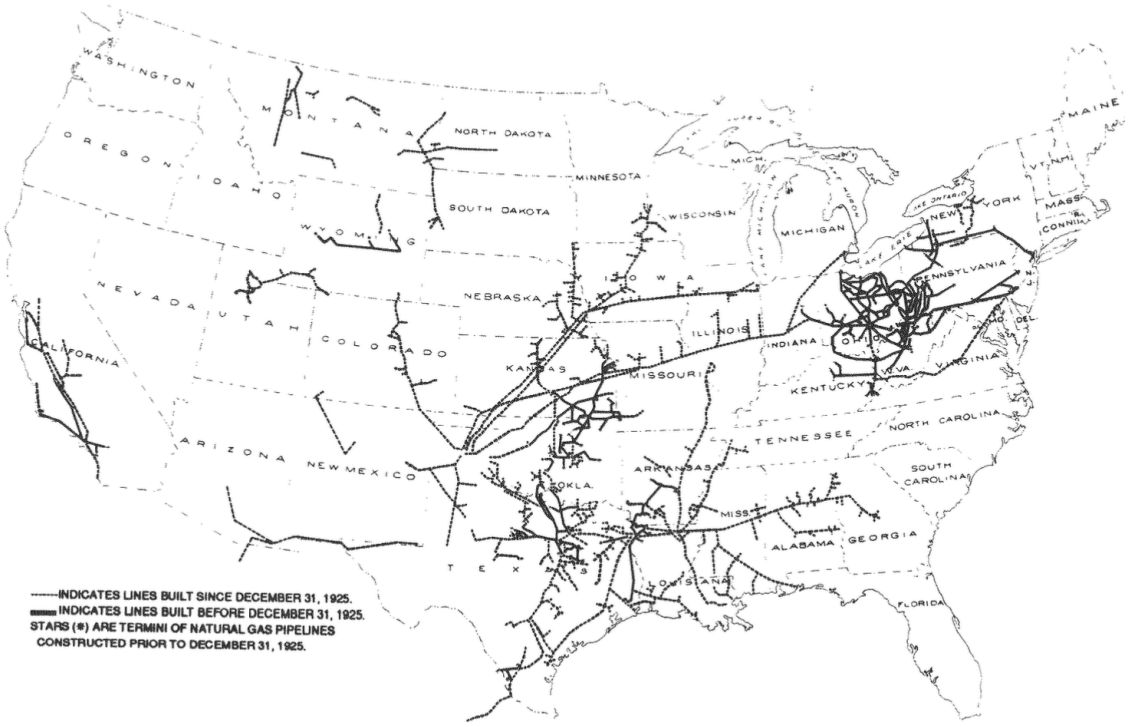
Notes: Schematic map of the major U.S. coal basins. During our study period, residential coal came predominantly from the Appalachian and Illinois basins; the Powder River basin became a major producer only later.

Figure 5: Map of Natural Gas Basins



Notes: Schematic map of the significant U.S. natural gas basins circa 1940–1970, keyed to the principal 1940 pipeline systems documented in Federal Trade Commission (1940). Blue basins were principal supply sources by 1940; brown basins expanded primarily during 1940–1970.

