THE REGULATION-INDUCED SHORTAGE
OF NATURAL GAS*

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Paul W. MacAvoy

MASSACHUSETTS
INSTITUTE OF TECHNOLOGY
50 MEMORIAL DRIVE
CAMBRIDGE, MASSACHUSETTS 02139
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In the last three years there have been an increasing and large number of important policy statements on the shortage of natural gas. Some have taken the form of assessments of the "seriousness" of the shortage, and others have sought to determine the ways in which it can be ameliorated. Almost all declarations on the subject have looked to the Federal Power Commission "area rates" (or ceiling prices at the well head) as the cause for the supply-demand difference, and many propose new area rate policies as the means for bringing excess demand to an end.

The sources of these statements have been so diverse as to suggest something of a consensus. Not only have producers claimed that there was excess demand (or that the ceiling prices they received under new contracts were too low) but also buyers see a serious shortage. For one, the chairman of the Columbia Gas (transmission) System recently announced that the company would limit its new sales commitments, "because customers have recently made requests for next winter far exceeding [previous] requirements.... we cannot obtain the additional gas to meet these demands." Chairman Loomis laid the shortage to "unrealistic area pricing policies on gas production," combined with unforeseen increases in demand.¹ Similar statements have been made by other large transporters, such as Consolidated Natural Gas Company late in 1969,² suggesting

¹ "Columbia Gas will limit new commitments to sell natural gas; short supply cited" Wall Street Journal, April 10, 1970.
² Cf. ibid.
that some buyers have begun to find the regulated prices below what
they would be willing to pay for additional production rather than
go without.

The Federal Power Commission has also acknowledged the existence
of a shortage, and has begun to consider new policy in light of this
condition. The staff dealing with natural gas regulation has issued
reports in recent years showing that additions to gas reserves of the
pipelines have been insufficient to meet "market requirements for ex-
tended periods of time."¹ Most recently, the staff seemed to be saying
that the pipelines could have met demands in 1963 for fifteen years
thereafter, while they likely could not meet 1968 demands for more than
seven years.² The staff view has been shared by the Commission, at
least to the point of considering the possibility that ceiling prices
have been too low to clear the gas field markets. In the opinion
issued on rehearing of the Southern Louisiana Area Rates decision, the
Commission concluded that "the vital importance of future additional
gas supply from offshore warrants ... further proceedings ... looking
towards a possible revision of the area rate proceedings for such gas."³

More seriously, the Commission has recently taken a stance on a
national policy issue outside its jurisdiction on the basis of the
"natural gas shortage" alone. Because supplies of new gas reserves

² Assuming in Chart 3, page 15, ibid., that two trillion cu. ft. of "normal replacement" reserves are forthcoming from extensions and revisions of present fields.
have not been sufficient, the Commission has urged that oil import quotas be maintained at present levels so as to provide every possible (indirect) incentive for finding gas in the quota-induced search for domestic oil.  

This position would seem illogical within a government of consistent and flexible policy making, since it says that prices of oil should be kept too high because F.P.C.-regulated prices of gas are too low. Also, it is very likely inexpedient policy within the markets for energy resources, since higher prices for oil increase the demand for gas, so as to increase excess demand. The case has been argued given only that the shortage of gas is acute and that the F.P.C. in its inertia and political insecurity is unable to raise natural gas field prices.

All these expressions of opinion are incomplete. They conclude that a natural gas shortage exists, as a result of regulated prices having been set too low to clear the field markets of excess demand, but they do not show the magnitude nor the source of the still-extant excess demand. The amount has to be known to motivate policy: a "large" and "growing" shortage implies large losses to those going without gas (against gains of those receiving gas at a lower price), and the need to make price changes quickly. The sources of excess demand are as important, because they might well be only those who would substitute gas for other fuels at prices below the market clearing level, which

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1 Cf. Cabinet Task Force on Oil Import Control, The Oil Import Question, Supplementary Views of the Chairman, Federal Power Commission, p. 369, et. seq.
once again implies the need to change prices quickly. Yet only the F.P.C. staff reports show measures of demand, and these are "requirements" in very narrowly defined markets not showing the effects of changes in prices of gas or of gas substitutes. The other views are based on personal example, or on qualitative assessments from the particular to the general, so that documentation of the shortage is still before us.

A schematic of likely circumstances makes the case for a quantitative assessment of how much gas there is and for whom there is not enough gas. There could have been "short term" shortages in the late 1960's of natural gas and coal for use in electricity production, the first as a result of unforeseen gas demand increases after problems in constructing first-generation nuclear reactors had slowed down the installation of substitute equipment, the second from unforeseen railroad car shortages having to do with war-related demands on all transportation facilities. Both sets of events may have been of two-three years duration, and both caused sharp increases in immediate demands for natural gas as boiler fuel. The new demands resulted in "excess demand" in the sense that there was not enough new gas production forthcoming in new pipeline-producer contracts for reserves. To be sure, more gas was produced, but the new customers were not being provided requisite service -- they were not taking delivery on gas with the usual twenty-year reserve backing. The companies meet these new demands by draining down established reserves, as well, so that established companies lose their reserve backing.
Of course the new excess demands might well have been long-lived. Natural gas is the cleanest of boiler fuels and demands for this fuel should have increased as requirements for environmental quality increased. Most important, excess demand may have followed from steadily-growing demands coupled with the declining supply, as a result of lack of profit incentives to explore for and develop new reserves.

The reasons for and results from excess demands will be examined in the sections that follow. The overwhelming factor in the examination is the lack of concrete information on the determinants of demand and supply, or even of elementary price and quantity information useful for first crude assessments of these determinants. An initial attempt to overcome the lack of information is made in the next section in the context of an "F.P.C. type" inventory analysis, in which data on inflow and dedication of gas reserves is put against new production in order to measure the shortage and its effects. The critical elements in the measures are the estimates of the effects on consumption of higher gas field prices; these are collected from a wide variety of extraneous sources, and can be considered no more than marginally useful. The second section of this study attempts to construct internally consistent measures from a small-scale econometric analysis of new gas production in the 1950's, to simulate behavior "without regulation" by extrapolating the analysis to the 1960's. The simulations of production and prices are compared with actual production and prices under area rate regulation to find the effects of regulation. The last
section carries the indicated effects to the realm of speculation by looking at who receives the new gas supplies in markets with continued and important shortages — the home consumer at regulated resale prices or the industrial user at unregulated prices. Regulation plays a large role in the for whom decision, and as a consequence the home consumer would not seem to do very well.

1.0 An "Inventory Approach" to A Measure of Excess Demand

The field markets for natural gas are not similar to other markets for industrial fuels because there are no well defined spot markets for the purchase and sale of gas as a fuel at one location in one day. Rather, reserves of gas are dedicated to a pipeline buyer for production into his line over an extended period of time. The dedication is a sale by contract according to prices beginning with the initial base price for the first year's production of these reserves. The contract markets clear if the amount of newly-dedicated reserves meets the inventory requirements for new production going by pipeline to final industrial and home consumers.

