Energy Policy: Does it Achieve its Intended Goals?

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ENERGY POLICY: DOES IT ACHIEVE ITS INTENDED GOALS?

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A good understanding of markets targeted by energy policy is necessary for energy tax policy to be successful. This paper analyzes coal, natural gas and oil markets to determine the extent to which these fuel prices move together. We find that there was a stable long-run relationship between coal and oil prices until 1974 and that this relationship changed after 1974. The long-run relationship found between coal, natural gas and oil prices implies that a single-fuel tax in these markets would not be effective as a single tax policy. Similarly, an equal percentage tax on these energy sources, which does not change relative prices initially, would not keep relative prices unchanged in the long run. Our results show that energy policy must take account of the long-run relationship between different energy prices. Otherwise, the long-run results of energy policy could be quite different than intended.

I. INTRODUCTION

Government energy policies generally have multiple objectives which are not necessarily compatible and are not always fulfilled. For energy policy to be successful, a good understanding of the markets targeted by policy is necessary. In particular, the long-run relationship between energy prices will determine the degree of success of any policy which targets a particular energy source.

If the goal of energy tax policy is to change the consumption of a

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particular energy source because of environmental concerns, then the fuel which pollutes most should be taxed the heaviest. If the goal is energy security, the policy should decrease consumption while increasing production of the targeted fuel. The Clinton administration's Btu tax proposal was initially hailed as a tax to curb pollution and promote energy security, but the proposed tax rates were not consistent with either goal. Coal and natural gas were taxed at equal rates, although natural gas is clearly the cleaner burning fuel, and oil was taxed at twice that rate. However, if the goal of energy taxation is only to raise revenue, then the tax should be structured so as not to change relative energy prices and consumption patterns.

Whether or not coal, natural gas and oil prices have a long-run relationship will be important in determining the success of energy policy. In this paper, we investigate whether such a long-run relationship exists, and whether the relationship has changed over the years. Then, depending on the goals of energy policy, our analysis can cast a light on whether the policy will achieve its intended goals.

II. COAL, NATURAL GAS AND OIL MARKETS

Whether coal, natural gas and oil prices are related in the long run depends on whether they are close substitutes for each other. If the three fuels serve the same markets, they are closer substitutes and one price will reflect movements in the other prices.

Coal, natural gas and oil constitute more than 88 percent of total U.S. energy consumption, of which 23.8 percent is imports. The United States is relatively self sufficient in coal and natural gas, exporting 13 percent of coal production and importing only 9.2 percent of natural gas consumed. The

United States is somewhat more reliant on world supplies of oil, importing 44.7 percent of the total oil and products consumed domestically.

The markets that these fuels serve, and the fuel balance of U.S. energy consumption has changed substantially since the end of the second world war. From accounting for almost 50 percent of energy consumption in 1947, coal use has declined to 23.5 percent of total energy consumption in 1990. Oil's share in consumption has increased somewhat, from 34.4 percent of consumption to 41.3 percent of consumption. Natural gas has made some inroads, increasing from 16 percent of total energy consumption in 1947 to near 24 percent in 1990 (see Figure 1).[1]

Aside from changing shares in energy consumption, the fuels' end-use markets have also changed. As Figure 2 shows, coal dominated the industrial market in the 1940's with a 55 percent share, with natural gas comprising 23 percent of industrial fuel input. In 1990, oil and natural gas were competing for the industrial market and coal use had shifted mainly to electricity generation. Coal's share in electricity generation has always been high, but it increased in the past few years as natural gas and oil's shares declined. In 1990, 86 percent of all coal consumed was used in electricity generation Figure 3). In 1947, coal also dominated the residential and commercial end-use markets with a 48 percent share. The picture has changed significantly since then as Figure 4 shows. Coal's share in the residential and commercial sector has dwindled to one-tenth of one percent, while the share of natural gas has increased from 15.7 to 46.6 percent. The share of oil in the residential and commercial market has been halved in the past 45 years to 14 percent of the market.[2]

One sector where the three fuels are clearly no longer competitive is the transportation sector (Figure 5). Coal and oil were competing fuels in the transportation sector in the 1940's, coal with 34.4 percent of the market, and oil with 65.3 percent of the market. In 1990, the share of coal in transportation was zero, and oil had grabbed 96 percent of the market. Natural gas had a measly 3.7 percent share. The share of natural gas is projected to grow, as a result of pollution and national security concerns about U.S. oil dependence.

III. EMPIRICAL ANALYSIS

To examine whether or not coal, natural gas and oil prices move together, time series methods are utilized. We first check whether the price series are stationary, and find that all of them have stochastic trends (or are integrated). For each of the series, we then test for cointegration.

