Coal, Smoke, and Death

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The use of coal for home and commercial heating increased rapidly, peaked in the mid-1940s, and declined sharply. The switch to cleaner fuels was driven by declining relative prices for natural gas and fuel oil, the end of war-related supply restrictions, and a series of coal strikes from 1946-1950. This paper documents these trends and uses newly digitized monthly state mortality data to estimate the mortality effects of changing coal consumption for heating over the period 1933-1958. The mortality effects are identified by variation in heating degree days across seasons and across years, variation in the use of coal for heating over time, and variation in coal intensity across states and regions. In the Northeast, Midwest, and West, a 1 percent decline in retail coal consumption was associated with a 0.06-0.10 percent decline in overall mortality. The effects of changing use of coal by industry and electric utilities are also examined.

1. Introduction

The use of coal for heating increased rapidly through the mid 1940s and then began to decline sharply. Part of the decline was driven by the end of war-related supply restrictions on oil and natural gas and the availability of conversion units for furnaces. The American coal strikes of the second half of the 1940s likely accelerated what was would have occurred anyway – the replacement of coal for residential, commercial, and transportation use with cheaper and cleaner fuel sources such as oil and natural gas. Several other changes during the 1930s and 1940s also played key roles in making a switch possible. For example, through the end of the 1930s, natural gas was in wide use for cooking. It could not, however, be used for heating because of pipeline capacity issues during the winter months. Only with the development of large-scale natural gas storage facilities in some eastern states could natural gas be successfully used for heating. The development of storage and distribution networks for oil and liquefied natural gas also played important roles in making these fuels feasible alternative to coal. Finally, in cities with severe air pollution problems, civil leaders had already begun to use the tools at their disposal to try to drive households towards cleaner fuels.

The move away from coal, which was predominantly bituminous, was particularly important for air quality and mortality. Residential, commercial and transportation users burned coal in dense urban areas, at relatively low temperatures, which increased the release of pollutants, and had low chimneys. In contrast, companies involved in manufacturing and electricity generation tended to be located away from the most densely populated areas, burned coal at high temperatures, and had high smokestacks that allowed for dispersion of smoke across a much wider area. The improvements in air quality had broad implications for mortality.

This paper documents the rapid shift away from coal for heating and uses newly digitized monthly state mortality data to estimate the mortality effects of this decline over the period 1933-1958. The mortality effects are identified by variation in coal for heating across seasons, over time, and across states. The paper also examines the mortality effects associated with the changing use of coal by industry and electric utilities.

This paper contributes to two literatures. The first is the small but expanding historical literature on fuel use and fuel transitions (Wright 1964, Herbert 1992, Castaneda 1999). The second is the literature on the causes of declines in infant and overall mortality. Compared to most previous work in economics (Currie and Neidell 2005, Chay and Greenstone 2003) and related work in epidemiology (Pope et al 2002, Laden 2006), this work examines a period in which air pollution was much more severe and investigates changes that occurred over longer time spans.[1]

2. Particulates and Mortality

[1] This paper is also closely related to work done by Lave and Seskin, much of which is summarized in their 1977 book. They investigated the relationship between particulates and mortality in 117 cities in 1960. Two other closely related papers are Almond et al (2009), which examines policies relate to the use of coal for home heating in China on total suspended particulates (TSP), and Clay and Troesken (2010), which examined the mortality effects of London fogs over the period 1855-1910.

A large epidemiological literature documents the link between pollution and more specifically airborne particulates and mortality. The studies use different measures of particulates – total suspended particulates (TSP), which are typically less than 25-45 microns, particulates less than 10 microns (PM_{10}), and particulates less than 2.5 microns ($PM_{2.5}$) – and different samples. In the United States, the main samples have been the Harvard Six Cities Sample (Laden et al 2006) and the American Cancer Society Cancer Prevention II study (Pope et al 2002). The studies began in the late 1970s and early 1980s, respectively. Their findings are based on tracking of sample participants, all of whom were adults when they entered the studies. The main outcome measure is overall mortality, although the studies also track cause of death data. The reason the studies focus on overall mortality is that cause of death is often subjective and attributions of cause of death may change over time.

Particulates are believed to cause mortality in the adult population through three main mechanisms (Pope et al 2004, DelFino et al 2005). The first is that particulates cause pulmonary and systemic inflammation and accelerated atherosclerosis. The second is that particulates adversely affect cardiac autonomic function, causing heart arrhythmias. The third, more minor mechanism, is through pneumonia, but the effects seem to be primarily for nonsmokers.

The studies examine mortality from particulate exposure at different frequencies, daily, monthly, and annually. One concern with the high frequency studies is that pollution is merely shifting the timing of mortality, but not affecting overall mortality. While shifts in the timing, known as 'harvesting', are for some individuals, the studies find that exposure to particulates also increases overall mortality (Schwartz 2000, Pope et al 2009).

Related work by economists has examined the effects of sharp declines in particulate levels on infant mortality in the United States (Currie and Neidell 2005, Chay and Greenstone 2003) and variation in pollution levels on overall mortality in London (Clay and Troesken 2010). Some epidemiological studies also use quasi-natural experiments to examine the effects of changes in particulate exposure on overall mortality (Pope et al 1992, Clancy et al 2002, Hedley et al 2002, Pope et al 2007). These studies all find strong links between particulates and mortality-related outcomes.

3. Particulate Creation by Use

Over the period 1933-1958, there was a rapid increase and equally rapid decline in the use of coal for home heating. Figure 1 shows national retail deliveries of bituminous coal over time.[2] Retail coal consumption was stable or falling during the mid-1930s and then rose sharply into the mid 1940s. Warm weather in 1938 and to a lesser degree in 1939 contributed to decreased coal consumption in those years. A colder winter in 1940 and higher per capita income relative to 1938 and 1939 led to increased coal sales. By 1950, retail coal sales were lower than they had been in 1935. By 1958, sales were less than one-third of the peak.

[2] A comparable series is not available for anthracite coal. The *Minerals Yearbook* suggests that roughly 80 percent of the coal was bituminous coal, and the remainder was anthracite coal. Anthracite coal tended to burn more cleanly than bituminous coal, but was predominantly mined in eastern Pennsylvania and consumed along the eastern seaboard. The remainder of the country used bituminous coal. State level time series are not available during this period.

Although coal for home heating was a relatively small share of overall coal consumption (Figure 2), a number of factors magnified its contribution to air quality. These include indoor air pollution, location of emissions, the temperature at which coal was burned, and seasonality. Some households burning coal did so in open hearth or other settings that led to smoke entering the house from the heat source, leading to low indoor air quality. Households in urban areas burned emitted particles from low chimneys in close proximity to individuals. In contrast, most non-retail coal (coal used for electricity generation, industrial purposes, and transportation) was burned in less densely populated areas and discharged through higher smokestacks. In households, coal was also burned at lower temperatures than coal used for non-retail purposes. This led to higher particulate emissions per ton of coal burned. Finally, household coal use was highly seasonal. Minerals Yearbook only begins reporting consumption by use by month in 1951. Figure 3 plots the consumption by month of retail and non-retail coal use for 1951 and 1958. January consumption for retail coal is more than three times the consumption in the lowest month, which typically falls in the May-July window. In comparison, non-retail use is only slightly seasonal.

Although only scattered evidence exists on air quality for the period 1933-1958, they are consistent with reductions in household use of coal having had a significant impact on air quality. Soot fall in New York and Pittsburgh peaked in the mid 1940s and declined rapidly thereafter (Eisenbud 1978, Davis and Davidson (2005). An analysis of hours of winter solar radiation in the United States shows gains in the 1950s, particularly for the North-Central region which has high numbers of heating degree days and intensive use of coal (Husar and Patterson 1980).

4. Changing Patterns in Home Heating

The first detailed household-level data on heating comes from the 1940 Census of Housing. Figure 4 provides data for coal and other heating fuels in 1940 and 1960. In 1940, 54 percent of U.S. households used coal for heat. The shares were: 23 percent wood, 11 percent gas, 9 percent fuel oil, and 3 percent other. Gas included natural gas, manufactured gas, which usually derived from coal, and mixed gas, which was a mixture of the two. In 1937, manufactured gas sales were about one third of total gas sales. In that year, only about 20 percent of manufactured gas was being sold for heating.

By 1960, the shares had changed dramatically. Natural gas and fuel oil were now the dominant fuels for home heating. 42 percent of households used natural gas and 38 percent used fuel oil. Coal was used by just 12 percent, and wood was used by 4 percent of households.

Demand for heat by households is a function of a number of factors, including the number of heating degree days, the price of fuel, and household income. Incomes were rising during much of the early twentieth century. The transition from having one or more fireplaces or stoves for heat to having central heating was occurring as households demanded more, and more even, heating. By 1940, 42 percent of households had central heat.

Figure 5 graphs real income and space heat per resident. Over the period 1935-1958, real income was rising, real fuel prices were falling, and space heat per resident in BTUs was rising. Space heat per U.S.

resident rose from roughly 38 BTUs (x 10^8) in 1935 to 62 BTUs (x 10^8) in 1958.[3] The actual difference is larger, because 1935 was colder, as measured by heating degree days, than 1958.

Figure 6 presents the trend in national relative (nominal) fuel prices over time. It indicates one reason for the dominance of bituminous coal over gas in 1940. Bituminous (and anthracite) coal was much cheaper. There were also significant supply issues, since gas pipelines had not fully been built out and seasonal demand required that companies local develop storage technology to meet winter demand. The question is why fuel oil was less prevalent. Part of the issue was distribution, since oil was moved in tankers until large-scale high volume pipelines were developed during WWII. If alternative fuels were similarly priced, customers preferred to switch away from coal. The *Greensburgh (PA) Daily Tribune* reported the results of a recent survey of residents' fuel choices in March 1946: "The survey disclosed that most local people are converting to natural gas because of the higher prices of coal, and because of the elimination of firing the furnace, removing ashes, and cleaning up basement dust by the use of gas. Gas furnaces are still somewhat more expensive to operate than coal furnaces, but the difference in most instances is not much considering the added conveniences."[4]

Availability and price of fuel varied both over time and across regions. For example, coal use was highest in the Midwest and Northeast, which were located closest to the bituminous coal districts. Figure 7 shows bituminous coal production districts, and Figure 8 shows household use of coal for heating by region and year. Coal use was more prevalent in regions closer to the coal fields. Table 2 lists states by the share of households using coal. Intensity is related to proximity to bituminous coal fields – in Ohio, Indiana, Illinois, and Pennsylvania more than 80 percent of households used coal. In distant states such as Maine, New Hampshire, and Vermont, less than 40 percent of households used coal.