These inventory needs certainly exceed the amount actually produced under a new contract in the first year of that contract. A pipeline would not make a connection with an industrial firm for a single year's deliveries, nor would it sign a 10 to 20 year delivery contract promising a replication of the first year's delivery to a retail gas distributing company without reserve backing. The question
is how much backing is optimal, given that more reserves promise more certainty, but also more reserves cost more.\footnote{In theory, at least, a longer waiting period for production imposes higher costs on the supplier, necessitating higher contract prices. This cost increase was not observable, however, in pre-regulation contract prices.\cite{McAvoy:1962} Cf. P. MacAvoy \textit{Price Formation in Natural Gas Fields} (Yale, 1962), pp. 262-267.} To some extent the regulatory process provides the answer: the Federal Power Commission has long considered the proper amount of reserves to be twenty times initial production, so that regulated demands for new reserves are based on "the assumption that each new market commitment is backed by a twenty year supply."\footnote{Federal Power Commission, \textit{A Staff Report on Gas Supply and Demand} (Bureau of Natural Gas, Washington, D.C., September, 1969), p. 18.}

The pipeline buyers may well have sought such extensive security in the past. New reserves have been demanded first to replace those that have been used up, so as to maintain delivery to established customers, so that reserve demand in year $t$ is $R_t = \alpha \beta Q_t$ where $\alpha$ is twenty years and $\beta Q_t$ is that proportion of total production $Q_t$ that depletes the reserves in the oldest contracts. On average, $\beta$ is probably five per cent of total contract reserves, so that $R_t = (20)(.05)Q_t = 0.5Q_t$. Demand for reserves $R_t$ in 1962, an early year of area price regulation, is estimated to be 13.6 trillion cubic feet or the amount delivered into pipelines that year (as in Table 1). Demand $R_t$ should continue to be the same amount in subsequent years, as equal volumes of reserves are depleted.
There are additional demands to meet reserve commitments to new or additional deliveries for final consumers. These are $R_t^*$ equal to twenty times additional production, or $R_t^* = \alpha \Delta Q_{t+1}$ where $\alpha$ is twenty years and $\Delta Q_{t+1}$ is the production increase from the new reserves in the following year. This amount of reserve demand is estimated in Table 1 by multiplying actual subsequent-year production changes by twenty.

1.1 The Maximum Conceivable Shortage

The sum of the replacement and expansion demands $R_t + R_t^*$ should equal total new contract reserves sought by all buyers, if all were regulated pipelines seeking twenty-year inventories. The supplies of new reserves that have come forth to meet these (hypothetical) demands consist of new discoveries and extensions of old discoveries. They amounted to 19.5 trillion cubic feet in 1962, slightly less in 1963, close to 20 trillion cubic feet from 1964 to 1967, but only 13.6 trillion in 1968 (as in Table 1). Not all of these amounts could have been sold to meet new contract demands, because of the costs of removing impurities, of pumping low-pressure sources, or of transporting it from remote locations. At best, then, supplies of new reserves would have been less than demand by more than 13 trillion cubic feet $(R_t + R_t^* - S_t)$ each year over the 1962-1968 period.¹

¹ The average value of $(R_t + R_t^* - S_t)$ over the period was 12.7 trillion cubic feet.
<table>
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<th>Year</th>
<th>$S_t$ (Additions to Reserves (trillions of cubic feet))</th>
<th>$R_t$ (Reserves Required to Replace Depleted Reserves (trillions of cubic feet))</th>
<th>$R^*_t$ (Reserves Required for Additional Production (trillions of cubic feet))</th>
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<tr>
<td>1968</td>
<td>13.6</td>
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</tbody>
</table>

Note: Column (4) consists of additions to production in the year following that year listed in column (1), multiplied by 20. For example, the net change in national production of gas in 1963 was 909 billion cubic feet, so that required reserves in 1962 equal (909) (20) or 18.2 trillion cubic feet.

Source: American Gas Association, Reserves of Crude Oil and Natural Gas in the United States, volume 23, May 1968.
This amount can be termed "maximum excess demand" if two conditions were present in natural gas field markets. First, there should have been no excess holdings of reserves during earlier years, to put against the "seven lean years" from 1962 to 1968. Second, there had to have been continued demands of established buyers for replacement reserves even when there were substantial field price increases. The first would seem to have been the case; base prices on new contracts were generally increasing during the five years previous to 1962, and there were deficits in reserves in each of these years averaging to 4.0 trillion cubic feet per annum. But the second condition may not have been realized. The price increases experienced in the 1950-1960 period should have been sufficient to induce many gas users to switch to residual fuels when long-term contracts under the old prices expired; indeed, the volume of use of gas in primary metals, for example, declined from 3.8 trillion cubic feet in 1954 to 0.9 trillion cubic feet in 1962.

This gas use was "extra marginal," and there were other industrial buyers in disadvantageous locations or with low-priced alternative fuel suppliers for whom demands were in the same category. The gas reserves for this production should not have been replaced -- or, at

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2 The 1955-1961 total deficit of "additions to reserves" under "demand for reserves" is estimated as 28.1 trillion cubic feet as calculated from American Gas Association statistics as noted in Table 1.

3 Cf. the Census of Manufacturers, op. cit.

4 In fact, the all-industries consumption of natural gas shown in the Census of Manufacturers declined from 5.9 trillion cu. ft. in 1954 to 4.3 trillion cu. ft. in 1962. This partial census alone implies that (1.6 trillion)(20) = 32 trillion cu. ft. of demand in that period was eliminated.
most, should have been replaced only in the short run during the phasing out of consumption.

These two conditions treat the term-length of inventories $\alpha$ as the central determinant of excess demand. The first requires that previous supply-demand balances were not achieved at significantly lower prices, while the second requires replacement of previous supply no matter the price difference. If both held, the value of $\alpha$ must have been close to the regulation-induced level of twenty.

But the simple facts of final industrial demand for gas make these conditions for $\alpha$ of twenty years highly improbable. As prices increased from 10 to 12 cents per m.c.f. in the years just before "area rate" ceilings and stabilized at a level between 17 and 19 cents per m.c.f., twenty-year replacement demand for reserves must have been reduced. The level of "requirements" for maintaining service as in Table 1 is not the level of "demand" because it does not take account of the effects of price increases on the volumes sought by established consumers.

Considering "requirements" as the basis for setting the maximum shortage can still be an interesting exercise, however. This level of reserves can approximate the "outer bound" of demands in a wide variety of conditions that make price effects of secondary importance. Also, the distributive effects among groups of consumers from such a large shortage can be assessed as the worst of all results.
1.2 The Distributive Effects of Maximum Excess Demand

The "area rates" established on an interim basis in 1960 for field gas had the economic effect of freezing prices at the level attained on the larger contracts in the late 1950's. These prices "cleared the market" given the demand and supply conditions of that time. Since then market conditions have not been the same — population and income increases, changes in consumer preferences favoring cleaner fuels, disruptions in the supply of atomic and coal fuels for industrial use, all have increased demands for gas by substantial magnitudes. The question is whether there has been additional supply forthcoming to satisfy the greater demands for new contract reserves. Under changing conditions of gas discovery, with effective competition in field markets, the imposition of 1959 price ceilings could only guarantee that the quantity supplied would reflect 1959 conditions. The 1970 (increased) demand and 1959 (constant) supply would imply excess demand, as seen above. Also, these conditions would imply a higher unregulated price level than achieved under "area rates" in the period 1960-1970.

Lower regulated prices provide gains for consumers, since the same amount of gas delivered to them is bought for less total expenditure.

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1 The effectiveness of competition here is one of the most researched topics in industrial economics in the last few years; there is tacit agreement even in the area rate cases to center analytical attention on the competitive model. Cf. review and citations in E. Kitch, "Regulation of the Field Market for Natural Gas", The Journal of Law and Economics, October, 1969.
The lower prices also reduce incomes of those receiving dividends from the gas producing companies. The gains have to be compared with the losses. Moreover, there are losses to consumers from not being able to obtain all the gas they want at the lower price, and as a consequence having to go to their next-best alternative sources of fuel or heat.

These gains and losses are illustrated in Figure 1, for a regional market containing new reserves of gas for sale under long term contract to pipelines. The demand for new reserves of gas to serve industrial and home consumers is shown as the curve D, as an illustration of the argument that additional reserves are sought by pipelines at lower prices. The supply of these reserves -- found in exploration for gas and oil, and developed by additional drilling beyond the exploratory well -- is shown by the curve marked SS. The curve illustrates only the tendency to find and dedicate more reserves given higher new contract prices. The market clears at price P cents per thousand cubic feet of reserves, and the quantity R trillion cubic feet of reserves dedicated to pipelines in new contracts in a single year. The Commission, however, sets area rates that average only P' so that the quantity demanded is R'' while the quantity supplied is R'.

