# AN EVALUATION OF NATURAL GAS CONSERVATION IN THE RESIDENTIAL SECTOR OF OHIO USING TIME-VARYING-PARAMETER MODELS

Stuart I. Bretschneider
Assistant Professor, College of Business and Economics,
and
The James W. Martin Graduate Center for Public Administration,
University of Kentucky

Wilpen L. Gorr
Associate Professor, School of Public Administration,
The Ohio State University

Philip R. Roblee
Research Associate, School of Public Administration,
The Ohio State University

THE NATIONAL REGULATORY RESEARCH INSTITUTE
2130 Neil Avenue
Columbus, Ohio 43210

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## EXECUTIVE SUMMARY


This paper estimates and evaluates conservation of natural gas in the residential sectors of the four largest distribution utilities in Ohio. The case studies include monthly data over the period from January 1970 until March 1980, and therefore, are comprehensive in the sense of including data on periods before, during, and after conservation pressures and incentives.

Both conventional and new time-varying-parameter models are combined in this paper in order to handle the dynamic behavior of consumers and to provide new information to the analyst in model construction. By themselves, conventional energy demand models in linear and log-linear forms fail to produce useful results due to the fact that base-price and personal-disposable-income effects are collinear and therefore not separable. As a result, estimated coefficients for conventional models have incorrect signs and tend to be statistically insignificant. Instead of the linear or log-linear forms, time-varying-parameter models show that the ratio of income and price, interacted with heating degree days, is powerful in explaining consumer behavior. Thus, the ratio form is used in this paper.

Average price data, obtained by dividing total residential revenue by total sales, are found to be an inappropriate variable for natural gas modeling. The fixed cost component of total price drives up the summertime average price, giving the spurious impression that high summer prices result in low consumption levels. This is incorrect as, of course, warm weather eliminates the use of natural gas for space heating in summer, and this is the cause for low consumption levels in summer. The marginal price variable does not suffer from this problem and is desirable for modeling consumer behavior but is difficult to obtain. To supply the needed marginal price data, this paper introduces a new time-varying-parameter model that estimates marginal prices from the readily available total revenue and sales data.

Results of modeling efforts show a total conservation in the range of 16% to 27% across the four cases with 10% to 24% attributed to price and income effects. The governor's call for voluntary emergency conservation during the 1976-77 gas emergency had little if any effect on consumers. Furthermore, the modeling results provide evidence that President Carter's tax rebate plan has had little if any effect.

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## Acknowledgments

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# 1. INTRODUCTION

The early 1970s marked the end of a long period of growth in residential space-heat demand in the U.S. This growth primarily had been due to increasing real income and decreasing real price of fuels and power. For example, Strout [1] examined space-heat demand for the period from 1935 through 1959 using national-level data and found in that period that disposable real per capita income increased 85% and a deflated price index for space heat decreased 27%. At the same time, per U.S. resident space heat increased 63%. The October 1973 Arab oil embargo signaled the end of such growth and the beginning of energy conservation.

While the oil embargo had little immediate effect on natural gas consumption in Ohio, by 1974 natural gas supply conditions were deteriorating markedly. In response, moratoriums on new customer hookups were declared, some nonresidential natural gas customers experienced peak-day and volumetric supply curtailments, and at the national level, natural gas prices were permitted to rise sharply. Thus, a general awareness of the conservation issue came into being.

Then, much of the eastern U.S. experienced the coldest-on-record 1976-77 heating season. This precipitated the 1976-77 gas emergency in which Ohio was among the hardest hit states. Portions of the industrial and commercial sectors were curtailed to plant protection levels resulting in significant unemployment impacts (see von Rabenau and Gorr [2]). On January 17, 1977, the governor of Ohio declared an energy emergency and called for voluntary emergency conservation measures in the residential and commercial sectors. Subsequently, schools were closed in Columbus, Ohio, to save additional natural gas. Awareness of the conservation issue was, perhaps, at its peak during this period.

The following 1977-78 heating season also was very cold, but supply conditions had improved and apparently conservation had contributed to a favorable supply and demand balance in Ohio. Perhaps contributing to the conservation experienced was the tax credit program of the Carter administration's National Energy Plan (see Hirst and Jackson [3]). This program included a 25% tax credit for retrofit conservation measures up to $800 plus 15% credit on the next $1,400 in the residential sector in effect from 1977 until 1984. While the tax credit program may have had some effect in early 1977, its effect is not likely to have been felt until the 1977-78 heating season due to delays in the program's approval. After a month or two into the 1977-78 heating season, the distribution utilities of Ohio, with the support of the Ohio Department of Energy, moved greatly to reduce or to eliminate volumetric curtailments to nonresidential customers. Since the 1977-78 heating season, there have been no volumetric curtailments in Ohio. Also, the moratoriums on new customer hookups were lifted, and new customers have been joining the system.

Thus, the 1970s produced pressures for conservation of residential natural gas in Ohio including economic incentives through natural gas price increases, a directive from the governor of Ohio to conserve on an emergency basis, a government incentive program through tax credit to implement conservation measures, and a great deal of information on the natural gas shortage and its impacts that appealed for voluntary conservation. The first of two purposes of this paper is to determine the extent of the resulting conservation and to evaluate the contribution of each conservation pressure or incentive on the total conservation effect. For this purpose, case studies were conducted on the four largest distribution utilities in Ohio. Monthly data on each utility have been collected for the period from January 1970 through March 1980. This provides a comprehensive study period encompassing before, during, and after implementation of conservation measures.

The second purpose of this paper is to introduce time-varying-parameter (TVP) models and the relatively new adaptive estimation procedure (AEP), due to Carbone and Longini [4,5], to the energy-modeling area. The TVP model has two related applications in evaluating energy conservation measures, and for evaluation research in general. First, this paper applies the TVP model as a new technique for Exploratory Data Analysis, an approach to modeling promoted by Tukey [6]. In particular, AEP is used in a modeling process called "expansion modeling" that provides a staged, inductive approach to model building. Second, several researchers in the energy-modeling field have noted that the behavior of energy consumers is dynamic, resulting in constantly changing relationships in demand models (see for example, Chapman et al. [7], Verleger [8], Mayer and Horowitz [9], Bopp and Lady [10], and Sonnino [11]). Unfortunately, until recently, there have been no data analysis techniques directly able to handle the estimation of dynamic systems. For example, the ordinary least squares (OLS) regression technique, often used to estimate demand models, requires the restrictive assumption of unchanging (constant parameter) relationships between variables of a model. In contrast, AEP was designed to estimate changing relationships through the TVP model specification. This allows the construction of models not possible before.

Section 2 of this paper reviews conventional energy demand models, and section 3 introduces expansion modeling and AEP. Section 4 presents the four case studies of residential natural gas conservation in Ohio. Section 5 is a summary of the paper.

## 2. REVIEW OF ENERGY DEMAND MODELS

Strout [1], Chapman et al. [7], Verleger [8], Mayer and Horowitz [9], Bopp and Lady [10], Nelson [12], Saha and Stephenson [13], and others have used constant-parameter energy demand models identical or similar to the following:

General Energy Demand Model

$$Q_1/N = \beta_o + \beta_1 P_1 + \cdots + \beta_m P_m + \beta_{m+1} I/N + \beta_{m+1} D + \varepsilon \qquad (1)$$

where m = number of substitutable fuels or power sources available for the case at hand;

$Q_1$ = aggregate demand per unit period for the particular fuel or power source under study, denoted as number 1 for notational convenience;

N = total number of customers generating $Q_1$;

$P_j$ = unit price of fuel or power source j;

I = income per unit period of the N customers being served;

D = sum of heating or cooling degree days per unit period;

$\beta_j$ = parameter to be estimated; and error term.

Generally, the parameters of model (1) are estimated using the OLS method.

Model (1) is stated in linear form. Often this model also is used in log-linear form that has the appearance of model (1) but requires transformation by taking natural logarithms of all input data. Strout [1] states that the linear model is best suited for data of a short unit time period, say a month or less, while the log-linear model fits annual data best. Engineering models of heat requirements for buildings, based on thermodynamic principles, yield a linear relationship between space heat and heating degree days (see Kusuda [14]). Section 4 uses a model retaining features of both the linear and log-linear forms.

The use of per customer demand, $Q_1/N$, in model (1) facilitates comparisons of model results across different geographic regions and time periods. As the price of fuel or power source 1 increases, it is expected that $Q_1/N$ will decrease so that $\beta_1$ should be negative. In contrast, if a price of a substitute fuel or power source increases, it is expected that $Q_1/N$ will increase so that $\beta_2$ through $\beta_m$ should be positive. There is some debate as to whether marginal or average prices should be used in energy demand models, although marginal prices are often preferred on theoretical grounds. Many studies use average prices, however, since marginal price data are difficult to obtain, but average prices are calculated easily from total sales and revenue data. Marginal prices are estimated in section 4.2 using a new TVP model from total sales and revenue data. Section 4.2 provides a breakthrough in making marginal prices available from commonplace data.

Model (1), as stated, is considered to be a long-run model, since the prices of substitute fuels or power sources are included. The assumption is that the stock of appliances requiring fuel or power can change in the long run, and the prices of competing, substitute fuels or power sources will indicate the impacts on demand for fuel 1. Houthakker and Taylor [15] and Balestra [16] provide so-called "dynamic" models for the long run. At first, they include the stock of appliances as a variable in model (1) but then eliminate it by assumptions and algebraic manipulations. Their approach does not appear to add much to analysis. If only price $P_1$, the own-price, is included in model (1), then the model is considered to be a short-run model with the stock of appliances fixed. Since substitutes have not been competitive overall to natural gas, it is reasonable to assume that the short run for residential natural gas consumption is a long period of time. Thus, prices $P_2$ through $P_m$ are excluded from model (1) in the case studies of section 4.

Per capita disposable income is an indicator of consumption $Q_1/N$. As income increases, it is expected that consumption will increase so that m+1 should be positive in model (1). Heating degree days for a given day are calculated as

$$D = \text{maximum} \left\{ 0, \ 65-T \right\}$$

where T = daily average or midrange temperature (°F).

The value "65" used in the calculation of D is actually a behavioral coefficient that should be estimated from historical data, since weatherization and lowered thermostat settings reduce this coefficient. Mayer and Horowitz [9] have attempted to estimate this coefficient over time but encountered severe limitations. Preliminary investigations on the Ohio case studies show that variations in this coefficient away from the value "65" can be ignored safely.

The results of demand models, such as model (1), are often reported in terms of the dimensionless quantities, elasticities of demand. For model (1), an elasticity is the percentage change in fuel 1 consumption per customer caused by a 1% increase in a specified price, income, or other variable. Elasticities for the log-linear form of model (1) are simply the estimated values $\beta_1, \cdots, \beta_{m+2}$. For the linear form, the elasticities are

$$\eta x_j = \hat{\beta}_j x_j / (Q_1/N) \tag{2}$$

where $\eta$ = elasticity of demand; and

$x_j$ = jth variable of model (1).

## 3. EXPANSION MODELING OF ENERGY DEMAND USING TIME-VARYING PARAMETERS

A straightforward estimation of model (1) for the case studies of this paper fails to produce useful results because the variables natural gas price and personal income are highly collinear in both original and logged forms. In particular, both of these variables increased during the study period so that their effects are not separable. As a result, signs of the estimated coefficients for these variables are not as expected in general, and usually one of the two variables is insignificant statistically. The purpose of an evaluation study such as this one, however, is to provide models with meaningful estimates of coefficients. Thus, it became necessary to attempt to go beyond conventional energy demand models and to search for new formulations to provide useful assessments of energy conservation pressures. This section, therefore, introduces an inductive modeling approach, one that builds on patterns discovered in the case study data, for this purpose. First, TVP models are introduced. These models provide the basis for a staged model-building procedure starting with aggregate models and then proceeding with detailing appropriate portions of the model as required. The second part of this section provides a top-down modeling process due to Casetti [17, 18] known as "expansion modeling." The use of TVP models as the basis for the top-level model is new.