Table 3 presents city-level prices for 1941-1954. In 1941, in cities such as Boston, Cincinnati, Cleveland, Minneapolis, Portland, and Seattle, fuel oil and natural gas were either cheaper than coal or were within 10 percent of the cost on a cents per BTU basis. In Chicago and Pittsburgh, gas became cheaper than bituminous coal in 1947. In some cities, gas became cheaper than bituminous somewhat earlier or later. In a few places, one fuel dominated through the period. In New York, Philadelphia, and Scranton, anthracite coal continued to offer the lowest prices. In Baltimore, bituminous coal was the least expensive. And in Cleveland, gas was the lowest cost fuel. Houston, Los Angeles, and San Francisco did not have other fuels that were competitive.

Two supply-related factors had significant impacts on the rise and decline of coal for home heating. The first factor is World War II. Figure 9 illustrates the rapid growth in sales of heating oil during the pre-War period. Roughly 70 percent of this volume was distillate oil, which would become Number 2 heating oil. The remainder was heavier residual oil, which would be sold for heating or blended with lighter oils before sale. Supply was becoming an issue even before the United States entered the war as shipping capacity became scarce. Rationing of fuel oil beginning in October 1942 limited the ability of coal users to switch to fuel oil and reportedly incentivized some fuel oil users to switched back to coal, which was not rationed. In New York in fall of 1945, the removal of rationing on oil and the strengthening of rationing of anthracite coal prompted a rush to convert to oil. The *New York Times* reported "The present

[3] Strout (1961), Table 1, p. 187.
[4] Greensburg (PA) Daily Tribune, March 22, 1946, p. 1.

wave of conversions to oil is not confined to systems that burned oil before the wartime shortage caused a shift to coal. Many systems that were originally installed for coal are being converted to oil or replaced with oil equipment."[5] The *Times* also noted that the original oil to coal conversion cost about $50 and the reconversion cost about $50 if the oil burner and controls were still in working order. The effects of restrictions on natural gas were less significant, because pipeline and storage issues precluded the use of natural gas for heating in many areas of the country (Herbert 1992). This evidence suggests that World War II delayed the switch away from coal, particularly the switch to fuel oil.

The second factor is the large-scale coal strikes in the spring of 1946 and in the fall of 1949 through the spring of 1950. Strikes had occurred in the pre-war period, notably in 1939 and 1941. With the exception of early 1941, however, Figure 10 shows that production was above 1 million net tons per day. The price of railroad fuel, which was correlated with the price of retail coal, was fairly stable at about $2/ton for much of the 1930s. But the strikes in 1946 and 1949-1950 sharply restricted production and adversely affected coal stocks. In both cases, daily production fell from 2 million tons per day to well below 1 million tons per day. In these same years, Table 1 indicates that the gas industry, which published statistics on furnaces, boilers, and conversion burners, experienced sharp upticks both in furnaces and in conversion burners. Conversion burners allowed homeowners to switch from using coal to natural gas without replacing the entire furnace. Overall, the coal strikes may have accelerated the switch away from coal.

By 1949, major expansion of natural gas pipelines had taken place. Part of the expansion came with the sale and conversion of the Big Inch and Little Big Inch pipelines, which had been proposed and built to move oil from Texas to the East Coast during World War II. In 1947, the pipelines were sold to the Texas East Transmission Company and were converted to natural gas. Figure 11 shows major gas pipelines in 1949, including the big and little inch. This spurred the development of further underground storage from 250 billion cubic feet in 1947 to 1,859 billion cubic feet in 1954. Storage was primarily located in former gas, oil, or mixed oil and gas fields in Pennsylvania, Michigan, Ohio, and West Virginia. Thus, by the 1949-1950 coal strikes occurred, natural gas was a viable alternative for many households. The share of residential gas customers using gas for heating rose from 36 percent in 1949 to 53 percent in 1954.[6]

5. Basic Patterns of Mortality

This paper argues that use of coal for home heating generated particulate pollution and thus raised overall mortality. Before moving to estimation, it is helpful to understand the basic patterns in the mortality data. The top panel of Figure 12 plots January and July mortality rate for every state in every year and the lowess curve for January and July. The January mortality rate is higher than the July mortality rate. Both lines are trending down, indicating declining overall mortality in both months. Further, the two lines begin to converge at some point in the mid 1940s. The pattern is clearer in the bottom panel of Figure 12, which plots January mortality rate as a fraction of the July mortality rate for each state and year. The relative mortality rate is steady through 1943 or 1944, at which point it begins to decline.

[5] New York Times, September 12, 1945, p. 22 (continued from page 1).
[6] Historical Statistics of the American Gas Association, Table 142, p. 239.

Although many factors may have affected the relative rate of mortality, the pattern is consistent with rising pollution levels partially or fully offsetting other improvements in winter mortality through the mid-1940s and declining pollution levels contributing to the partial convergence of the two mortality rates after then.

6. Data and Identification

The empirical analysis draws on a number of different data sources. Mortality is the monthly state mortality rate per 100,000 from all causes and is taken from *Vital Statistics*, various years.[7] Monthly data at the city level and by cause of death would also be of interest, but *Vital Statistics* of the United States have not yet been digitized for the years of interest. Monthly temperature and precipitation data are from NOAA. Annual national coal use by type is from *Minerals Yearbook*, various years. Demographic controls are interpolated from data in the decadal censuses of population. Further details are available in the data appendix.

Before considering coal, it is useful to think about explaining the state monthly mortality rate. Equation 1 allows the mortality rate to be a function of state-month, state time trends, (national) year fixed effects, monthly temperature and precipitation, and demographic variables. State-month fixed effects capture state-specific average monthly mortality. Year fixed effects capture year-to-year variation in national mortality caused by variation in the severity of seasonal flu and other infectious disease, the development of new drugs, the economy, or other factors. State time trends capture public health initiatives and other factors likely to lower state mortality over time. The temperature and precipitation variables allow for differential effects of unusually high or low temperatures or precipitation by month. Demographic controls include average age, share living in urban locations, share white, and share foreign born. The demographic controls are linearly interpolated between census years. Equation (1) is estimated with clustered standard errors at the state level.

(1) $\log \text{drate}_{imy} = a + b_{im}\text{state}_i \times \text{month}_m + c_i\text{state}_i \times \text{time} + d_y\text{year}_y + e_m\text{temp}_{imy} + f_m\text{precip}_{imy} + \text{demog}_{iy} + \varepsilon_{imy}$

States will consume different amounts of retail coal and generate different amounts of particulates depending on (at least) two factors. The first is the number of heating degrees in state i in month m. Heating degrees = 65 – average monthly temperature. Warmer states will have fewer heating degree days and require less coal. The second is the share of households using coal. In principle, variation in the number of degree days and fuel sources within states over time will allow us to identify the effects of retail coal on mortality. Table 4 reports the number of heating degrees and coal heating degrees, which is heating degrees times the share of households using coal in 1940. If this share changes proportionately over time, coal heating degrees will be highly correlated with the states' share of retail coal consumption over time. The correlation between the share of households using coal in 1940 and 1950 is 0.93 and between 1940 and 1960 is 0.69.

States will also consume different amounts of non-retail coal and generate different amounts of particulates from this source as well. Unlike retail coal, the use of non-retail coal is less variable over

[7] Alan Barreca kindly supplied the data.

time and across seasons. It does, however, vary across regions and this will be used to help identify the effects of non-retail coal.

The key identification issue is to separate the effects of variation in temperature, which can effect mortality, from variation in coal use. Like equation (1), equation (2) includes both state-month fixed effects and monthly temperature effects. It also, however, includes a full set of interaction effects for coal heating degrees and log(retail coal) and controls for non-retail coal. Thus, any effects of variation in temperature are captured by the state-month fixed effects, monthly temperature effects, and coal heating days (CHD). The effects of coal are captured by log(retail coal) and by the interaction effects of CHD with log(retail coal). The former captures baseline effects, since some coal is burned in the summer to heat hot water. The latter captures the increased burning of coal that occurs when temperatures are colder and more households use coal.

(2) $\log drate_{imy} = a + b_{im}state_i \times month_m + c_i state_i \times time + d_y year_y + e_m temp_{imy} + f_m precip_{imy} + g demog_{iy} + hCHD_{imy} + iCHD_{imy} \times \log(\text{retail coal})_y + j_r \log(\text{retail coal})_y + k_r \log(\text{non-retail coal})_y + \varepsilon_{imy}$

7. Results

Table 5 establishes the plausibility of a relationship between retail coal consumption and mortality. Column 1 shows that higher consumption of retail coal is associated with higher mortality, controlling for the variables in equation (1) and the log of non-retail coal. Column 2 shows that the effect of retail coal is higher in the Northeast, Midwest, and West than in the South. The relative magnitudes of the effects are consistent with patterns in the bottom panel of Table 4. That is, the coefficient is highest for the Midwest, which has the highest number of coal heating degree days, second highest for the Northeast, which has the second highest number of days, and third highest for the West, which has the third highest number of days. Column 3 shows that the effects of coal are seasonal. Relative to the Northeast in the third quarter, the effect of retail coal consumption in the Northeast is the highest in the first quarter, falls in the second and third quarters, and then rises in the fourth quarter. It is worth noting that the estimated effect in the second quarter is larger than in the fourth quarter, despite the fact that the number of coal heating degrees is 5.1 in the second quarter and 13.5 in the fourth quarter. This would be consistent with coal-related pollution dispersing with some lag in the second quarter and taking a while to build up in the fourth quarter. The results are quite similar, although the magnitudes are somewhat smaller, in columns 4-6 when the lagged mortality rate was included in the regression.

Table 6 shows that the monthly mortality rate is related to retail sales of coal and that the effect increases with coal heating degree days. Column 1 assumes that the effect of retail coal consumption is constant across states. Column 2 relaxes this assumption and allows the effect of retail coal consumption to vary across regions. The marginal effect of higher exposure is lower, and the regional baseline effects are consistent with Tables 4 and 5. Column 3 allows the lagged coal heating degree days interacted with retail coal to have an effect on the monthly mortality rate. The lagged effect is much smaller than the contemporaneous effect. Column 4 controls for the lagged monthly mortality rate. The regional effects of coal fall, but the coefficient on coal heating degree days interacted with retail coal changes very little.

