PRICES AND SHORTAGES: EVALUATING POLICY OPTIONS*

FOR THE NATURAL GAS INDUSTRY

by

Robert S. Pindyck
Massachusetts Institute of Technology
July 1977

#MIT-EL 77-022WP

*The author would like to thank Joseph Langsam, Kevin Lloyd, and Roy Henrikson for their excellent research assistance.

PRICES AND SHORTAGES: EVALUATING POLICY OPTIONS FOR THE NATURAL GAS INDUSTRY

1. Introduction

Over the last thirty years, natural gas has become an increasingly important source of energy in the United States. Between 1945 and 1970 natural gas production and consumption increased by 450%, from 4 trillion cubic feet (Tcf) per year to 22 Tcf per year, and as a share of total energy consumption, natural gas rose from 12% to about 33%. Natural gas became the major fuel for home heating; for the U.S. as a whole, it now accounts for over 40% of residential energy consumption, and in some regions of the country, the fraction is much greater. And because gas prices have been maintained at low levels, this fuel has increasingly become the choice of electric utilities and large industrial consumers. This, of course, is not surprising; gas has been clean, convenient, and most of all cheap.

Between 1970 and the present, the demand for natural gas has continued to grow at an average annual rate of 5.3%. Production, however, ceased growing in 1970, and began declining in 1972. The result has been a growing shortage. This shortage began in 1971, when some industrial consumers found their non-interruptable ("firm") contracts being interrupted.[1] By 1973 it was no longer possible to have gas lines installed in new homes built in many regions of the country, and a larger number of industrial consumers found their supplies curtailed. The Federal Power Commission and the Federal Energy Administration predicted serious shortages for the Winter of 1975-1976, and the Congress considered proposals for allocating natural gas in case these shortages occurred. That winter was

[1] In fact the FPC found production to be 3.7% below demand in 1971. Among those consumers who were curtailed were farmers who used natural gas to dry their newly harvested grain, which resulted in grain that could not be dried quickly enough and rotted.

mild, so the actual shortage was only about 2.5 Tcf (10% of total demand), but the following winter was particularly severe, and large shortages materialized. By the FPC's own reckoning, curtailments nationwide were 23% of "firm" requirements, and the shortage was particularly severe in several states. Aside from the direct cost of unfulfilled demand, the shortage resulted in additional unemployment of about one million people during the month of January, and over $4 billion of lost GNP.

The direct cause of this shortage has been price regulation by the Federal Power Commission. By maintaining an artificially low price, the FPC made natural gas the choice fuel (for those consumers who could obtain it), so that demand grew rapidly. At the same time, low prices depressed supplies. This occurred for two reasons. First, the incentive was removed for the exploration and discovery of new natural gas reserves, and as a result total U.S reserves of gas fell by about a third between 1967 and 1976. This dwindling reserve base made it impossible for producers to satisfy the demand for new long-term contracts. Second, low prices removed the incentive to produce gas out of existing higher cost reserves, so that production fell even with respect to a particular level of reserves. This situation of rapid growth in demand combined with dwindling supplies can only grow worse if recent policies of price regulation are continued.

How did we manage to institute this system of price controls, given that it has resulted in shortages? The FPC was originally authorized by the Natural Gas Act of 1938 to regulate the transport charges of the interstate pipeline companies (which indeed have considerable monopoly power in several regional consumption markets). But the scope of the Act was unclear, and as prices paid by gas consumers began increasing, pressure was brought on the FPC to extend controls to wellhead prices. The FPC refused to extend its jurisdiction until

1954, when the Supreme Court, in the Phillips Decision, ordered it to regulate the prices of gas sold to the interstate pipelines.[2]

The FPC first attempted to regulate wellhead prices following the practices of state public utility commissions, i.e. by choosing an allowed rate of return on capital, and then determining the price that would equate revenues with the sum of operating costs, depreciation, and the allowed rate of return applied to undepreciated capital. However this approach resulted in wellhead prices nearly doubling between 1954 and 1959, and the FPC becoming bogged down in a backlog of cases. As a result, the FPC turned to area-wide price ceilings that were based on regional average accounting costs. The result was that wellhead prices were essentially frozen after 1960.[3] The average new contract price was 18.2¢ per thousand cubic feet (mcf) in 1961, and only rose to 19.8¢ per mcf in 1969, and the average wholesale price paid by utilities only rose from 32¢ per mcf to about 33.2¢. Wholesale oil and coal prices, on the other hand, increased by 15% and 22% respectively during this period.

After shortages began occurring in 1971, the FPC ended its price freeze, and in a series of rate decisions allowed new contract prices to rise.[4] By 1972 average new contract prices had increased to 33.6¢ per mcf, although with considerable regional variation. In July, 1975, the FPC announced a uniform

---

[2] This case against the Phillips Petroleum Company, brought by the Attorney General of Wisconsin, was based on the argument that although the pipelines were regulated, wellhead price increases by large petroleum companies could be passed through as "costs" in pipeline wholesale prices, thereby increasing retail prices to the consumers. The Supreme Court, although not claiming that gas producers had monopoly power, did find that the FPC should regulate wellhead prices. For further discussion, see P.W. MacAvoy and R.S. Pindyck, The Economics of the Natural Gas Shortage (1960-1980), pages 12-14.

[3] Price ceilings forced producers to limit exploratory effort to low cost drilling projects - which in turn maintained low price ceilings. See MacAvoy and Pindyck, op cit, pages 14-16.

[4] For a discussion of these decisions, and estimates of what free market new contract prices would likely have been, see P.W. MacAvoy and R.S. Pindyck, Price Controls and the Natural Gas Shortage, American Enterprise Institute, 1975, pages 15-19, and P.W. MacAvoy and R.S. Pindyck, The Economics of the Natural Gas Shortage (1960-1980), North-Holland Publishing Company, Amsterdam, 1975, pages 17-21.

"National area rate" of 42¢ per mcf; this rate was raised by the FPC to 51¢ in November 1975, and cost-justified price increases were to be allowed in future years. In fact new contract prices averaged about 55¢ in 1974 and 60¢ in 1975, because of allowances by the FPC. While these prices are about three times those prevailing in 1969, they are still grossly below the true value of natural gas. In terms of barrels of oil-equivalent, the world price of energy in 1975 was about $12 per barrel, but 60¢ gas is equivalent (in thermal content) to oil at $3.50 per barrel. Thus the price increases that occurred up to and including 1975 were not sufficient to bring the price of natural gas anywhere near its free market level.

In order to avert extreme shortages, the wellhead price of gas had to be increased significantly. Congress failed to pass legislation to deregulate natural gas prices, but instead considered various emergency allocation schemes to deal with the shortages that they recognized were inevitable.[5] Fortunately the FPC took a step in the right direction in June 1976 when it announced in Opinion 770, that the National area rate for new contracts would be nearly tripled to $1.42 per mcf, with future price increases of 4¢ per annum. This decision was immediately challenged in the courts, leaving the effective price of natural gas in doubt for about a year. However, on June 16, 1977 the U.S. Court of Appeals for the District of Columbia unanimously upheld the FPC decision.[6] Thus the new contract price in 1977 will average about $1.46 per mcf.

---

[5] A House bill and a related Administration proposal would have allowed interstate pipelines to purchase gas in intrastate markets if the consuming areas served by those pipelines were expected to have significant curtailments. In the Administration proposal, pipelines would have paid whatever free market prices prevailed in the intrastate market, and this higher price gas would be "rolled in" with the lower interstate prices. The House bill (H.R. 9464) would have placed a ceiling on the intrastate price. For estimates of the probable impact of such a plan on interstate and intrastate gas markets, see R.S. Pindyck, "Emergency Proposals to Deal with the Natural Gas Shortage," testimony before the House Committee on Interstate and Foreign Commerce, Subcommittee on Energy and Power, Sept. 24, 1975.

[6] American Public Gas Association et al. vs. FPC, Decision 76-2000. The Consumer Federation of America may appeal the decision further, but except for the Phillips decision, the Supreme Court has in the past supported FPC authority and methodology in establishing natural gas prices.

Unfortunately the new FPC area rates still do not go far enough in bringing natural gas prices up to free market levels. Natural gas at $1.46, for example, is equivalent to oil at about $8.50 per barrel, again well below the world market price. Also, 4¢ per annum price increases will result in natural gas prices falling in real terms (unless the aggregate rate of inflation drops below 3%, which is unlikely). As a result, we will continue to be threatened by natural gas shortages. There is thus a pressing need to revise our natural gas policy.