### 3.1 Time-Varying-Parameter Models

In general terms, a TVP model is denoted

$$Y(t) = \beta_o(t) + \beta_1(t)x_1(t) + \cdots + \beta_m(t)x_m(t) + \varepsilon(t) \qquad (3)$$

where $Y(t)$ = dependent variable at time t;

$x_j(t)$ = jth independent or explanatory variable;

$_j(t)$ = TVP of the jth independent variable; and

$(t)$ = unspecified model error term.

Energy demand model (1) is easily extended to this form by adding the t subscript to all model coefficients. The estimated model is denoted

$$\hat{Y}(t) = \hat{\beta}_o(t) + \hat{\beta}_1(t)\ x_1(t) + \cdots + \hat{\beta}_m(t)\ x_m(t)$$

Two self-adaptive data analysis techniques are available to provide the $\hat{\beta}_j(t)$ estimates: AEP due to Carbone and Longini [4,5], and Least Mean Squares due to Widrow et al. [19] and further developed by Wheelwright and Makridakis [20]. Both techniques are based on feedback principles and were developed heuristically to yield good performance characteristics. Bretschneider and Gorr [21] have shown some theoretical properties of these and related techniques. This paper uses AEP.

The approach of AEP is as follows. At time t, a one-step-ahead forecast is made using known parameter estimates from t-1 and independent variable data from t:

$$Y^F(t) = \hat{\beta}_o(t-1) + \hat{\beta}_1(t-1)\ x_1(t) + \cdots + \hat{\beta}_m(t-1)\ x_m(t)$$

Next, the forecast error $Y(t)-Y^F(t)$ is calculated. Through the direction of a simple pattern recognizer in the AEP filter, small adjustments are made to $\hat{\beta}_j(t-1)$ to yield $\hat{\beta}_j(t)$ $(j = o,\ldots,m)$. The new coefficients reduce, but do not eliminate, the forecast error $Y(t) - Y^F(t)$. This process is repeated recursively with each new observation so that estimated parameter paths drift over time to capture dynamic effects of the system under study.

## 3.2 Expansion Modeling

Work initiated by Carbone and Gorr [22] suggests that TVP models are useful in inductive modeling procedures. Inductive modeling has been legitimized in recent years by the Exploratory Data Analysis movement introduced by Tukey [6]. The idea here is that analysts should look for patterns in available data as an aid to modeling a phenomenon under study. This is in sharp contrast to the classical modeling approach that requires that analysts determine the model completely on theoretical grounds and then obtain data needed for estimation of the model.

The modeling process introduced and applied in this paper involves a series of modeling efforts in which the goal is to introduce a sufficient number of appropriate variables to eliminate systematic variation in TVP paths. This results in a final, constant-parameter model. Three steps are required: (1) a top-level, aggregate TVP model is specified and estimated; (2) each TVP with systematic variation is expanded (or modeled) through the introduction of new independent variables, and (3) all parameters of the expanded model are estimated simultaneously. Each of these steps is discussed in some detail below.

An example of a top-level model is the commonly used heating degree day model supplemented with the TVP specification:

$$Q_1(t)/N(t) = \alpha_o(t) + \alpha_1(t)D(t) + \varepsilon(t) \tag{4}$$

where $\alpha_o(t)$ and $\alpha_1(t)$ are top-level TVPs.

As is true for all top-level models, the terms of model (4) provide mutually exclusive and exhaustive categories for sources of variation in the dependent variable. These are the non-space-heating, $\alpha_o(t)$, and the space-heating, $\alpha_1(t)D(t)$, terms. Another property of top-level models is that some of their parameters are expected to vary over time due to identifiable independent variables not yet included in the model. These are the variables used to expand the TVPs in the second step. In model (4), systematic declines in $\alpha_o(t)$ and $\alpha_1(t)$ are expected in the Ohio case studies due to conservation pressures and incentives.

The results of top-level models are useful in directing subsequent modeling steps. First, the direction, magnitude, and timing of parameter variation are informative. Such patterns are suggestive of which additional variables might be helpful in expanding $\hat{\alpha}_j(t)$s in the second step of this procedure. If a particular $\hat{\alpha}_j(t)$ does not vary significantly over time, then it is not necessary to collect data on additional variables to expand that $\hat{\alpha}_j(t)$. This is an economy that might not otherwise be had. Second, if time and resources are short, the results of the top-level model are inexpensively and quickly obtainable and may be sufficient when coupled with judgment to make necessary decisions.

After the top-level model has been estimated and studied, the next step is to expand the set of $\hat{\alpha}_j(t)$s that has significant, systematic variation as follows:

$$\hat{\alpha}_j(t) = \hat{\gamma}_{oj} + \hat{\gamma}_{1j}x_{1j}(t) + \cdots + \hat{\gamma}_{mj}x_{mj}(t) \qquad (5)$$

where m = number of independent variables in the jth expansion,

$x_{ij}$ = ith independent variable of the jth expansion; and

$\hat{\gamma}_{ij}$ = parameter i of the jth expansion.

While the expansion model (5) is stated as a constant-parameter, general linear model, any functional form as needed may be used and any estimation technique may be employed to estimate coefficients $\gamma_{ij}$. Of primary importance here is the task of determining which variables $x_{ij}$ are useful in explaining $\hat{\alpha}_j(t)$ and which functional form is most appropriate (linear, multiplicative, etc.). The estimates $\hat{\gamma}_{ij}$ generally are not themselves used in the final model, obtained in step 3.

The expansion step carries out the analytical process started with the top-level model. The top-level model provides diagnostic information on which $\hat{\alpha}_j(t)$s to expand and what independent variables might be useful. The expansion step then allows the analyst to focus on one component of the total system at a time, in terms of firming up the form of the final model. In step 3, the model form as in (4) is expanded by substituting for $\hat{\alpha}_j(t)$ the model forms found successful in model (5).

## 4. CASE STUDIES

This section presents case studies on natural gas conservation in the residential sectors of the four largest distribution utilities in Ohio: Cincinnati Gas and Electric, Columbia Gas of Ohio, Dayton Power and Light, and the East Ohio Gas Company. Appendix A contains the raw data for these cases including 123 monthly observations for each utility covering the period from January 1970 through March 1980. Also included in the appendix are discussions of various aspects of the data.

Table 1 contains descriptive statistics on the data of appendix A. It is seen in this table that mean per customer consumption is about the same for three of the utilities, but the typical customer of East Ohio Gas consumes about 20% more natural gas than those of the other companies. The heating degree day data of table 1 provide a partial explanation of this difference. The heating season of East Ohio Gas customers, in northern Ohio, is about 10% colder than those of the other utilities, and since space heat is the dominant portion of residential natural gas consumption, this accounts for nearly 10% of the 20% difference. There is no explanation available at this time for the remaining 10% difference. The average price variable in table 1 was obtained by dividing monthly revenue by monthly consumption. The range of prices shows the price increases over time, from about \$0.85 to \$3.60 per mcf--an increase of about 425% in 10 years. At the same time, national personal income rose from \$779 x $10^9$ to \$2,070 x $10^9$, only an increase of 265% as compared to the increase in natural gas prices. Note that national personal income data are used because state and city-level income data were not available on a monthly basis. On an annual basis, the national and Ohio data have a correlation of 0.99, so that the national-level variable provides useful information.

TABLE 1

DESCRIPTIVE STATISTICS BY DISTRIBUTION UTILITY FOR MONTHLY DATA CONCERNING RESIDENTIAL NATURAL GAS CONSUMPTION

| Variable | Company* | Units | Sample Size | Mean | Standard Deviation | Minimum Value | Maximum Value |
|---|---|---|---|---|---|---|---|
| Natural Gas Consumption per Customer | CG&E | mmcf | 123 | 0.0130 | 0.00939 | 0.00265 | 0.0327 |
| | CGO | | 123 | 0.0142 | 0.00953 | 0.00322 | 0.0339 |
| | DP&L | | 123 | 0.0131 | 0.00930 | 0.00263 | 0.0345 |
| | EOG | | 122 | 0.0168 | 0.01089 | 0.00395 | 0.0388 |
| Heating Degree Days | CG&E | Total | 123 | 457 | 409.5 | 0.00 | 1399 |
| | CGO | Monthly | 123 | 491 | 425.5 | 0.00 | 1462 |
| | DP&L | °F | 123 | 488 | 426.7 | 0.00 | 1384 |
| | EOG | | 122 | 531 | 434.4 | 3.00 | 1398 |
| Natural Gas Average Price | CG&E | $/mcf | 123 | 1.84 | 0.86 | 0.87 | 3.58 |
| | CGO | | 123 | 1.91 | 0.84 | 0.86 | 3.74 |
| | DP&L | | 123 | 1.81 | 0.81 | 0.75 | 3.49 |
| | EOG | | 122 | 1.70 | 0.70 | 0.79 | 3.64 |
| National Personal Income | -- | $\$10^9$ | 123 | 1280 | 377 | 779 | 2070 |
| Consumer Price Index | -- | 1967 = 100 | 123 | 159 | 34.7 | 113 | 240 |

*CG&E = Cincinnati Gas and Electric
CGO = Columbia Gas of Ohio
DP&L = Dayton Power and Light
EOG = East Ohio Gas

Sources: Consumption, revenue, and number of customers data were obtained directly from the utilities; degree day data were obtained from *Climatological Data*, National Climatic Center, Asheville, North Carolina; income data were obtained from *Survey of Current Business*, U.S. Department of Commerce; and Consumer Price Index data were obtained from *CPI Detailed Report*, U.S. Department of Labor

### 4.1 Top-Level TVP Models

This section provides estimates of top-level model (3). In keeping with the philosophy of Exploratory Data Analysis, several graphs are presented first that guide model construction. The Columbia Gas case is used to illustrate supporting concepts, but top-level modeling results are given for all cases.

Figure 1 depicts the time series of monthly per customer consumption for Columbia Gas, and figure 2 shows the corresponding time series of degree days. Clearly, these figures show very similar patterns due to the strong seasonality of degree days. Heating degree days are zero or nearly zero in July, August, and September so that consumption from these months represents non-space-heat consumption. Note that consumption peaks in January and February are 10 times higher than the summer troughs.

Further examination of figures 1 and 2 shows some indication of conservation. First, note that the non-space-heat troughs of figure 1 decline noticeably starting in 1976 or 1977. Also, figure 2 has as its highest peak degree days from the 1976-77 heating season, the coldest winter on record and significantly colder than the winters of 1969-70 through 1971-72. Note, however, that the 1976-77 consumption peak in figure 1 is about the same as those for the 1969-70 through 1971-72 heating seasons. This is a clear indication of conservation in the space-heat component of consumption.

The scatter plot of figure 3 more clearly depicts the relationship over time between per customer consumption, degree days, and conservation for Columbia Gas. Here, the plot character is the last digit of the year of observation with X's drawn for 1980 to distinguish 1980 from 1970. At any point in time, figure 3 shows that approximately a linear relationship exists between per customer consumption and degree days. As time passes, the slope and intercept of this relationship decrease continuously; thus, the TVP model (4) is appropriate.