The magnitudes of the effects in Tables 5 and 6 suggest that a 1 percent increase in retail coal sales caused a 0.06-0.10 percent increase in the overall monthly mortality. If we assume that a 1 percent change in retail coal sales led to a 1 percent change in TSP – an admittedly heroic assumption – then it is possible to compare our results with Chay and Greenstone (2003), who use declines in TSP caused by the 1981-1982 recession to identify the effects on mortality. They find a 1 percent decline in TSP resulted in a 0.35 percent decline in infant mortality. In a related paper, Chay and Greenstone (2003b), they use declines in TSP caused by the Clean Air Act of 1970 to identify the effects on mortality. They find a 1 percent decline in TSP resulted in a 0.50 percent decline in infant mortality. The effects in this study are smaller, but the overall population is less sensitive to environmental pollutants than are infants.

8. Conclusions and Future Research

This research, although preliminary, suggests that reductions in coal use for heating had significant impacts impacts on air quality and mortality.

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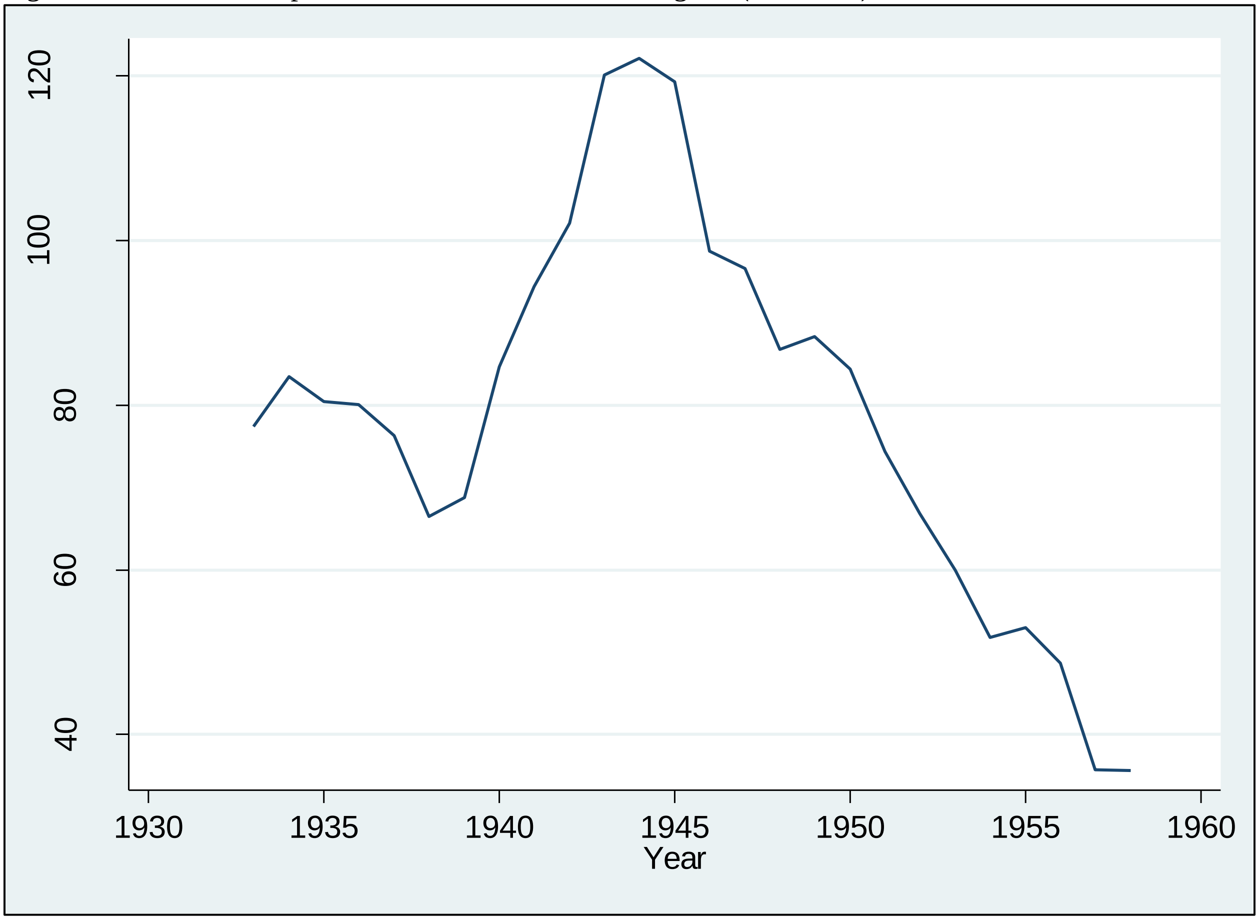
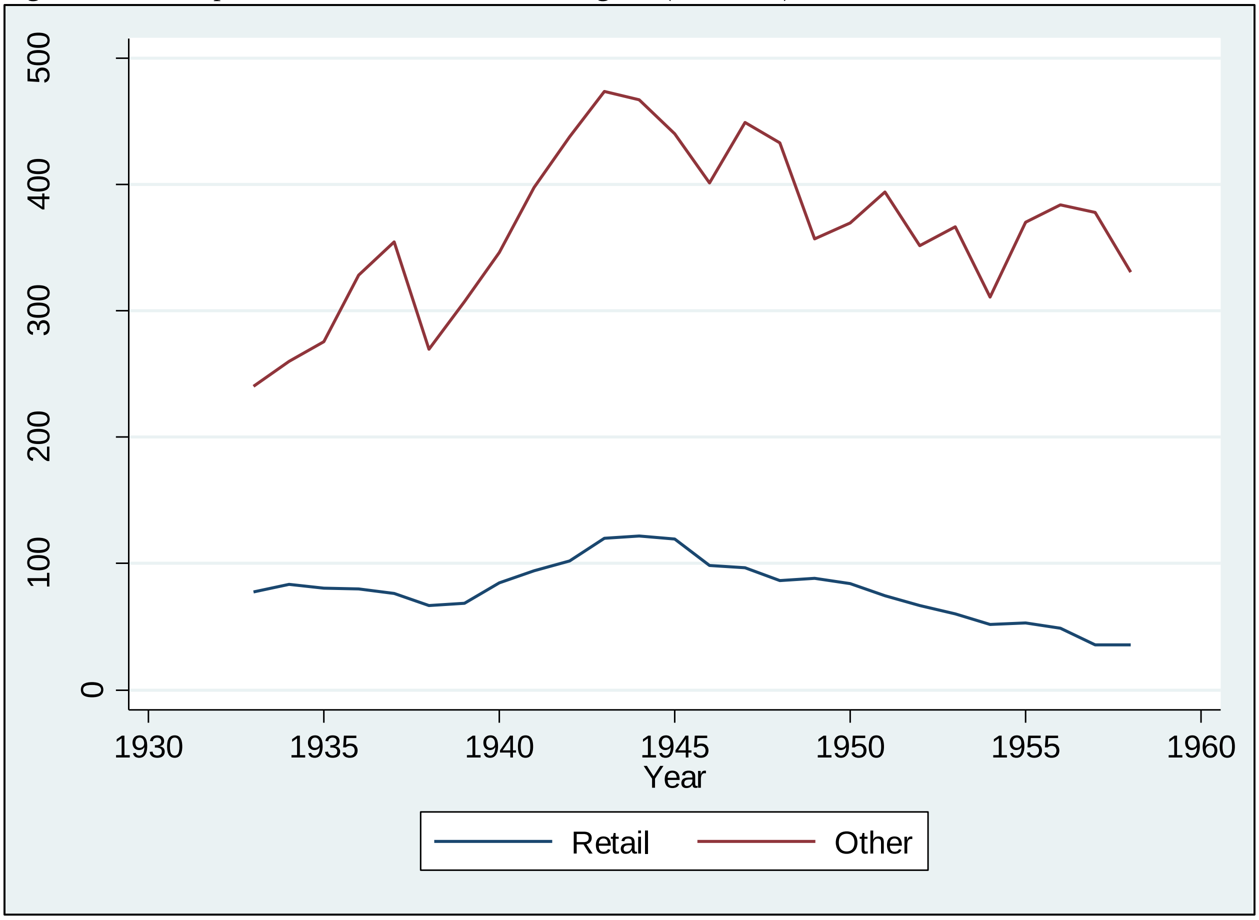
Figure 1: Retail Consumption of Bituminous Coal and Lignite (Soft Coal)



Source: *Minerals Yearbook*, various years.