It is important to recognize that any natural gas policy involves a trade-off between two evils - higher prices to consumers, and growing shortages. Evaluating any particular policy thus requires estimating the magnitudes and effects of higher prices, and the magnitudes and effects of shortages, that are likely to result. In the next two sections we will use a detailed econometric model of the natural gas industry developed at M.I.T. to project the effects on prices and on shortages through 1985 of three alternative natural gas policies: a continuation of current FPC National area rates, President Carter's plan to increase new contract wellhead prices of "new" gas and tax industrial consumers of gas, and a plan of phased deregulation in which new contract prices would be raised in steps towards their free market level. In Section 4 we evaluate these three policies by estimating and comparing the costs of higher prices and the costs of shortages for each. This will provide us with a basis for determining a preferred policy.

2. What is at Stake - Higher Prices

It is not surprising that this country's natural gas policy (and for that matter, its entire energy policy) has been dominated by a desire to hold down prices. Policy makers are not ignorant of the simple economics of supply and demand (although they may have underestimated the impact of price effects). Rather, there has been a strong political incentive to prevent consumer prices from rising, and to prevent producing companies from receiving large profits from price increases. In effect, a major goal of our natural gas policy has been distributional in nature; politicians are reluctant to pass legislation that would redistribute income from gas consumers to gas producers. With this in mind, let us consider what might happen to natural gas prices under alternative policies.

There are three policies that must be considered, since these have provided the basis for most recent public debate over natural gas regulation. The first is simply a continuation of current FPC National area rates (under the assumption that the FPC does not by itself change this pricing policy). New contract prices would increase by 4¢ per year from the 1977 level of $1.46. As old contracts expired, average wellhead prices for gas sold on interstate markets would rise, but would remain will below new contract prices for several years, only reaching about 87¢ per mcf in 1980. Average wholesale prices (i.e. prices charged by the pipelines to public utilities and large "mainline" industrial consumers) would depend on the particular distribution of gas through the pipeline network and the cost of transmission, which in turn would depend on changing patterns of regional demand. Although we can not know what these prices will be with certainty, we can predict their likely values using our econometric model of the natural gas industry. We can expect these prices to average about 98¢ in 1978, and $1.16 in 1980. Similarly, based on projected demands and projected interstate supplies, we can project that intrastate wellhead prices would reach $2.00 in 1978 and $2.40 in 1980. To project retail prices, we assume that the 1976 average retail to wholesale markup remains constant in real terms on an mcf basis; we then extrapolate the markup assuming a 6 1/2% rate of inflation.[7] Based on these markups, we estimate that in 1980 average residential retail price would reach $2.83, while the average industrial retail price will reach $1.92. (There will be considerable regional variation in these prices, however.)

A second alternative policy is that laid out in President Carter's National Energy Plan.[8] The main aspects of that plan that deal with natural gas are as follows:

(a) The new contract price for "new" gas would be set equal to the BTU equivalent of the average refiner acquisition price of all domestic crude oil, while prices of "old" gas would continue to be limited to existing FPC National area rates.[9] Based on projections of crude oil prices under the Carter plan, we would expect the price of "new" gas to begin at $1.75 per mcf and rise to $2.40 in 1980 and $3.10 in in 1985.[10] We

---

[7]This markup is regulated by state regulatory commissions, and is usually based on an allowed rate of return on undepreciated capital. Unless there are major changes in supply, capital requirements are not likely to change much in the future. Assuming that labor costs and nominal interest rates reflect the aggregate rate of inflation, it seems reasonable to assume that the markup will remain constant in real terms, as it more or less has in the past.

As an alternative means of forecasting retail prices, we fit a regression equation relating retail prices to average wellhead prices over data from 1960 to 1976. For the residential retail price, the resulting regression equation is:

$$P_r = \underset{(.0419)}{0.7224} + \underset{(.1359)}{2.1218}P_w, \quad R^2 = .984 \quad \text{(Standard errors in parentheses.)}$$

For the industrial retail price, our equation is:

$$P_i = \underset{(.0123)}{0.0421} + \underset{(.0399)}{2.0722}P_w, \quad R^2 = .999$$

With these equations, retail prices would be somewhat higher in 1980 and 1985. For example, in 1980, the residential retail price could range from $2.57 to $3.48 under the alternative policies, while the industrial price could range from $1.84 to $2.74.

[8]See The National Energy Plan, Executive Office of the President, April 1977.

[9]"New" gas includes new discoveries "from onshore wells more than 2 1/2 miles from an existing well, or 1000 feet deeper than any existing well within a 2 1/2 mile radius," and offshore gas "produced from wells on new Federal leases granted on or after April 20, 1977, or old leases which had been abandoned and are subject to re-leasing," Ibid, page 53.

[10]These prices are in nominal (undeflated) terms, and based on an assumed 6.5% rate of general inflation.

would also expect "new" gas to account for only about 25% of all new contracts in 1978, but nearly 100% of all new contracts by 1981. As a result, the average new contract price on interstate sales would be about $1.58 in 1978, and $2.20 in 1980.

(b) New contract prices for intrastate gas would also be regulated. All new contracts of intrastate gas (both "old" and "new" gas) would be tied to the price of "new" interstate gas, i.e. would increase from $1.75 initially to around $2.40 in 1980. Average wellhead prices of intrastate gas would thus be below their free market levels, but only for a few years, and not by very much (since the price of "new" gas will rise as the average refiner acquisition price of domestic crude oil rises over the next 5 years).

(c) Pricing policy would discourage the use of gas by industry and electric utilities. The wellhead cost of higher-priced ("new") gas would be allocated to residential rather than industrial users. In addition, beginning in 1979 a tax would be levied on industrial users of gas which would be keyed to the difference between the price of gas and the BTU equivalent price of oil. This tax would increase so that on an mcf basis, the effective industrial price of gas would be $1.05 below the BTU equivalent price of oil in 1979, and equal to the BTU equivalent price of oil in 1985 and beyond.[11] Based on projections of oil prices, we estimate that this tax would increase from about 25¢ per mcf in 1979 to about $1.00 per mcf in 1985. Based on our projections[12] of average wellhead prices and average wholesale prices under the Carter plan, we estimate that the average retail industrial price of gas (including the tax) would be about $2.39 in 1980 and $4.07 in 1985. Despite the tax and allocation of higher-priced gas to industrial users, residential retail prices would still be higher because of the relatively high cost of retail distribution to residential consumers: $2.93 in 1980 and $4.31 in 1985.[13]

---

[11] Fact sheet on President's energy program issued by White House Energy Staff, and "The National Energy Plan."

[12] Obtained using our econometric model.

[13] These retail prices are again based on the markup forecasts described earlier.

The third alternative policy is designed to increase the new contract price of all gas towards its free market level over the next five years. This would provide a greater incentive to producers to increase supplies of gas, by exploring for new discoveries (thus increasing reserves of "new" gas), by exploring near and extending existing reservoirs (thus increasing reserves of "old" gas), and by increasing production from higher-cost reserves (that would otherwise be uneconomical). Our policy would raise the new contract price in steps, to $2.00 in 1978, $2.40 in 1979, $2.55 in 1980, $2.70 in 1981, with further increases of about 20¢ per year (to keep pace with general inflation). As a result of this policy, average interstate wellhead prices would rise to 80¢ in 1978, $1.30 in 1980, and $2.21 in 1985, while new contract <u>intrastate</u> wellhead prices would rise to $2.55 in 1980, and $3.50 in 1985. Using our econometric model, we project average wholesale prices to be $1.06 in 1978, $1.53 in 1980, and $2.32 in 1985. Finally, average residential retail prices would be $2.53 in 1978, $3.20 in 1980, and $4.61 in 1985, while industrial retail prices would be $1.73, $2.29, and $3.36 in the respective years.

These price projections, together with recent actual prices, are summarized in Table 1. Because there is so much regional variation in retail prices, the table also shows projections of residential and industrial retail prices for different regions of the country.