Producers clearly lose in these circumstances, by an amount shown as area "A". These are profits foregone, at least before taxes. At the same time, consumers both lose and gain. Consider the possibility that each consumer receives the same proportion of "rationed"
gas $R'$ that he would have gotten of the market clearing amount $R$. This would occur if pipeline buyers allot shares in keeping with "willingness to pay", or if they resold gas to each other and to final consumers in an informal auction market on a bid basis. With restricted supplies, the loss to consumers is shown by shaded area $B^*$ in the diagram, since this is the graphical representation of the net amount over costs that all of the (unsatisfied) consumers would have paid to receive the "lost" output $R - R'$.

The losses from depreciation to consumers have to be balanced against their own income gains from receiving some gas at lower prices. These gains are the "politically acceptable" transfer of income shown as area $A$; only part of $A$ is credited as gains because some of the transfer is to other industries besides the gas producing industry, and some is foregone tax payments which would have been given over by government to those with "socially-more-desirable" incomes than the consumers benefitting from gas price reductions. We shall attempt to estimate the losses and this net income gain as well.

The losses of unsatisfied gas consumers in recent years have not been directly observable. Even if they were great, the losers themselves were not aware of their circumstances because the pipelines

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1 The other possibility is that some consumers receive as much as they wish, while others go without. The favored consumers would have demand $D'$, a curve not drawn on the diagram but having the same intercept as $D$ and going through the point $P',Q'$. The possible loss is the whole area between the two curves $D$ and $D'$ above the supply curve. This would occur if new groups of consumers are excluded outright and all of the demands of other consumers are met, principally as a result of denying applications of new pipelines for certificates because reserves are "not sufficient".
have been providing them gas. This was done by providing almost all demanders with production now that ran down reserve inventories that would have been available for the future. Faced with new contract reserves less than the amounts necessary to make deliveries to new customers over the next twenty years, the pipelines have provided gas to all new sources of demand, and all other sources as well, for a shorter time period. The losses to customers are from the shortened commitment -- from gas not available to continue delivery in the eighteenth, nineteenth, and twentieth years. They can be detected only very indirectly in the supply-demand behavior of the gas field reserves markets.
Here the losses are assessed by (1) calculating the magnitude of excess demand \( (R'' - R') \), then estimating (2) the area under the demand function between \( R' \) and \( R'' \), and last subtracting out (3) the area under the supply curve \( SS \) between \( R' \) and \( R'' \) plus the area under the demand curve between \( R \) and \( R' \). This procedure leaves the shaded area \( B^* \) in Figure 1 as a residual.

(1) Excess demand \( (R'' - R') \) depends on the amount of new reserves needed to meet commitments to new buyers and on the amount needed to replace depleted reserves for established buyers. The "inventory approach" showed that, if all of replacement demand existed, then average excess demand has been close to 13 trillion cubic feet per annum. The amount of demand, as compared to excess demand, has been almost 19 trillion cubic feet (as shown by the average of the annual estimates in Table 1).

(2) The area under the demand function over the range of excess demand can be approximated by using the estimates of excess demand and of "cleared" demand, given an estimate of the elasticity of demand for additional reserves. In fact, there are many demand analyses of final users of gas, the most complete and analytically convincing being those of Pietro Balestra, that provide estimates of

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1 The area under the demand curve between \( R' \) and \( R'' \), and above the existing regulated price \( P' \), is approximated by \( \Delta P \Delta R/2 \). Here \( \Delta R = R'' - R' \) and \( \Delta P = P' \Delta R/R_p \) with \( e_p \) equal to the elasticity of demand for new reserves. Then \( \Delta P \Delta R/2 = P' (\Delta R)^2/2R_p e_p \).

elasticities. The Balestra studies of incremental demands of home consumers provide an indication of the demands for new reserves to be used to provide more home consumption; they show a price elasticity of -1.3 in the last year of the study (1962). Demands of industrial users, accounting for almost 65 per cent of the total volume of production at the present time, have not been assessed in a comparable dynamic analysis; but studies of industrial buyers at different locations with varying gas prices show elasticities in consumption exceeding -2.7. The weighted average of home and industrial elasticities is close to -2.2. Given this estimate, the gross area under the demand curve above price $P'$ is estimated at $204 million per annum.

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1 op. cit., section 4. 3. 7., pp. 95-99.
3 Cf. The Federal Power Commission's econometric model, as in Testimony of J. Harvey Edmonston, Federal Power Commission Docket AR61-2, "South Louisiana Area Rate Proceeding". The model contained in this testimony has been severely criticized because of feedback from demand to supply that always "clears the market" at the demand-determined price. But the industrial demand sub-system has not been open to such criticism; indeed, it is used here because it is the same as many other studies of industry demand for gas.
4 The average follows from assuming that household and commercial demand both have the same elasticity and comprise 35% of the total new demand for reserves. The industrial demand includes electric power and gas transmission demand and comprises 65% of total consumption. Consumption and reserve demand are assumed to be the same in all cases -- an assumption that holds only if there is no decline in industrial consumption with rising prices, as above. Cf. the F.P.C. Annual Report, op. cit., p. 45.
5 Here $P'$ the unregulated price is 17 cents per m.c.f., $\Delta R$ or excess demand is 13 trillion cubic feet, $R''$ the total of realized and excess demand is 32 trillion cubic feet, and $e_D$ is -2.2.
(3) The net loss is equal to this gross loss minus the costs that would have been incurred to provide the additional service. These costs are shown as the area under the supply curve over the range of excess demand up to \( R \), and they can be estimated with the calculations made in (1) and (2) plus additional information on elasticity of the supply function \( e_s \) and the market clearing quantity \( R \) at the unregulated price.

To find the elasticity of supply, we turn again to the F.P.C. econometric model of gas prices. There we find that reserves

\[ R = 3.5 + .257f \cdot Y \]

where \( f \) is footage drilled per well, and \( Y \) is the number of discovery wells, a factor dependent upon both price and production; removing the defective feedback from production (demand) to reserves (supply) in \( Y \) results in a direct price-supply relationship with an elasticity close to +.239.\(^1\)

The market clearing quantity \( R \) can be found indirectly. The change in price \( P \) to bring forth market clearing supply is equal to the change in price required to reduce demand to the market clearing level, so that \( \Delta P/P = (R-R')/R' \). \( 1/e_s = -(R''-R)/R'' \). This equation can be solved for \( R \). For the indicators available here, the

\[^{1}\text{Cf. the testimony of P.H. Cootner in rebuttal of J. Harvey Edmonston, Docket AR61-2, "South Louisiana Area Rate Proceeding". Professor Cootner recalculates the equation after removing this feedback condition, and the recalculation is used here.}\]

\[^{2}\text{In shortened form } Y = aP^{.257} \text{, and } R = 3.5 + .257Y \cdot f, \text{ so that } R = 3.5 + .257(aP^{.257}) \cdot f. \text{ Then } e_s = \frac{\partial^2 R}{\partial P^2} = \beta( .257afP^{.257} )/R = \beta(R-3.5)/R. \text{ In this case, taking } R = R' = 19(10^{1.2}) \text{ and } \beta = .293 \text{ (from P.H. Cootner, } op. \ cit.) \text{ results in } e_s = +.239.}\]
estimated market clearing quantity $R$ is close to 20 trillion cubic feet in a "typical" year in the late 1960's.  

These estimates of $e_s$ and $R$ imply that the costs of additional supply $R-R'$ are great. Because additional supply would thus be negligible at higher prices, the area under the supply curve is only $18$ million per annum.  

The last calculation is that for "excess demand" generated entirely by the regulated price. This is the area under the demand function between $R''$ and $R$ -- that is, the "willingness to pay" only at prices below the market clearing level. The area of excess demand below price $P$ is $174$ million, reflecting the high elasticity of demand. This area is equal to $\Delta P \Delta R/2 = P'(R''-R)^2/2R'e_D$ for unregulated price $P'$, the total of realized excess demand $R''$ and market clearing demand without regulation $R$. This area is not consumers' loss. It is excess demand that would not be satisfied in an unregulated market because costs are greater than unregulated prices for these amounts.  

The losses to consumers from excess demand are estimated as equal to $204-192$ million or $12$ million per year. This is the greatest likely dollar equivalent to the shaded area in Figure 1.