Estimation and testing uses annual data from 1947 to 1990. We use minemouth prices for bituminous coal and lignite for the coal price variable, U.S. crude oil price at the wellhead for oil, and wellhead prices for natural gas.[3] All prices are converted to a dollars per Btu basis.There have been structural changes in the oil market during 1947-1990 time period. OPEC became a much more potent force in the world oil market after the early seventies. The end of 1973 and beginning of 1974 were tumultuous times in the oil market. In October 1973, OPEC raised the price of oil by 70 percent. By January 1974, the price of oil had tripled to more than $11.00 per barrel. These dramatic changes in the oil market could change the relationship between coal, oil and gas prices (see Figure 6). Therefore, in addition to using the full sample, we divide the sample period up into two sub-samples, 1948 to 1974 and 1975 to 1990 to see whether the relationship between coal, gas and oil prices has changed over the two periods.

A. Integration

As an initial step in our econometric work, we checked whether our price series were integrated or stationary. A time series which is integrated is said to have a stochastic trend or a unit root. A non-stationary, integrated series signifies that any shock to the time series will be permanent. Unlike a stationary series which reverts back to its mean after a shock, an integrated time series will not revert back to its pre-shock level even in the long run.

Applying conventional econometric techniques to an integrated time series can give rise to misleading results.[4] Therefore, we tested for integration with both an augmented Dickey-Fuller and a Phillips-Perron test. We checked for integration with and without a linear time trend for the full sample (1947-1990) and for the two subsamples (1947-1974; 1975-1990) and found the series to be integrated in all cases. All price series were integrated of order one, i.e., the first differences of all series were stationary. Table 1 reports the augmented Dickey-Fuller statistics testing for the null hypothesis that each series is integrated.

B. Cointegration

After determining that each price series was integrated of order one, we tested the three prices described for cointegration. Two integrated time series are called cointegrated if they move together. Cointegration implies a stationary, long-run relationship between the two series and the cointegrating term provides information about the long-run relationship. Furthermore, if cointegration is not accounted for, any model involving the two cointegrated variables would be misspecified and/or the parameter estimates could be underestimated.[5] We employed the Johansen procedure to estimate the cointegrating relationship between coal, natural gas and oil prices.[6]

The cointegration relationships varied with the sample periods. We found no cointegration among the variables for the full sample, 1947 to 1990. The lack of cointegration in the full sample is natural if the sub- samples have completely different cointegrating relationships. This is indeed the case. For the subsample period 1947 - 1974, we find a cointegrating relationship between coal and oil, and for the subsample period 1974-1990, we find a cointegrating relationship between all the three variables.

Because each estimated cointegrating relationship is stationary, the cointegrating terms provide an efficient estimate of the long-run relationships between the cointegrated variables. In the 1947-1974 sub-sample only the prices of coal and oil are cointegrated. This implies that a one percent increase in the price of oil will be met by a β percent increase in the price of coal in the long run. Similarly, a one percent increase in the price of coal will be met by a $1/\beta$ percent increase in the price of oil in the long run. In our test, β is less than one, implying that the change in the price of coal is less than the change in the price of oil.

As Table 2 shows, a permanent one percent increase in the price of oil brings about a 0.63 percent increase in coal prices. This result is consistent with our knowledge of these two markets. Prices in the coal industry were largely based on long-term contracts, which were of the order of thirty years or more, and hence would be less variable than oil prices. The onset of pollution regulations in the coal industry in 1969 and the early

1970s could also be a factor in the smaller changes in coal prices. Because coal is a dirtier fuel, consumers may not be switching out of oil into coal, and equilibrium is reached without coal prices rising as much. Another argument could be that productivity in the coal sector was increasing drastically, and hence coal prices did not go up as much to get back into long run equilibrium.

The natural gas market was a heavily regulated market in the 1947-1974 period, and this is likely the major cause for the lack of cointegration between natural gas and the other fuels in the first subsample. Wellhead prices of natural gas were regulated in 1954, with the price of natural gas based on average historical costs. This regulated price was below the market value of natural gas in the 1960s and 1970s and was quite unresponsive to market forces. Moreover, natural gas, like coal, was sold under long-term contracts which likely contributed to the lack of cointegration of gas with coal and oil.

In the second subsample period 1974 - 1990, the results are qualitatively similar to the first subsample although we find cointegration between all three variables. Because it was difficult to identify the changes in the prices from the three-price cointegrating relationship, we also checked for pairwise cointegration in this subsample.

To obtain a lower and upper bound for the changes in coal and natural gas prices, given a change in the price of oil, we assume one of the prices stays constant and calculate how the other price would have to respond to a change in the oil price in order to return to long-run equilibrium. If the price of oil increases by one percent, holding the price of natural gas constant, coal prices would have to fall by 1.6 percent to get back to long-run equilibrium. On the other hand, if coal prices are kept constant, natural gas prices would have to increase by 0.75 percent to be back at equilibrium.