Observe that although the different policies would have very different implications for new contract prices (particularly in later years), in terms of percentage differences, the impact on retail prices is much smaller. For example, in 1985 new contract interstate prices under "Phased Deregulation" would be about double those under "FPC Area Rates." Average residential retail prices, however, would only be about 22% higher. The reason is that the largest component of the residential retail price is the cost of local transmission and distribution, and this cost would not change as wellhead and wholesale prices

Table 1 - Natural Gas Prices*

A. U.S. Average Prices

	Interstate New Contract			Average Interstate Wellhead			Intrastate New Contract			Average Wholesale			Average Retail: Residential			Average Retail: Industrial**		
1965	0.19			0.17			-			0.30			1.01			0.35		
1970	0.22			0.18			-			0.33			1.06			0.38		
1975	0.60			0.32			1.25			0.52			1.57			0.75		
1976	1.00			0.50			1.75			0.73			1.98			1.29		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
1978	1.50	1.58	2.00	0.69	0.70	0.80	2.00	1.80	2.00	0.98	0.98	1.06	2.45	2.45	2.53	1.65	1.65	1.73
1979	1.54	1.85	2.40	0.78	0.86	1.04	2.20	2.15	2.40	1.08	1.12	1.29	2.65	2.69	2.86	1.79	2.09	2.00
1980	1.58	2.20	2.55	0.87	1.01	1.30	2.40	2.40	2.55	1.16	1.26	1.53	2.83	2.93	3.20	1.92	2.39	2.29
1982	1.66	2.65	2.90	1.02	1.36	1.70	2.60	2.65	2.90	1.30	1.56	1.90	3.19	3.45	3.79	2.16	3.05	2.76
1985	1.78	3.10	3.50	1.25	1.93	2.21	3.00	3.10	3.50	1.49	2.02	2.32	3.78	4.31	4.61	2.53	4.07	3.36

B. Regional Retail Prices

	Residential Retail				Industrial Retail			
	1976	1980			1976	1980		
		(a)	(b)	(c)		(a)	(b)	(c)
New England	3.70	5.10	5.20	5.47	2.58	3.62	4.09	3.99
Middle Atlantic	2.63	3.69	3.79	4.06	1.71	2.47	3.94	2.84
East No. Central	1.87	2.68	2.78	3.05	1.40	2.06	2.54	2.44
West No. Central	1.53	2.24	2.34	2.61	0.91	1.42	1.89	1.79
South Atlantic	2.23	3.16	3.26	3.53	1.25	1.87	2.34	2.24
East So. Central	1.60	2.33	2.43	2.70	1.02	1.56	2.03	1.93
West So. Central	1.71	2.47	2.57	2.84	1.29	1.92	2.39	2.29
Mountain	1.58	2.30	2.40	2.67	0.95	1.47	1.94	1.84
Pacific	1.76	2.54	2.64	2.91	1.46	2.14	2.61	2.51

* - In current $/mcf

** - Includes tax under Carter Plan

(a) FPC area rates (b) Carter Plan (c) Phased Deregulation increased. The percentage increase in industrial retail prices would be larger; by 1985 "Phased Deregulation" would result in prices 33% higher than under continued FPC area rates, while the "Carter Plan" would result in prices 61% higher (largely because of the tax on industrial use of gas). Finally, note that there has been, and is likely to continue to be, considerable regional variation in retail prices. Part of this variation is due to the differences in interstate transmission costs, and part is due to differences in local distribution costs.

There is no doubt that our three alternative policies imply significant differences in retail prices of gas to residential and industrial consumers. The relevant question, however, is what is the total cost to consumers of a higher-priced policy, and how does it compare to the cost of shortages resulting from a lower-price policy? We will answer this question in Section 4, after first projecting the shortages that are likely to result under the alternative policies.

3. What is at Stake - Shortages

Our vehicle for predicting shortages under alternative policies is the M.I.T. econometric model of the natural gas industry. This model explains in detail the simultaneous behavior and interaction of natural gas and oil exploration and reserve accumulation, natural gas production out of reserves, natural gas distribution, and finally, natural gas demand. It is therefore ideally suited for forecasting the effects of alternative price policies. The model is described in detail elsewhere, but we summarize its overall structure in the Appendix.[14]

---

[14] The model was constructed by P.W. MacAvoy and R.S. Pindyck, and various versions are described in P.W. MacAvoy and R.S. Pindyck, "Alternative Regulatory Policies for Dealing with the Natural Gas Shortage," The Bell Journal of Economics and Management Science, Vol. 4, No.2, Autumn 1973, P.W. MacAvoy and R.S. Pindyck, The Economics of the Natural Gas Shortage (1960-1980), North-Holland Pub. Co., Amsterdam, 1975, and P.W. MacAvoy and R.S. Pindyck, Price Controls and the Natural Gas Shortage, American Enterprise Institute, Wash. 1975. In 1976 the model was structurally revised and re-estimated using an updated data base. The most recent version of the model is described in R.S. Pindyck, "Higher Energy Prices and the Supply of Natural Gas," Energy Systems and Policy, Autumn 1977.

The three policies of interest to us were described in the last section in the context of their implications for wellhead, wholesale, and retail prices. We review them here, with reference to their simulation using the econometric model:

(1) FPC area rates. New contract prices of gas are increased by 4¢ per year from \$1.46 in 1977. Intrastate prices range from \$2.00 in 1978 to \$2.40 in 1980, and remain constant in real terms thereafter.

(2) Carter Plan. "New" gas prices, which rise from \$1.75 to \$2.40 in 1980, are the relevant new contract prices for determining exploratory drilling and new discoveries, while "old" gas prices, the same as those in (1) above, are the relevant new contract prices for determining extensions and revisions of gas reserves. Average new contract prices (which determine average wellhead and average wholesale prices) are calculated by assuming that the fraction of "new" gas in new contracts rises from 25% in 1978 to 100% in 1981. Intrastate prices begin at \$1.80 in 1978, but reach \$2.40 by 1980. Finally, a tax is added to the wholesale price of gas facing industrial consumers. This tax ranges from 25¢ per mcf in 1979 to \$1.00 in 1985.

(3) "Phased Deregulation." In this policy a set of new contract prices is chosen that results in shortages dropping to about 3 Tcf. (Thus we can not claim that exactly these prices would result from actual deregulation.) Such a shortfall would be small enough to be filled by manufactured gas and LNG imports. New contract prices are increased to \$2.00 in 1978, \$2.40 in 1979, \$2.55 in 1980, \$2.70 in 1981, and by 20¢ per year thereafter. Intrastate new contract prices are assumed to equal those for interstate gas from 1978 onwards.

The econometric model contains a number of exogenous variables for which assumptions must be made in order to generate forecasts. With the exception of oil prices, our assumptions about these variables are the same for all three policies. The exogenous determinants of the reserves and production of gas include the field price of crude oil in the producing regions, average drilling costs, interest rates, the amount of offshore acreage leased by the Bureau of Land Management each year, and the number of drilling rigs operating offshore. We assume that crude oil prices increase in nominal terms by $1.00 per year from a base of $8.00 in 1977. (In simulating the Carter Plan we add the tax to the wholesale price of refined oil products used in the industrial sector.) We assume that average drilling costs increase in nominal terms by 10% annually, that interest rates remain constant at 10%, that 2 million acres of offshore lands are leased annually, and that five additional drilling rigs are installed each year in offshore Louisiana. Determinants of demand include state-by-state personal income, value added in manufacturing, new capital expenditures in manufacturing, population, and prices of alternative fuels. We assume that income, value added, and capital expenditures all grow in real terms at a rate of 6% in 1976, 5% in 1977, 4% in 1978 and 79, and 3.5% thereafter. Prices of coal and electricity are projected to rise in real terms by 6% per year. Finally, we assume that 1 Tcf of gas will be imported from Canada each year, and we include this Canadian gas in our supply forecasts.