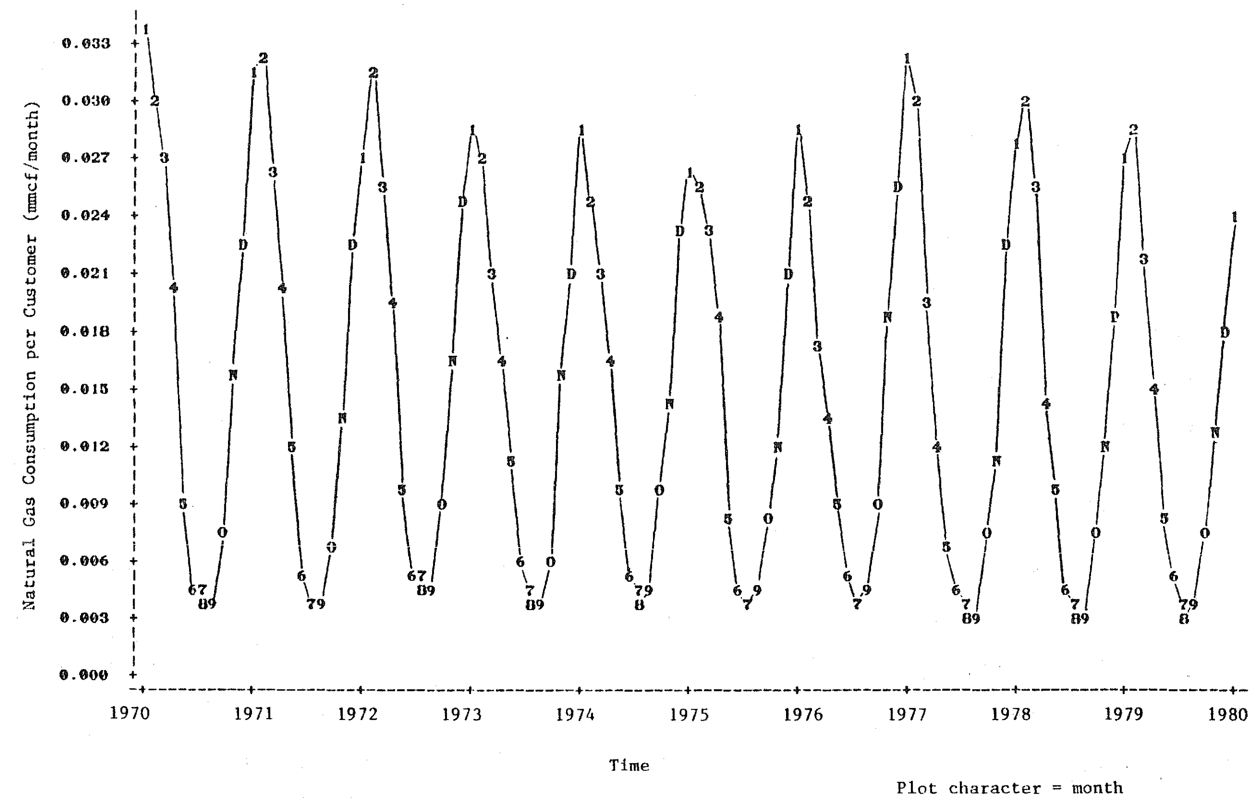


Fig. 1 Time series plot of residential natural gas consumption per customer: Columbia Gas of Ohio

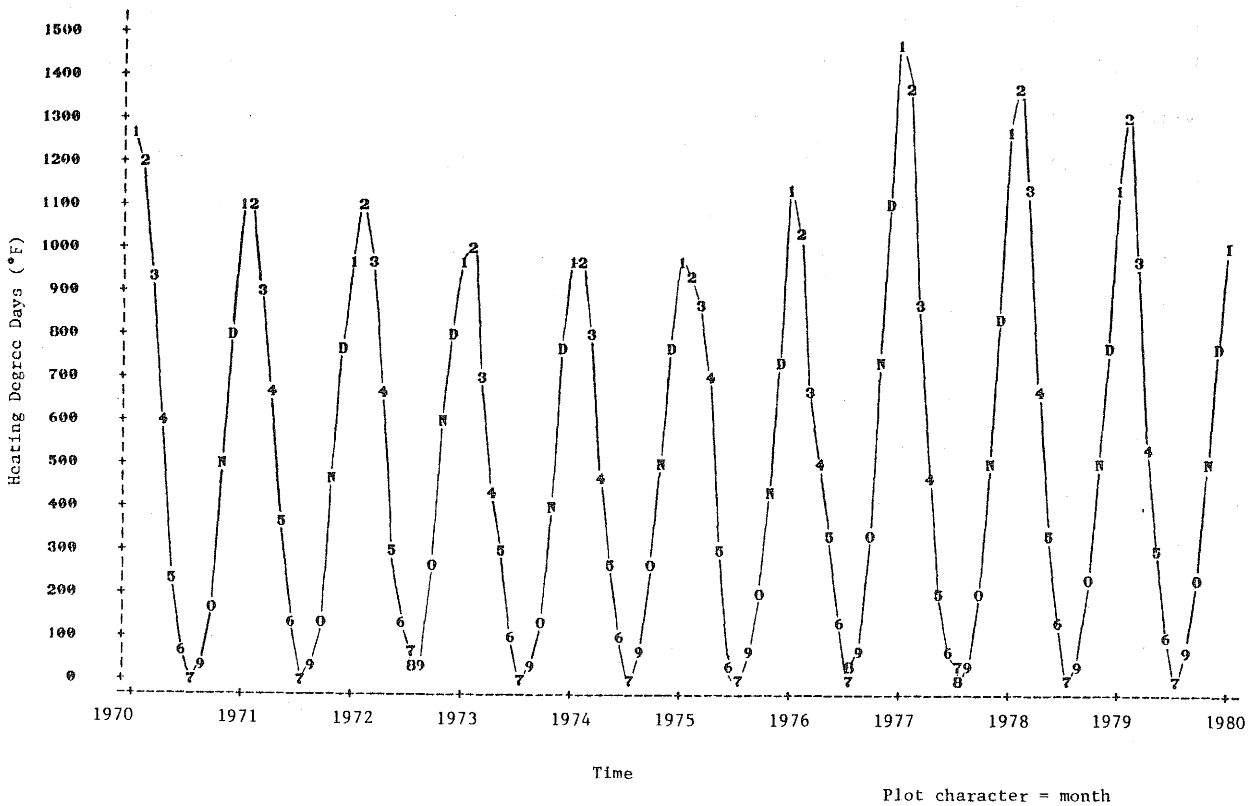


Fig. 2 Time series plot of heating degree days from the Port Columbus International Airport

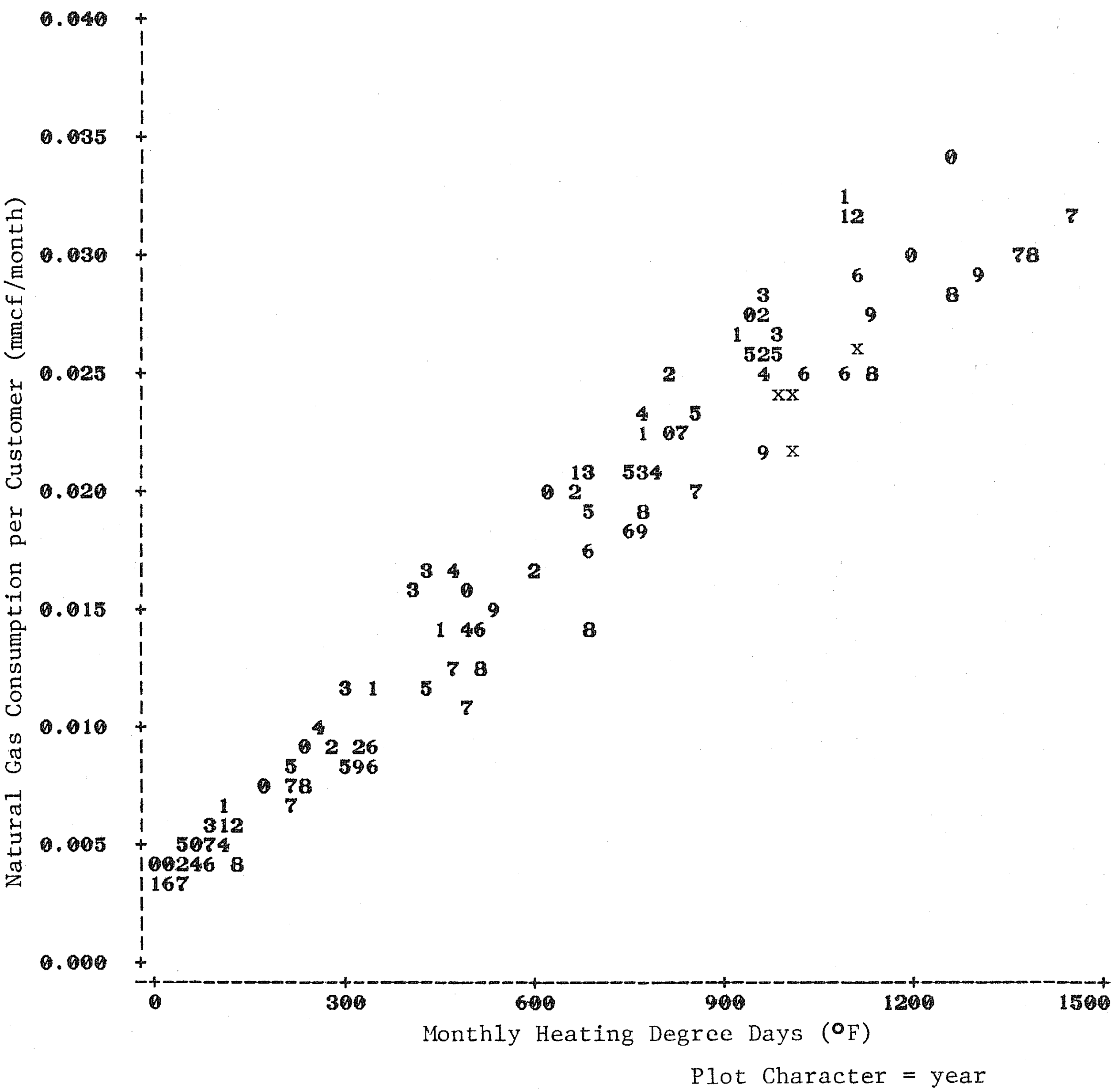


Fig. 3 Scatter plot of residential natural gas consumption per customer versus heating degree days: Columbia Gas of Ohio

Values selected for various constants and initial values for use in AEP calculations included damping factor = 0.2, smoothing constant for means of explanatory variables = 0.01; correction limit = 0.2; $\alpha_o(0)$ = $\alpha_1$ = 1; and the number of forward and backward cycles through the data = 40. The damping factor and correction limit are roughly twice as large as values generally found to be satisfactory and were necessary to remove all systematic patterns from residuals of model (4). As a result, the estimated parameter paths for model (4) presented in figures 4 through 11 are less smooth than usual. The standard error of estimate averages 0.0013 for these AEP models. Compared to the average per customer consumption of 0.014 mmcf/mo. for the four utilities, this standard error indicates an excellent fit of model (4) to the data.

Figures 4 and 5 present estimated parameter paths for the intercept $\hat{\alpha}_0(t)$ and slope $\hat{\alpha}_1(t)$ as estimated for Cincinnati Gas and Electric. The intercept declined steadily until about January 1977, after which it remained approximately constant. The total decline was about 16%. The slope increased erratically until September 1972, declined until about March 1973, remained fairly constant until April 1977, then declined sharply until April 1977 after which it remained roughly constant. The overall decline for the slope from January 1974 to January 1978 was 17%. Using a value of 900°F for monthly degree days and parameter estimates from January 1974 and January 1978, per customer consumption is estimated to have declined 16% in total. In summary, figures 4 and 5 clearly show the impacts of conservation measure for Cincinnati Gas and Electric. The sharpest impacts were produced during the severe 1976-77 heating season, but shortly thereafter conservation was arrested or reversed. Apparently, the tax credit program had little or no effect on conservation according to the TVP model, since the program was not approved until April 1977.