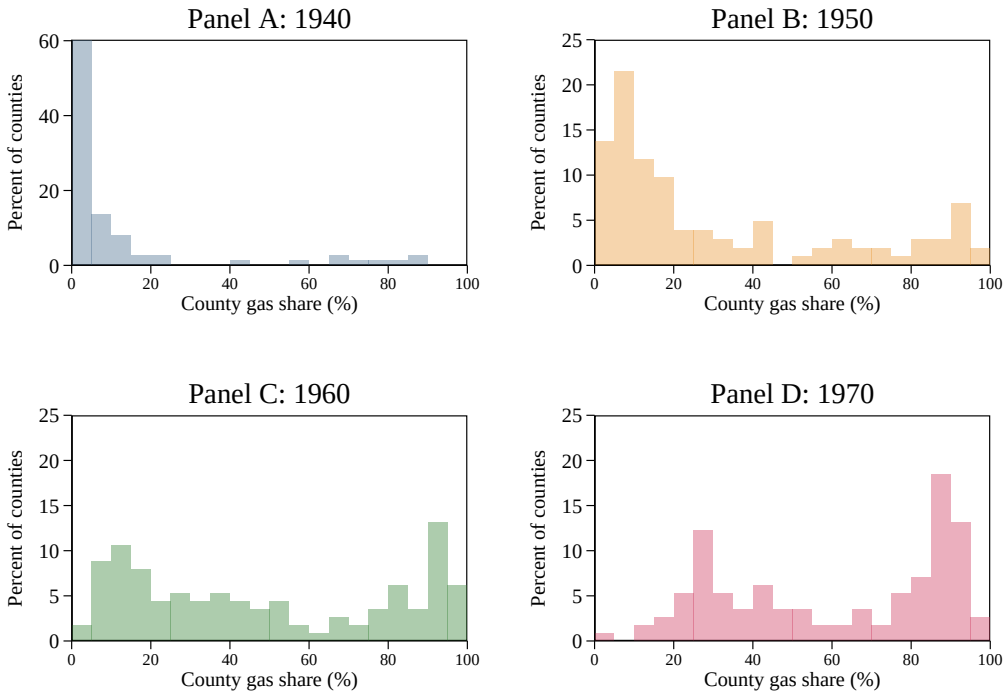
Figure 6: Map of Natural Gas Pipelines



Principal natural gas pipeline systems in the United States, 1940. Source: Federal Trade Commission Monograph no. 36 on Natural Gas Pipelines in USA. Published as Temporary National Economic Committee Report no. 76-3 (Senate Committee Print). Washington, DC: U.S. Government Printing Office, 1940.

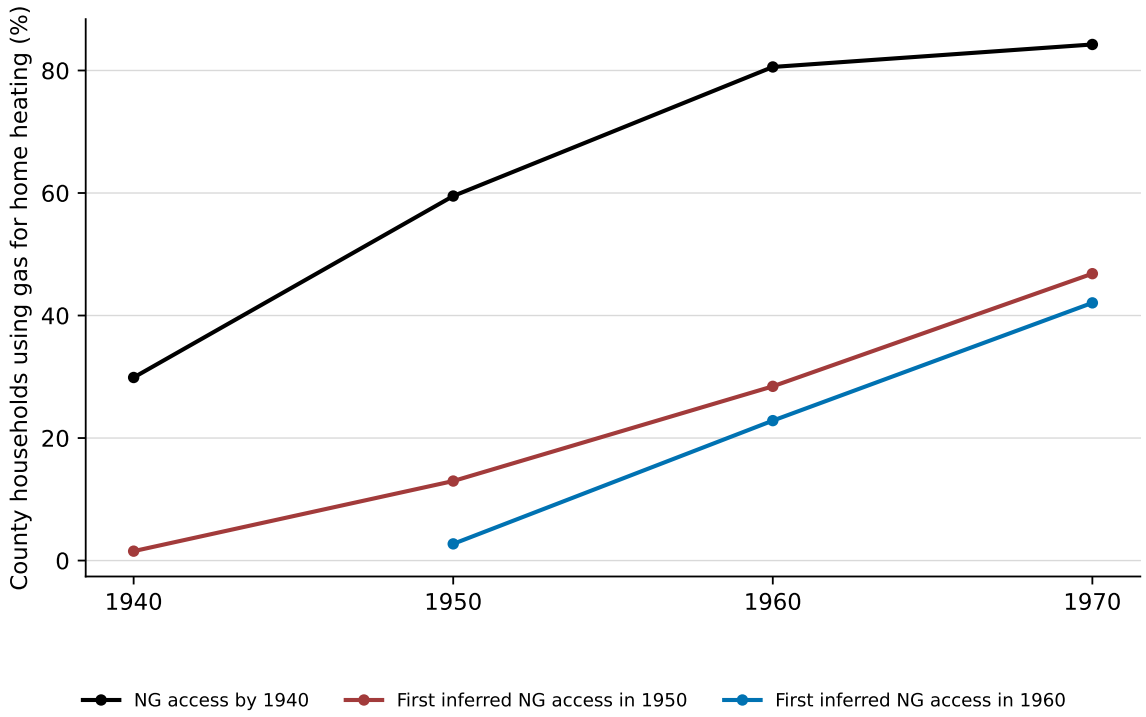
Notes: Principal natural gas pipeline systems in the United States as of 1940. Heavy lines indicate pipelines built before December 31, 1925; light dashed lines indicate pipelines built after that date; stars mark termini of pipelines constructed prior to December 31, 1925. Source: Federal Trade Commission (1940).

Figure 7: Gas Distribution by County and Decade



Notes: Each panel is a histogram of county-level gas-heating shares for one census year, for the balanced sample of tracts harmonized to 1970 boundaries. A county's share is total housing units heating with gas divided by total heating units, aggregated across the county's sample tracts; each county receives equal weight.