The results of our forecasts are shown in Tables 2, 3, and 4, and in Figures 1, 2, 3, and 4. Observe that under a continuation of FPC area rates, production of gas will fall off steadily, demand for gas will rise rapidly, and excess demand will exceed 11 Tcf by 1980 and 20 Tcf by 1984. Part of this excess demand (probably about half) will take the form of curtailments, while the remainder will take the form of residential consumers unable to install new gas lines in homes, and industrial consumers unable to contract for gas deliveries. The first component of excess demand (curtailments) will result (as it did during the winter of 1976-77) in unemployment and lost GNP, and, as excess demand grows, cutoffs in residential deliveries. The second component of excess demand (consumers unable to contract for purchases) will result in an increased demand for oil and coal, as

Table 2 - Forecast of FPC Area Rates

Year	Exploratory Wells Drilled	New discoveries of gas (Tcf)	Additions to gas reserves (Tcf)	Onshore Production (Tcf)	Offshore Production (Tcf)	Total gas production (Tcf)*	Residential Commercial Demand (Tcf)	Industrial Demand (Tcf)	Total demand for gas** (Tcf)	Excess Demand
1976	6282	9.3	10.8	19.4	4.2	24.6	9.2	19.8	30.5	5.9
1977	6045	12.0	16.7	18.5	4.6	24.1	9.4	20.4	31.3	7.2
1978	5896	11.4	15.4	17.3	5.3	23.6	9.6	20.9	31.9	8.3
1979	5524	10.6	13.2	16.0	6.1	23.2	10.2	21.4	33.0	9.8
1980	4860	10.3	11.4	14.3	7.1	22.4	10.6	22.0	33.9	11.5
1981	4317	10.3	11.1	12.2	8.1	21.3	10.9	22.8	35.0	13.6
1982	3957	10.3	11.2	10.3	9.0	20.3	11.4	23.8	36.3	15.9
1983	3646	10.4	12.0	8.5	9.9	19.4	11.8	25.0	37.8	18.4
1984	3385	10.5	12.6	7.1	10.6	18.7	12.3	26.4	39.6	21.0
1985	3136	10.6	13.6	5.9	11.3	18.1	12.9	28.0	41.8	23.7

Table 3 - Forecast of Carter Plan

Year	Exploratory Wells Drilled	New Discoveries of gas (Tcf)	Additions to gas Reserves (Tcf)	Onshore Production (Tcf)	Offshore Production (Tcf)	Total gas Production (Tcf)*	Residential Commercial Demand (Tcf)	Industrial Demand (Tcf)	Total Demand for Gas** (Tcf)	Excess Demand
1976	6282	9.3	10.8	19.4	4.2	24.6	9.2	19.8	30.5	5.9
1977	5967	10.4	14.3	18.4	4.6	24.0	9.4	20.4	31.3	7.3
1978	5651	10.0	12.9	17.0	5.5	23.5	9.6	20.9	31.9	8.4
1979	5201	12.3	14.0	15.6	6.5	23.1	10.2	20.1	31.6	8.6
1980	4640	13.3	15.0	13.4	7.6	22.1	10.5	19.3	31.0	9.0
1981	4380	13.8	15.8	11.5	8.7	21.2	10.8	18.4	30.4	9.1
1982	4110	14.1	16.3	9.8	9.9	20.8	11.0	17.5	29.7	8.9
1983	3820	14.4	17.4	8.4	11.1	20.5	11.2	16.7	29.0	8.5
1984	3538	14.8	18.2	7.1	12.3	20.4	11.5	15.8	28.3	7.9
1985	3276	15.2	19.3	6.0	13.3	20.4	11.7	15.0	27.7	7.3

* - Includes 1 Tcf of Canadian imports.

** - Includes lease and plant fuel demand (i.e. use of gas as energy source for extraction and pressurization at field site).

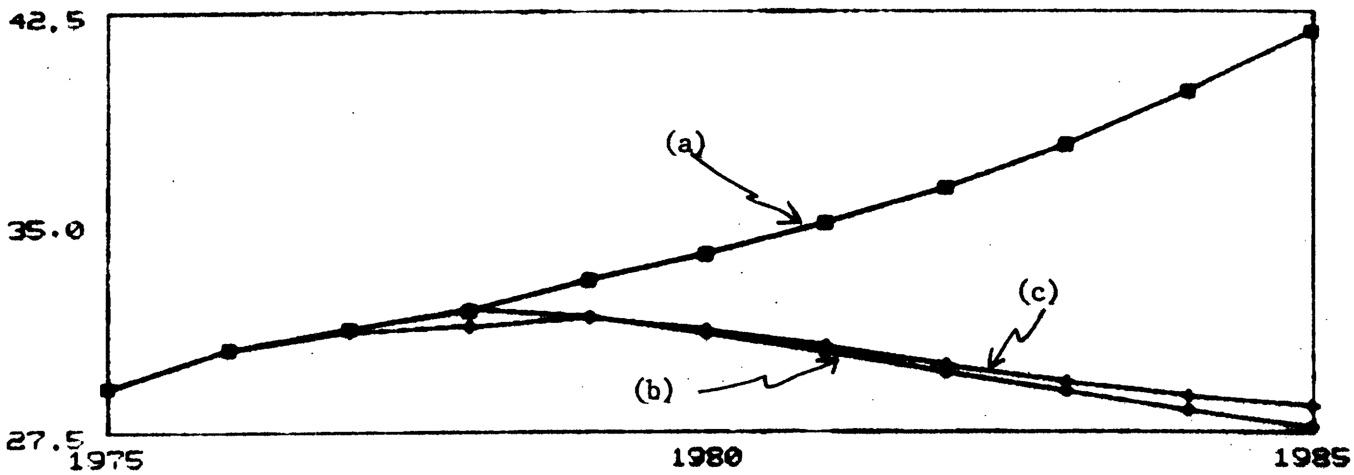
Table 4 - Forecast of Phased Deregulation

Year	Exploratory Wells Drilled	New Discoveries of Gas (Tcf)	Additions to gas Reserves (Tcf)	Onshore Production (Tcf)	Offshore Production (Tcf)	Total Gas Production (Tcf)*	Residential Commercial Demand (Tcf)	Industrial Demand (Tcf)	Total Demand for Gas** (Tcf)	Excess Demand
1976	6282	9.3	10.8	19.4	4.2	24.6	9.2	19.8	30.5	5.9
1977	6120	14.0	19.0	18.5	4.8	24.4	9.4	20.2	31.1	6.8
1978	6424	18.8	24.9	17.6	5.7	24.3	9.5	20.4	31.4	7.0
1979	7066	22.8	31.1	17.2	6.7	24.9	10.1	20.1	31.6	6.7
1980	7275	19.9	29.5	17.2	7.8	26.1	10.2	19.4	31.2	5.1
1981	6671	17.6	24.1	17.0	9.1	27.1	10.3	18.7	30.6	3.5
1982	5557	16.5	19.0	15.7	10.4	27.1	10.3	18.1	29.9	2.9
1983	4784	16.4	16.5	13.6	11.7	26.3	10.3	17.5	29.3	3.0
1984	4263	16.6	15.5	11.3	12.8	25.2	10.4	17.1	28.8	3.6
1985	3912	16.9	15.9	9.0	14.0	24.0	10.5	16.7	28.5	4.4

* - Includes 1 Tcf of Canadian imports.

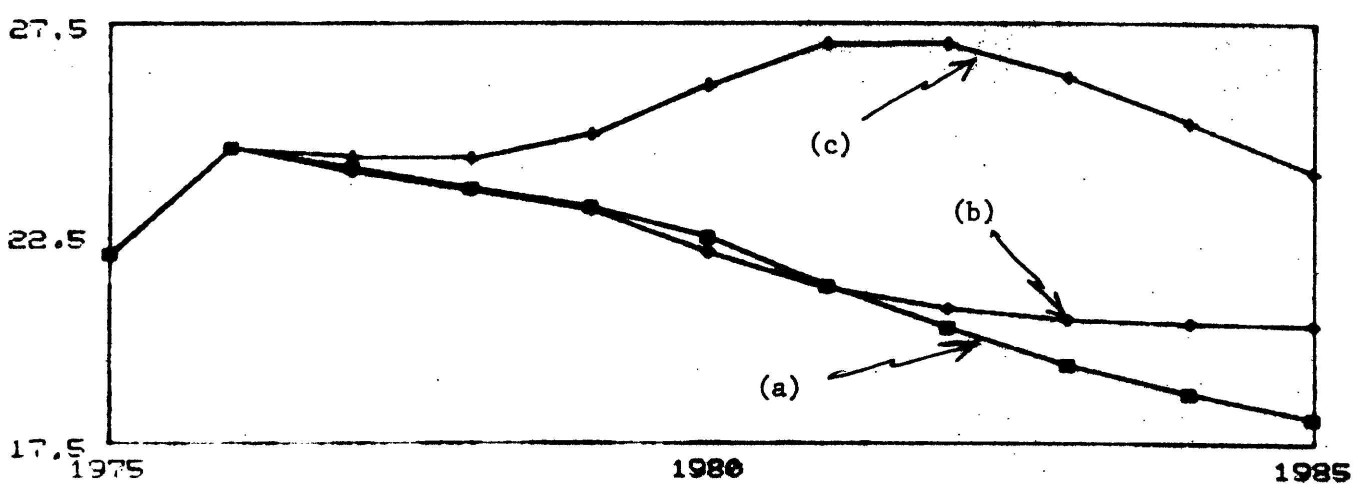
** - Includes lease and fuel plant demand.