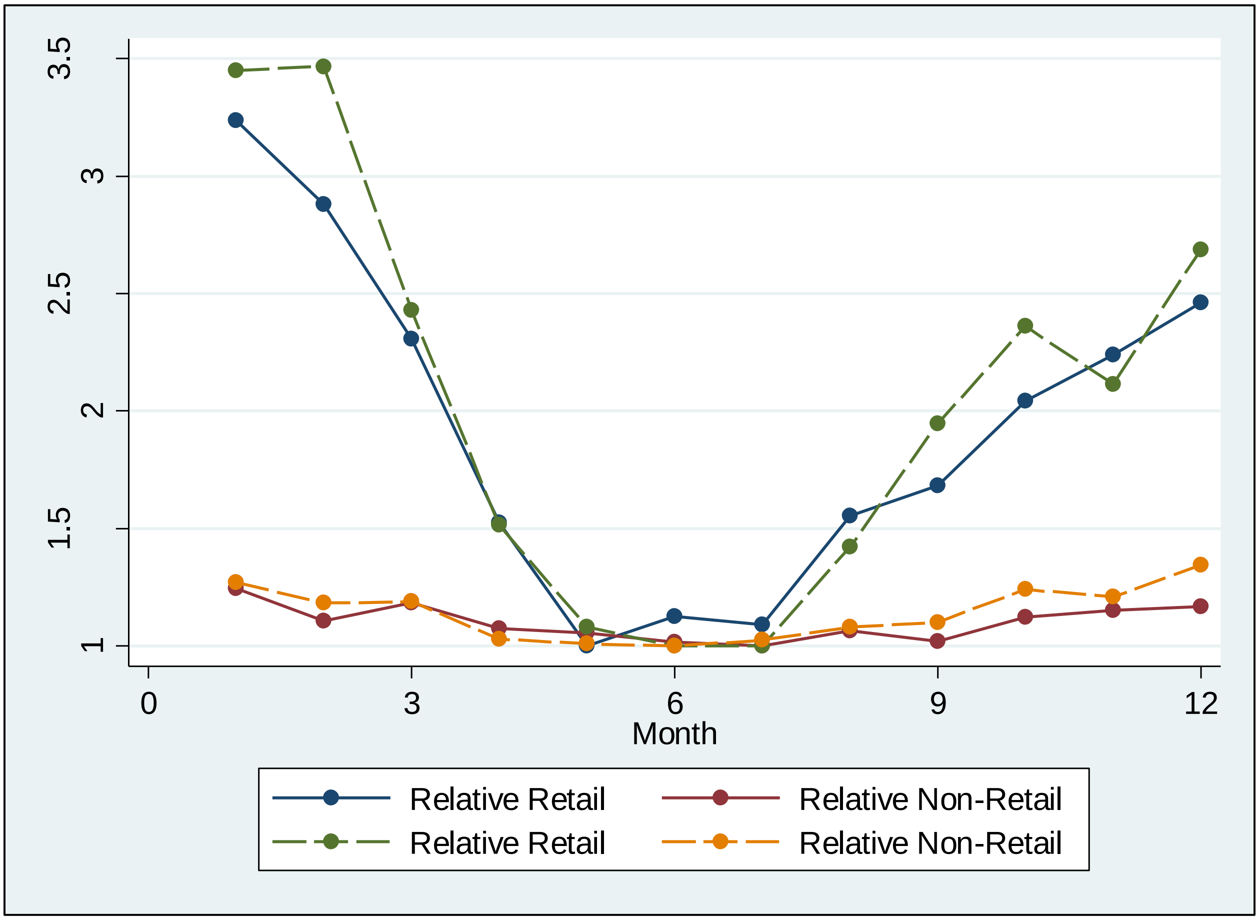
Notes: Retail sales of Anthracite coal, which was much cleaner, are not available until the 1950s. At that point, they were 20 percent of retail coal sales on a tonnage basis.

Figure 2: Consumption of Bituminous Coal and Lignite (Soft Coal)



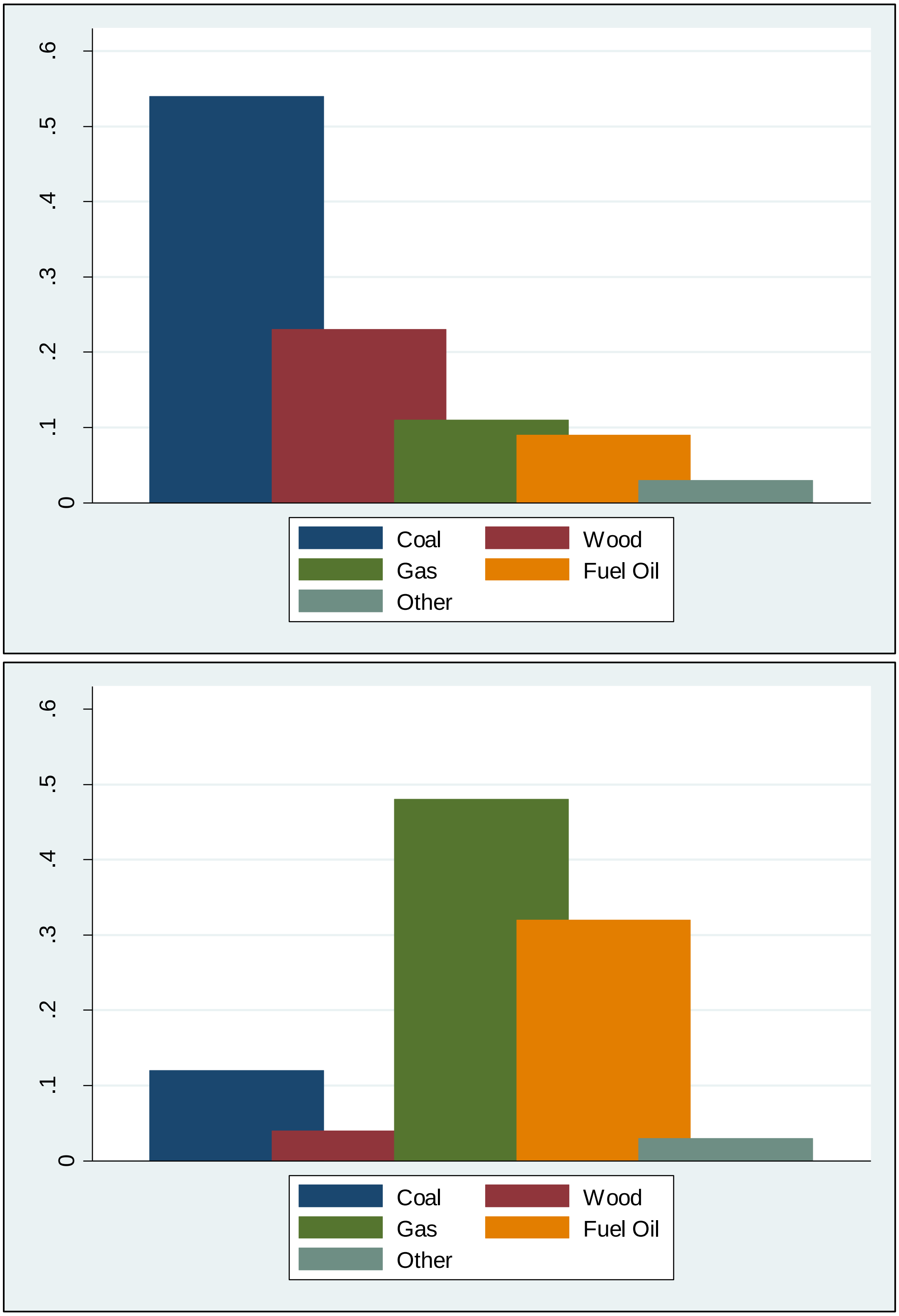
Source: *Minerals Yearbook*, various years.

Figure 3: Seasonality of Retail and Non-Retail Coal Consumption in 1951 and 1958



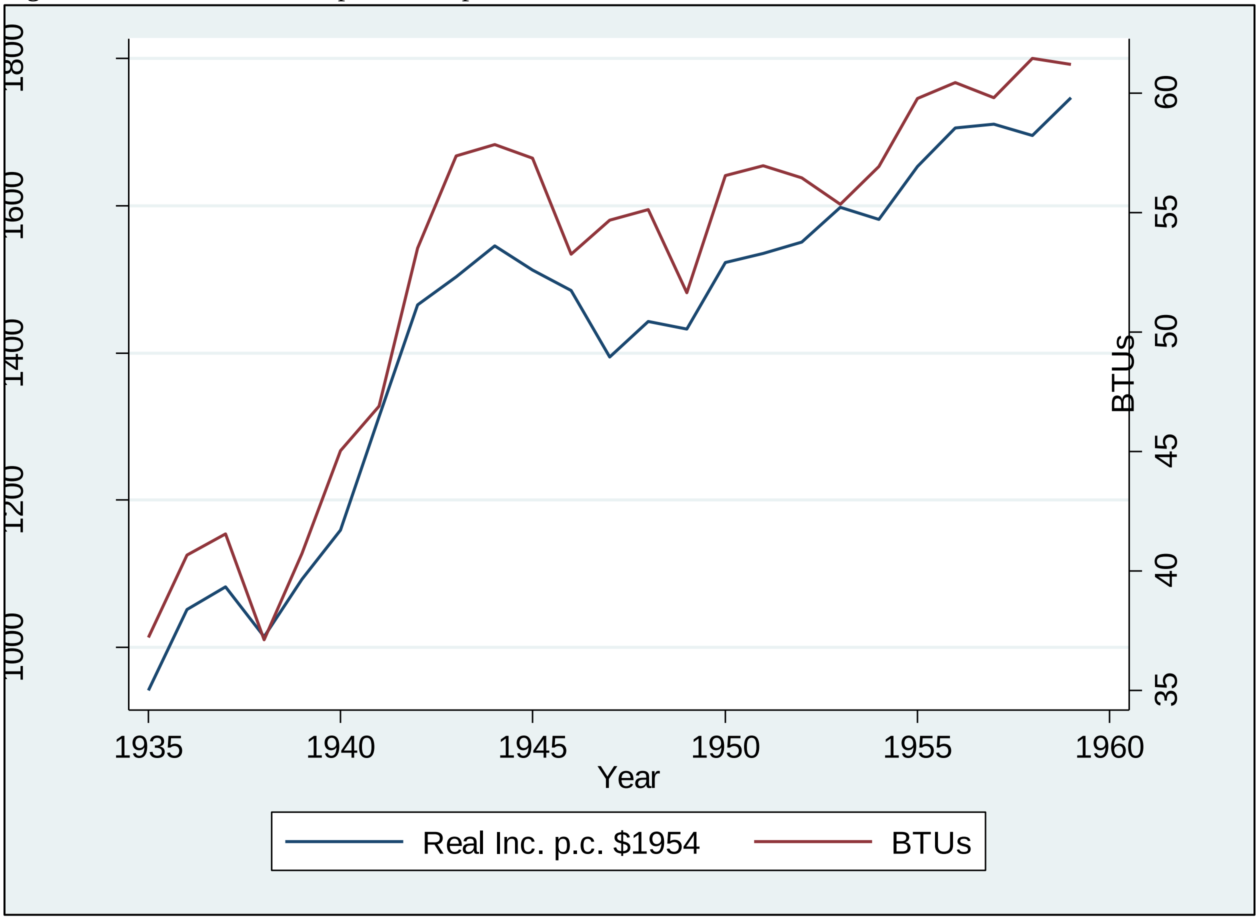
Notes: Solid lines are 1951 and dashed lines are 1958.
Source: *Minerals Yearbook* 1952, 1958.