The above experiment seems to suggest that as oil prices increase, there is not much substitution into coal. If the price of natural gas falls relative to oil (i.e. natural gas prices kept constant), consumers would shift into gas from oil. But, since the price of coal has to fall to get back into equilibrium, consumers must be shifting out of coal into gas. This could come about if gas was perceived to be a better substitute for oil than coal. On the other hand, there probably is not be much shifting out of gas into coal, because the price of natural gas has to rise to return to the long-run equilibrium relationship.

In the pairwise cointegration tests for the 1974 -1990 period, we find somewhat similar results. When oil is paired with natural gas, we find a β of 1.129. This implies that a one percent change in the price of oil, would lead to a 0.89 percent change in the price of natural gas in the long run. Oil and natural gas are relatively good substitutes, and the β values close to 1.0 are consistent with this fact.

When coal and oil are paired together, the cointegrating relationship is similar to the one found in the earlier subsample. As Table 2 shows, if the price of oil increased by one percent, the price of coal would have to increase by 0.535 percent to bring the relationship back into equilibrium, although this β value is not significant. The β in the later sample is somewhat smaller than the β in the earlier sample, possibly implying that oil and coal have begun to serve more diverse markets.

Finally, if coal and natural gas are paired together, we see that the pairwise relationship is quite similar to the three-price cointegrating relationship. A one percent change in the price of coal would lead to a 0.5 percent change in the price of natural gas in the long run, same as in the earlier result, when oil prices were held constant. This seems to imply that in the later subsample, 1974-1990, the price of coal did not affect oil prices much. This finding is consistent with the insignificant β we found in the coal-oil relationship above.

SUMMARY AND CONCLUSION

A good understanding of markets targeted by energy policy is necessary for energy tax policy to be successful. Given that we find a long-run relationship between coal, natural gas and oil prices, it is imperative that energy tax policy take account of this relationship, otherwise the long-run results of energy policy could be quite different than intended.

The long-run relationship that we found between coal, natural gas and oil markets suggests that a single-fuel tax in these markets would not be effective as a single-fuel policy. Because all three markets are cointegrated, a tax on any single fuel would be reflected in other fuel prices in the long run.

If the goal of energy tax policy is to only raise revenue, the best tax would be one which did not change the long-run relationship between the fuels, assuming that we are initially at a long-run equilibrium. The least disruptive tax would be to tax oil and natural gas at relatively similar rates, and tax coal at half that rate. In such a case, the tax would not disturb the consumption patterns in the coal, natural gas and oil markets. An equal percentage tax on these energy sources, which does not change relative prices initially, would not keep relative prices unchanged in the long run.

On the other hand, if the goal is to alter energy prices, it is not necessary to tax all fuels in order to change their prices, given the cointegration between coal, natural gas and oil prices. A politically feasible tax on one fuel could be used to change prices and consumption patterns of other fuels. For example, a gasoline tax which is relatively easy to administer and collect, has a predictable impact on oil prices. A change in the gasoline tax, working through the oil price, will also change the prices of natural gas and coal in a manner dictated by the long-run cointegrating relationship between the fuels. Knowledge of the cointegrating relationship between energy sources will be helpful in ensuring that energy policy achieves its intended goals in the long run.

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Table 1. Augmented Dickey-Fuller Tests for Unit Roots

	1947 - 1990		1947 - 1974		1974 - 1990	
	τ_μ	τ_τ	τ_μ	τ_τ	τ_μ	τ_τ
COAL	-6.19	-7.72	0.154	17.89	0.893	-9.64
NAT GAS	-7.51	-22.11*	-1.00	-3.92	-2.68	-0.918
OIL	-5.25	-15.00	-7.79	-15.10	-3.59	-3.54

The above statistics are for testing the null hypothesis that each variable contains a unit root. τ_μ is without a linear deterministic time trend and τ_τ is with a linear deterministic time trend. All, except the * component, are insignificant at the 10 percent level.

Table 2. Cointegration of Coal, Natural Gas and Oil Prices

Cointegration Between the Three Fuels

	1947 - 1974		1975 - 1990	
	β	Sig.	β	Sig.
Coal	1.0	.01	1.0	.045
Natural gas	.244	.30	2.087	.000
Oil	.628	.007	-1.569	.000

Pairwise Cointegration 1975-1990

	β	Sig.
Natural Gas - Coal	.466	.001
Coal - Oil	.535	>.20
Oil - Natural Gas	1.129	.000

1.Nuclear energy which was nonexistent in 1947 now accounts for 8 percent of total energy consumption (21 percent of electricity generation is from nuclear fuels).