Figure 1 - Total Demand for Gas



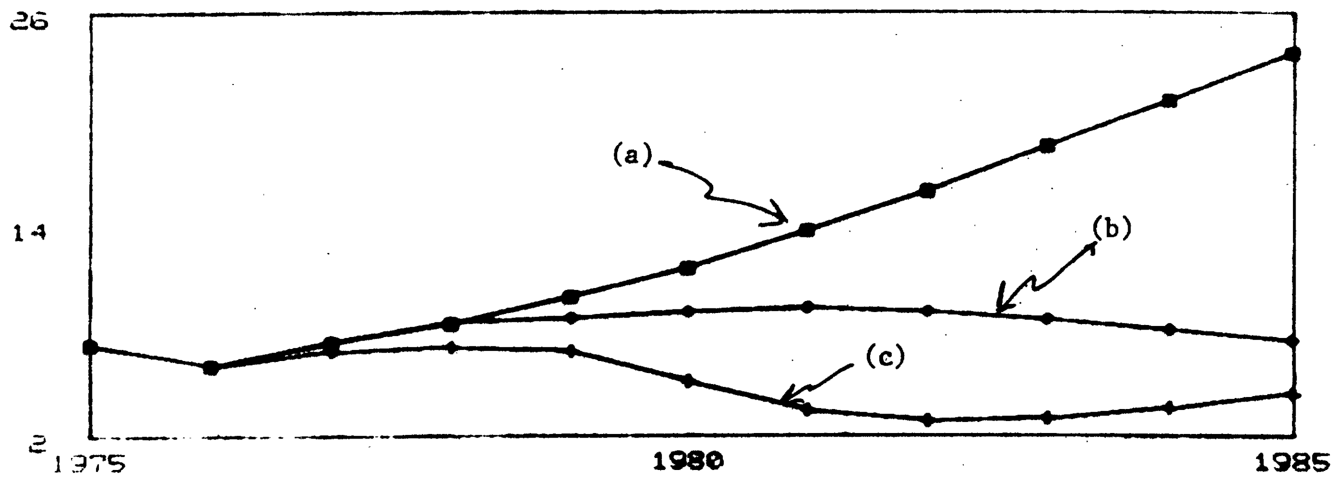
(a) FPC area rates (b) Carter (c) Deregulation

Figure 2 - Supply of Gas



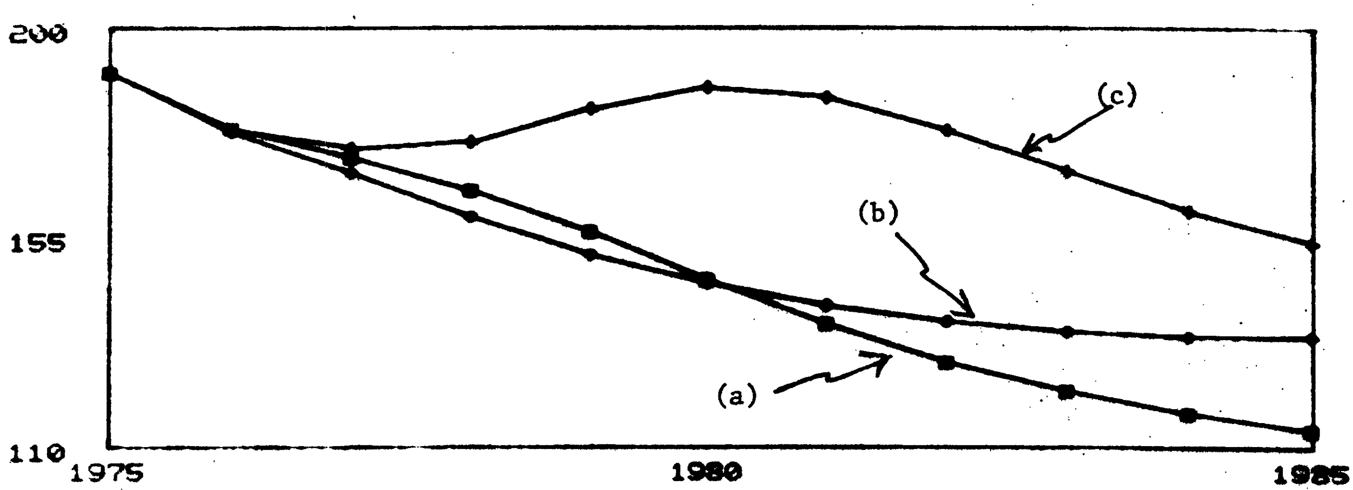
(a) FPC area rates (b) Carter (c) Deregulation

Figure 3 - Excess Demand for Gas



(a) FPC area rates (b) Carter (c) Deregulation

Figure 4 - Reserves of Natural Gas



(a) FPC area rates (b) Carter (c) Deregulation consumers are forced to look for alternative fuels. This in turn will drive up the prices of those fuels, or, if those prices are regulated, result in greater imports of oil.

The Carter Plan would help considerably in reducing excess demand. It would have its effect largely by reducing the demand for natural gas. Since industrial consumers account for the majority of total gas demands, and since they have a higher elasticity of demand, the imposition of a tax on those consumers would cause a major shift to alternative fuels, as well as some decrease in total energy consumption. Under the Carter Plan, total demand for gas would decrease by about 10% over the next nine years, whereas it would increase by about 30% if current FPC area rates are maintained. Unfortunately, the Carter Plan would not succeed in bringing forth significant new supplies of gas. Wellhead prices would rise only slowly, and producers would have little incentive to do additional exploratory drilling, or to extend existing pools and reservoirs. The net result would be an increase in excess demand to a peak of 9 Tcf by 1980, and then a slow decrease to about 7 Tcf in 1985. While this scenario is far preferable to the first, it would still result in significant shortages.

Excess demand can be reduced to about 3 Tcf per year if new contract wellhead prices are increased in steps according to our "Phased Deregulation" scenario. This would result first in additional exploratory and development well drilling so that new discoveries and reserve extensions would be larger, and second in additional production out of any given level of proved reserves. Total production of gas would be about 4 or 5 Tcf higher than under the Carter Plan, while total demand for gas would be about the same as under the Carter Plan. But by increasing supplies as well as decreasing demands, shortages could be averted.

These forecasts set forth the trade-off between higher prices and shortages. Evaluating the alternative policies, however, requires estimating the dollar cost of higher prices and the dollar cost of a shortage. We now turn to the calculation of these costs, and their use in assessing the policies.

4. The Cost of Higher Prices and the Cost of Shortages

We begin by estimating the cost of higher prices. This cost is just the resulting increase in expenditures for those consumers able to obtain gas at the lower price.[15] Since the highest price would result from our policy of "Phased Deregulation," we calculate the cost of higher prices for this policy relative to continued FPC area rates, and relative to the "Carter Plan." These costs are calculated for the residential/commercial and industrial sectors for each of nine regions and for each year over the period 1977-1985, based on projected gas production and retail prices under each alternative policy. By summing these costs across regions and over the 9 year horizon, we can compare policies in terms of the relative cost to the U.S. of higher prices.

The costs of higher prices are presented in Tables 5 and 6. Each number in Table 5 represents, for consumers in a particular region and in a particular year, the cost of higher prices resulting from a policy of "Phased Deregulation" replacing a policy of "FPC Area Rates." (Table 6 represents the same costs for "Phased Deregulation" replacing the "Carter Plan.") Thus we see, for example, that a shift to "Phased Deregulation" will cost consumers in New England an additional $108 million in 1980 and an additional $143 million in 1985. For the U.S. as a whole, the corresponding costs would be $6.45 billion in 1980 and $8.52 billion in 1985, of which a little more than half would be incurred by industrial consumers.

Summing over all nine years in Table 5, we see that the total cost to U.S. consumers from higher prices resulting from "Phased Deregulation" (as opposed to

---

[15] Note that this is not the change in consumer surplus resulting from a price increase. The net loss in consumer surplus resulting from a price increase would be smaller than this increased expenditure because of the gain in surplus to those consumers now able to obtain gas who were unable to before. We measure this second component of consumer surplus, however, when we evaluate the cost of a shortage.