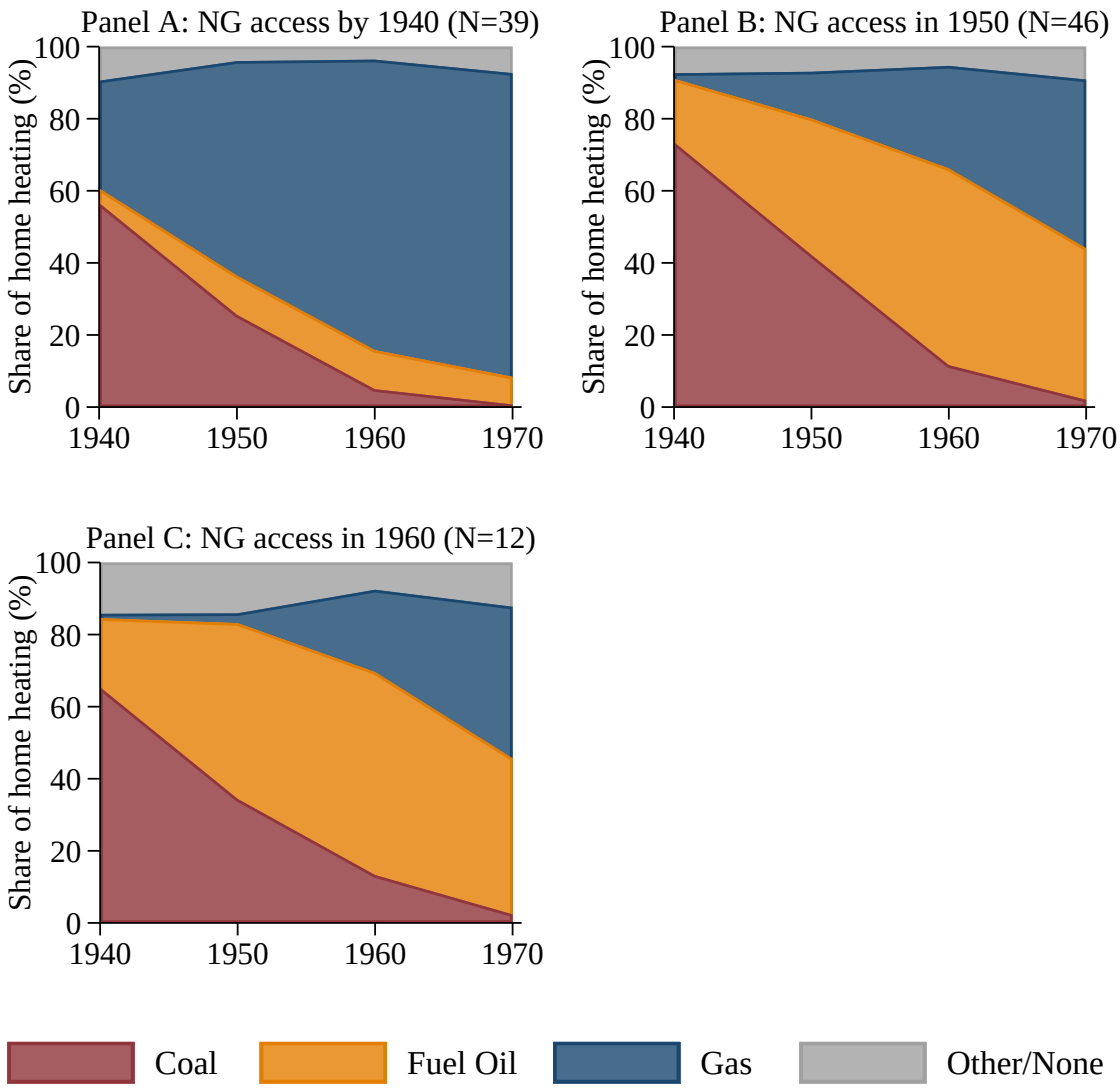
Figure 8: Adoption of Natural Gas by Gas-Access Cohorts and Over Time



Notes: Hybrid NG-access cohorts combine the county 5% heating-share proxy with FPC 1942 and AGA 1949 natural-gas service for counties missing 1940 or 1950 heating data. Cohorts contain 39, 46, and 12 counties; plotted county counts can vary by year when the census outcome is unobserved. County shares use summed gas and heating units; cohort means give observed counties equal weight.

Notes: Each line shows the mean county gas-heating share by census year for one gas-access cohort (39, 46, and 12 counties, respectively). Cohorts are defined by the county 5 percent gas-heating-share proxy, filled in with Federal Power Commission (1942) and American Gas Association (1949) records of natural gas service for the 16 counties whose census heating data cannot date the threshold crossing. A county's share is total gas units divided by total heating units across its sample tracts; cohort means give counties equal weight. Sample: balanced tract panel harmonized to 1970 boundaries; plotted county counts can vary by year where the census heating outcome is unobserved.