Next, figures 6 and 7 depict parameter paths for Columbia Gas. The intercept behaved erratically until January 1974, after which it declined rapidly until early 1977. Since then, it increased slightly. The decline

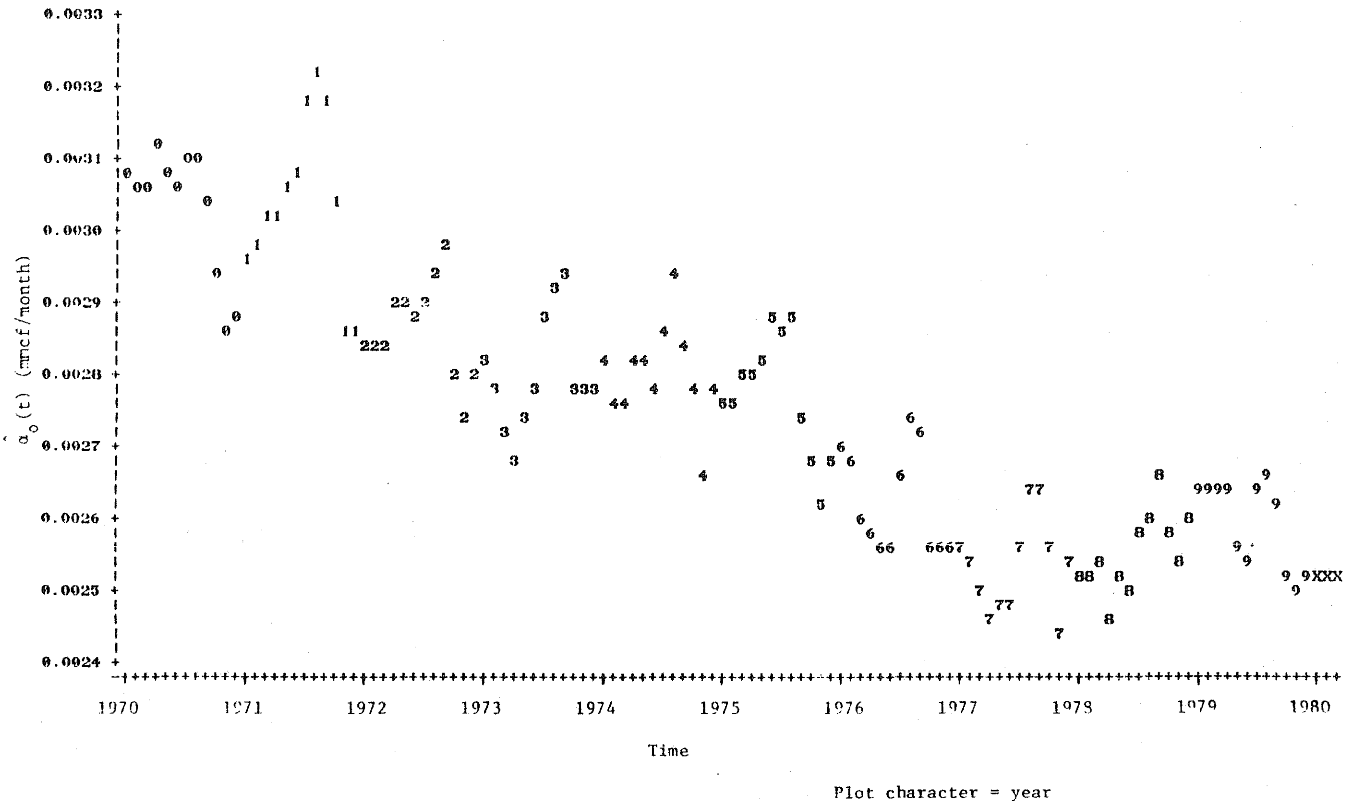


Fig. 4 Parameter path for the intercept term of the linear heating degree day model: Cincinnati Gas and Electric

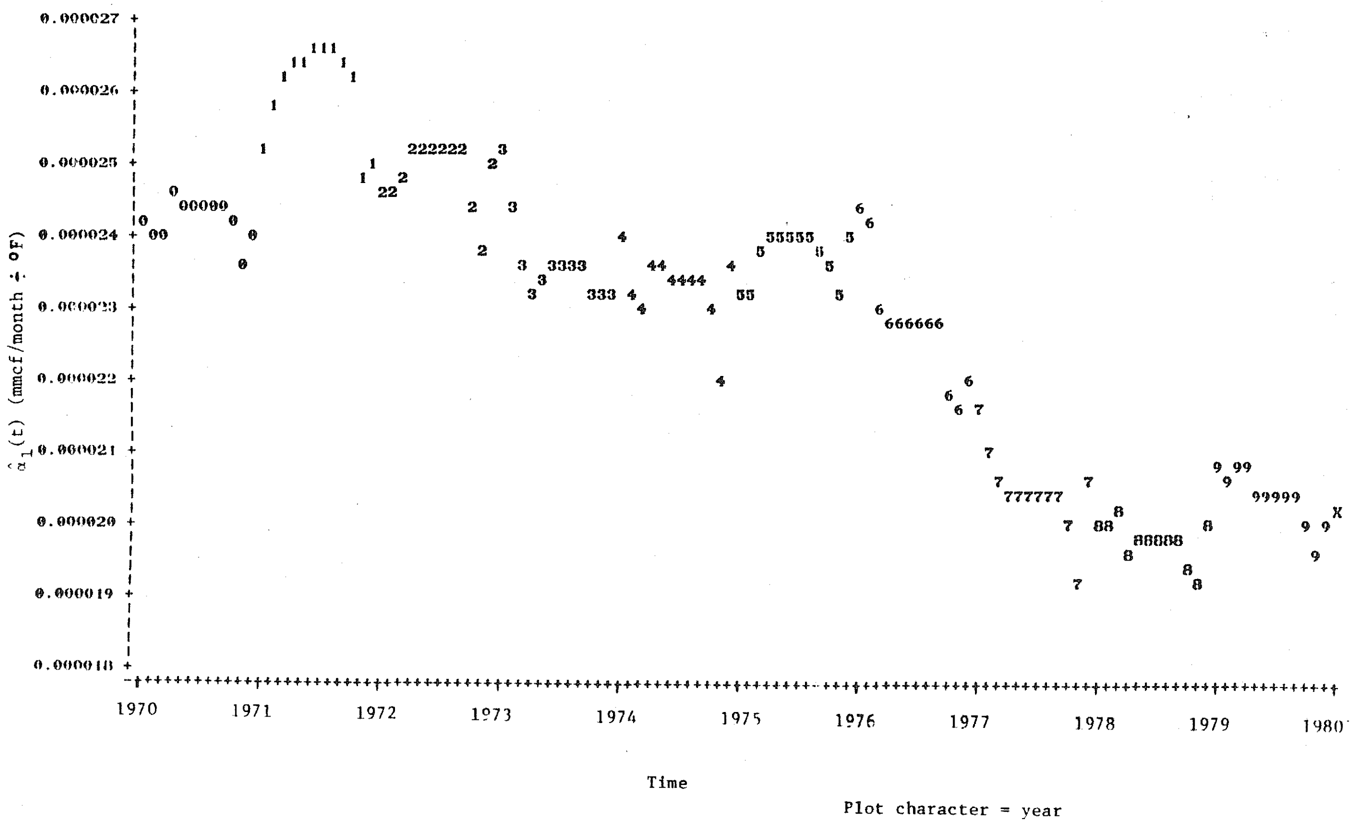


Fig. 5 Parameter path for the heating degree day term of the linear heating degree day model: Cincinnati Gas and Electric

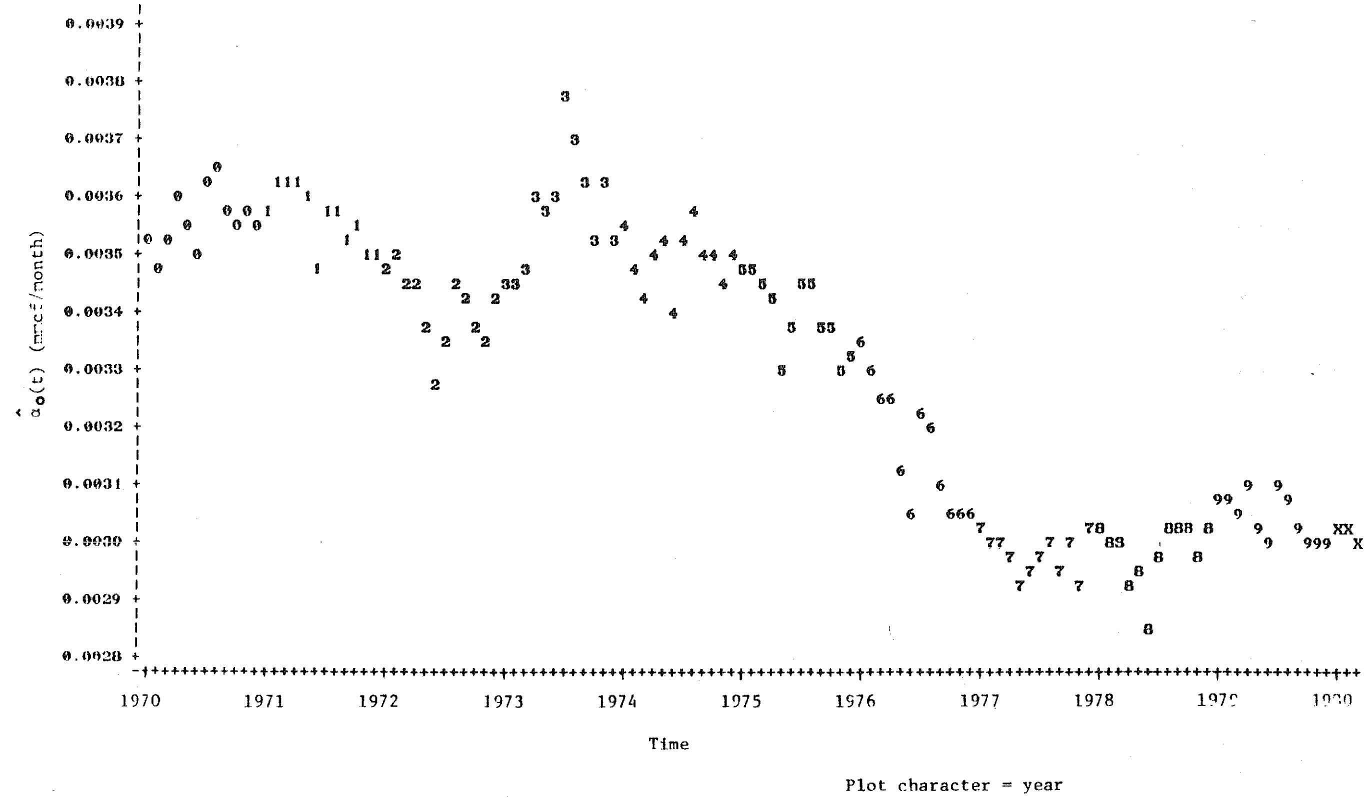


Fig. 6 Parameter path for the intercept term of the linear heating degree day model: Columbia Gas of Ohio