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1 It should be noted that this amount is very close to the 19 trillion cubic feet found on average under regulation, as a result of the very low estimated elasticity of supply.

2 This area is found by solving $\Delta P \Delta R/2 = P'(R''-R)^2/2R'e_D$ with the values in the text.
No one knows how long such annual losses will continue to be part of the regulatory results in setting gas field prices. At one extreme, they could continue for the lifetime of an area rate schedule set this year, with the schedule lifetime extending to ten years. At the other extreme, 1970 could be the last year of excess demand if the Commission moved rapidly to raise the interim rate ceilings in the pending cases and to revise upwards those in the Permian Basin decision. The area rate proceedings themselves have taken or will take more than five years to complete, so that the losses from "one year's regulation" are only one fifth this amount; for comparability with benefits from that one year's activities, the one to ten years of benefits have to be divided by five. The negative benefits for unsatisfied consumers range close to $12 million per year of fixed price regulation.

The income gains of established consumers. Consumers able to obtain some part of the amounts of gas they demanded have gained real income in the process from the price reductions imposed by the Federal Power Commission. The amount depends on the prices that would have been set by purchasers in the absence of regulation --- on price $P$

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1 The assumption leading to the maximum loss of $12 million is that the area rate reviews will be complete after five years, and that ten years of present value of negative benefits will follow. Then "one year's" benefits from regulation are $\frac{1}{10} \sum_{t=1}^{10} B_t / (1+r)^t$ for 10 years at $r = 15\%$. In this calculation this equals $B_1 (1.0037)$ where $B_1 = $12 million.
rather than $P'$ in Figure 1. If the circumstances were those of excess demand in keeping with $12$ million losses to unsatisfied consumers, the market price $P$ would have been some two cents higher than the regulated price. The difference $(P-P')$ on the completed sales $R'$ were the maximum income redistribution gains for the "satisfied" portion of reserve sales to go to production for final home consumers.

The consumers' gains here were producers' and government tax losses. The case can be made for net gains only on sales to home consumers, because lower dividends to some and higher dividends to others (from lower gas fuel costs to industry and consequent higher industry profits) result in no apparent distribution advantage. The net social gain was limited to that part of new reserve sales made to interstate pipelines for resale to home consumers.\(^1\) In each of the last few years, approximately $19$ trillion cubic feet of new reserves were dedicated to interstate pipelines under the rate ceilings, and approximately one third of this amount was for delivery to home consumers.\(^2\) Then the gains were limited to two cents per thousand cubic feet on $6.3$ trillion cubic feet, or $126$ million each year.

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1 The argument here is that income recipients from all industrial producers are in the same income class, and that they will receive the dollar of rate reduction. Of course, the fuel reduction could be passed on in lower final output prices, or in higher rents of scarce resources in the fuel consuming industry. If the first, then gains are understated but if the second, then they may be overstated (if rentiers already are wealthier than gas company dividend recipients).

2 This percentage assumes that residential and commercial sales are both mostly "home sales". Cf. the Annual Report of the Federal Power Commission, statistics on gas reserves and sales for resale to home consumers in the 1966, 1967, and 1968 issues.
The losses in government tax receipts were at least 50 per cent of this price reduction, because the petroleum-gas companies probably would have paid about two thirds of this percentage as income tax in excess of depletion allowances, and then dividend receivers would have paid the rest as income taxes on their net receipts from the companies. The losses to government should not be treated as net gains, because they quite conceivably should have gone into more direct social welfare programs. The net income loss to dividend receivers should be treated as net gains, given that the F.P.C. in effect has a congressional mandate to be an additional tax authority on that amount. The net income redistribution gains -- counting the non-tax losses of dividend receivers as income that should be redistributed -- could not have been more than $63 million in one year at a maximum.

The problem with these income gains is that they have been realized on the basis of only interim ceiling prices, and these regulated prices may be lower than the final area prices set in the formal rate proceedings. Additional rate reviews are likely to result in smaller price reductions in face of pressures from excess demand. The chance of higher prices is great enough that future gains must be discounted not only at the 15 per cent rate, but must be assumed

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1 It is assumed that consumers gain (t) dollars for every dollar of reduced dividend income, and that t = .33 holds for non-depletion revenues, and t = .17 for final dividend receivers on the remainder because of high incomes they earn from this and other sources.
to be limited to ten years. Also, five years are required to complete any of these area rate proceedings, so that the total gains for established consumers have present value of approximately $63 million. ¹

The net benefits to consumers as a group could have been equal to the gains on actual deliveries of $63 million minus the losses on reduced deliveries of $12 million. The losses of producers are not counted at all, except on the share going to taxes. At least such an estimate is plausible, if not convincing. The point in the argument that is at fault is the assumption of unabated replacement demand at rising prices, while the price elasticity of expansion demand is taken to be more than -2.0; one source of demand is price inelastic as a matter of historical precedent, while the other is highly elastic because it occurred much later. The overall view is that this trade-off of $63 million for some consumers against the loss of $12 million for non-consumers each year is the result from the worst of conceivable shortages.

¹ This calculation assumes that it will take five years of regulatory expenditure to attain ten years of gains of $63 million per annum. As a first approximation, one year of regulation results in 1/5 of ten years benefits of $63 million but where each year of the ten is taken at present value with a discount rate of 15 per cent.
2.0 Statistical Models of Gas Reserve and Production Markets

Rather than using a number of separate estimates of excess demand, elasticity of demand, and elasticity of supply, the approach might be to analyze gas markets to find these estimates all from the same sources and time periods. The advantage is that they might well be relevant estimates -- those for demand conditions would not be an amalgam of demand and supply, and those for one time period are not "merged" with those of another period in which market structure was different. The disadvantage is that all estimates could be determined by errors in variables that are specific to a market or time period.

The advantages seem justification enough for at least an introductory simultaneous supply-demand analysis. Here a three-equation model is to be introduced and used to determine \( R_t \) (reserves added in a producing district in year "t"), \( Q_t \) (production from new contracts signed in that district in "t"), and \( P_t \) (initial base price in new contracts in "t") for the pre-regulation years from 1955 through 1960 in two markets, gas for the East Coast and Mid-west (EMW) and gas for the West Coast (W). Then this model is used to simulate the regulation years. The simulated values \( \hat{R}_t \), \( \hat{Q}_t \), and \( \hat{P}_t \) for "no regulation" are compared with the actual values achieved under regulation. The difference in production \( Q_t - \hat{Q}_t \) is the "production shortage", in \( R_t - \hat{R}_t \) the "reserve shortage" from regulation.
2.1 An Introductory Statistical Analysis

The most direct analysis of the process of finding new gas reserves is based on the view that they are discovered in searching for gas and incidentally in searching for oil, when there is a profit to be expected from one activity or the other. Reserves $R_t$ in any oil and gas drilling district are greater when $P_t$ is higher, when $P_0$ is higher (a higher price of oil implies more "fallout" of new gas reserves from more intensive oil drilling) and when total expenditures $C_t$ on drilling are greater, 1 or $R_t = f_1(P_t, P_0, C_t)$. With complete information on costs, reserves, and prices, this argument could be tested; here, a modified version has to be used for a beginning analysis in a world of very incomplete information.

The best indications of prices expected to be received on new reserves are not the initial base prices on new contracts signed in the year of discovery in that region, but those on contracts there the previous year. Exploratory operations are subject to great uncertainty, and what is found is seldom close to what was expected to be found the year before; as a result, the only concrete indicator of incentives to drill is the previous year's price (the only information on what was happening in that market when drilling commenced). The analysis should be modified for $R_t = f_1(P_{t-1}, P_0, C_t)$; for the same reason, the previous year's oil price should be a better indicator of motivation so that $R_t = f_1(P_{t-1}, P_0, C_t)$.