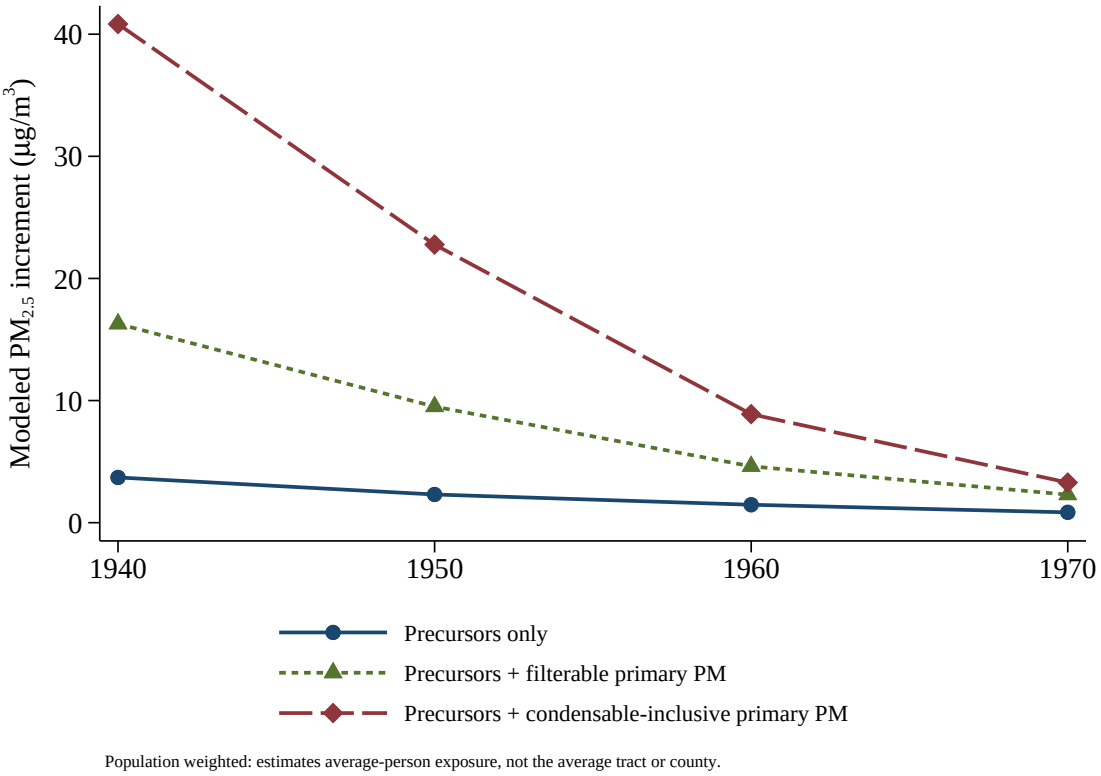
Figure 9: Fuel Mix by Gas-Access Cohorts and Over Time



Hybrid access proxy combines the county 5% rule with FPC 1942 and AGA 1949 service.
County outcome support varies by decade where census heating data are unobserved.

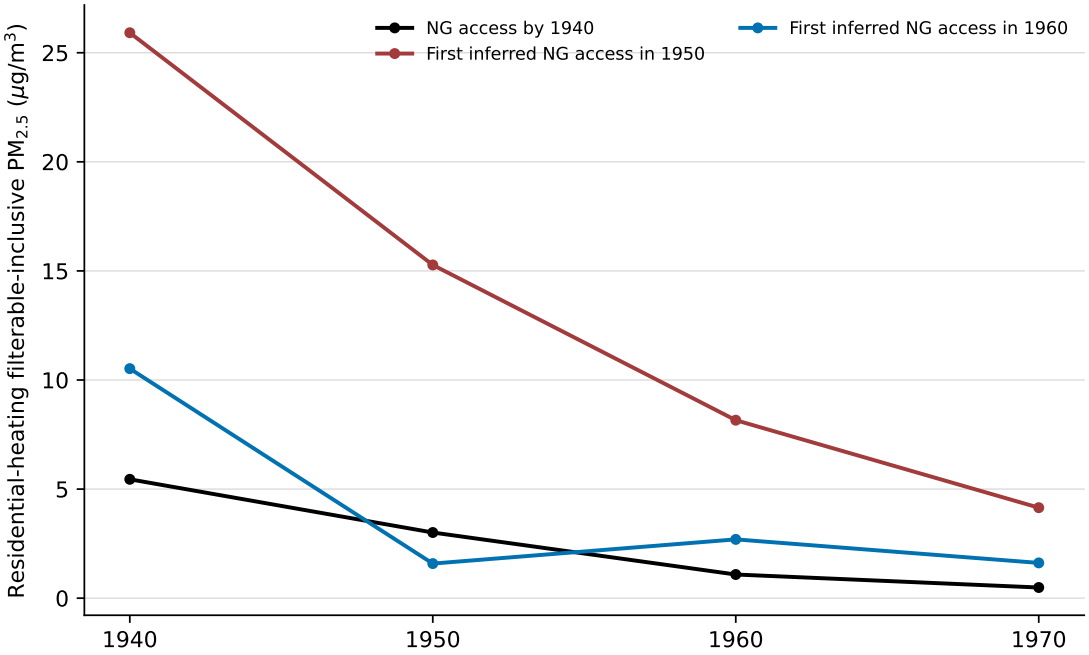
Notes: Each panel shows the evolution of the heating-fuel mix (shares of heating units using coal, fuel oil, gas, and other/none) for one gas-access cohort, defined as in Figure 8 (N = 39, 46, and 12 counties). Shares are computed from housing-unit counts aggregated across each county's sample tracts and averaged with equal county weights. Sample: balanced tract panel harmonized to 1970 boundaries.