2.The relative share of coal is actually greater than 0.1 percent. Twenty one percent of the residential/commercial market is serviced by electricity, of which coal is the main energy source.

3.The coal data is from *Historical Statistics of the U.S.* published by the U.S. Department of Commerce, Bureau of the Census; *The U.S. Coal Industry, 1970-1990: Two Decades of Change* published by the U.S. Energy Information Administration, Department of Energy; and *Coal Data: A Reference*, published by the Energy Information Administration, Department of Energy. The natural gas and oil data are from the *Oil and Gas Journal Energy Database*.

4. See Balke (1991), Sims, Stock and Watson (1990) and Stock and Watson (1988).

5.See Engle and Yoo (1987).

6. The Johansen procedure is a maximum likelihood method. We chose it over several other procedures because it provides the most efficient estimates of the cointegrating relationships. In addition, it provides estimates of the number of cointegrating relationships. The cointegration tests were done without a trend because the real price data do not appear to have a time trend.

Figure 1
Energy Consumption by Source

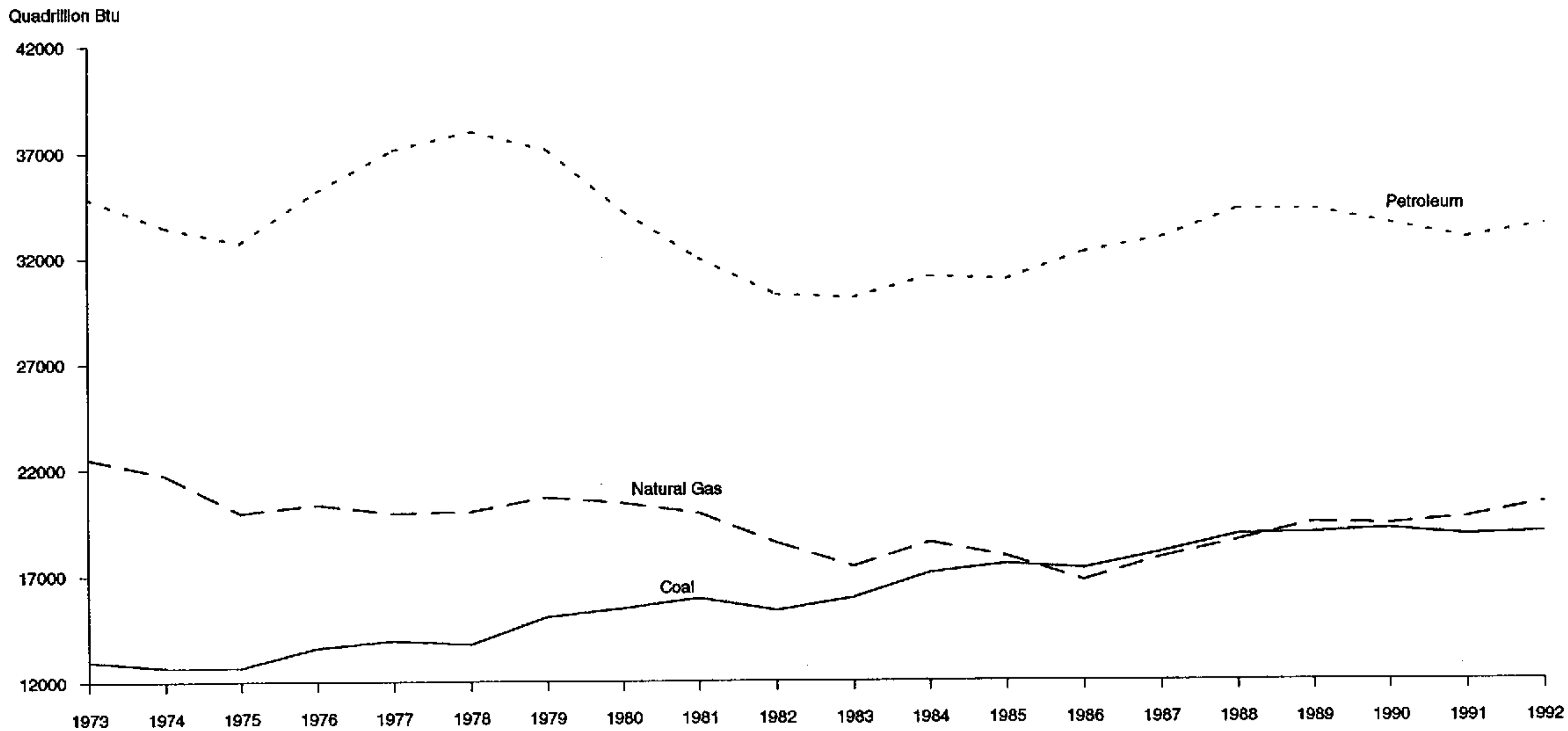


Figure 2
Demand for Energy Inputs
in the Industrial Sector

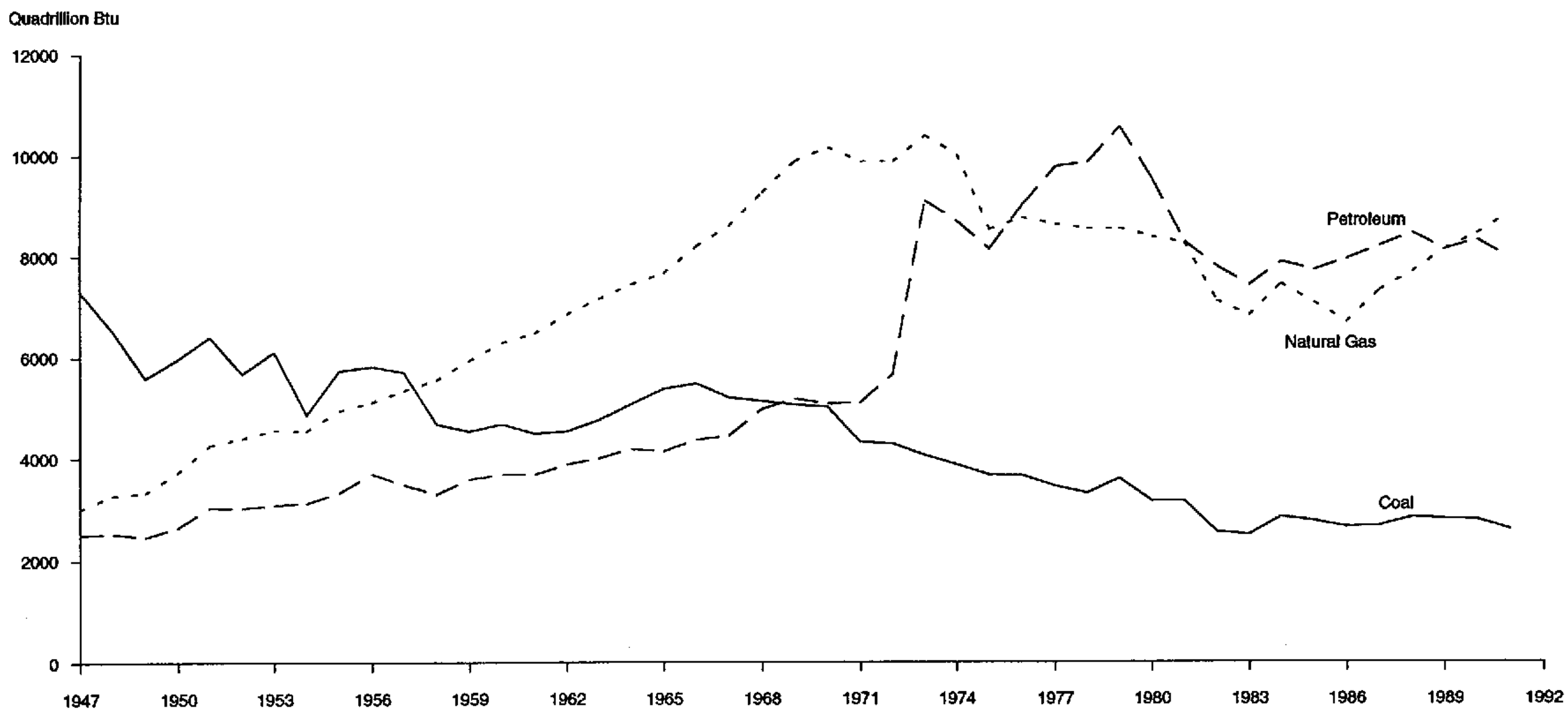


Figure 3
Demand for Energy Inputs
in the Electric Utilities Sector

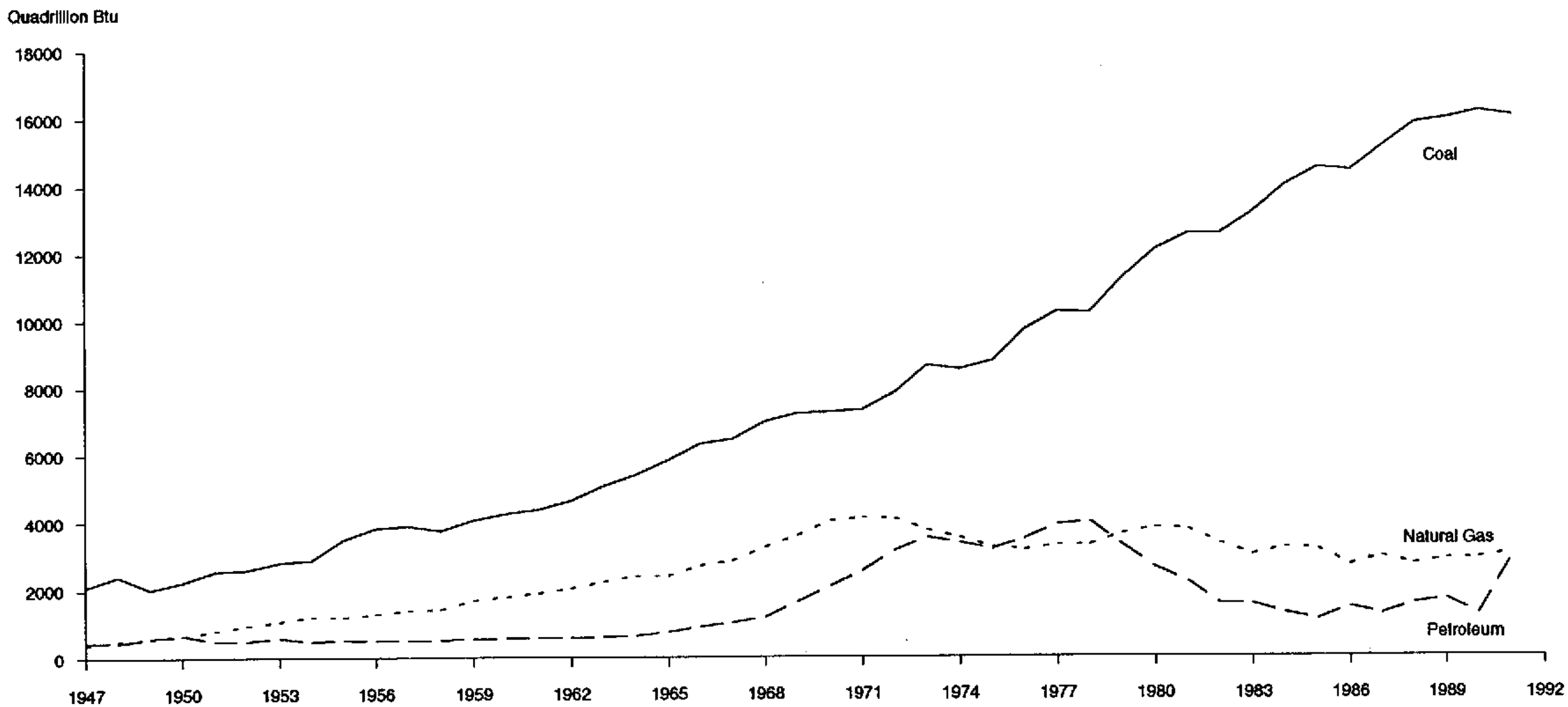


Figure 4