---

1 This last argument is the reversal of the commonplace marginal cost argument: for $C = f(Q, A)$ then $\partial C / \partial Q > 0$ for $C$ total costs. Here $\partial Q / \partial C > 0$ in $Q = f(P, C)$. 
There are no detailed statistics on costs of exploratory and development activities in gas fields. The only data of sufficient detail show development wells in the 1950's and 1960's, by drilling region. These are not wholly indicative of costs; some wells cost much more than others, because of depth and strata conditions, and wells themselves are factor inputs both of "capital" that has costs and of "knowledge" that may not have direct costs. The knowledge input is particularly important; after a point, further wells contribute no more knowledge of a trap or field formation; any more drilling is done to put producing capital in place. Since only the first relates to reserves, then substituting wells $W_{t-1}$ for $C_t$ in:

$$R_t = f_1(P_{t-1}, P_{0_{t-1}}, W_{t-1})$$

could result in a positive or negative reserve-well relation.

The supply of new production $Q_t$ is related to the supply of new reserves $R_t$; as a matter of course, it is asserted that new production has to come from new reserves or else there would be reduced "supply assurance" to established final buyers out of keeping with pipeline and Commission rulemaking. Supply of new production also depends on initial base price in the new contracts: the higher the price, the more production promised both now and later from a stock of reserves. Also, the greater the pure extraction or production costs $P_{C_t}$ from known formations, the greater the quantity of production $Q_t$.

1 The argument here is the same as in the preceding footnote, as applied to production increases rather than reserve increases.
This is to state that \( Q_t = f(R_t, P_t, PC_t) \) and that an increase in any of the independent variables should lead to an increase in \( Q_t \).

This second equation also does not correspond closely to available annual data series on each drilling region. The initial year's production and base price can be estimated for all new contracts in each region, and reserve accumulations can be estimated for each of the same drilling regions.\(^1\) But there are no detailed series of annual production costs; rather, a regional index \( G \) of geological activity is used, where the higher the index the more difficult the geology of production and the higher the potential drilling and operation costs. \(^2\) Here the supply of production \( Q_t = f(P_t, R_t, G) \).

The demand for new production under new contracts is also dependent on new discoveries of reserves in that region. Large discoveries provide the opportunity to put in large-scale gathering lines which reduce the cost of transport for the pipeline buyers; in simplest terms, the quantity demanded \( Q_t^* \) in a region depends on reserves \( R_t \) there, and on offer prices \( P_t \) at that location: \( Q_t^* = f(R_t, P_t) \).

There is one more obvious determinant of demand. The greater the final demand for gas by home and industrial users, the greater the

---

\(^1\) All series are described in detail in Appendix A.

\(^2\) It was found on a first attempt to scale production activity in a region by well depth and "drilling difficulty" that the values conformed closely to distance from either North Louisiana (EMW) or mid-California (W). Distance "D" itself is treated as a demand variable below; as a consequence, \( G \) and \( D \) are given the same values throughout.
field demand; using the year to year change in time itself as a surrogate for increases in final demand, \( DQ_t = f(R_t, P_t, T) \).

The supply-demand relationships before field price regulation can be characterized as follows:

1. \( R_t = a_1 + b_1 P_{t-1} + c_1 P_{t-1} + d_1 W_{t-1} \)
2. \( Q_t = a_2 + b_2 P_t + c_2 R_t + d_2 G \)
3. \( Q_t^* = a_3 + b_3 P_t + c_3 R_t + d_3 T \)

and \( Q_t = Q_t^* \) in any one year, absent limited lags in putting contracts in effect the year the transaction is completed and other minor imperfections in competitive field markets.

The procedure for fitting these with data on 1955-1960 has been to complete a two-part least squares regression analysis. First, the least squares regression of (1) is as follows:

\[
R_t = -8541.1 + 200.5 P_{t-1} + 563.0 P_{t-1} + 4.735 W_{t-1}; \quad R^2 = .26
\]

for 66 observations of 11 drilling regions for EMW. Then equation values of \( R_t = \hat{R}_t \) for the given values of the exogenous variables in each observation are used with the given values of the exogenous variables in (2) and (3) to fit two more least squares equations. These two "reduced form" equations are set up by solving the production supply-demand system for the two endogenous variables \( Q_t \) and \( P_t \), so that they take the form \( P_t = f_1(\hat{R}_t, G, T) \) and \( Q_t = f_2(\hat{R}_t, G, T) \). The least squares

\[1\] Here \( T \) is a shift variable that takes on the value zero for 1955-1957, and the value one for 1958-1960. If there are absolute increases in final gas demand that are translated back to increases in field demand, then the coefficient of \( T \) in the fitted equation will be positive.
results from the same 66 observations of EMW before regulation are as follows:

\[ P_t = 11.6 + .002\hat{R} + .002G + .769T; \quad R^2 = .41 \]
\[ Q_t = 19.2 + .007\hat{R} - .009G + 3.464T; \quad R^2 = .17 \]

A cursory inspection shows that these fitted equations meet minimum standards of "goodness of fit" as well as those for economic analysis. Tests for time series correlation and independence of the variables are passed on the first of three equations. Reserves increase as prices and drilling activity increase, at least in this period and market. The second and third or reduced form equations indicate the presence of serial correlation; but they solve for positive supply-price and negative demand-price relationships, as expected within a well functioning competitive market. But these are minimum standards. The quantity equation explains only a small part of the variance in the dependent variable, and it has only one independent variable \( \hat{R}_t \) with a statistically significant coefficient.

---

1 The value of the Durbin-Watson test is 0.42, and the simple correlation coefficients for pairs of independent variables do not exceed +.35.

2 The value of the Durbin-Watson for the price equation is 1.87, which makes it impossible to reject the hypothesis of serial correlation.

3 The value of \( b_2 = +4.51 \) and of \( b_3 = -4.50 \) in (2) and (3) where \( Q_t \) is in billions of cubic feet per region per year, and \( P_t \) is cents per thousand cubic feet.
The regression equations can be used, as imprecise as they are in explaining variance, in an initial attempt to simulate "unregulated" sales in gas field markets in the 1960's. If the conditions described by the equations for the 1950's were continued through the 1960's, they would include prices and production conforming to forecast values $\hat{P}_t$ and $\hat{Q}_t$ derived by inserting actual 1961-1966 values of $R_t$, $G$, and $T$ into the reduced form regressions. The values $\hat{P}_t$ and $\hat{Q}_t$ would be the result of replication of 1955-1960 "market regulation" conditions with 1961-1966 "market variable" conditions. In that sense, the simulated $\hat{P}_t$ and $\hat{Q}_t$ can be said to describe behavior as if there were no field price regulation.

The "regulated" and "unregulated" prices and quantities are shown in Table 2 for the first six years of the 1960's. The two price series are very much the same: simulated price was higher than the average of the area rates in only one year, lower in two years by one cent per m.c.f., and roughly equal in the other three years. There would seem to have been no detectable price effect from area rate regulation. In contrast, actual production was much greater than that simulated for markets without regulation. The actual levels of production averaged 54 per cent greater than the simulated levels over

---

1 1967, 1968, and 1969 are not shown for two reasons. First, data on actual prices and production for the 11 drilling regions are not yet available from the Federal Power Commission. There is also a substantive reason: restrictive conditions in financial markets in the later 1960's have been another reason for 1950's-1960's differences, and this cannot be separated from regulation effects.
Table 2: Prices and Production of Gas for the East Coast and the Midwest, 1961-1966

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Price* (c/mcf)</th>
<th>Simulated &quot;unregulated&quot; Average Price (c/mcf)</th>
<th>Production of New Reserves (billions of cubic feet)</th>
<th>Simulated &quot;unregulated&quot; Production (billions of cubic feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td>17.6</td>
<td>16.6</td>
<td>400</td>
<td>248</td>
</tr>
<tr>
<td>1962</td>
<td>17.1</td>
<td>16.1</td>
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<td>244</td>
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<tr>
<td>1963</td>
<td>16.7</td>
<td>16.8</td>
<td>475</td>
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<td>1964</td>
<td>16.5</td>
<td>15.9</td>
<td>441</td>
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<tr>
<td>1965</td>
<td>16.8</td>
<td>16.5</td>
<td>325</td>
<td>270</td>
</tr>
<tr>
<td>1966</td>
<td>16.9</td>
<td>16.5</td>
<td>280</td>
<td>263</td>
</tr>
</tbody>
</table>

* The weighted average price $\frac{\sum \text{Price}_i \times Q_{ti}}{\sum Q_{ti}}$, where $Q_{ti}$ is production in drilling region $i$ in year $T$.