Figure 10: $PM_{2.5}$ From Home Heating Over Time



Notes: Each line shows the population-weighted mean of modeled annual-average $PM_{2.5}$ from home heating ($\mu g/m^3$) across the balanced sample of tracts, under the three measures defined in Section 3.2: precursors only (lower bound), precursors plus filterable primary PM (headline), and precursors plus condensable-inclusive primary PM (upper bound). Weights are contemporaneous tract population.

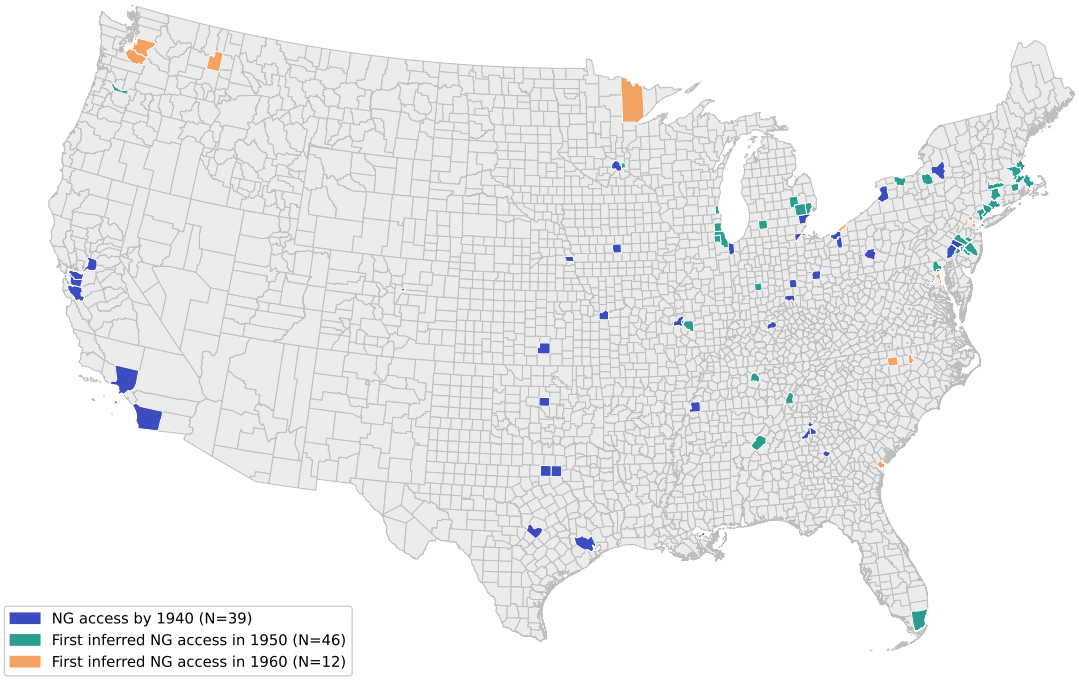
Figure 11: $PM_{2.5}$ By County Gas-Access Cohorts and Time



Notes: Hybrid NG-access cohorts use the county 5% heating-share proxy, filled in with FPC 1942 and AGA 1949 natural-gas service for counties missing 1940 or 1950 heating data. Cohorts contain 39, 46, and 12 counties; plotted county counts can vary by year where the census outcome is unobserved. County exposure is population-weighted within county; cohort means give observed counties equal weight. All measures use pinned 2005 ISRM chemistry.

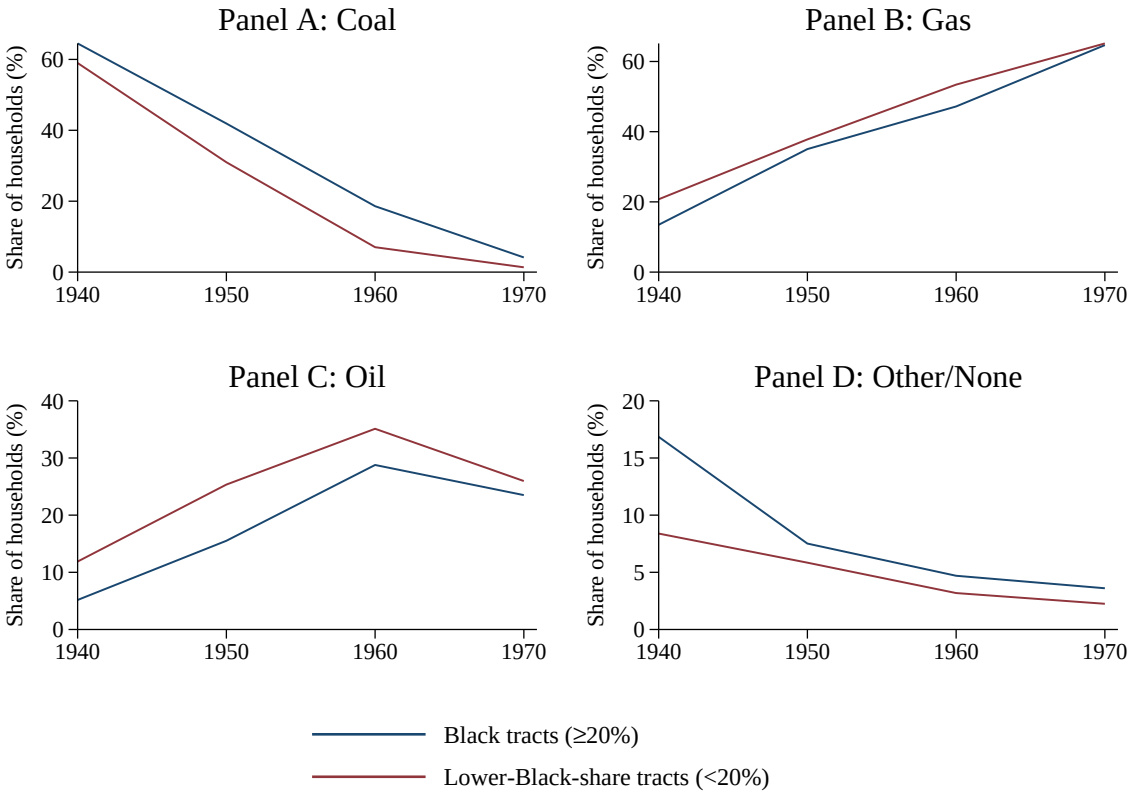
Notes: Each line shows mean county exposure to modeled annual-average $PM_{2.5}$ from home heating ($\mu g/m^3$, headline filterable-primary measure) by census year for one gas-access cohort, defined as in Figure 8 (N = 39, 46, and 12 counties). County exposure is the population-weighted mean across the county's sample tracts; cohort means give counties equal weight. Sample: balanced tract panel harmonized to 1970 boundaries; plotted county counts can vary by year where the census heating outcome is unobserved.