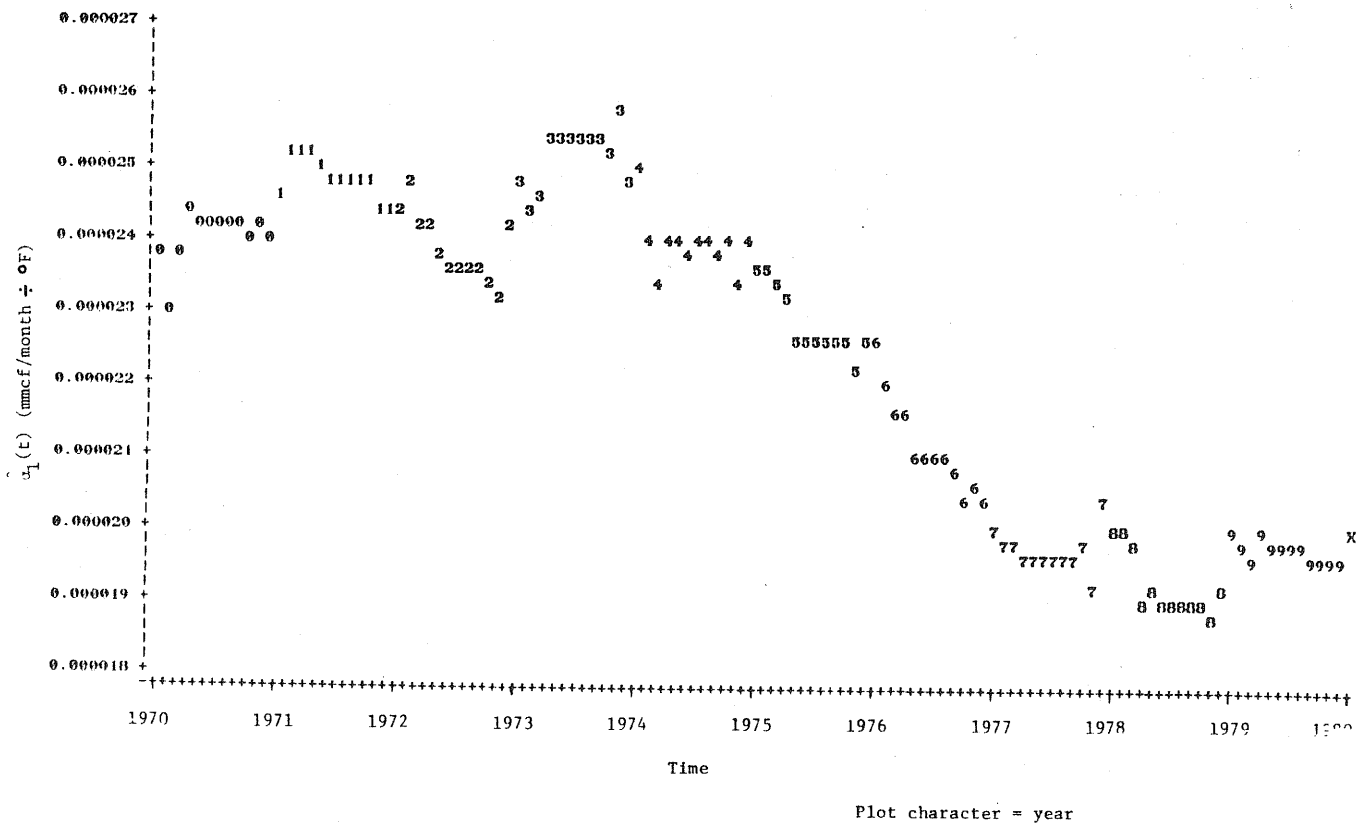


Fig. 7 Parameter path for the heating degree day term of the linear heating degree day model: Columbia Gas of Ohio

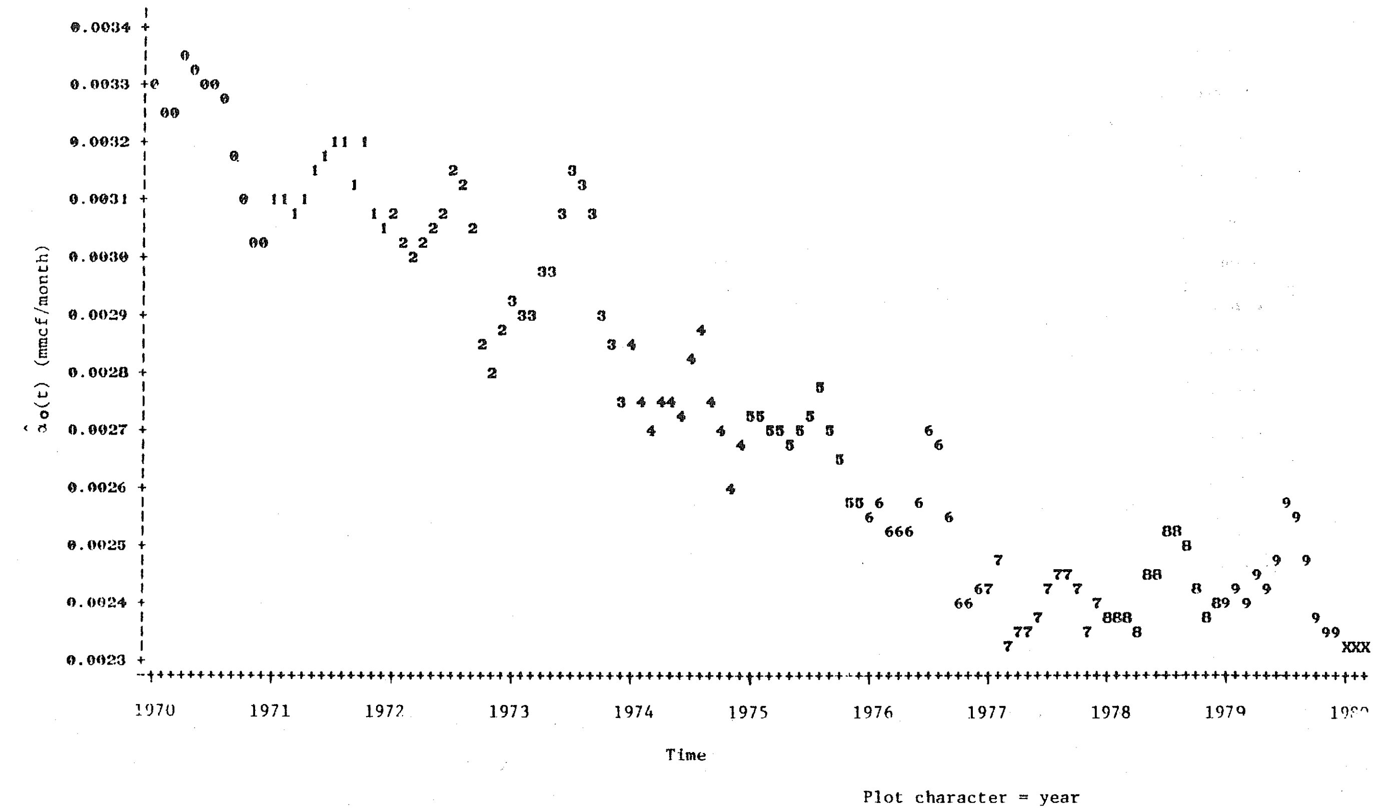


Fig. 8 Parameter path for the intercept term of the linear heating degree day model: Dayton Power and Light

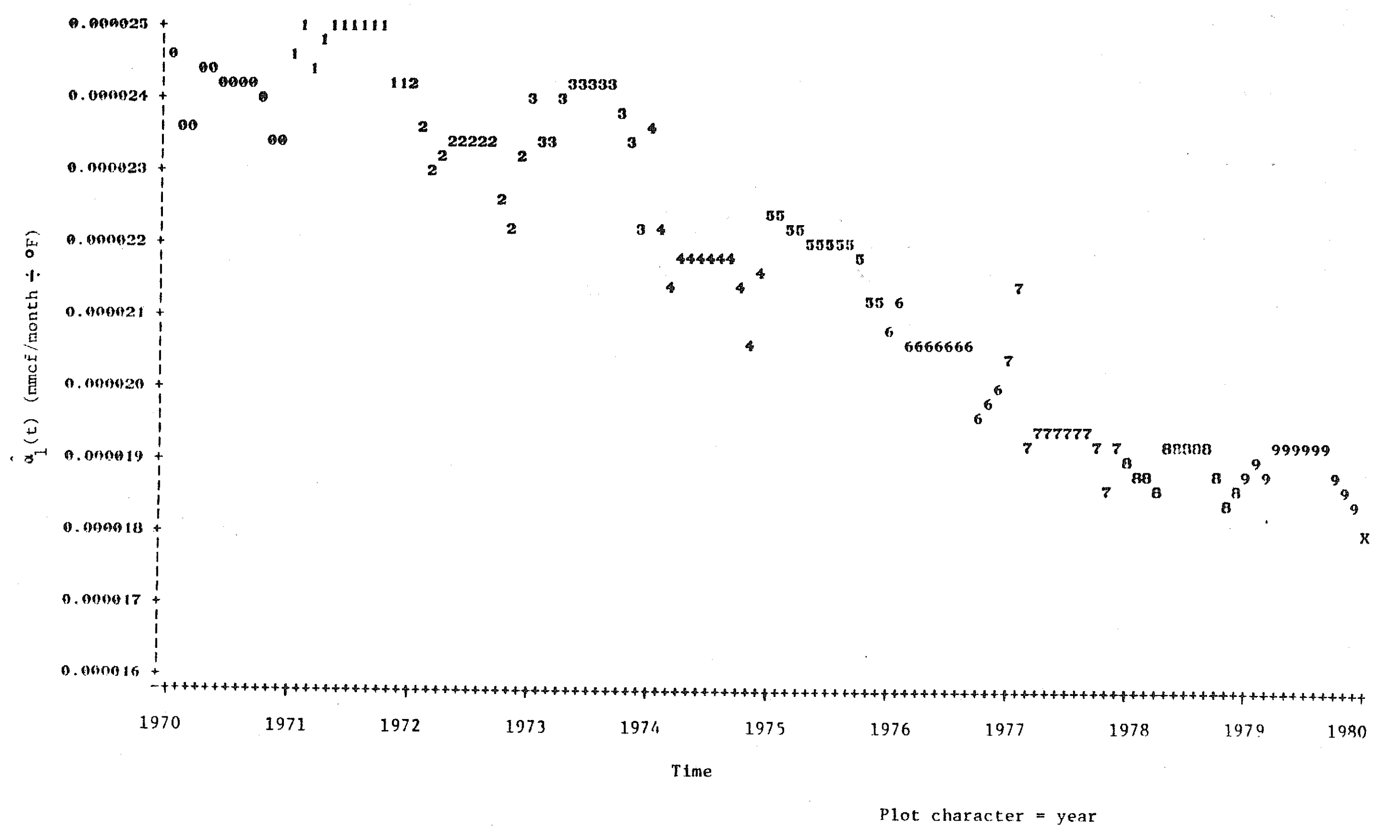


Fig. 9 Parameter path for the heating degree day term of the linear heating degree day model: Dayton Power and Light

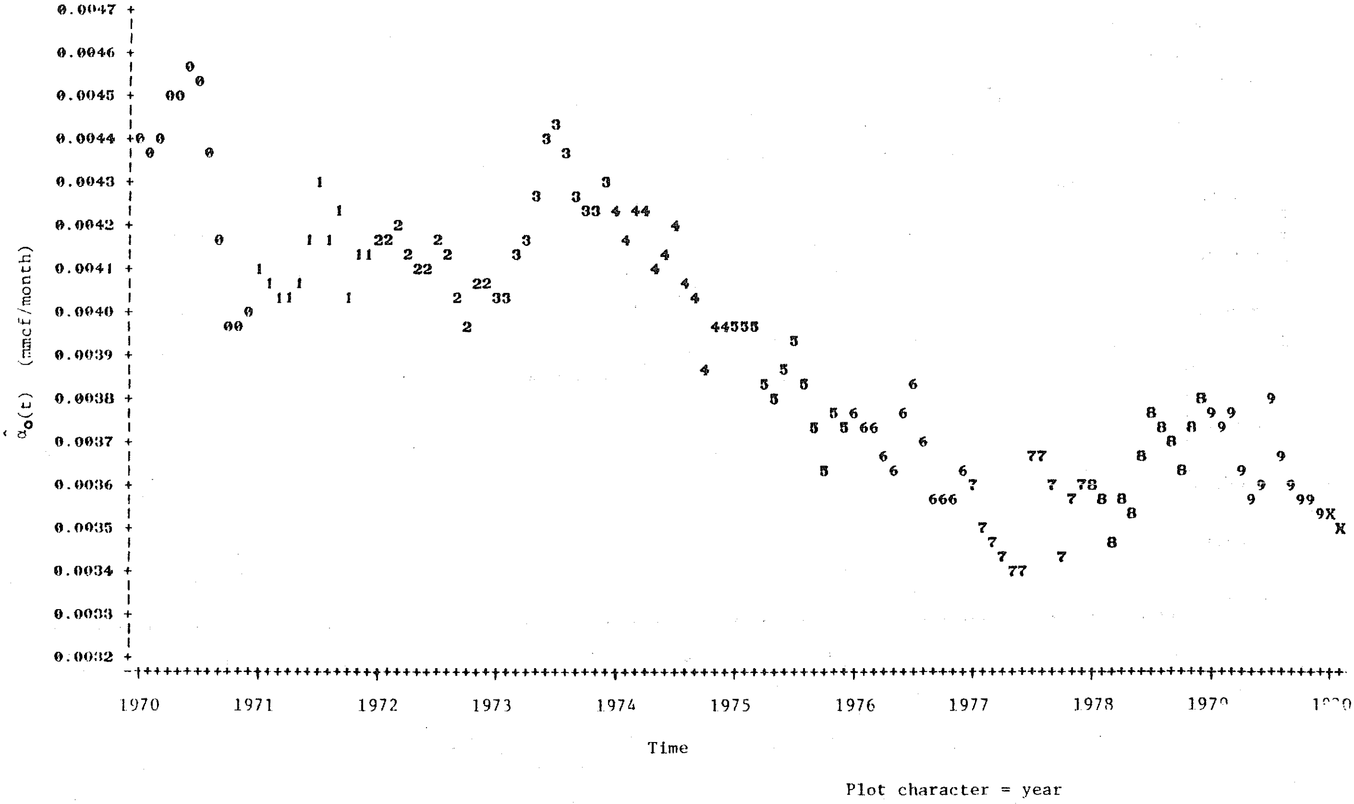


Fig. 10 Parameter path for the intercept term of the linear heating degree day model: East Ohio Gas