Figure 4: Household Heating Fuels in 1940 and 1960



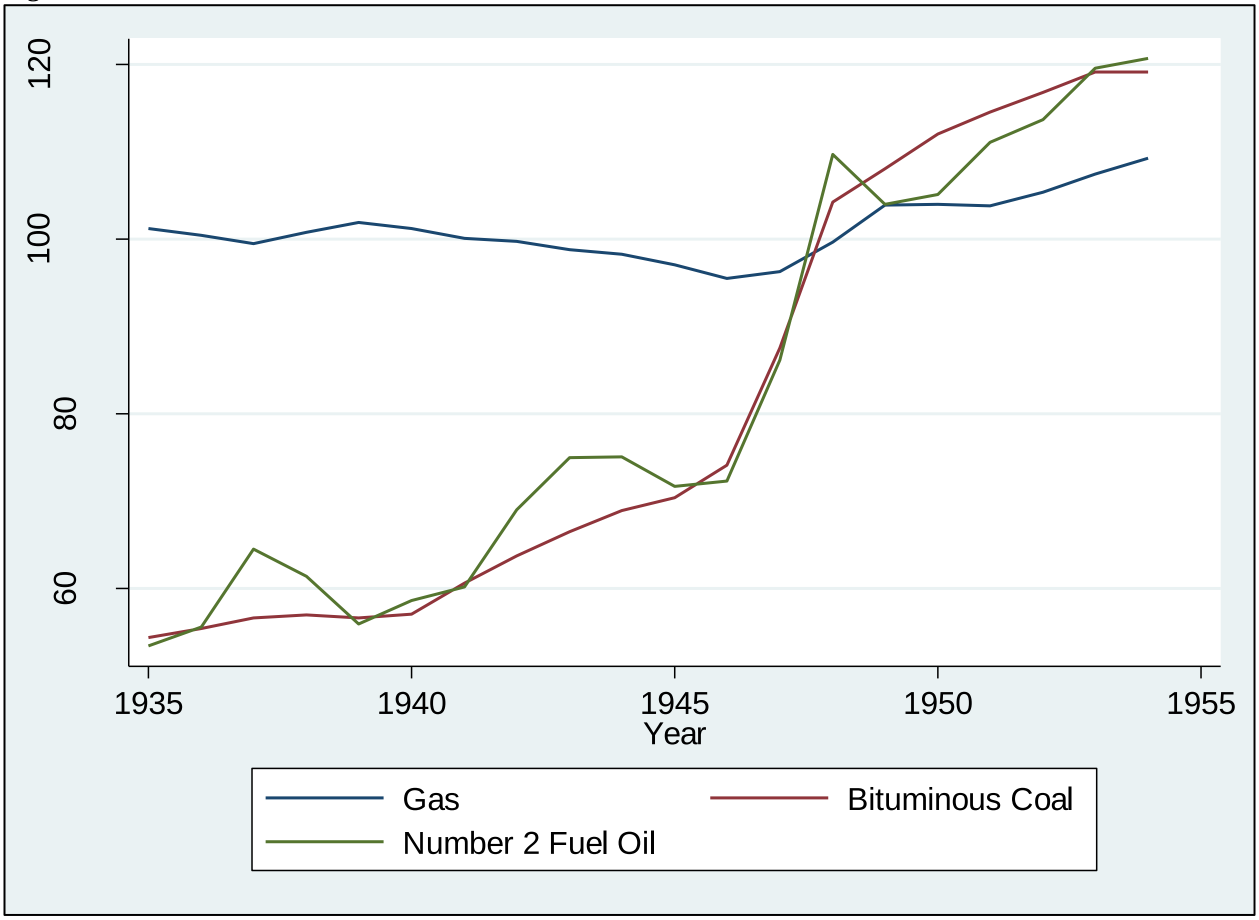
Source: *1940 Census of Housing*, *1960 Census of Housing*.

Figure 5: Real Income and Space Heat per Resident



Source: Strout 1961, Table 1

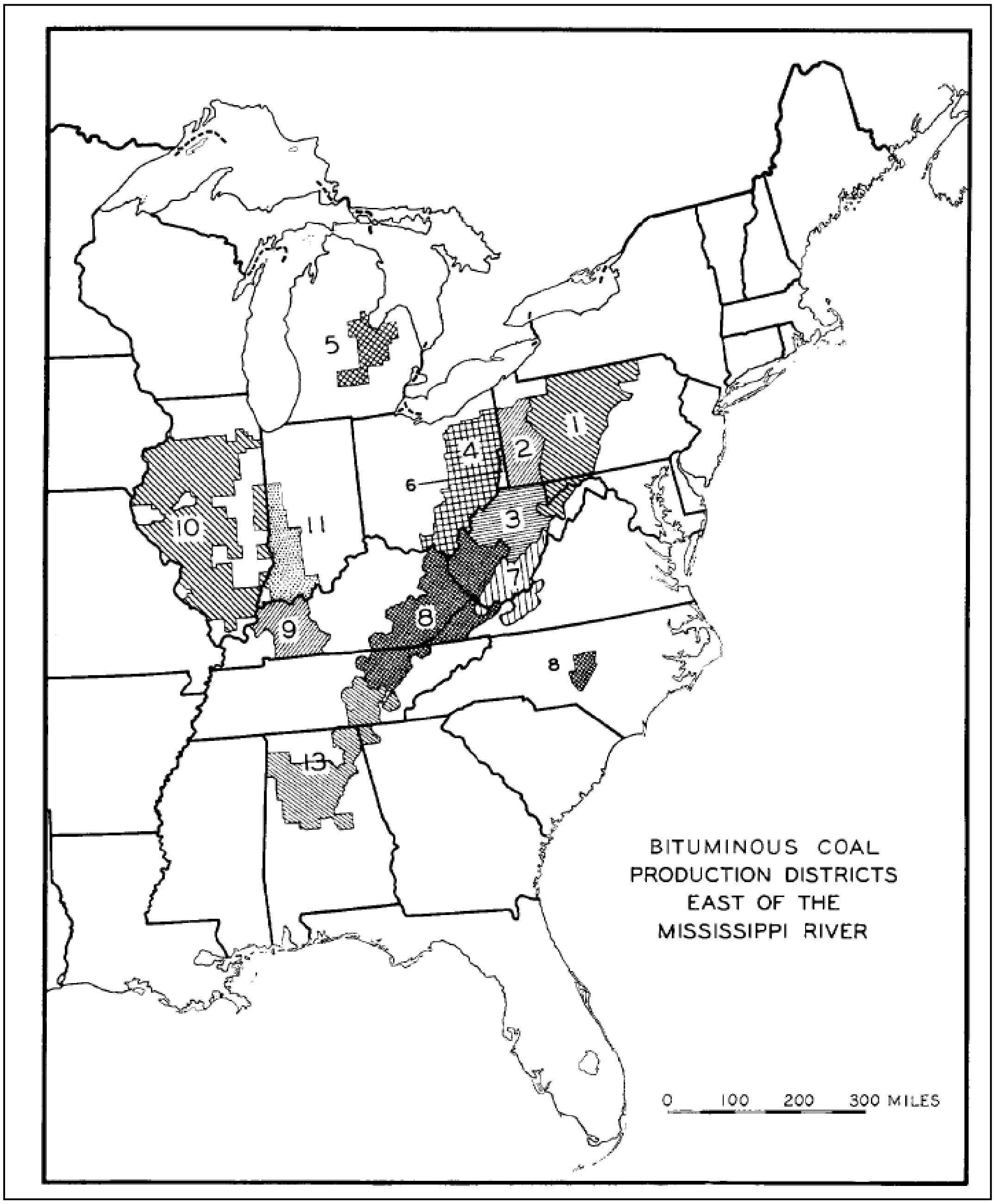
Figure 6: Nominal National Fuel Prices over Time



Source: Bureau of Labor Statistics as reproduced in *Historical Statistics of the American Gas Association*, Table 228, p. 308.

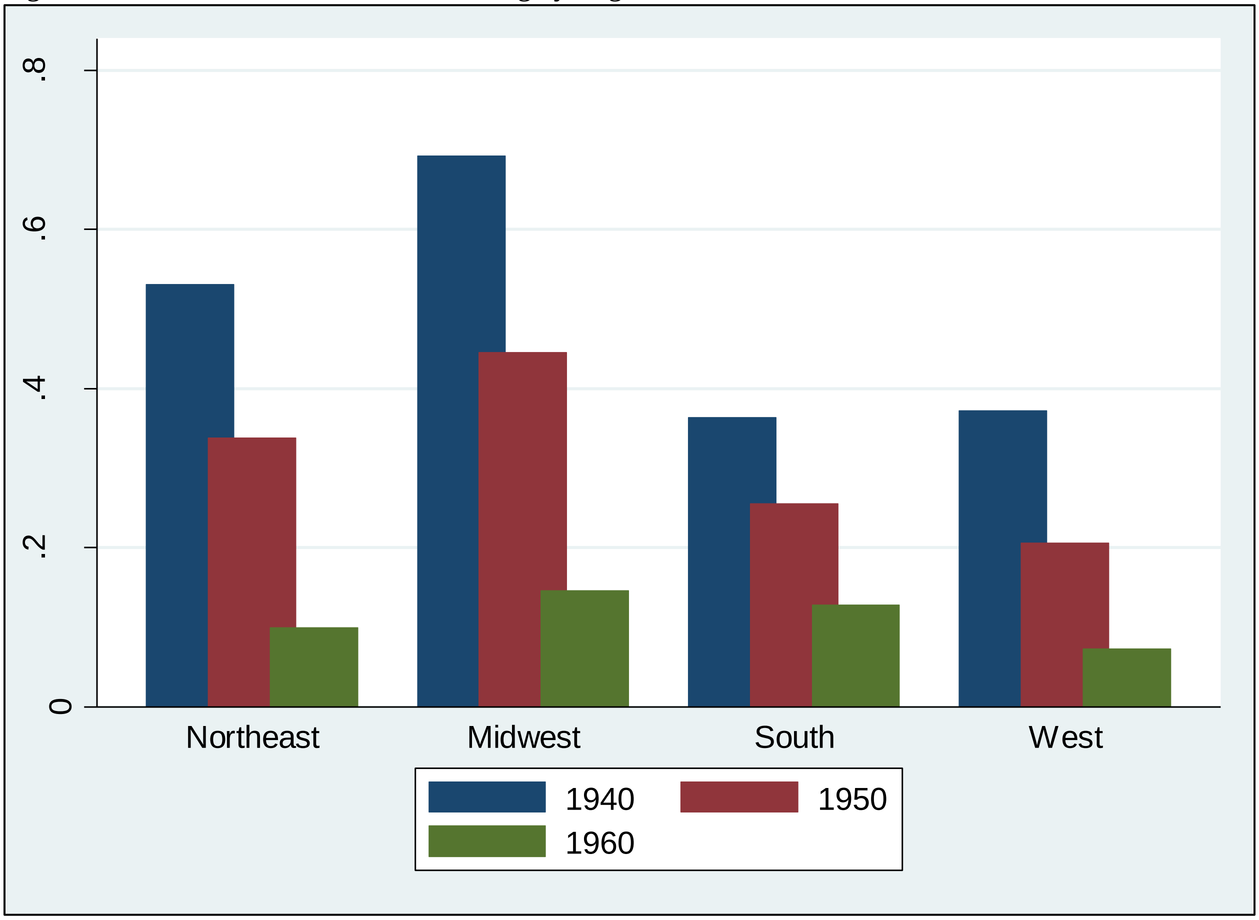
Notes: The cost per BTU of coal and gas was approximately equal in 1947-1948.