Figure 12: Map of Census Tract Counties By Gas-Access Cohort



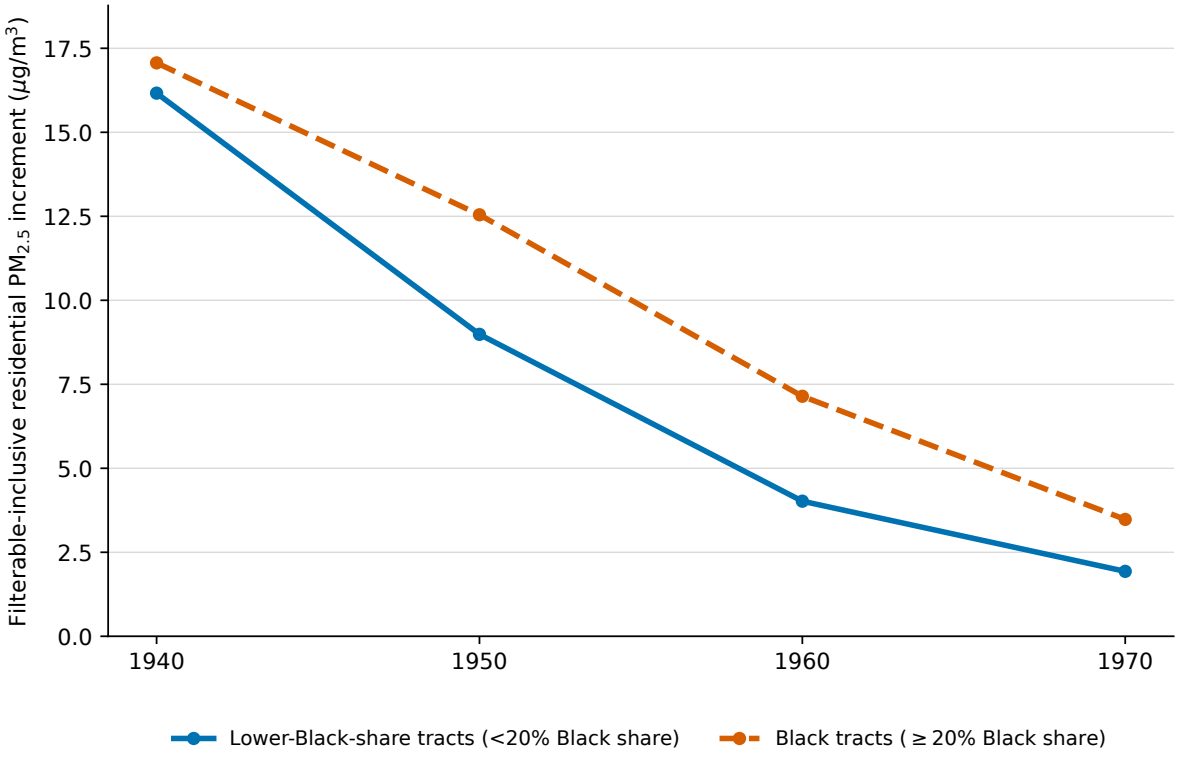
Notes: This map shows the 97 sample counties (1970 boundaries) colored by gas-access cohort: natural gas access by 1940 (N = 39), first access in the 1940s (N = 46), and first access in the 1950s (N = 12). Cohorts are defined by the county 5 percent gas-heating-share proxy, filled in with Federal Power Commission (1942) and American Gas Association (1949) records of natural gas service for the 16 counties whose census heating data cannot date the threshold crossing.