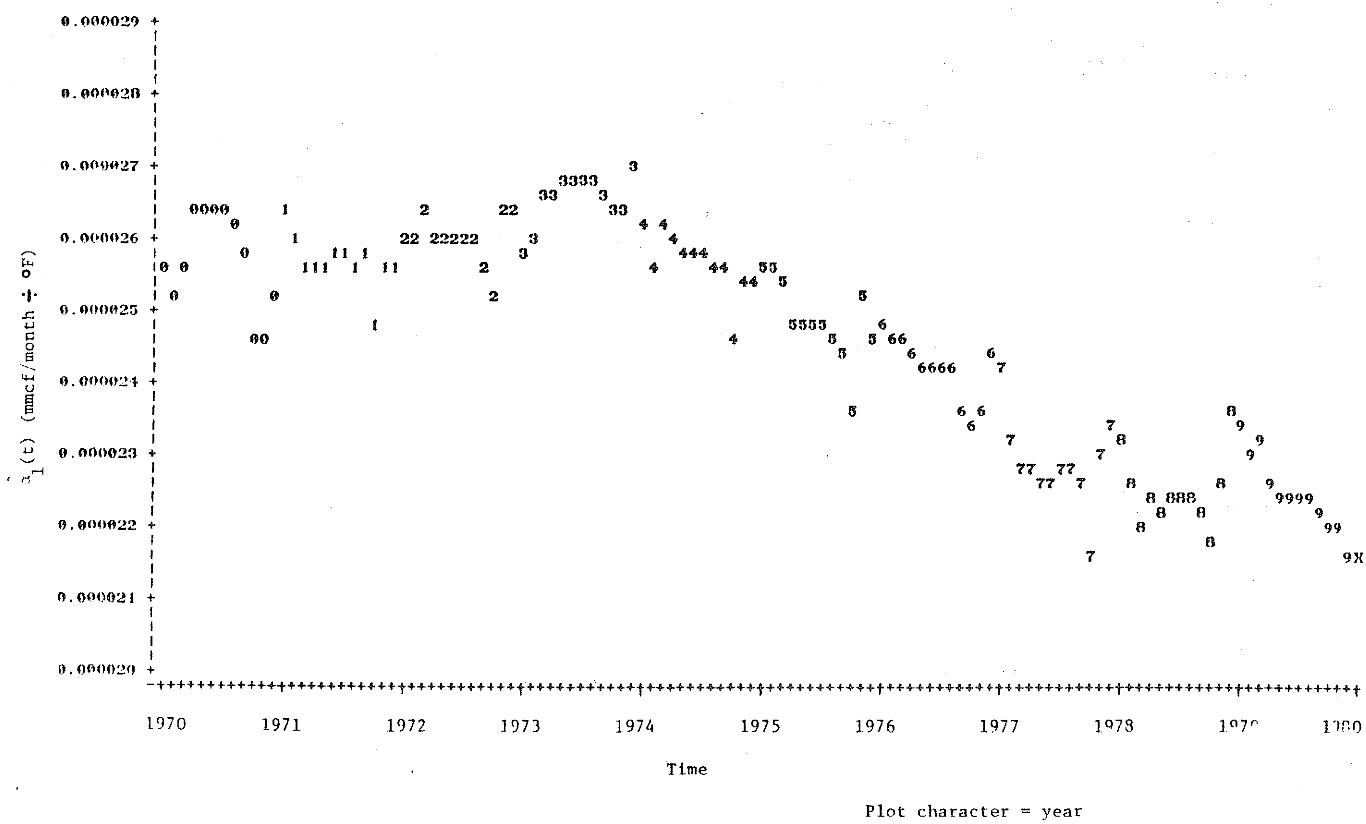


Fig. 11 Parameter path for the heating degree day term of the linear heating degree day model: East Ohio Gas

in the slope from January 1974 until January 1978 was 21%. Again using 900°F and January 1974 and 1978 parameter estimates, the total decline in consumption was 20%. These figures for Columbia Gas show patterns somewhat different from those of Cincinnati Gas and Electric; for example, the decline from 1974 to 1977 was more steady for Columbia Gas. Again, the tax credit program appears to have had little or no conservation effect.

Figures 8 and 9 portray the case of Dayton Power and Light. The patterns in these figures are quite similar to those of Cincinnati Gas and Electric; however, the declines in parameters are much stronger. This is probably due to the fact that Dayton Power and Light has the highest percentage of residential customers in the total mix of customers for the four case studies. As there were proportionally fewer nonresidential customers to curtail during supply shortages, this put increased pressure on residential customers to conserve. The intercept declined 28%, and the slope declined 22% over the period from January 1974 until January 1978. Consumption fell 23% using 900°F and January 1974 and 1978 as before. Once again, we have evidence that the tax credit program was ineffective.

Last, figures 10 and 11 give the case of East Ohio Gas Company. The patterns in these figures are very similar to those of Columbia Gas. The intercept term for East Ohio Gas declined 13%, while the slope declined 14% over the period from January 1974 to January 1978. Overall, the decline in per customer consumption was 14% using calculations as above. As before, the tax credit program appears ineffective.

In summary of this section, the parameter paths from estimates of top-level model (4) via AEP provide explicit models of structural changes in the non-space-heat and space-heat components of each case study. The two smaller companies in the southwest of Ohio, Cincinnati Gas and Electric and Dayton Power and Light, are quite similar in behavioral patterns, although the latter company shows higher levels of conservation. The two largest utilities, East Ohio and Columbia Gas, show similar patterns with steady improvements in conservation from 1974 to 1977. As will be seen in the next section, natural gas prices and income were favorable for slight growth in consumption until 1974, after which pressures steadily increased for conservation until they stopped in 1977.

The tax credit program, if it had an effect on conservation, would have shown up as declines starting in the 1977-78 heating season in the degree day paths of figures 5, 7, 9, and 11. To the contrary, the paths leveled off or increased during this period for all four utilities. This provides strong evidence that the tax credit program was ineffective as a conservation measure.

It should be noted that model (4) should provide excellent short-run forecasts using the AEP forecasting procedures due to Bretschneider et al. [24], Bretschneider [25], and Bretschneider and Carbone [26]. Roblee [27] is pursuing the short-run forecasting issue including all three sectors (residential, commercial, and industrial) for the cases of the four distribution utilities of this paper.

## 4.2 The Expansion Modeling Step

Four independent variables are under consideration to expand model (4):

- $P_1$ = marginal price of natural gas;
- I = personal income;
- E = dummy variable for the 1976-77 natural gas emergency (E = 1 for January through April 1977 and 0 otherwise); and
- T = dummy variable for the tax credit program (T = 1 after April 1977 and 0 otherwise).

Since a straightforward estimation of model (1) showed that $P_1$ and I are not separable due to multicollinearity problems, it was decided to attempt various combinations of these two variables including the ratios $P_1/I$ and $I/P_1$. Before pursuing this subject further, it is necessary to address the subject of average versus marginal prices of natural gas, which is done in section 4.2.1.

The dummy variable T was shown to be ineffective in impacting $Q_1/N$ in the top-level models of section 4.1. Thus, this variable is not included in the expansion of model (4). Furthermore, dummy variable E affects only 2 months of the 120-month study period, and these months are at the end of the period of significant decline in the parameters being expanded. Thus, E is not included in the expansion step of the modeling process either.

One notable missing variable in this model is a measure of conservation pressures for voluntarism. Campaigns to inform consumers of the need to preserve scarce resources, impacts of fuel shortages in the commercial and industrial sectors, goals to become less dependent on foreign supplies of fuels, etc., all can have impacts on conservation. Unfortunately, it is difficult to obtain a measure of voluntarism pressures. Perhaps content analysis could be applied to provide such a measure, but this has not been attempted in this paper. Even if such a measure were available it probably would not be useful in the sense that it likely would be collinear with other explanatory variables. Peck and Doering [28] and Walker [29] provide some results on voluntarism in energy conservation.

### 4.2.1 TVP Model for Marginal Price

Natural gas costs to the consumer are made up of a fixed monthly charge plus a variable cost calculated as the product of the unit price times the volume of natural gas consumed. Declining block rates are not used for residential natural gas customers of any of the utilities examined in this paper, so that the unit price, constant at any point in time, is the marginal price. While marginal price data are desirable in modeling consumption, such data are not readily available. For example, Columbia Gas of Ohio negotiates separate price tariffs with over 700 municipalities in Ohio. In this case, it is impractical for an independent researcher to determine an aggregate residential sector marginal price using accounting methods; however, it is possible to estimate such marginal prices using a TVP model as explained below in this section. First, it is instructive to demonstrate the inadequacy of average cost data.

Data available in appendix A allow the direct calculation of average price as follows:

$$AP_1(t) = R_1(t)/Q_1(t)$$

where $AP_1(t)$ = average price,

$R_1(t)$ = monthly revenue from residential-sector sales; and

$Q_1(t)$ = monthly residential-sector sales.

Figure 12 gives a time series plot of the ratio $I(t)/AP_1(t)$ for Columbia Gas. The long-range trend of this plot shows conditions conducive to growth in consumption until 1974, pressures for conservation from 1974 until 1977, and no charge thereafter. The seasonality of this plot, reflecting high average price in the summer and low average price in the winter, provides false information on consumption impacts of the ratio $I(t)/AP_1(t)$. Natural gas consumption is low in summer so that most of the cost is due to the fixed cost component of total cost. Thus, pricing policies using fixed and variable components of cost cause the seasonality of figure 12. Model (1), however, attributes low consumption in summer to consumer behavior in response to high average natural gas costs in summer; This is incorrect. This results in average cost playing too large a role in model (1) at the expense of the heating degree day term. Clearly, marginal price, which is expected to increase smoothly over time without seasonality, is desirable for accurately modeling consumer behavior here.