Table 5 - Cost of Higher Prices: Phased Deregulation Relative to FPC Area Rates*

Year / Region	1977	1978	1979	1980	1981	1982	1983	1984	1985
New England	.012	.027	.068	.108	.133	.141	.138	.143	.143
Middle Atlantic	.072	.176	.425	.679	.836	.879	.869	.893	.899
East No. Central	.177	.433	1.049	1.675	2.062	2.171	2.144	2.204	2.218
West No. Central	.076	.183	.444	.708	.871	.918	.905	.931	.937
South Atlantic	.054	.131	.319	.510	.627	.660	.652	.670	.674
East So. Central	.037	.091	.220	.352	.432	.456	.450	.463	.466
West So. Central	.130	.317	.768	1.227	1.509	1.589	1.569	1.613	1.622
Mountain	.042	.105	.252	.404	.496	.523	.516	.531	.533
Pacific	.082	.198	.486	.776	.954	1.005	.991	1.020	1.026
U.S. Total	.678	1.664	4.034	6.452	7.929	8.347	8.239	8.475	8.524
Residential/ Commercial	.317	.778	1.886	3.012	3.707	3.902	3.852	3.962	3.985
Industrial	.361	.886	2.148	3.431	4.222	4.445	4.387	4.513	4.539

* - All numbers are in billions of 1976 dollars.

Table 6 - Cost of Higher Prices: Phased Deregulation Relative to the Carter Plan*

Year / Region	1977	1978	1979	1980	1981	1982	1983	1984	1985
New England	.012	.027	.036	.053	.056	.053	.030	.022	.013
Middle Atlantic	.071	.175	.174	.264	.264	.246	.081	.021	(.044)
East No. Central	.175	.432	.319	.507	.476	.437	(.026)	(.194)	(.371)
West No. Central	.075	.182	.087	.137	.108	.093	(.131)	(.213)	(.297)
South Atlantic	.053	.131	.038	.075	.051	.040	(.131)	(.193)	(.257)
East So. Central	.037	.090	.015	.038	.016	.010	(.113)	(.158)	(.203)
West So. Central	.128	.315	(.097)	(.069)	(.187)	(.198)	(.703)	(.888)	(1.072)
Mountain	.042	.103	.032	.062	.043	.036	(.098)	(.147)	(.197)
Pacific	.082	.200	.110	.184	.159	.143	(.091)	(.175)	(.264)
U.S. Total	.676	1.658	.705	1.253	.986	.862	(1.179)	(1.922)	(2.691)
Residential/ Commercial	.316	.775	1.520	2.168	2.387	2.266	1.912	1.786	1.623
Industrial	.360	.883	(.815)	(.915)	(1.401)	(1.404)	(3.091)	(3.708)	(4.314)
Tax Revenue Under Carter Plan	0	0	3.088	4.413	5.671	6.756	7.748	8.713	9.638

* - All numbers are in billions of 1976 dollars. Numbers in parentheses indicate lower retail prices under "Phased Deregulation."

FPC area rates) would be \$54.34 billion.[16] Similarly, by summing over the nine years in Table 6, we see that "Phased Deregulation" would cost consumers an additional \$0.35 billion in higher prices as compared to the Carter plan. The reason for this small cost, however, is that industrial consumers actually pay much more (in later years) under the Carter plan because of the tax. The tax revenues themselves add up to \$46.03 billion over the nine years. Since these tax revenues are available for public consumption (and in fact may be in part rebated to taxpayers), they should be subtracted from the cost of higher prices under the Carter plan - or, equivalently, added to the cost of "Phased Deregulation." Adding in these tax revenues, we find that the total cost of "Phased Deregulation" relative to the Carter plan is \$46.38 billion.

These costs must now be compared to the costs of shortages resulting from lower price policies. There are three components to the cost of a shortage:

(1) Some consumers are unable to obtain gas. There is thus a direct loss of consumer surplus, measured as the value to these consumers of the gas they otherwise would have purchased.

(2) The shortage of natural gas results in increased demand for other fuels (oil and coal), raising the prices of those fuels to all consumers.[17]

(3) Curtailments of gas result in unemployment and thus lost GNP.

We estimate each of these components of the cost of shortages, again comparing FPC area rates and the Carter plan to "Phased Deregulation."

We begin with the direct loss of consumer surplus. This is given by the shaded area in Figure 5. P_o and Q_o correspond to the free market price at which there is no shortage, while P_1 is the regulated price at which only Q_1 is pro-

[16] We could have computed this cost by summing over a longer time horizon, but there is too much uncertainty over natural gas supply and demand after 1985 to make such a calculation meaningful.

[17] We have made the assumption that in the short term, consumers of gas switch to oil and coal only if they are unable to purchase gas (i.e. the effective price of gas to them is infinite), but not if the price of gas increases. This assumption of near zero cross-price elasticity in the short term was necessary since we do not have a complete econometric model of inter-fuel substitution.

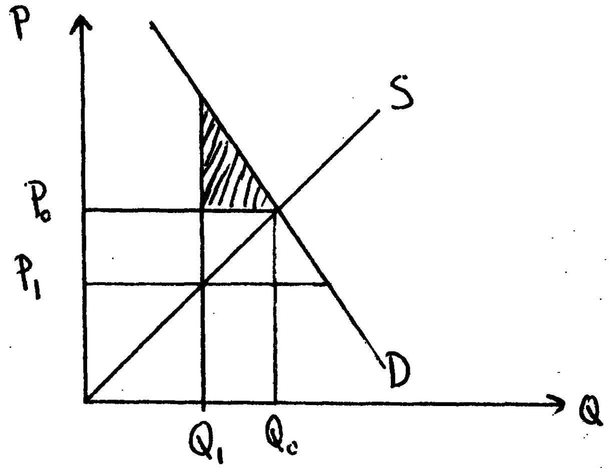


Figure 5 - Lost Consumer Surplus from a Shortage

duced. The demand function itself is needed to compute this lost surplus, since it determines the value of the quantity difference $Q_o - Q_1$. We use aggregate residential and aggregate industrial demand functions obtained from our econometric model of the natural gas industry, based on a five year adjustment period. The calculated surplus losses corresponding to lower price policies are shown in Table 7. Note that the total consumer surplus "benefit" is about $11.8 billion when "Phased Deregulation" is compared to FPC area rates, and $8.6 billion when it is compared to the Carter plan.

Next we measure the cost of shortage-induced expenditures on oil and coal. To obtain a conservative estimate of this cost, we assume that only half of the excess demand for natural gas is satisfied (on a BTU equivalent basis) by oil and coal. Further we assume that at 1976 prices, the long-run price elasticities for oil and coal demand and supply are -0.5 and 0.4 respectively.[18]

[18]The actual elasticities are probably smaller, and the use of larger elasticities will give us an underestimate of the induced expenditure on oil and coal. Again, we choose the larger elasticities in order to obtain as conservative an estimate of the induced expenditure as possible.

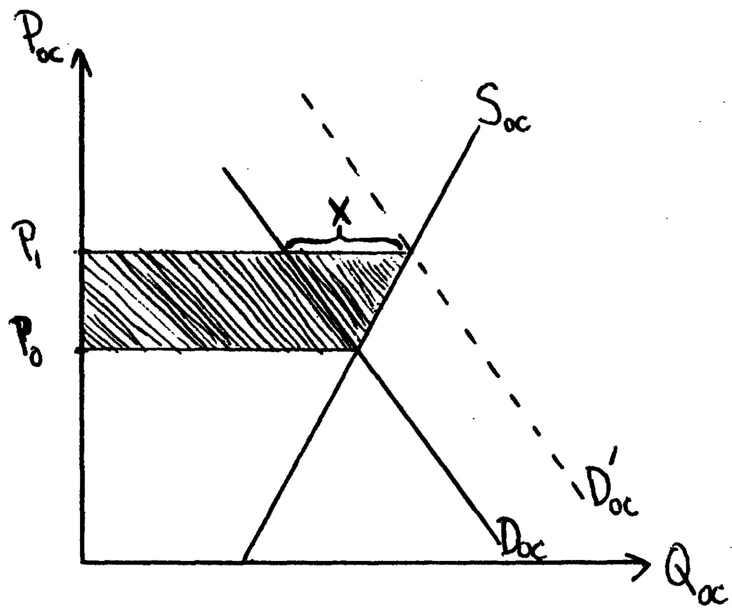


Figure 6 - Shortage-Induced Expenditure on Oil and Coal

The induced expenditure on oil and gas is given by the shaded area in Figure 6, where S_{oc} and D_{oc} are the aggregate supply and demand curves for both oil and coal, and X is the additional demand for oil and coal (i.e. one-half of the BTU shortage of natural gas). Note that the increased expenditure on oil and coal comes about for two reasons: a larger quantity is consumed, and the shift in demand causes the price to rise.