Demand for Energy Inputs
in the Household and Commercial Sectors

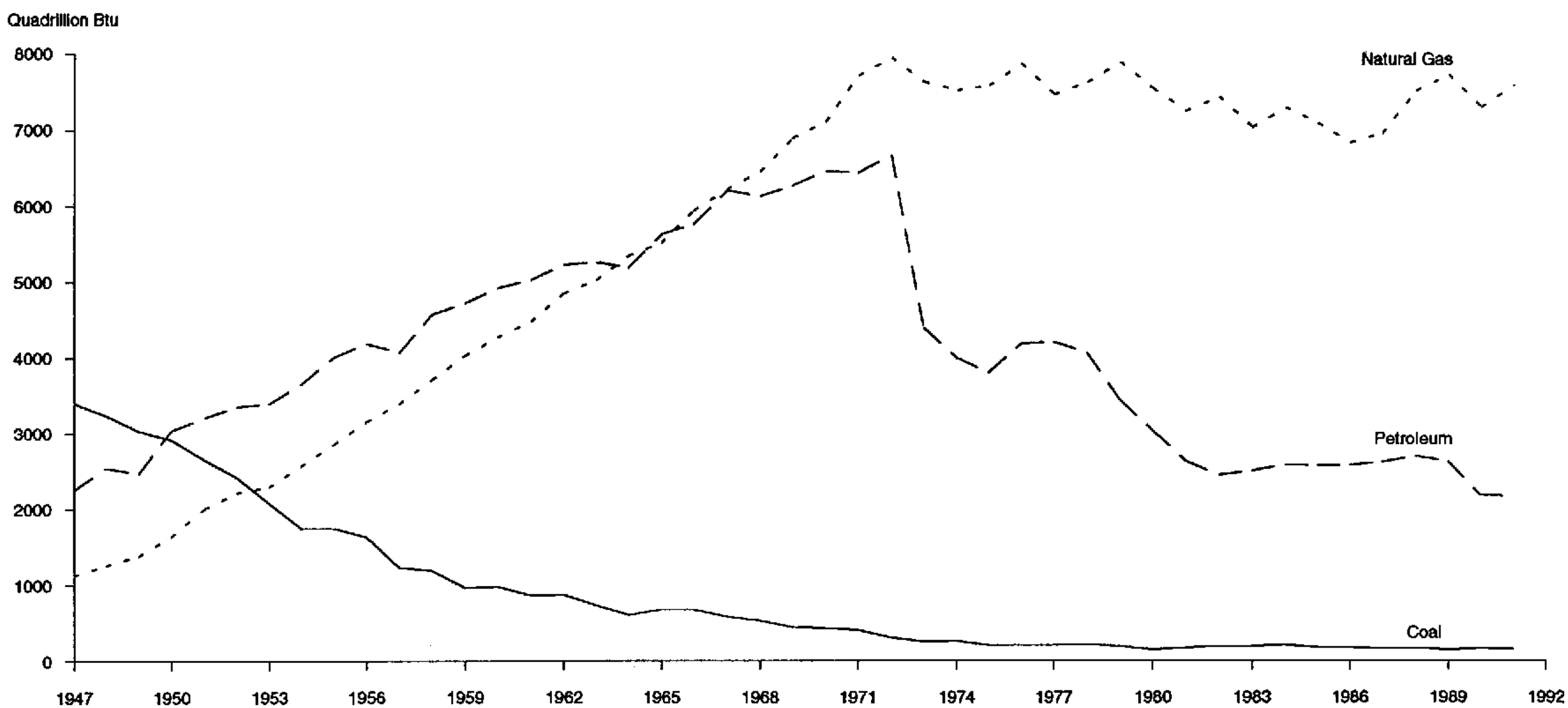


Figure 5
Demand for Energy Inputs
in the Transportation Sector

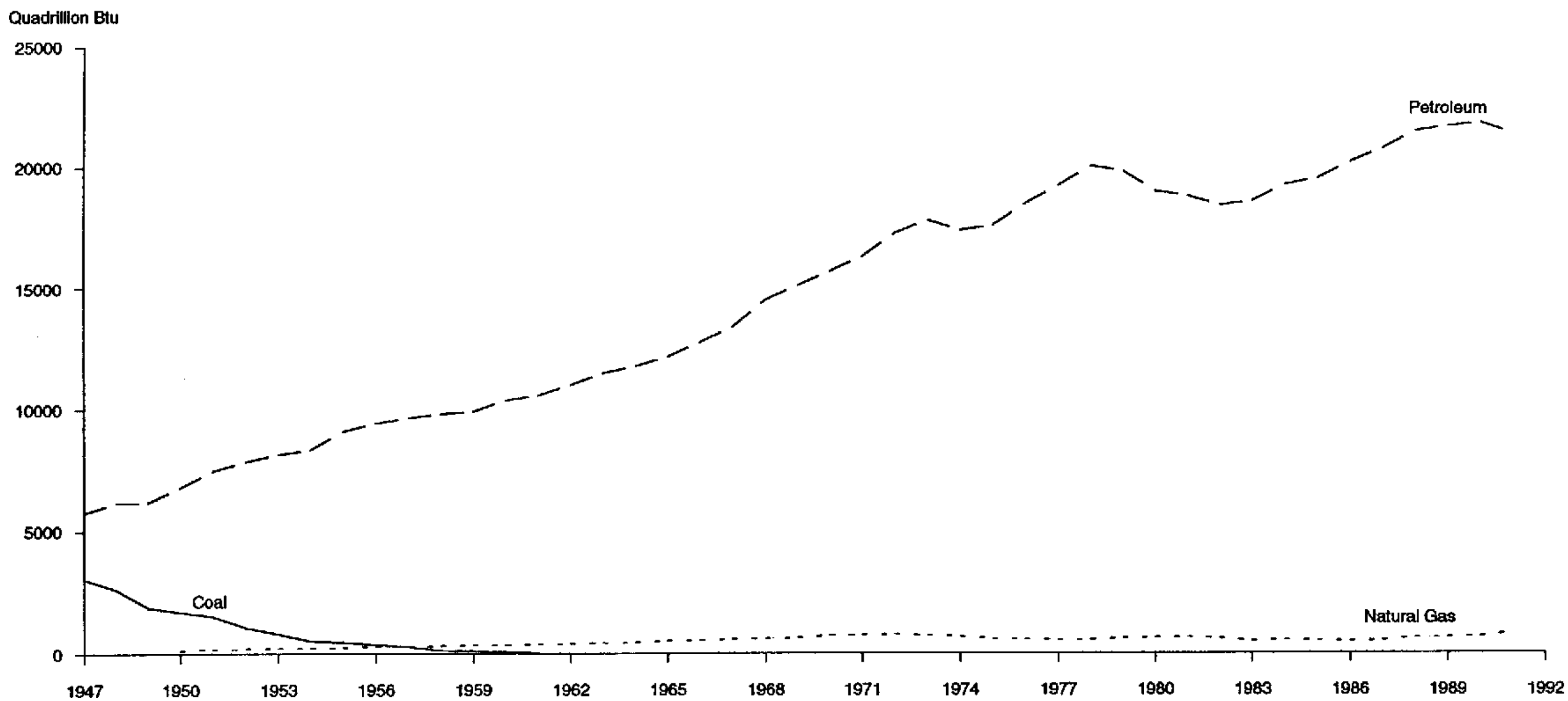
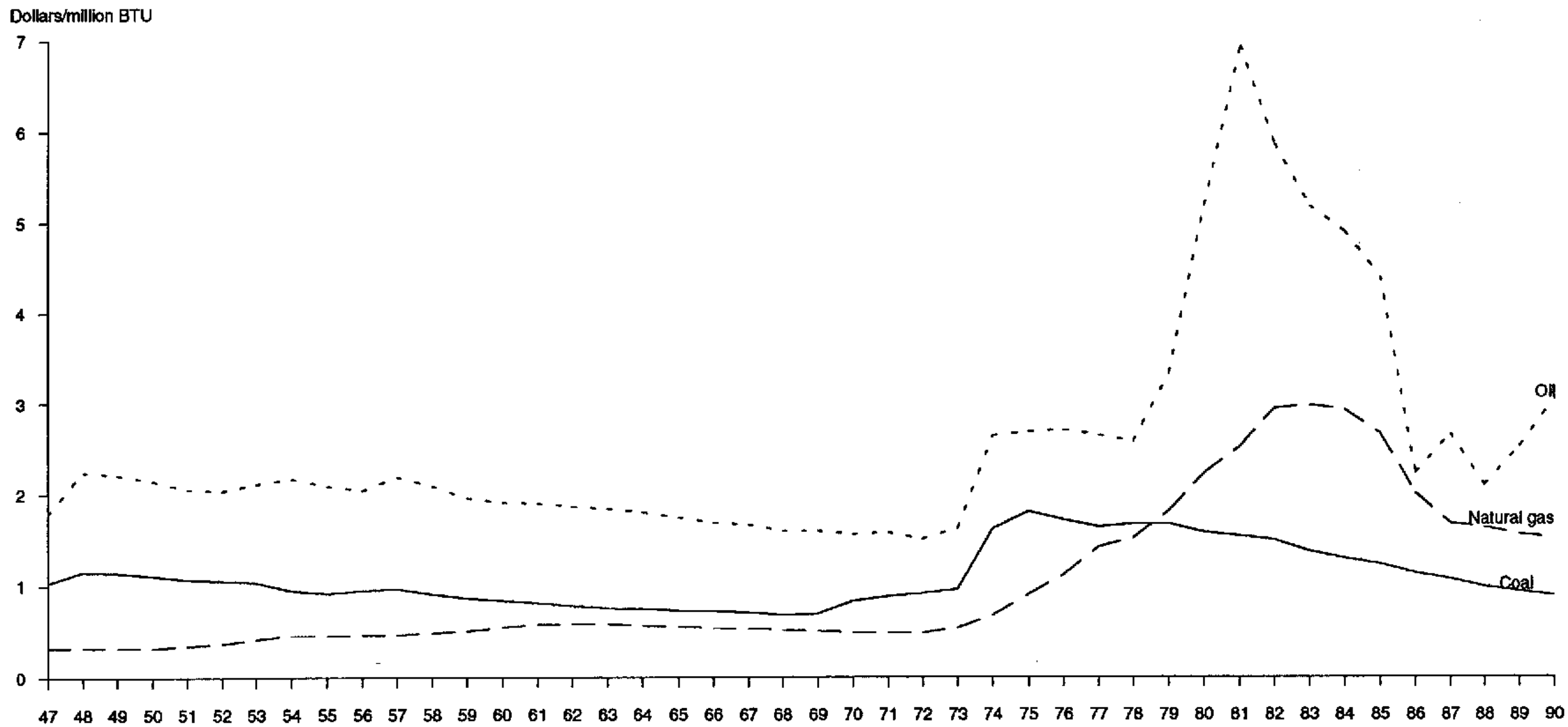


Figure 6
Oil, Natural Gas and Coal Prices



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