Figure 13 provides a scatter plot of $R_1(t)$ versus $Q_1(t)$ for Columbia Gas of Ohio. As in figure 3, the plot character is the last digit of the year of observation with X's drawn through zeros to distinguish 1980 from 1970. Evidently, at any point in time, the relationship between $R_1(t)$ and $Q_1(t)$ is approximately linear. Hence, a TVP model is appropriate as follows:

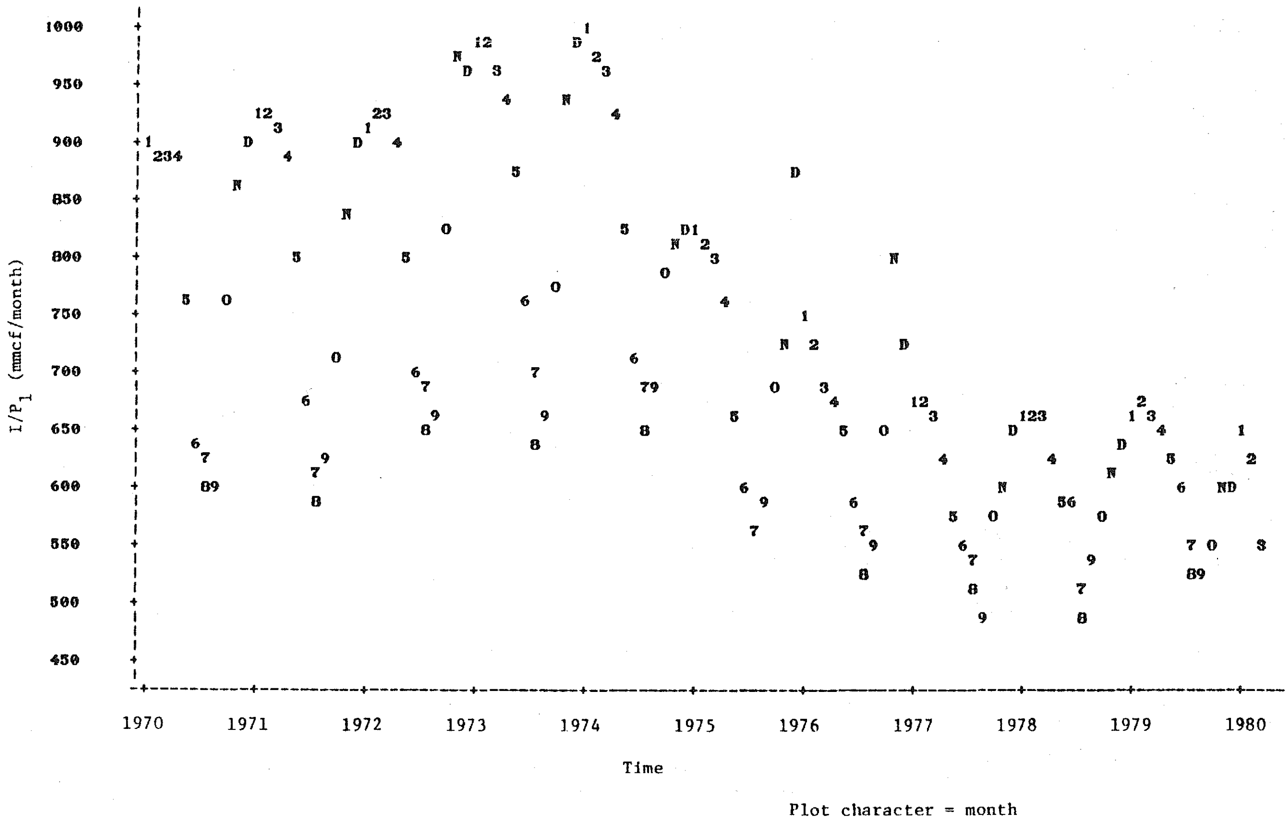


Fig. 12 Time series plot of national personal income divided by natural gas average price: Columbia Gas of Ohio

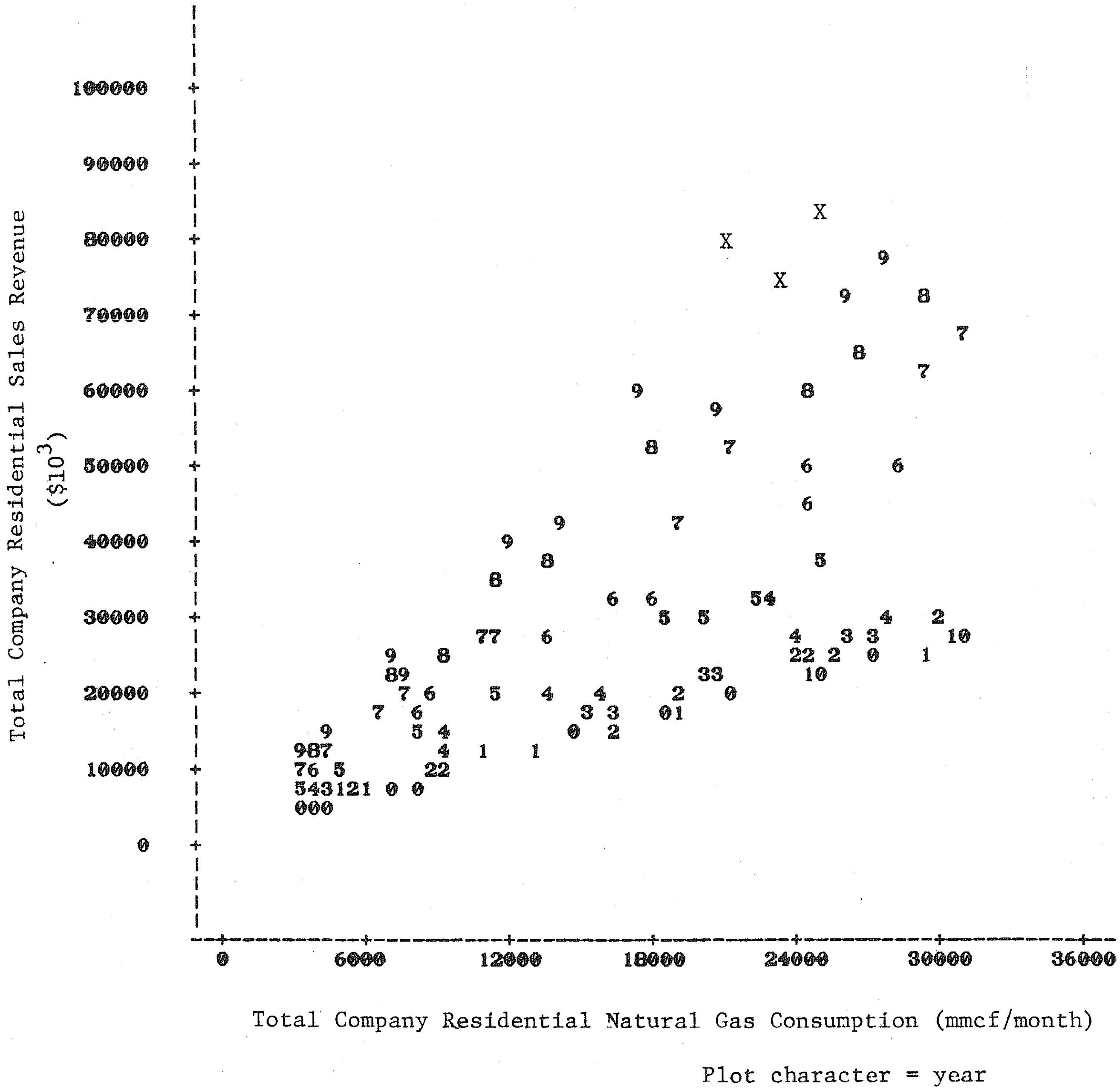


Fig. 13 Scatter plot of residential natural gas revenue versus total consumption: Columbia Gas of Ohio

Marginal Price Model

$$R_1(t) = \lambda_o(t) + \lambda_1(t)\, Q_1(t) + \varepsilon(t) \tag{6}$$

where $\lambda_o(t)$ = fixed cost; and
$\lambda_1(t)$ = marginal cost (\$/mcf).

Here, $\lambda_1(t)$ yields the aggregate, residential-sector marginal cost needed in model (1) so that $P_1(t) = \lambda_1(t)$.

Values selected for constants and initial values for use in AEP calculations to estimate model (6) included damping factor = 1.0; smoothing constant for means of explanatory variable = 0.01; correction limit = 0.2; $\lambda_o(0) = \lambda_1(0) = 1$; and the number of forward and backward cycles through the data = 30. The large value of 1.0 used for the damping factor is unprecedented and is necessary in order to have AEP keep up with the rapid changes in price. Figure 14 presents the resultant parameter path for $\lambda_1(t)$, the marginal price estimates, for Columbia Gas. In spite of the large damping factor, this is a fairly smooth path showing sharp increases after 1974. Finally, figure 15 shows the $I(t)/P_1(t)$ ratio resulting from use of the estimates from figure 14. Compared to figure 12, which showed this ratio calculated from average cost data, figure 14 shows very little seasonability. The small cyclic behavior from 1975 onward in figure 15 is believed to be an artifact of estimation due to the use of the extremely high damping factor in AEP.

4.2.2 Expansion Model for $_1(t)$

Now that marginal price $P_1$ is available via model (6), it is possible to address the expansion of $_o(t)$ and $_1(t)$ of model (4) as seen in figures 4 through 11. Attention focuses on $_1(t)$, since the space-heating term accounts for over 90% of per capita natural gas consumption. Figures 5, 7, 9, and 11 show that $_1(t)$ was constant or increased slightly from 1970 to January 1974; it declined sharply from January 1974 through mid-1977; and finally it remained constant or increased slightly

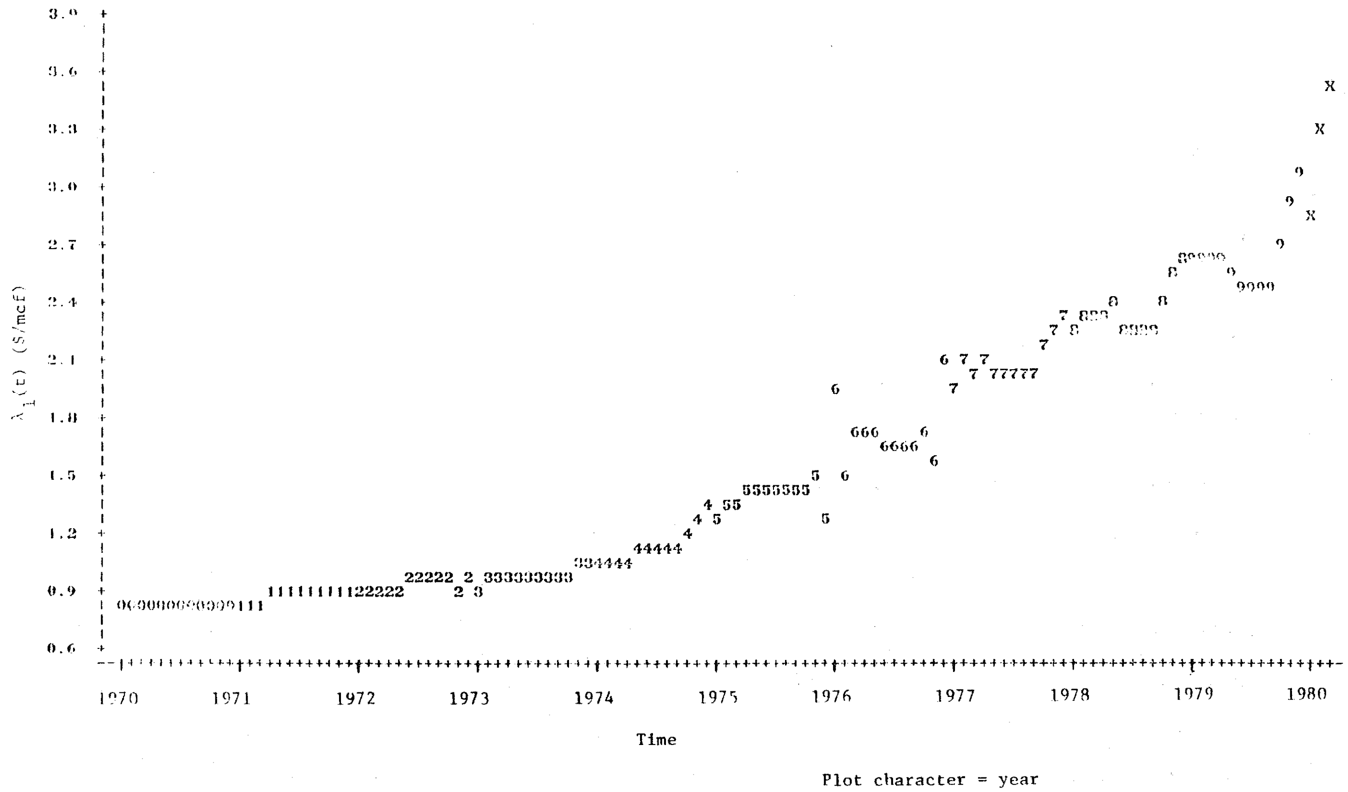


Fig. 14 Parameter path for the slope term, $\alpha_1(t)$.
of the marginal price model: Columbia Gas of Ohio