Figure 13: Fuel Use by Race Over Time



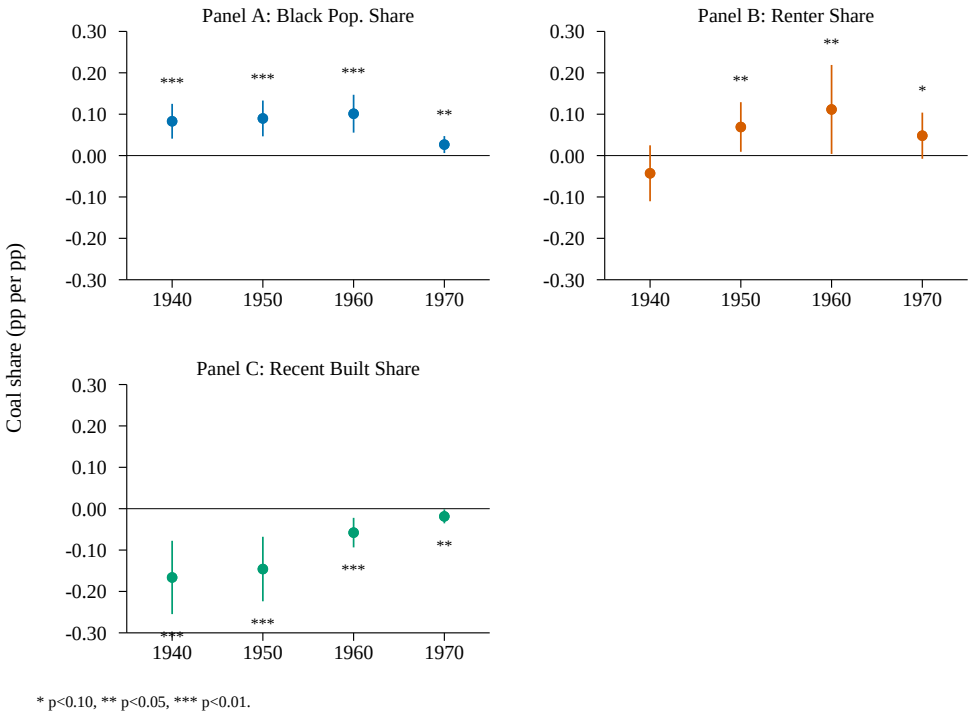
Notes: Each panel shows unweighted mean tract shares of housing units heating with one fuel, separately for higher Black-share tracts (contemporaneous Black population share of at least 20 percent) and lower Black-share tracts (below 20 percent). Sample: balanced tract panel harmonized to 1970 boundaries.

Figure 14: $PM_{2.5}$ from Heating by Race Over Time



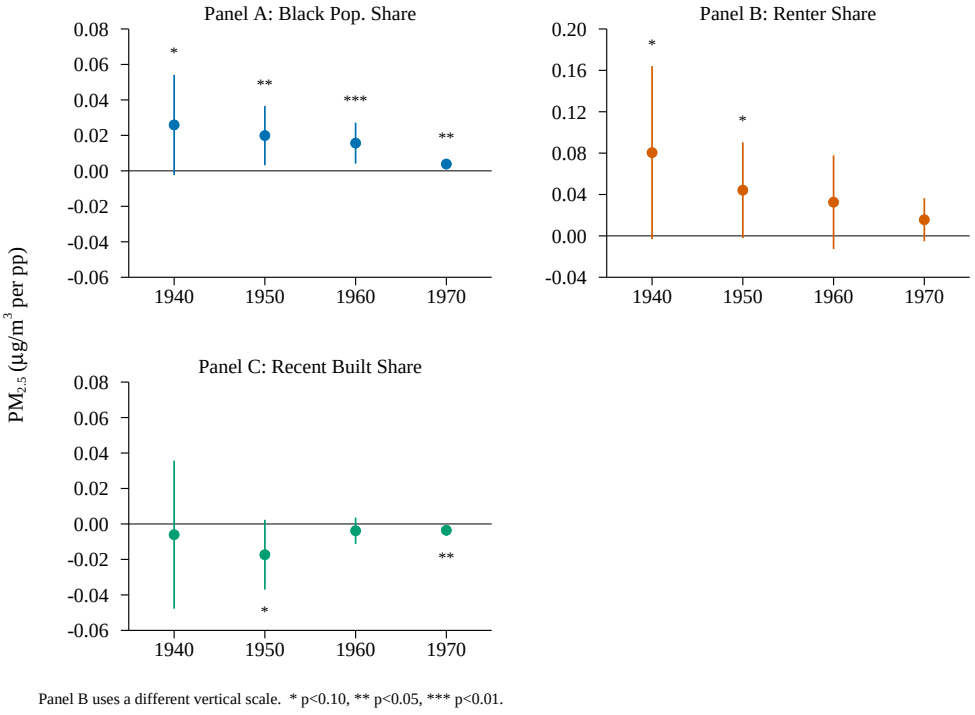
Notes: Each line shows the population-weighted mean of modeled annual-average $PM_{2.5}$ from home heating ($\mu g/m^3$, headline filterable-primary measure), separately for higher Black-share tracts (contemporaneous Black population share of at least 20 percent) and lower Black-share tracts (below 20 percent). Sample: balanced tract panel harmonized to 1970 boundaries.