Figure 7: Bituminous Coal Fields East of the Mississippi



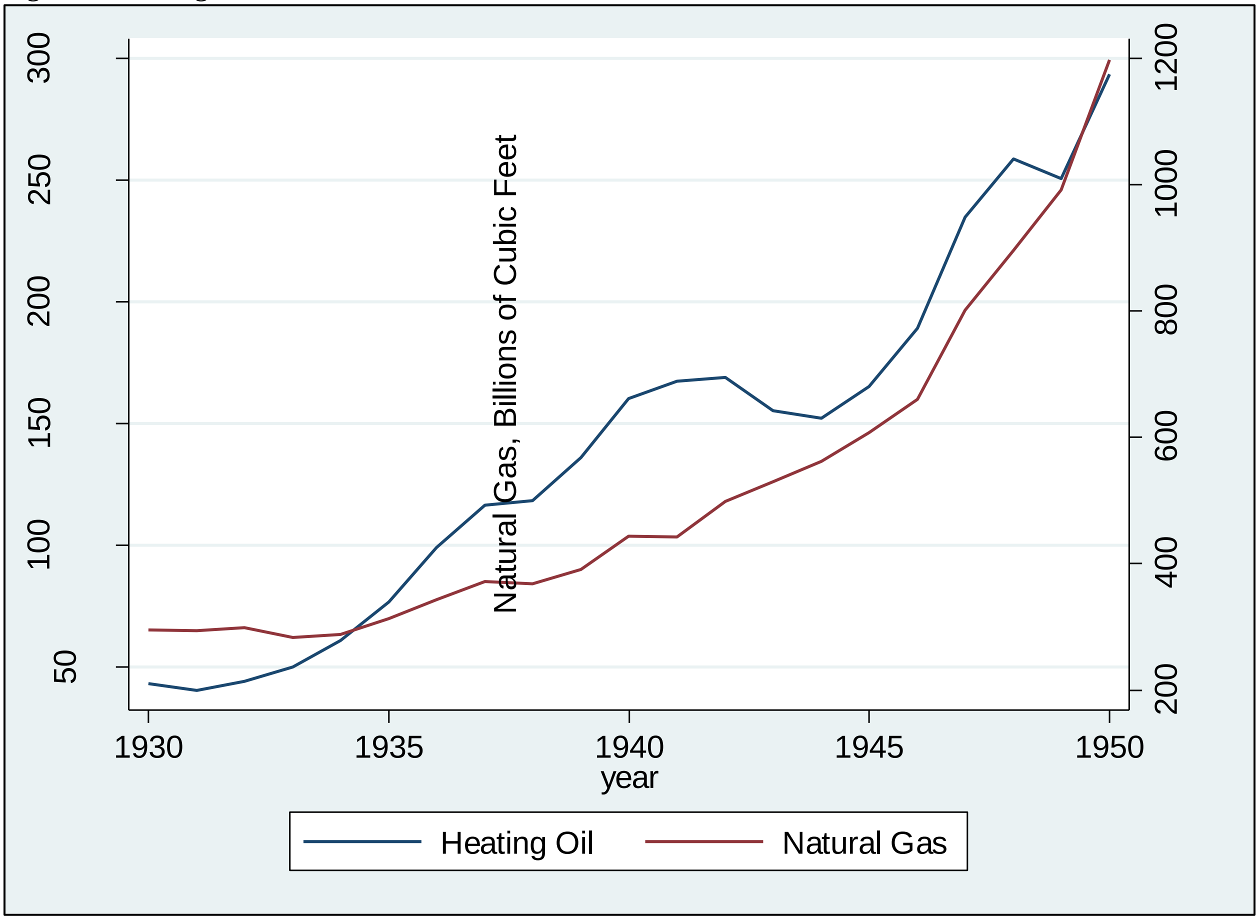
Source: Voskuil (1943), Figure 1, p. 118.

Figure 8: Household Use of Coal for Heating by Region and Year



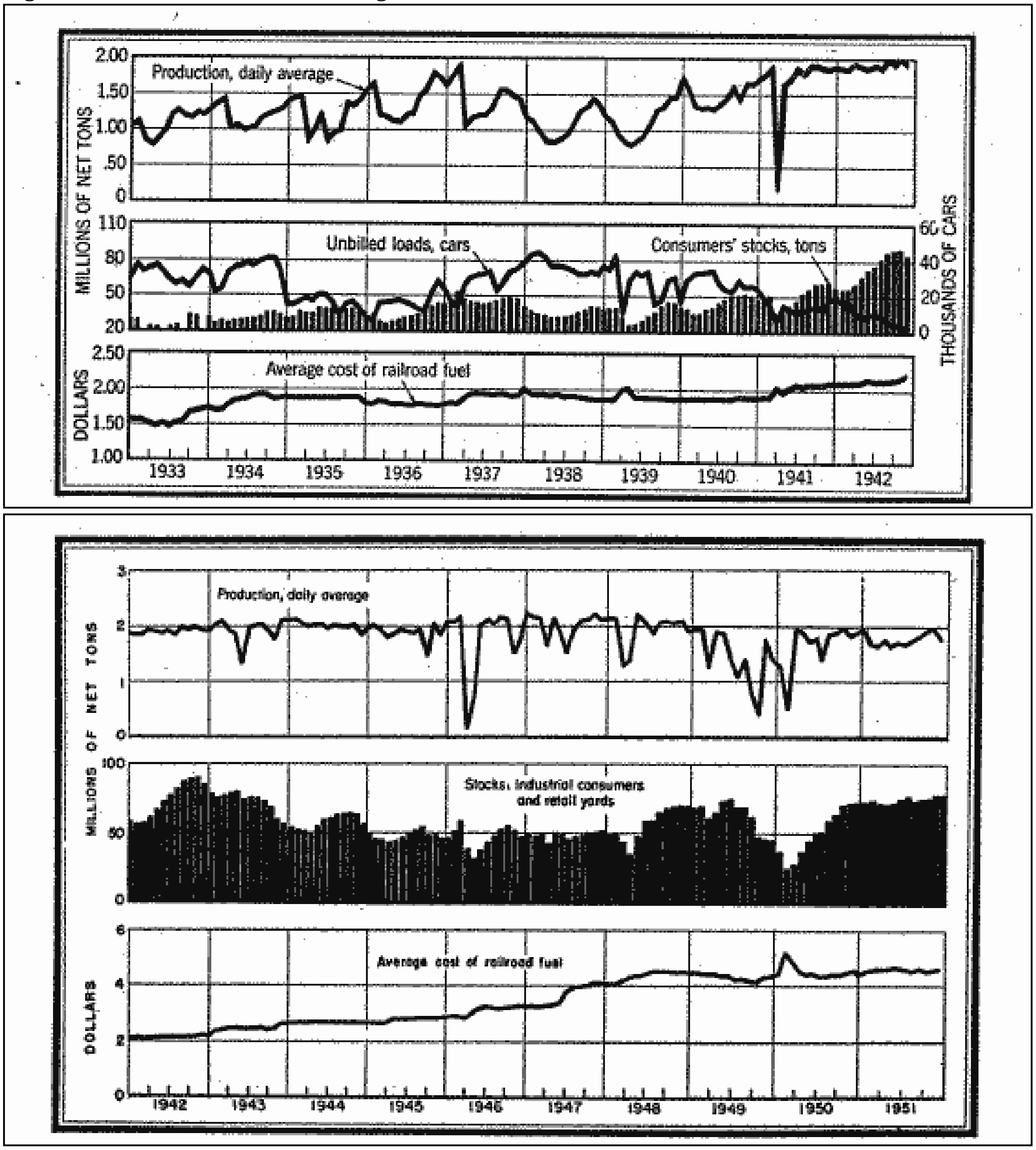
Source: *1940, 1950, 1960 Censuses of Housing*.
Notes: For 1940, Table 60, p. 101 available at http://www2.census.gov/prod2/decennial/documents/36911485v2p1ch1.pdf . For 1950, Table 20, pp. 127-130 available at http://www2.census.gov/prod2/decennial/documents/36965082v1p1ch1.pdf . For 1960, Table 7, pp. 1-29-1-33 available at: http://www2.census.gov/prod2/decennial/documents/41962442v1p1ch04.pdf

Figure 9: Heating Oil and Natural Gas Sales, 1930-1950



Notes: Heating oil includes distillate fuel oil, residual fuel oil, and crude oil burned as fuel.*Minerals Yearbook*, various years. U.S. Natural Gas Consumption by End Use. Energy Information Administration. Data available from: http://www.eia.gov/dnav/ng/ng_cons_sum_dcu_nus_a.htm. Natural gas consumption includes consumption for cooking.

Figure 10: Bituminous Coal and Lignite Production, Stocks and Prices, 1933-1951



Source: *Minerals Yearbook*, 1942, p. 832. *Minerals Yearbook*, 1951, p. 307.