Source: as described in the text.
the six year period -- both levels being based on the experienced additions to reserves. This greater production is not "something for nothing"; rather, it is greater first year's production from given reserve findings. The pipeline buyers seem to have taken more gas out of reserves for immediate use, leaving less for final retail distribution in later contract years.

Much the same results follow from an analysis of production of gas under new contracts for delivery to pipelines to the West Coast. The statistics on transactions in the 1955-1960 period were used to fit the three equations for $W$ as follows:

\[
R_t = -751.5 + 30.5 P_{t-1} + 69.1 P_{t-1} + 0.424 W_{t-1}; \quad R^2 = 0.20
\]

\[
P_t = 0.336 + 0.008 R_t + 0.013 G_t + 0.713 T_t; \quad R^2 = 0.61
\]

\[
Q_t = 41.9 + 0.006 R_t - 0.034 G_t + 3.504 T_t; \quad R^2 = 0.02
\]

These equations fit the data very poorly -- if anything, worse than those given above describing sales for EMW buyers. The reserve and the production equations explain a very minor part of the variance in dependent variables, and the exogenous variables all have statistically insignificant coefficients.\(^1\) None of the equations exhibits strong

\[^1\] On the usual tests for the ratio of the computed coefficient to the computed standard error of the coefficient (shown below each coefficient in parenthesis). The ratios do not exceed the value of 2.0 necessary to reject the hypothesis that the coefficient value is zero.
serial correlation, however, so that imprecise but unbiased simulation values \( \hat{P}_t, \hat{Q}_t \) can be constructed. They show "unregulated" prices almost on cent per m.c.f. higher than the average regulated area rates.

In this case, it would be expected that the rate of production from the reserve stock under regulation would be greater because of the increase in demands resulting from the regained price reductions. The 1964 and 1965 new production quantities exceeded the simulated rates of new production (by 20% and 120%); but in the other years actual production and simulated production were much the same.

The comparisons for both regions show the great imprecision in using a simple three equation model of gas field markets for assessing the effects of field price regulation. The regulated prices were similar to the regression-derived "unregulated" prices — presumably in part because the fitted regressions so poorly explained prices in the periods from which they were derived. The regulated production quantities, however, seem to have been greater than expected from markets without regulation. Even with poor regression models, it seems possible to detect a systematic tendency to utilize new reserves at a faster rate in the regulated 1960's. The production rate difference, as an

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1 The values of the Durbin-Watson statistics are all less than 0.6.
2 The average simulated price was 0.7 cents per m.c.f. greater.
3 The average ratio of actual to simulated production over the six years was .96, because of low actual sales in the last (reported) year.
estimate of excess demand, was less than excess inventory demand (in section 1.0, above). But any final assessment of the effects of excess demand requires a more detailed analysis of gas field market behavior.

2.2 A More Complete Statistical Analysis

The three regression equations for reserves, production and prices barely begin to describe the field markets for natural gas. More complete descriptions ought to be interesting in and of themselves, and also they may lead to a more revealing simulation of the world of gas sales without regulation. The gas reserve supply equation can be expanded to take account of cumulative knowledge of formations continuing hydrocarbons in a drilling region. The production supply equation ought to take account of capital inputs actually used in production in that region, and of technical progress in using these (drilling) capital inputs. The demand equation should take account of the effects of changes in the prices of alternatives to gas, and of changes in the size of final markets for gas in consuming centers.

The determinants of reserves include the promised price for production from these reserves and the amount of exploratory drilling capacity. As argued above, \( R_t = f(P_{t-1}, W_{t-1}) \) so that higher prices or the presence of more well capacity in the year before new reserves are actually found increase the amount of new reserves that are proved and finally reported. It is assumed that \( P_{t-1} \) is used as a surrogate
for the forecast price for future actual production from contracts for these reserves, because this is the only price available to the exploratory company when their work begins. As an alternative approach to the practical problems of finding the true "forecast" \( P \), however, it can be assumed that the forecast price equals actual price \( P_t \) so that \( R_t = f(P_t, W_t) \). As an alternative to the simple analysis of capacity, well capacity \( W_t \) is defined more narrowly as exploratory wells \( W_t^* \) only. Also, the analysis should recognize an additional variable -- the amount of information gathered in the previous year on the "promise" of new reserves in that region. The best indicator of this information is the amount of similar reserves found in the previous year, \( R_{t-1} \). The supply relation has been taken to be

\[
(4) \quad R_t = a_t + b_t P_t + c_t W_t + d_t R_{t-1}
\]

for each drilling region in the EMW and W markets in the 1955-1960 period.

The supply of production from new reserves each year depends, as hypothesized above, on the amount of new reserves \( R_t \) and an initial base price \( P_t \) on new contracts in that drilling region. Also, the amount \( Q_t \) should depend not only on geological characteristics (labeled "C" above) but more directly on the amount of actual new production capacity installed in that period. Capacity constraints are more binding on production in natural gas than in many industries -- a gas well can produce out to m.e.r. (the engineering "maximum efficient
rate") with about the same total cost level as at half this rate; the 
available indicator of the constraints is the actual number of pro-
duction wells drilled \( W_{t}^{**} \). Last of all, the production relation has 
been taken to be affected by new drilling and extraction techniques 
introduced over the last two decades. Although the causal relation 
cannot be measured, it may be shown by the 'shift variable' \( T \) (with 
the value zero in 1955-57 and one in 1958-60) in the full equation

\[
Q_{t} = a_{2} + b_{2}P_{t} + c_{2}R_{t} + d_{2}W_{t}^{**} + e_{2}T 
\]

for each drilling region in the same markets and time periods as (4).

The demands for new production are of course assumed to depend 
on contract prices \( P_{t} \) and on the volume of new reserves \( R_{t} \) available 
for shipment from that drilling region. As a point of industry prac-
tice, however, the relationship probably should be considered to be 
the reverse: the offer price of pipeline buyers \( P_{t} = f(Q_{t}, R_{t}) \), the 
amount of new production likely to occur that year, and the amount 
of new reserves likely to be found that year. Offer price is also 
likely to be less when the distance \( D \) to final markets is greater, 
and when final demand is less by substantial magnitudes. The reasons 
for slackening final demand might be two. First, the prices of sub-
stitute fuels may decline (or hold steady in an inflationary economy) 
so that final demands for energy go to these alternative fuels; as a 
result, we might observe in \( P_{t} = f(Q_{t}, R_{t}, D, P_{0t}) \) for the case of the 
price of oil \( P_{0t} \) that the change in offer prices is in the same direc-
tion as the change in oil offer prices. Second, the final demand for 
gas at home and in industry may decrease because of business cycle
reductions in goods demand throughout the economy. Terming these new demands $\Delta V_t$, the greater $\Delta V$ in $P_t = f(Q_t, R_t, D, P_0_t, \Delta V)$ the greater the presumed offer price. In terms of a linear relation,

$$(6) \quad P_t = a_3 + b_3Q_t + c_3R_t + d_3D + e_3P_0 + f_3\Delta V$$

for the same regions and time periods as well.