Figure 15: Correlates of Tract Level Coal Use



Notes: Each point is the coefficient on the labeled regressor from a separate year-specific regression of tract coal share (percentage points of heating units) on Black population share, renter share, and recently built share, controlling for median household income, heating degree days, and population density, with county fixed effects (equation 1). Coefficients are in percentage points of coal share per percentage point of the regressor; spikes are 95 percent confidence intervals based on county-clustered standard errors. Sample: balanced tract panel harmonized to 1970 boundaries, unweighted. Full estimates are in Table 2.

Figure 16: Correlates of Tract Level $PM_{2.5}$



Notes: Each point is the coefficient on the labeled regressor from a separate year-specific regression of modeled tract $PM_{2.5}$ from home heating ($\mu g/m^3$, headline filterable-primary measure) on Black population share, renter share, and recently built share, controlling for median household income, heating degree days, and population density, with county fixed effects (equation 1). Coefficients are in $\mu g/m^3$ per percentage point of the regressor; spikes are 95 percent confidence intervals based on county-clustered standard errors. Sample: balanced tract panel harmonized to 1970 boundaries, unweighted, restricted to tracts with modeled $PM_{2.5}$. Full estimates are in Table 2.

Table 2: Correlates of Tract-Level Coal Use and $PM_{2.5}$ from Home Heating

	Coal share (pp)				Filterable-inclusive $PM_{2.5}$ ($\mu g/m^3$)			
	(1) 1940	(2) 1950	(3) 1960	(4) 1970	(5) 1940	(6) 1950	(7) 1960	(8) 1970
Black pop. share (pp)	0.083***	0.090***	0.101***	0.027**	0.026*	0.020**	0.016***	0.004**
	(0.021)	(0.022)	(0.023)	(0.010)	(0.014)	(0.009)	(0.006)	(0.001)
Renter share (pp)	-0.043	0.069**	0.111**	0.048*	0.080*	0.044*	0.033	0.016
	(0.034)	(0.031)	(0.055)	(0.028)	(0.043)	(0.024)	(0.023)	(0.011)
Recent-built share (pp)	-0.166***	-0.146***	-0.058***	-0.019**	-0.006	-0.017*	-0.004	-0.004**
	(0.045)	(0.040)	(0.018)	(0.009)	(0.021)	(0.010)	(0.004)	(0.002)
Median HH income (thousand dollars)	-1.008***	-1.226***	-0.228	0.029	-0.000	-0.181	0.044	0.021
	(0.370)	(0.239)	(0.223)	(0.085)	(0.189)	(0.221)	(0.055)	(0.019)
Heating degree days (1,000s)	1.241*	0.320	0.529	0.165	-0.116	-0.659	-0.494	-0.178*
	(0.649)	(0.556)	(0.391)	(0.119)	(0.335)	(0.449)	(0.338)	(0.103)
Pop. density (1,000/km^2)	0.211**	0.213**	0.226**	0.066	0.439***	0.300***	0.191***	0.085***
	(0.085)	(0.096)	(0.090)	(0.053)	(0.077)	(0.087)	(0.052)	(0.029)
Constant	35.920**	26.451*	-8.298	-5.363	8.445	20.948*	13.601*	5.544**
	(17.374)	(13.975)	(10.304)	(4.927)	(7.807)	(10.979)	(7.399)	(2.458)
Observations	10,444	14,417	14,774	14,885	10,444	14,417	14,774	14,885
R^2	0.900	0.729	0.516	0.338	0.894	0.845	0.802	0.852
Adj. R^2	0.899	0.727	0.513	0.334	0.893	0.844	0.801	0.851

Notes: Year-specific cross-sectional regressions (equation 1) on the balanced tract panel harmonized to 1970 boundaries, unweighted. Columns 1–4 use the tract coal share (percentage points of heating units) as the dependent variable; columns 5–8 use modeled $PM_{2.5}$ from home heating ($\mu g/m^3$, headline filterable-primary measure). All regressions include county fixed effects; standard errors, in parentheses, are clustered by county. Median household income is in thousands of current dollars (1950 medians are reported directly, 1960 and 1970 medians are bin-interpolated, and the 1940 columns use 1950 income as a proxy because no 1940 tract income exists); heating degree days are in thousands; population density is thousands of persons per square kilometer of 1970 tract land area. The $PM_{2.5}$ sample is restricted to tracts with modeled exposure, and both samples drop observations with missing income, degree-day, or density data. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.