Figure 11: Major Interstate Gas Pipelines in 1949

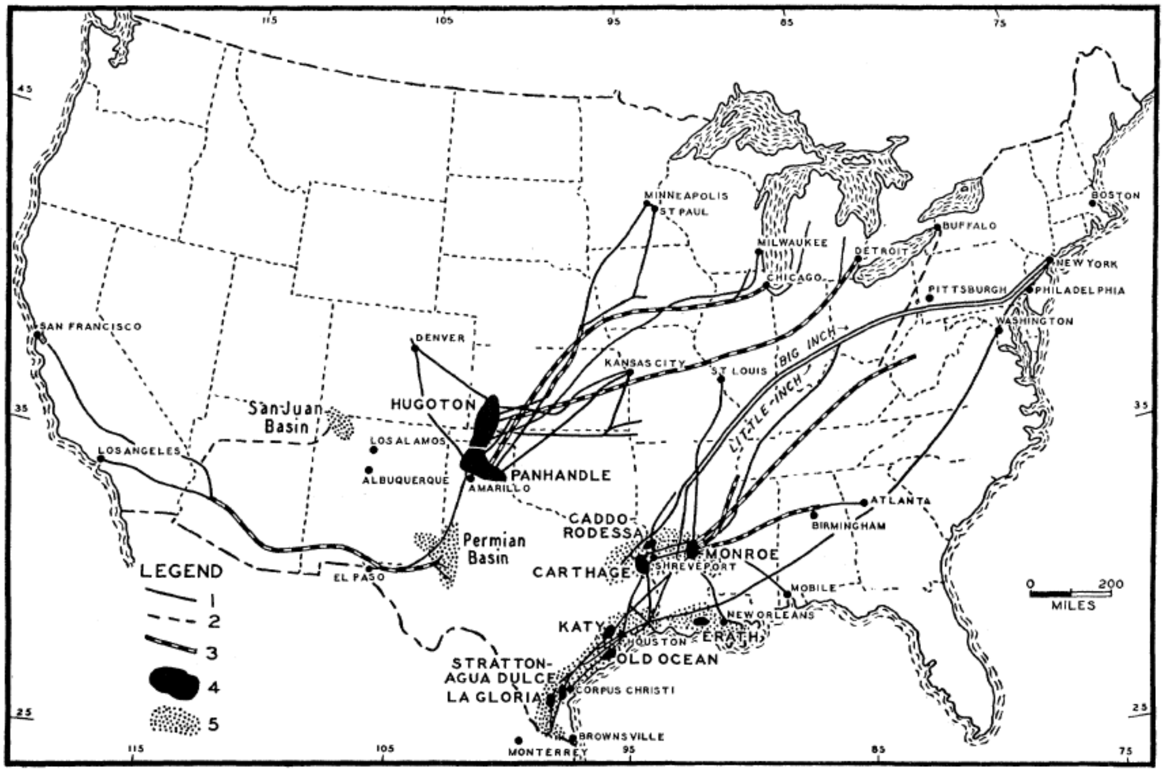
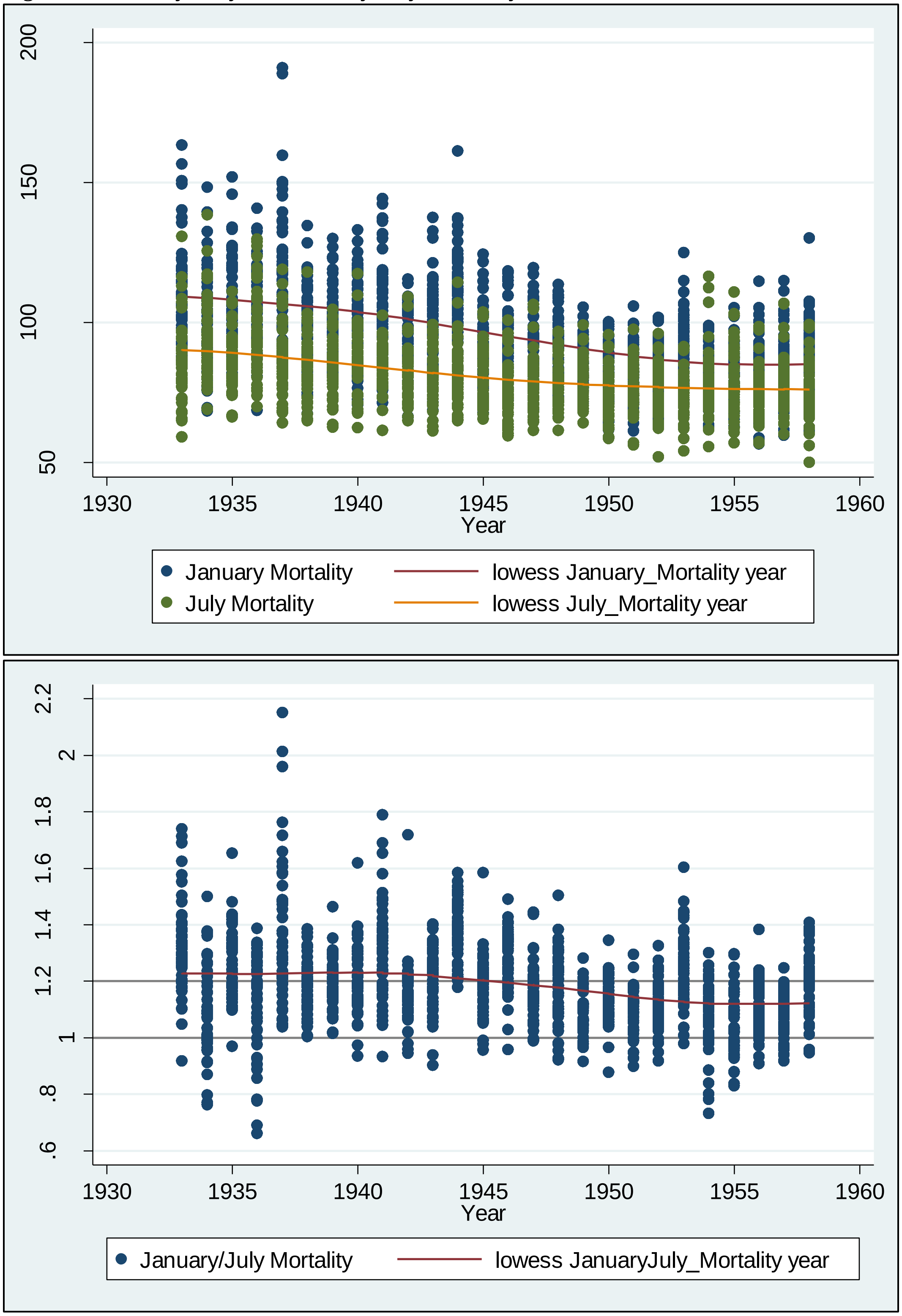


FIG. 1. Major interstate gas pipe lines in the United States, 1949. Legend: 1, pipe lines of 16-inch diameter or more originating in Mid-Continent and Gulf Coast areas; 2, pipe lines proposed or authorized; 3, double pipe lines; 4, principal gas fields; 5, other areas of scattered production supplying major interstate transmission lines.

Notes: Parsons (1950), p. 165.

Figure 12: January, July, and January/July Mortality Patterns, 1933-1958



Notes:

Table 1: Gas Heating Equipment Sales, in Thousands of Units

Year	*Warm Air Furnaces*	*Conversion Burners*	*Boilers*	*Total*
1936	21	38	11	70
1937	20	34	11	75
1938	35	19	7	61
1939	56	29	7	92
1940	85	22	10	117
1941	155	36	15	206
1942	44	6	11	61
1943	7	1	4	12
1944	19	3	5	27
1945	52	14	15	81
1946	230	400	33	663
1947	188	70	47	305
1948	188	49	31	268
1949	299	309	52	660
1950	600	345	80	1,025
1951	393	164	61	618
1952	464	227	69	760
1953	504	213	72	789
1954	659	225	80	961

Notes: *Historical Statistics of the American Gas Association*, Table 143, p. 239

Table 2: Household Use of Coal for Heating in 1940 by State

State	Share of Households Using Coal		Share of Households Using Coal
Lowest Quartile		Second Highest Quartile	
California	0.02	Idaho	0.53
Texas	0.03	Nebraska	0.55
Florida	0.04	Massachusetts	0.56
Oregon	0.04	Delaware	0.56
Arizona	0.05	Tennessee	0.56
Arkansas	0.06	Maryland	0.58
Louisiana	0.07	Wyoming	0.58
Mississippi	0.11	West Virginia	0.60
Oklahoma	0.13	Missouri	0.61
Washington	0.20	Wisconsin	0.62
New Mexico	0.24	South Dakota	0.65
Maine	0.29	District of Columbia	0.65
Second Lowest Quartile		Highest Quartile	
New Hampshire	0.34	New Jersey	0.70
Nevada	0.34	Iowa	0.71
Vermont	0.36	New York	0.72
South Carolina	0.36	Kentucky	0.72
Georgia	0.39	Michigan	0.79
Alabama	0.40	Colorado	0.82
Kansas	0.41	Utah	0.82
North Carolina	0.42	Pennsylvania	0.85
Montana	0.46	North Dakota	0.85
Connecticut	0.48	Illinois	0.86
Rhode Island	0.48	Indiana	0.87
Minnesota	0.51	Ohio	0.88
Virginia	0.51		