Competitive markets that clear gas reserves $R_t$, gas production $Q_t$ and initial contract prices $P_t$ in a year are thus assumed to depend on the exogenous variables $W_t^*, W_t^{**}, T, D, P_0, \Delta V$. Data series for each of these variables have been constructed for the pre-regulatory period 1955-1960 in eleven drilling regions in EMW and four drilling regions serving the W final demand territory (as described in Appendix A). These data can be used to fit the (4), (5), (6) relations only if all are fitted at once, because the three endogenous variables are simultaneously determined. The procedure used here recognizes this state of affairs directly by first fitting "reduced form" equations for each of $R_t, Q_t, P_t$ separately, each subject to all the endogenous variables, and then using the fitted values $\hat{R}_t, \hat{Q}_t, \hat{P}_t$ in further least squares regressions for (4), (5), and (6). The reduced form regressions for EMW are as follows:

$$R_t = \frac{-4895.4 + 0.864R_{t-1} + 0.157W_t^* - 0.139W_t^{**} + 207.248T}{0.071} + 0.047D + 482.058P_0 - 0.037\Delta V; \quad R = .77$$

$$(0.554) \quad (372.923) \quad (0.036)$$
\[ Q_t = -7.536 + 0.043R_{t-1} + 0.007W^*_t + 0.049W^{**}_t - 1.827T^{(1.068)} \\
+ 0.008D + 1.395PO^t + 0.001AV; \]
\[ R^2 = .88 \]
\[ P_t = 6.749 + 0.001R_{t-1} - 0.001W^*_t - 0.000W^{**}_t + 1.631T^{(1.068)} \\
- 0.001D + 0.965PO^t - 0.000AV; \]
\[ R^2 = .34 \]

for 66 observations in 11 drilling regions over the six year pre-regulation period ending in 1960. Little can be said of these equations since they are not direct tests of economic relations; however, they do not fit well in the usual statistical sense, given that many coefficients are statistically insignificant, the time-series correlation tests show poor results, and the explained variation in \( P \) is little more than 34 per cent.\(^1\) The forecast of instrumental values \( \hat{R}_t, \hat{Q}_t, \) and \( \hat{P}_t \) for each observation in the sample vary from the observed values by an appreciable extent. The "simultaneously determined" prices and quantities of gas may well depart widely from actual experience in that period.

The values \( \hat{R}_t, \hat{Q}_t, \) and \( \hat{P}_t \) were used to find three regressions, one for the supply of reserves, the second for the supply of production, the last for the demand for production. The volume of new reserves during the 1955-1960 period was:

---

\(^1\) The "\( t \)" tests for significant coefficients indicate insignificance for all coefficients except \( R_{t-1} \), and the Durbin-Watson values are approximately 2.3 in the first equation and 2.7 in the second equation. Neither D-W value allows rejection of the hypothesis that there is observable serial correlation in \( (\hat{R}_t - R_t) \) and \( (\hat{Q}_t - Q_t) \).
indicating a strong cumulative effect from previous reserve findings but neither significant price nor well-capacity effects. Production supply from the new reserves was found to be as follows:

\[ R_t = 650.998 + 14.470P_t + 0.183W_t^* + 0.849R_{t-1}; \quad R^2 = .76 \]
\[ (205.697)t \quad (0.328)t \quad (0.170)^{-1} \]

The equation shows a strong production-reserve relation, which increases over time \( T \); but price has an insignificant and, if anything, slightly negative effect. The inference is that supply of new contract gas to EMW in the late 1950's was quite inelastic. The demand relation was also estimated by least squares; here the regression was:

\[ Q_t = 50.231 - 5.061P_t + 0.053R_t + 0.056W_{t-1} + 17.723T; \quad R^2 = .87 \]
\[ (7.350)t \quad (0.007)t \quad (0.042)t \quad (10.523) \]

with statistically insignificant coefficients for all variables and only 28 per cent explained variance. The elasticity of demand at average price and quantity was only -0.04, and the effects of oil price and final demand increases were either negative or perverse. The fitted values \( \hat{Q}_t, \hat{P}_t, \) and \( \hat{R}_t \) in the equations show great variation, and have little explanatory value, except for \( \hat{R}_t \) in the second regression. The more complete analysis shows no more than the simple model — that the prices of new production at any location are dominated by the recent finds of new reserves at that location, and that finds themselves are relatively impervious to economic incentives.

These conditions make it unlikely that regulation has had a substantial effect on gas reserve accumulation and disposition. In
order to assess this possibility for the contracts for East Coast gas in the 1960's, the three "second stage" regression equations have been used, along with 1961-65 values of the independent variables, to simulate $R_t$, $Q_t$ and $P_t$ without regulation. The simulated values are compared with actual values in Table 3.

The simulated reserves and production show the dominance of found reserves over the system. They also show that, although actual yearly new reserves declined over time, they should have declined even more in 1964 and 1965 given the cumulative effect of previous findings and of well drilling in the various regions. Unless more research indicates a strong additional relation of price to cumulative reserve findings, and to drilling at the exploration stage, it would seem possible to conclude only that simulated "unregulated" reserves were more than actual "regulated" reserves early in the 1960's, but not during the 1963-1966 period.

Production was much greater than expected from either actual or simulated reserves. Simulated production was close to 200 billion cubic feet from new contracts each year, while actual production was more than 280 billion cubic feet each year, and more than 400 billion in three years. Simulated production was on average less than one half of actual production, so that the hypothesized "unregulated" rate of utilization of new reserves would have been much less than the actual or "regulated" rate.

One reason for the difference in rates may have been price, at least at the margin. The simulated "unregulated" price appears to be roughly three cents greater than the actual price, principally
Table 3: Prices and Production of Gas for the East Coast and Midwest 1961-66

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Price (c/mcf)</th>
<th>Simulated Price (c/mcf)</th>
<th>Production (billions of cu. ft.)</th>
<th>Reserves (billions of cu. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>actual</td>
<td>simulated</td>
</tr>
<tr>
<td>1961</td>
<td>17.6</td>
<td>19.6</td>
<td>400</td>
<td>396</td>
</tr>
<tr>
<td>1962</td>
<td>17.1</td>
<td>20.9</td>
<td>335</td>
<td>173</td>
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<tr>
<td>1963</td>
<td>16.7</td>
<td>26.9</td>
<td>475</td>
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<td>1964</td>
<td>16.5</td>
<td>16.2</td>
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</tr>
<tr>
<td>1965</td>
<td>16.8</td>
<td>25.2</td>
<td>325</td>
<td>174</td>
</tr>
<tr>
<td>1966</td>
<td>16.9</td>
<td>16.4</td>
<td>280</td>
<td>290</td>
</tr>
</tbody>
</table>

Source: as described in the text.
as a result of very high simulated prices on a number of large reserve dedications in 1962 and 1965 that in fact were sold for the regulated 16.5 to 17 cents per m.c.f. The higher prices would have curtailed demand (and perversely, if insignificantly, supply as well).

The overall impression is the same as that from the simpler statistical analysis of production and prices. The amounts of new reserve findings would have been little different if there had been no field price regulation, but the rate of production from new reserve dedications would have been much lower. The pipeline buyers under regulation have been taking roughly the same amounts of reserves under new contracts and at similar or slightly lower contract prices, and producing these amounts at a greatly increased rate. To the extent that the rate allows the satisfaction of additional "regulation-induced" demands, then there will be future shortages for established consumers when these reserves are depleted.\(^1\)

\(^1\) Much the same conditions were found for the West Coast market in the more extensive statistical analysis as in the simple analysis presented in the last section. The three reduced form equations contained some variables with statistically significant coefficients; in particular, the reserves variable lagged one period was statistically significant in the \(R_t\) equation, the exploratory wells variable was significant in the \(R_t\) and the \(Q_t\) equations, and the distance variable was statistically significant in all three equations. The \(R^2\) values ranged from .45 (for the \(P_t\) equation) to .72 (for the \(P_t\) equation). The three "second stage" regressions, with the forecast values of \(\hat{R}_t\), \(\hat{P}_t\), and \(\hat{Q}_t\) inserted where appropriate, were statistically no more acceptable than the reduced form equations. The supply of reserves was directly related to previous year's reserves and the number of exploratory wells, but inversely related (although statistically insignificant) to the price variable \(P_t\). The demand price for new production was related positively and significantly to reserves \(R_t\) and distance, and negatively significantly related to \(Q_t\), and insignificantly to oil prices and the volume of final demand \(\Delta V\).
3.0 The Effects of Gas Shortage on Final Consumers

One can take a number of different views of the so-called "shortage of natural gas" attributed to Federal Power Commission field price regulation. All are subject to error as a result of deficiencies in information on new reserves and new contracts for the production of gas. Each, however, seems to show that the production of new reserves has been greatly accelerated under regulation.