The calculated increases in oil and coal expenditures are shown in Table 8. Note that these increased expenditures are quite large, and in the case of "Phased Deregulation" relative to FPC area rates, the expenditure by itself outweighs the cost of higher prices.

Finally we measure the lost GNP that would result from shortages. To do this, we begin with an estimate prepared by the American Gas Association of the added unemployment resulting from natural gas shortages during the winter of 1976-77.[19] The A.G.A. found the following unemployment to be directly attributable to the shortage:

[19] "Economic Impact of Winter 1976-77," Statistics Directorate, American Gas Association, May 10, 1977. These estimates are quite close to those issued by private economic forecasting firms.

Table 7 - Consumer Surplus Losses from Shortages*

		1977	1978	1979	1980	1981	1982	1983	1984	1985	TOTAL
FPC Area Rates Relative to Phased Deregulation	Residential /Commercial	.002	.013	.080	.382	.932	1.296	1.381	1.284	1.110	6.480
	Industrial	.002	.010	.064	.311	.768	1.073	1.145	1.066	.922	5.361
	Total	.004	.023	.144	.693	1.700	2.369	2.526	2.350	2.032	11.841
Carter Plan Relative to Phased Deregulation	Residential /Commercial	.004	.017	.090	.446	.965	1.113	.975	.700	.413	4.723
	Industrial	.003	.013	.072	.363	.795	.921	.809	.581	.343	3.900
	Total	.007	.030	.162	.809	1.760	2.034	1.784	1.281	.756	8.623

* - All numbers are in billions of 1976 dollars.

Table 8 - Shortage-Induced Expenditures on Oil and Coal*

	1977	1978	1979	1980	1981	1982	1983	1984	1985	TOTAL
FPC Area Rates Relative to Phased Deregulation	0.378	1.232	2.946	6.084	9.610	12.414	14.785	16.816	18.786	83.051
Carter Plan Relative to Phased Deregulation	0.472	1.327	1.801	3.688	5.279	5.646	5.172	4.044	2.728	30.157

* - All numbers are in billions of 1976 dollars.

Date		Number Unemployed
Jan.	11	0
	26	240,000
	27	650,000
	28	840,000
Feb.	4	1,212,000
	8	870,600
	12	532,000
	18	218,000
	26	92,500
March	4	65,400
	14	10,000

We convert this unemployment into an average increase in the unemployment rate on an annual basis, which we find to be 0.093%. We attribute this increase in the unemployment rate to the year 1976, for which we have estimated the natural gas shortage to be 5.9 Tcf. We now assume that changes in the size of the gas shortage (as measured by our econometric model) will result in proportional changes in the induced increase in the unemployment rate, so that our projections of future shortages under alternative regulatory policies can be used to project induced unemployment. Next, we obtain the cost of this unemployment in terms of los GNP by using Okun's Law, which says that a 1% increase in the unemployment rate corresponds to approximately a 3% loss of "potential GNP."[20] Finally, we assume that potential GNP grows in real terms by 3.5% annually from its 1976 value of $1692.4 billion.

Our alternative policies are compared in terms of relative shortage-induced unemployment and corresponding lost GNP in Table 9. By summing the lost GNP over the nine years 1977-1985, we obtain the third component of the cost of shortages.

The cost of higher prices and the costs of shortages are summarized in Table 10. Observe that in comparing "Phased Deregulation" to continued FPC area rates

[20]For a recent empirical estimate of Okun's Law, see G.L. Perry, "Potential Output and Productivity," Brookings Papers on Economic Activity, 1977:1.

Table 9 - Shortage-Induced Unemployment and Lost GNP

		1977	1978	1979	1980	1981	1982	1983	1984	1985	Tototal
FPC Area Rates Relative to Phased Deregulation	Increase in average unemployment rate over year	.0063	.0205	.0490	.1011	.1280	.2054	.2433	.2749	.3049	----
	Lost GNP*	0.33	1.11	2.76	5.89	7.72	12.82	15.72	18.38	21.10	85.86
Carter Plan Relative to Phased Deregulation	Increase in average unemployment rate over year	.0078	.0221	.0300	.0616	.0885	.0948	.0869	.0995	.0458	------
	Lost GNP*	0.41	1.20	1.69	3.59	5.34	5.92	5.61	6.65	3.17	33.58

* - Measured in billions of 1976 dollars.

Table 10 - Cost Comparisons of Alternative Policies*

	Cost of higher prices	Costs of Shortages			Total Cost (Benefit)
		Lost consumer surplus	Induced Expenditure on oil and coal	Lost GNP	
"Phased Deregulation" vs. "FPC Area Rates"	54.34	(11.84)	(83.05)	(85.86)	(126.41)
"Phased Deregulation" vs. "Carter Plan"	46.38	(8.62)	(30.16)	(33.58)	(25.98)

* - All costs summed over 1977-1985, and measured in billions of 1976 dollars.

or to the Carter plan, the cost of shortages resulting from the lower price policy outweighs the cost of higher prices. "Phased Deregulation" is clearly a far superior policy to continued FPC area rates; over the nine-year period the cost of higher prices totals about $54 billion, while the cost of shortages is over $180 billion. By taxing industrial use of gas and providing a somewhat higher price for "new" gas, the Carter plan will significantly ameliorate shortages, the shortages still resulting would be more costly than the higher prices of "Phased Deregulation." We find "Phased Deregulation" to have a total benefit over the Carter plan of about $26 billion over the nine year period, and this is a highly conservative estimate, since we have taken the entire tax revenue under the Carter plan and attributed it to consumers as a benefit. (Had we included the tax revenue as a cost, the total benefit of "Phased Deregulation" would be $72 billion.) There is thus a significant gain to be had by letting natural gas prices rise towards free market levels, and thereby eliminating shortages.

5. Revising Our Natural Gas Policy

A regulation-induced shortage only makes sense from the point of view of total public welfare if the gain to consumers from lower prices exceeds the losses created by the shortage. We have seen that in the case of natural gas, continued regulation-induced shortages cannot be justified, since the cost of these shortages would far outweigh the gain that some consumers would receive by being able to pay lower prices.

We have, of course, ignored the question of *which* consumers would end up paying higher prices under deregulation. There is no doubt that even a moderate increase in the residential price of natural gas would result in an unacceptable increase in the living expenses of some low-income consumers. But the use of energy policy is the wrong way to achieve equity in income distribution and living standards. Distributional goals can be better attained through the use of tax and transfer policy. For example, expanding our existing food stamp program - by increasing stamp allotments and allowing the stamps to be applied to heating bills (or that portion of rent allocated to fuels) - would be an effective way of buffering low-income groups from the effects of higher energy prices.[21]

We have already incurred unnecessarily higher costs from the regulation-induced shortage of natural gas. Hopefully, our energy policy in the future will be guided by a better understanding of the trade-off between the cost of higher prices and the costs of the shortages, distortions, and growing foreign dependence that result from policies that attempt to maintain low prices.

---

[21] This proposal was presented in R.E. Hall and R.S. Pindyck, "The Conflicting Goals of National Energy Policy," The Public Interest, Number 47, Spring 1977.