Table 3: City-Level Fuel Prices in Nominal Cents/BTU in December, 1941-1954

City	*Fuel*	*1941*	*1942*	*1943*	*1944*	*1945*	*1946*	*1947*	*1948*	*1949*	*1950*	*1951*	*1952*	*1953*	*1954*
Atlanta	Bituminous	67.3	66.7	71.9	73.1	74.4	89.6	106.7	118.5	118.5	120.6	125.8	129.2	129.2	129.2
	Gas	78.8	78.8	78.8	78.8	76.5	75.2	69	63.5	63.8	63.8	67	67.3	71	73
Baltimore	Anthracite	71	78.3	78.1	78.2	84.5	94.2	105.3	119.2	119.7	125.5	133.7	143.9	136.9	126.3
	Bituminous	59.8	60.2	64	64	66.5	72.5	85.4	99.4	99.2	101.2	102.7	105.6	105.8	104.6
	Fuel Oil	90.5	110.2	114	114	95.1	112.8	135.6	153.9	147.4	157.5	157.5	171.9	169.3	177.5
	Gas	125	125	125	125	125	125	144.6	144.6	175.4	139.3	139.3	139.3	138.1	136.9
Boston	Anthracite	85.5	86	93.4	92.6	99.4	109	117.1	129.8	133.1	143.2	152.6	165	160.6	165.3
	Fuel Oil	91.2	110.2	114	114	96.3	111.4	141	155.6	150.7	158.4	159.6	169.8	169.8	177.4
	Gas	107.9	107.9	107.9	107.9	107.9	107.9	131.5	131.5	182.4	209.4	212.3	214.6	197.8	175.1
Chicago	Bituminous	69.8	70.2	74.2	75.2	77.5	85.6	106.7	120.6	122.5	125.4	126.9	132.3	128.7	125.2
	Fuel Oil	b	b	b	b	b	b	b	b	165.8	180.2	186.8	186.8	193.3	193.3
	Gas	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	87.5	109.6
Cincinnati	Bituminous	63.1	63.7	67.1	67.9	70.2	77.5	96.2	108.5	109.4	119.4	120	123.5	129.6	129.6
	Gas	69.9	62.4	62.4	62.4	64.5	64.5	73.1	73	73	71.8	70.6	78.1	80.3	87.4
Cleveland	Bituminous	72.5	73.1	76.2	78.1	80.6	89.8	110.8	123.5	126.2	132.7	134.2	139.2	142.5	144.8
	Gas	62.5	62.5	62.5	62.5	625	62.5	62.5	64	64	64	64	65.5	71.4	71.4
Detroit	Bituminous	72.5	72.7	77.9	79.6	81.9	89	112.5	120.2	124.6	133.1	137.9	142.3	143.7	144.2
	Fuel Oil	b	b	b	b	b	b	b	b	176.1	174.6	177.5	177.5	187.9	187.9
	Gas	82.3	82.3	82.3	55.1	78	78.4	77.4	77.1	86.9	88.6	97.5	99.1	103.4	100.4
Houston	Gas	73.4	70.3	66.5	66.5	66.5	67.9	67.9	67.3	68	68	67.5	67.5	69	69.3
Kansas City	Bituminous	38	38.5	41	41.9	42.7	41.5	59.5	67.3	65.3	68	69.3	71.5	70	69.2
	Fuel Oil	93.9	96.1	98.8	98.8	98.8	115.8	166.5	171.7	153.9	166.1	167.4	168.4	171.7	171.7
	Gas	61.4	61.4	61.4	61.3	61.4	61.4	54.9	56	56.9	56.4	57.8	58.6	59.5	69.8
Los Angeles	Gas	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9	61.5	61.5	63.8	68.1	69.9
Minneapolis	Bituminous	98.7	99.2	109	111	113.7	124	150.8	172.3	175.4	166.5	166.5	170.4	176.9	182.7
	Fuel Oil	95.1	99.1	102.8	102.6	102.6	116.5	173.3	178.6	147.2	173.3	177	181	171.4	171.4
	Gas	95.6	95.6	95.6	86	79.8	78.1	78.8	78.8	82.5	78.8	79.3	86	94.5	94.5

New York	Anthracite	70.6	70.8	78.4	78.1	85.3	95.5	b	b	125.8	138.4	149.7	160.8	153.5	141.3
	Fuel Oil	92.1	111.4	115.1	115.1	96.3	114.6	153.3	161	149.8	160	161	172.1	174	182.6
	Gas	120.5	120.5	120.5	120.5	120.5	120.5	131.4	131.4	186.4	186.4	186.4	178.8	182.9	180.1
Philadel.	Anthracite	69.4	69.7	77.3	78.1	85.6	95.5	104.7	116.1	118.1	125	134.4	137.3	136.8	130
	Fuel Oil	90.9	108.4	113.3	113.2	94	109.3	139.6	151.9	146.7	154.6	154.6	164.7	163.9	174.4
	Gas	117.9	1179	117.9	117.9	117.9	117.9	141.5	155.6	155.6	156.8	156.8	156.8	156.8	155.9
Pittsburgh	Bituminous	37.7	39.6	41	39.4	39.8	46.7	75.2	82.5	78.3	80	83.1	89.2	90.2	88.1
	Gas	60.3	59.9	59.9	60.5	60.4	60.4	60.6	60.6	60.6	60.8	60.3	64.4	66.4	69.8
Portland	Bituminous	127.9	129.6	130.6	132.1	135	141	166	175.6	177.9	179.4	188.5	197.9	199	199
	Fuel Oil	76	76	79.8	79.8	76.7	105.1	122.3	147.4	147.4	153.3	153.3	153.3	177.4	177.4
	Gas	88.5	88.5	88.5	88.5	88.8	108	175.1	206.4	159.4	161	161	176.6	181.3	199.3
St.Louis	Bituminous	45.8	45.8	49.3	50	51.7	60.3	77.5	86.9	86.8	93.1	94.6	99.3	103.7	110.2
	Gas	77	77	77	77	77	77	77	77	76.3	76.3	84.5	84.5	94.5	94.5
San Francisco	Gas	52.5	50.3	48	48	48	42.1	42.1	42.1	42.1	43.5	43.5	56.8	56.9	56.9
Scranton	Anthracite	48.7	48.7	56.6	57.3	64	74.2	78.2	87.3	87.3	92.9	101	112.4	113.2	106.1
	Gas	150.4	150.4	150.4	150.4	150.4	150.4	150.4	150.4	150.4	150.4	167.3	167.3	167.3	167.3
Seattle	Bituminous	113.5	115	135	136.2	139	145.6	164.4	172.7	176.9	185.2	189.4	193.7	201.5	201.5
	Fuel Oil	81.6	81.6	85.4	85.4	81.6	113.2	130.5	160.2	160.2	167.2	167.2	167.2	197	197
	Gas	114.4	114.4	114.4	114.4	114.4	125.8	125.8	189.9	188.8	203	216.1	216.1	230.3	230.3
Washington DC	Anthracite	72.7	73.2	80	80	86.3	96.1	105.8	115.8	121	130	139.2	149.8	151	150
	Fuel Oil	96.3	115.3	119.1	119.1	100	117.7	138.1	155.8	152.4	162.8	162.8	174.7	174.4	183.3
	Gas	126.6	130	130	130	129.9	129.5	129.5	129.5	132.1	138.1	134.5	140.9	149.8	141.3

Notes: b denotes price information was not available. *Historical Statistics of the American Gas Association*, Table 231, p. 3

Table 4: Average Daily Heating Degrees and Coal Heating Degrees

	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
Northeast, HD	37.6	10.3	1.7	26.1
Midwest, HD	38.5	8.3	1.1	27.0
South, HD	17.8	2.0	0.0	12.4
West, HD	27.0	8.5	1.5	20.7
Northeast, CHD	19.4	5.1	0.7	13.5
Midwest, CHD	26.7	5.8	0.7	18.7
South, CHD	7.3	1.0	0.0	5.2
West, CHD	13.5	4.4	0.8	10.4

Notes: Heating Degrees = Max(65 - Monthly temperature, 0). Coal Heating Degrees = Heating Degrees*1940 Share Using Coal.

Table 5: Coal and Mortality, Basic Patterns

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Log(mrate)	Log(mrate)	Log(mrate)	Log(mrate)	Log(mrate)	Log(mrate)
Weighting	Pop	Pop	Pop	Pop	Pop	Pop
logretail	0.095***			0.071***		
	(0.019)			(0.011)		
Logdrate (lagged)				0.435***	0.391***	0.376***
				(0.020)	(0.017)	(0.017)
Logretail x Northeast		0.112***			0.062***	
		(0.029)			(0.017)	
Logretail x Midwest		0.138***			0.081***	
		(0.016)			(0.011)	
Logretail x West		0.084***			0.048***	
		(0.019)			(0.013)	
Logretail x NortheastQ1			0.075***			0.047***
			(0.006)			(0.005)
Logretail x NortheastQ2			0.054***			0.028***
			(0.006)			(0.006)
Logretail x NortheastQ4			0.025***			0.030***
			(0.004)			(0.003)
Logretail x MidwestQ1			0.103***			0.076***
			(0.020)			(0.015)
Logretail x MidwestQ2			0.066***			0.041***
			(0.020)			(0.015)
Logretail x MidwestQ3			0.025			0.023
			(0.020)			(0.015)
Logretail x MidwestQ4			0.036*			0.043***
			(0.020)			(0.015)
Logretail x SouthQ1			-0.052**			-0.014
			(0.020)			(0.016)
Logretail x SouthQ2			-0.085***			-0.042***
			(0.020)			(0.016)
Logretail x SouthQ3			-0.083***			-0.035**
			(0.020)			(0.015)
Logretail x SouthQ4			-0.124***			-0.059***
			(0.021)			(0.017)
Logretail x WestQ1			0.037*			0.040**
			(0.019)			(0.016)
Logretail x WestQ2			-0.015			0.005
			(0.019)			(0.015)

Logretail x WestQ3			-0.035*			-0.003
			(0.018)			(0.015)
Logretail x WestQ4			-0.030*			0.006
			(0.018)			(0.014)
State, state x time, year, monthly temp, monthly precip FE	Y	Y	Y	Y	Y	Y
Demographic and non-retail coal controls	Y	Y	Y	Y	Y	Y
Constant	4.064***	5.364***	4.992***	0.991***	2.563***	2.371***
	(0.261)	(0.219)	(0.245)	(0.312)	(0.204)	(0.222)
Observations	14976	14976	14976	14928	14928	14928
R-squared	0.844	0.863	0.867	0.885	0.889	0.890

Table 6: Coal and Mortality, With A Measure of Exposure

	(1)	(2)	(3)	(4)
Dependent Variable	Log(mrate)	Log(mrate)	Log(mrate)	Log(mrate)
Weighting	Pop	Pop	Pop	Pop
Coalhdd	0.0034***	0.0024***	0.0020***	0.0019***
x log(retail coal)	(0.0004)	(0.0002)	(0.0002)	(0.0001)
Lagged Coalhdd			0.0003***	0.0000**
x log(retail coal)			(0.0000)	(0.0000)
logretail	0.0583***			
	(0.0181)			
Logretail x Northeast		0.0882***	0.0872***	0.0440**
		(0.0308)	(0.0302)	(0.0186)
Logretail x Midwest		0.1117***	0.1123***	0.0616***
		(0.0161)	(0.0159)	(0.0109)
Logretail x West		0.0821***	0.0801***	0.0475***
		(0.0177)	(0.0178)	(0.0114)
Lagged log(mrate)				0.3806***
				(0.0165)
State, state x time, year, monthly temp, monthly precip FE	Y	Y	Y	Y
Demographic, coalhdd and non-retail coal controls	Y	Y	Y	Y
Constant	2.7139***	4.6531***	4.5276***	2.8321***
	(0.4646)	(0.4278)	(0.4122)	(0.2283)
Observations	14976	14976	14928	14928
R-squared	0.859	0.867	0.870	0.891