What are the gains and losses for final consumers under such production conditions? The answer must lie in the realm of speculation. Clearly more gas now for a given number of retail consumers, along with low cost Liquified Natural Gas later as a result of further technical progress would be an improvement over the restricted rate of utilization that would occur without regulation. It is conceivable that this would be the case: commercial development of LNG is conceptually possible within the coming decade and the rate of use of presently available new reserves may well cause reserve backing to be depleted. All of the additional new gas production occurring at the

The supply of production was significantly related to reserves $R_t$ and the time variable $T$, but insignificantly related to the number of development wells and (negatively) to the instrument $P_t$. Each equation had a value of $R^2$ greater than .4, and the Durbin-Watson tests for serial correlation showed no correlation. The problems included not only statistically insignificant (and inversely related) prices but also a very high level of correlation between the independent variables $R_{t-1}$, $P_t$, and $W_t$. In this case predicting with the second stage regression equations was the same as in the simple model: simulated (unregulated) prices were very close to the actual price averages in each drilling region, and quantities of simulated and actual reserves were approximately equal. In this market area, however, there was only a slight tendency for simulated production to be less than actual production but the difference was not great enough to have occurred other than by chance.
present under regulation might well be going to home consumers, and would leave them better off.

This set of circumstances seems highly unlikely. Incremental demand in the residential market during the late 1950's - early 1960's had become more a matter of normal growth of population, household formulation and the like, since all of the untapped final markets had been filled by the construction of new pipelines. The rate of growth of dollar sales of gas fell from approximately 16 per cent per annum in the 1950-1957 period to 10 per cent per annum in the period 1956-1962, and it is clear that the reduction was due both to price reductions and quantity reductions. At the same time, industrial sales were growing at more than a 10 per cent rate in 1957-1962 as a result of substantial increases in prices and only slightly less substantial increases in the physical volume of consumption. More gas was being put into both residential and industrial consumption, but reallocation at the margin was taking place away from residential consumption and in favor of industrial consumption.

In the period 1962-1968, both customer formation rate and consumption growth in industry exceeded those in residential use. The allocation of supply had shifted in favor of industrial users.

3 Cf. ibid.
4 Schlarb points this out in his insightful review; cf. p. 59 et seq.
The rate of growth of revenue was 7 per cent for industrial sales, and 5 per cent for residential sales, while the rate of growth of physical volumes consumed was 7 per cent in industrial use and 5.5 per cent in residential use.\(^1\) Average revenue in cents per therm declined by 2 per cent on residential sales and increased by twice this amount on industrial sales. That is, the ratio of residential to industrial consumption declined for the first time since 1950 while the ratio of residential to industrial price declined to the lowest level in twenty years.\(^2\) The pipelines were allocating relatively more gas to industrial users because of relative (unregulated) price and profit increases there.

The most likely hypothesis is that prices under regulation in natural gas fields had become the basis for final regulated rates for deliveries to retail public utility companies in the middle 1960's. The price charged the final home consumer changed only when field gas prices or delivery costs changed. In contrast, prices to industrial consumers depended only on conditions in markets for energy for boiler fuel or industrial use, since direct sales to industry were not regulated. These market conditions continued to favor natural gas, particularly when new requirements for pollution-free sources of energy were made by local governments. As a consequence of frozen field prices and rising industrial demand, industrial sales of gas must have been

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\(^1\) Cf. Schlarb, Table III-2.

\(^2\) Cf. Schlarb, Table III-7.
increasingly profitable for the pipeline companies.

This is to suggest that regulation in natural gas fields had produced a much more rapid rate of production from new reserves, in order to increase the rate of sales to industrial users at unregulated prices. The inventory analysis in section 1.0 suggested further that these sales would not have taken place at free market or unregulated field prices. There was further evidence of substantial increases in the demand for faster production at frozen regulated field prices from the statistical analyses in both the simple and more detailed regression formulations. The suspicion is that regulation has had the effect of reallocating supplies from home consumers under the aegis of the Federal Power Commission to the industrial users still buying in unregulated energy markets.
Appendix A

The data used in the regressions and simulations were all obtained from publicly available sources. These consisted of the official publications of various agencies of the United States Government, and from the publications of professional associations related to petroleum activities. A brief description of the variables and their respective sources of measurement follows.

Reserves ($R_t$): The figures used represent the additional reserves found in a given pricing area in a given year. The series is taken from the latest Reserves of Crude Oil, Natural Gas Liquids and Natural Gas in the United States and Canada as of December 31st, 1968, Volume 23, published jointly by the American Gas Association, the American Petroleum Institute and the Canadian Petroleum Association (1969), Table XVII, Summary of Estimated Annual Discoveries of Natural Gas Reserves. The data file contains the values for the 1954-1968 period, expressed in billions of cubic feet.

Production ($Q_t$): The figures in this series refer to the deliveries by natural gas producers to interstate pipeline companies made in 1967, broken down according to the year of basic contract. The figures were obtained from: Sales by Producers of Natural Gas to Interstate Pipeline Companies - 1968, Federal Power Commission, Washington, D.C. (1969).
It should be noted that these figures include additions to and modifications of the original contract. They exclude intrastate sales. The contracts have a nominal life of twenty years, although they remain in force until such time as the F.P.C. issues a certificate permitting the discontinuation of supply from a given contract. The production is expressed in billions of cubic feet.

Prices \( P_t \): The price series used relates to the production \( Q_t \) described above. It is the average price at which the production of the contracts in a given year was sold to the interstate pipeline companies. The data source is the same as for production. Prices are in 1967 dollars.

Exploratory drilling \( W_t^* \): Data for this series were obtained from the June issue of the *Bulletin of the American Association of Petroleum Geologists* (AAPG), which is devoted to the drilling activity of the previous year in and off the North American Continent. The data for the period 1955-1960 are summarized in *Statistics of Exploratory Drilling in the United States 1945-1960* by F. A. Lahee, and published by the AAPG. The series contains the total number of "exploratory oil wells, gas wells, condensate wells and dry holes" drilled in a pricing area in a given year.

Development Drilling \( W_t^{**} \): Figures for the period 1954-1966 were obtained from the Review Forecast issue of the *Oil and Gas Journal*, published annually the last week of January. The numbers refer to the
Field Well Completions — Gas Producers, and include the condensate producers.

Distance (D): The variable expresses the pipeline distance between the center of a drilling region and the center of the area of consumption. Los Angeles is the consumption center for gas produced in the Texas Railroad Commission (TRRC) Districts, 7e, 8, 8a, and 9, New Mexico Northwest (the San Juan Basin) and New Mexico Southeast (the Permian Basin). Cleveland is the consumption center for the TRRC Districts 1, 2, 3, 4, 5, 6, 7b, and 10, Louisiana Northern, Louisiana Southern and Offshore, Oklahoma and Kansas.

Oil Price (POt): The same regional basis was used as in computing the distance. For the first region, the Los Angeles price of PS200 and medium diesel oil was used; for the second region, the New York medium distillate no. 2. Prices are expressed in cents per gallon (current dollars) and were obtained from the U.S. Bureau of Labor Statistics Wholesale Prices and Price Indexes, Washington, D.C., final June figures for the years 1955-1968. The items referred to are 573.01 and 573.04 respectively.

The Demand Variable (ΔV): For each region, the change in the value added in manufacturing industry was used as a measure for the change in demand for natural gas. The figures were obtained from the Statistical Abstract of the United States published annually by the Bureau of the Census under the heading "Manufacture by States."
series was published on an annual basis until 1963. Since that date figures have been published biennially. Figures for the intervening years have been estimated using the assumption of a constant growth rate between observations. For region 1, changes in the value added of the following states were aggregated: Washington, Oregon, California, New Mexico, Arizona; for region 2: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Iowa, Kansas, Missouri, Oklahoma, and Nebraska. The series is lagged one period in advance.

Dummy Variable (T): This variable takes on a value of zero for the years 1955-1958 and for the subsequent three years.