APPENDIX - OVERVIEW OF THE ECONOMETRIC MODEL OF THE NATURAL GAS INDUSTRY

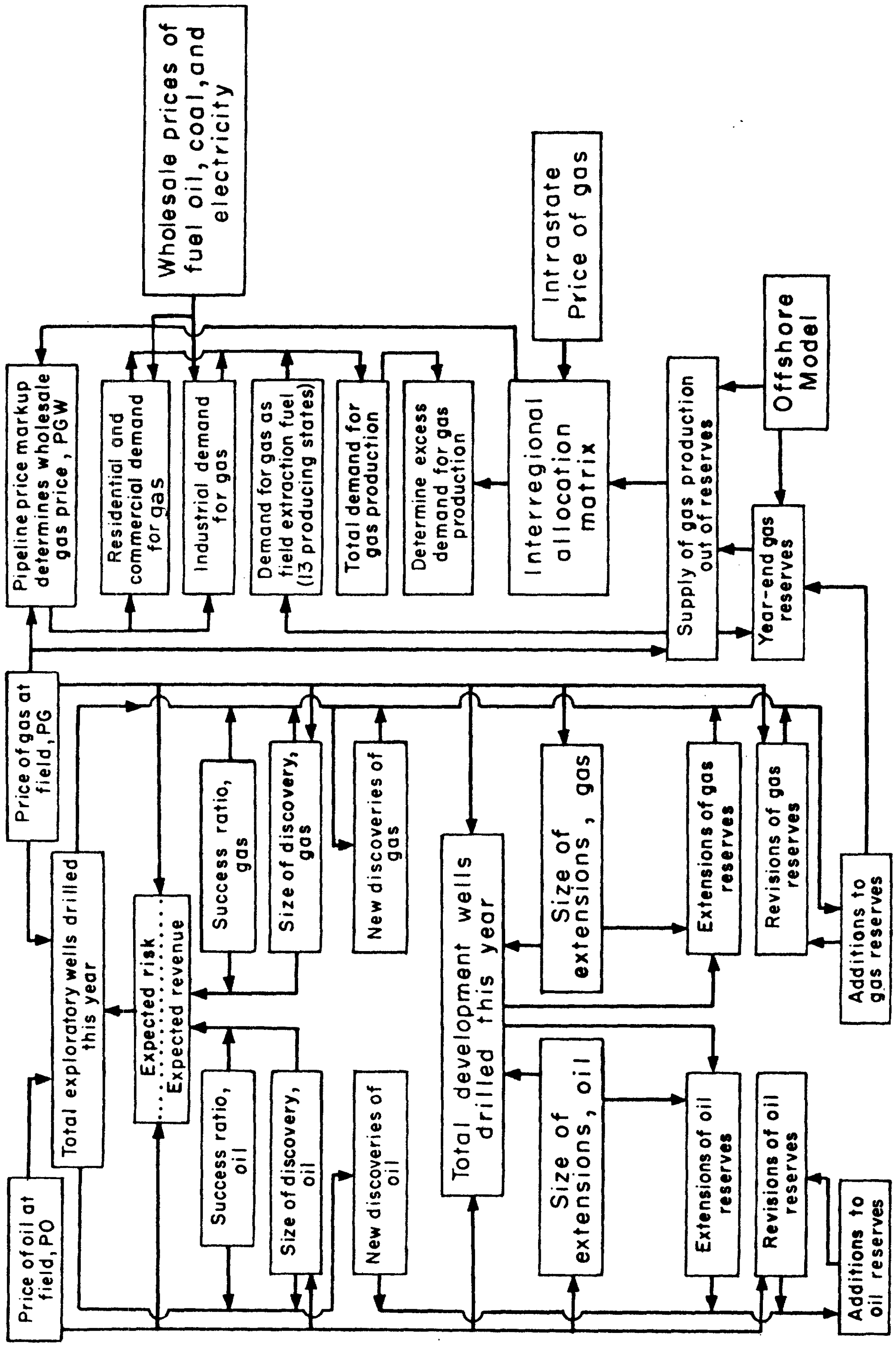
Our model of the natural gas industry simultaneously describes gas supplies and demands in both the market for reserve additions (gas producers selling new reserves to pipelines at the wellhead price) and the market for wholesale deliveries (pipelines selling gas on long-term contracts to retail utilities and industrial consumers). The model is highly disaggregated on a regional basis, and describes in detail the spatial structure of the industry; reserve additions are contracted for in regional field markets and gas production is delivered by pipelines to regional wholesale markets, and these regional markets are interconnected by the pipeline network. A block diagram of the model is shown in Figure A-1 that ignores - for simplicity - the regional interconnections between production districts and regional wholesale markets.

Equations for new discoveries of gas and oil are specified and estimated that account for shifts in directionality (gas vs. oil) and for shifts between drilling on the extensive (high-risk) and intensive (low-risk) margins in response to price changes. New discoveries begin with the drilling of exploratory wells, of which some will succeed in discovering gas, some will succeed in discovering oil (with or without associated gas), and some will be unsuccessful. An equation predicting the number of exploratory wells drilled is specified based on the assumption that producers respond rationally to economic incentives as they form portfolios of drilling ventures that may be extensive or intensive, or may favor gas or oil. Economic incentives enter the equation through expected gas and oil revenue (the product of expected prices, success ratios, and sizes of finds), expected risk (an estimate of the variance of expected revenue), average drilling costs, and the

[1]For a detailed descritpion of the model, see P.W. MacAvoy and R.S. Pindyck, The Economics of the Natural Gas Shortage (1960-1980), North-Holland, Amsterdam, 1975, and R.S. Pindyck, "Higher Energy Prices and the Supply of Natural Gas," Energy Systems and Policy, Fall 1977.

FIGURE A-1

SIMPLIFIED BLOCK DIAGRAM OF THE ECONOMETRIC MODEL



interest rate (reflecting capital costs). Two equations then describe the fraction of wells drilled that will succeed in finding gas, and the fraction that will succeed in finding oil. Finally, two equations determine the size of discovery per successful well for gas and oil respectively, and include the effects of price changes and resource depletion. All of these equations were estimated for a set of 20 FPC production districts. Thus new discoveries for gas and oil can be determined on a regional basis as the product of number of wells, success ratio, and size of find per successful well. This level of detail is needed given that oil and natural gas are joint products that must be treated symmetrically.[2]

The model also contains a detailed description of reserve extensions and revisions. An equation is estimated that determines the total number of development wells drilled in any year. (Development wells are drilled in preparation of producing gas or oil from a newly discovered field, and it is these wells, rather than exploratory wells, that lead to extensions and revisions of reserves.) The number of development wells drilled depends on prices and on direct drilling costs, capital costs, and existing reserve levels. Two equations then determine sizes of finds for gas extensions and oil extensions. Explanatory variables in these equations include price (which explain directionality), drilling costs (which could induce operators to change drilling patterns and thereby alter the size distribution of the resulting extensions), and an index that describes the process of geological depletion. Extensions of gas and oil are thus determined as the product of development wells and sizes of finds of extensions. Revisions on the

[2]If higher prices in fact shift exploratory effort to the extensive margin, one would have certain a priori expectations regarding the signs of the coefficients of price terms in the success ratio and size of find equations. Estimation of the latest version of the model gives no evidence of clear-cut shifts toward the extensive or intensive margin in response to price increases. Much of the variation in success ratios, for example, was found not to be caused by changes in price but rather by regional differences and depletion effects. Although the size of find for gas does show a clear positive dependence on the price of gas, the size of find for oil shows no dependence. Thus the impact of changes in price on new discoveries occurs largely through the level of exploratory activity.

other hand do not depend on well drilling, but instead are functions of price, prior reserve and production levels, and changes in production.

Year-end reserves of gas in any year are equal to reserves in the previous year plus additions to reserves (the sum of discoveries, extensions, and revisions) minus production of gas. Production out of reserves depends on the size of the reserve base and on prices that buyers are willing to pay for increasd deliveries. In our model production supply is based on marginal cost pricing, i.e. the marginal cost of developing existing reserves determines a particular level of annual flow, and as the reserve-production ratio becomes smaller, marginal costs rise sharply. Also, there are critical reserve-production ratios below which marginal costs rise extremely sharply. These critical levels could not be estimated econometrically since they have not yet been reached (at least on an aggregate level), but in the model we use engineering estimates to introduce them explicitly. Thus, given some level of year-end reserves in any one production district, the level of gas production in that district will increase with price, but only insofar as the reserve-production ratio stays above a minumum level.

The discovery and production of offshore natural gas is particularly important in policy evaluation, since as both gas and oil prices increase and as more offshore acreage is leased by the federal government, offshore fields will probably provide an increasing share of gas production. The model therefore contains a complete offshore "sub-model" that relates reserves and production of gas off the coast of Louisiana to such policy variables as the new contract field price and the amount of acreage leased annually, and to exogenous variables such as interest rates, the price of oil, and the number of drilling rigs operating offshore. The sub-model operates through three interacting blocks of equations that determine total acreage, producing acreage, and reserves additions and production.

The wholesale demand for natural gas is a function of the wholesale price, as well as prices of alternative fuels and "market size" variables such as population, income, and investment. Average wholesale prices for gas are computed in the model for each consumption region in the country through a series of pipeline price markup equations, which are based on operating costs, capital costs, and regulated rates of profit for the pipeline companies. Finally, the distribution of natural gas is determined from a regional input-output table connecting production districts with consuming regions.