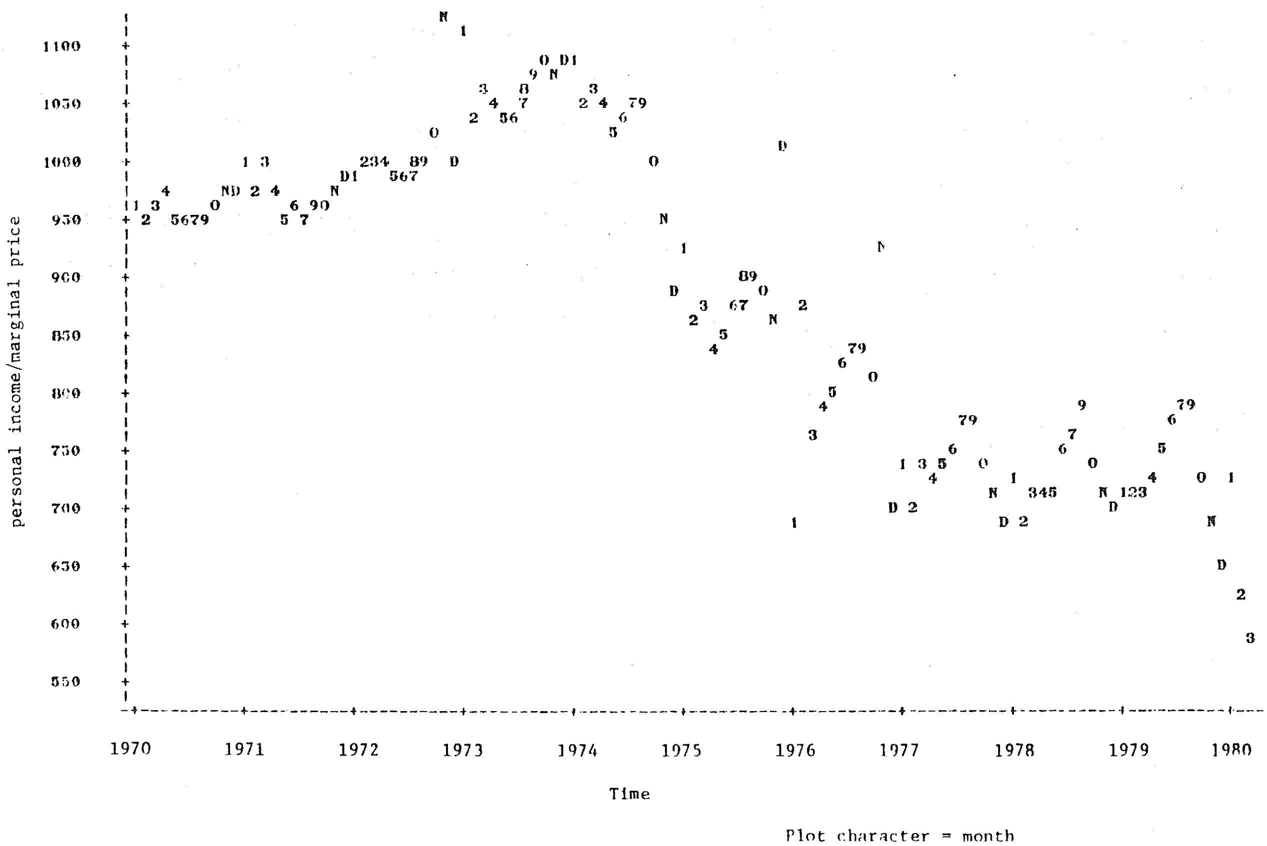


Fig. 15 Time series plot of national personal income divided by natural marginal price: Columbia Gas of Ohio

from mid-1977 through the beginning of 1980. The problem is, then, to find a model using available variables to produce such behavior as in $\hat{\alpha}_1(t)$. Exploratory analysis provided an answer in figure 15: the ratio $I/P_1$ qualitatively follows the same pattern as $\hat{\alpha}_1(t)$ over time. Therefore, it was decided to use this ratio to expand $\hat{\alpha}_1(t)$ in a model of the form

$$\hat{\alpha}_1(t) = \hat{\gamma}_1(I/P_1)^{\hat{\gamma}_2} \quad (7)$$

in order to match $\hat{\alpha}_1(t)$ and $I/P_1$ quantitatively. In raw data form, $I/P_1$ declines proportionally more than $\hat{\alpha}_1(t)$ so that $\hat{\gamma}_2 < 1$ is expected. Values for $\hat{\gamma}_2$ were found to be roughly 0.5 for Cincinnati Gas and Electic and East Ohio Gas, and 0.7 for the remaining two companies.

### 4.3 The Final Model

The results of the top-level model and expansion modeling of sections 4.1 and 4.2 provide the final model specification

$$Q_1/N = \beta_o + \beta_1 \; (I/P_1)^{\gamma_2} \cdot D + \beta_2 E \cdot D + \beta_3 \; T \cdot D + \varepsilon \quad (8)$$

where $\gamma_2$ has the value of 0.5 or 0.7 depending on the distribution utility as given in the previous section. It is not desirable to estimate $\gamma_2$ simultaneously with parameters $\beta_o, \cdots, \beta_3$ since this would call for a nonlinear estimation procedure. Fortunately, the expansion modeling step provides estimates for $\gamma_2$ that are usable here. Note that it is unlikely that the term involving $I/P_1$ would have been discovered using a conventional modeling procedure. Also note that the term involving T is included here in spite of the evidence from the top-level model that the tax rebate program was ineffective. The inclusion of this term provides a further test as to whether or not the tax rebate program was effective. Both E and T are linked to space-heating uses of natural gas, and so, are interacted with D.

Table 2 summarizes the OLS estimates of model (8) for the four distribution utilities of the case study. The coefficients for the intercept and income price degree day terms are highly significant; whereas, the emergency coefficient is insignificant, and the tax credit program is insignificant or has the incorrect sign for all but the East Ohio Gas Company. Thus, it appears as if income and price effects in combination with degree days, as expected, explain most of the variation in comsumption. The standard errors of estimates in table 2 are seen to be about a tenth of the average gas consumption, and $R^2$ ranges between 0.969 to 0.986. These are indicators of a good fit to the data. At a significance level of 0.01, the Durbin-Watson test concludes that there is no serial correlation in the estimated models.

Table 3 shows the conservation achieved between January 1974 and January 1978 for all four utilities. Calculations were made here using D = 900°F, roughly the normal winter monthly degree days, to control for temperature differences. The total savings of 16% to 27% compares favorably to similar estimates made from the top-level model in section 4.2.2. Since model (8) of this section is expanded, it is now possible to decompose the total savings of gas per customer into component parts. Thus, table 3 shows the percentage of total savings due to income-price effects versus the tax credit program. Except for East Ohio, 90% to 97% of the savings were due to income-price effects. It is believed that the East Ohio results are not valid, that an alternative transformation of $I/P_1$ would eliminate the impact of the tax credit dummy variable.

## 4.4 A Final Diagnostic Check

A goal of the top-down modeling procedure is effectively to guide the analyst in building a complete, constant-parameter model. Systematic variation of TVPs is an indication of missing variables and/or incorrect functional form and in both such cases the model is incomplete. The Durbin-Watson statistics of table 2 indicated no serial correlation in the estimated model (8). This means, possibly, that no systematic variation in parameter paths remains. As a direct check on this conclusion, the TVP version of model (8) was estimated via AEP using the following constants:

TABLE 2

REGRESSION MODEL RESULTS FOR EVALUATION OF
RESIDENTIAL NATURAL GAS CONSERVATION

| | Parameter Estimates | | | | Statistics | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Company | Intercept | (Income/Price)$^{\gamma_2}$ Degree Days | Emergency Degree Days | Tax Credit Degree Days | Number of Observations | F-Value | Standard Error | Average Consumption per Customer | Durbin-Watson Statistic | $R^2$ |
| Cincinnati Gas & Electric | 0.00250* | 0.000000810* | 0.000000421 | -0.000000256 | 123 | 2268 | 0.0012 | 0.0130 | 1.59 | 0.982 |
| Columbia Gas of Ohio | 0.00314* | 0.000000197* | -0.000000118 | 0.000000601° | 123 | 2696 | 0.0012 | 0.0142 | 2.07 | 0.986 |
| Dayton Power & Light | 0.00264* | 0.000000184* | 0.000000518 | 0.000000005+ | 123 | 1266 | 0.0016 | 0.0131 | 1.69 | 0.969 |
| East Ohio Gas | 0.00350* | 0.000000844* | 0.000000854 | -0.000001462* | 121 | 2330 | 0.0014 | 0.0168 | 1.84 | 0.984 |

1 * = 0.01 or better significance level for two-sided t test
+ = 0.01 to 0.05 significance
° = .05 to 0.10 significance

2 $\gamma_2$ = 0.5 for Cincinnati Gas and Electric and East Ohio Gas
$\gamma_2$ = 0.7 for Columbia Gas and Dayton Power and Light

TABLE 3

ESTIMATED RESIDENTIAL NATURAL GAS CONSERVATION
(mmcf/mo. with Percentages in Parentheses)*

| | Per Capita Consumption, January 1974 | Per Capita Consumption, January 1978 | Total Savings | $I/P_1$ Savings | Tax Rebate Savings |
|---|---|---|---|---|---|
| Cincinnati Gas & Electric | 0.0249 (100) | 0.0210 (84) | 0.0039 (16) | 0.0038 (97) | 0.0001 (3) |
| Columbia Gas of Ohio | 0.0268 (100) | 0.0206 (77) | 0.0062 (23) | 0.0058 (94) | 0.0003 (5) |
| Dayton Power & Light | 0.0254 (100) | 0.0186 (73) | 0.0068 (27) | 0.0061 (90) | 0.0005 (7) |
| East Ohio Gas | 0.0288 (100) | 0.0242 (084) | 0.0046 (16) | 0.0029 (63) | 0.0014 (30) |

*These estimates use model (8) with estimates from table 2 and data from appendix A. D = 900°F was used in all calculations.

damping factor = 0.06; smoothing constant for means of explanatory variables = 0.01; correction limit = 0.2 $\beta_o(0) = \beta_3(0) = -1$, $\beta_1(0) = \beta_2(0) = 1$; and the number of forward and backwards cycles through the data = 30.

Figures 16 through 19 show the results for $\beta_1(t)$, the coefficient of $(I/P_1)^{\gamma_2} \cdot D$, for each of the four utilities in the case study. As indicated in tables 2 and 3, this is by far the most important term of the model. Indicated on each graph is the percentage decline from the maximum value vertically to the minimum value. These declines are considerably smaller than those of comparable values for the top-level model coefficient $\hat{\alpha}_1(t)$, the coefficient of D.

First, in viewing these figures, all but the East Ohio Gas Company show a similar pattern of decline from 1971 until 1974, followed by an increase throughout the rest of the study period. This pattern is believed merely to be a further transformation of the power law transformation used in the expansion of $\hat{\alpha}_1(t)$ from the top-level model. In other words, the transformation using $\hat{\gamma}_2$ in $(I/P)^{\hat{\gamma}_2} \cdot D$ was inadequate so that AEP, via the parameter paths in figures 16 through 18, is further transforming the data to improve the fit. A similar argument can be made for figure 19.

Declines from maximum to minimum values are 28%, 26%, 28%, and 22% respectively for figures 5, 7, 9, and 11 of the top-level model. The declines in figures 16 through 19 of 10%, 4%, 14%, and 5% show significant improvement of the final, expanded model versus the top-level model.

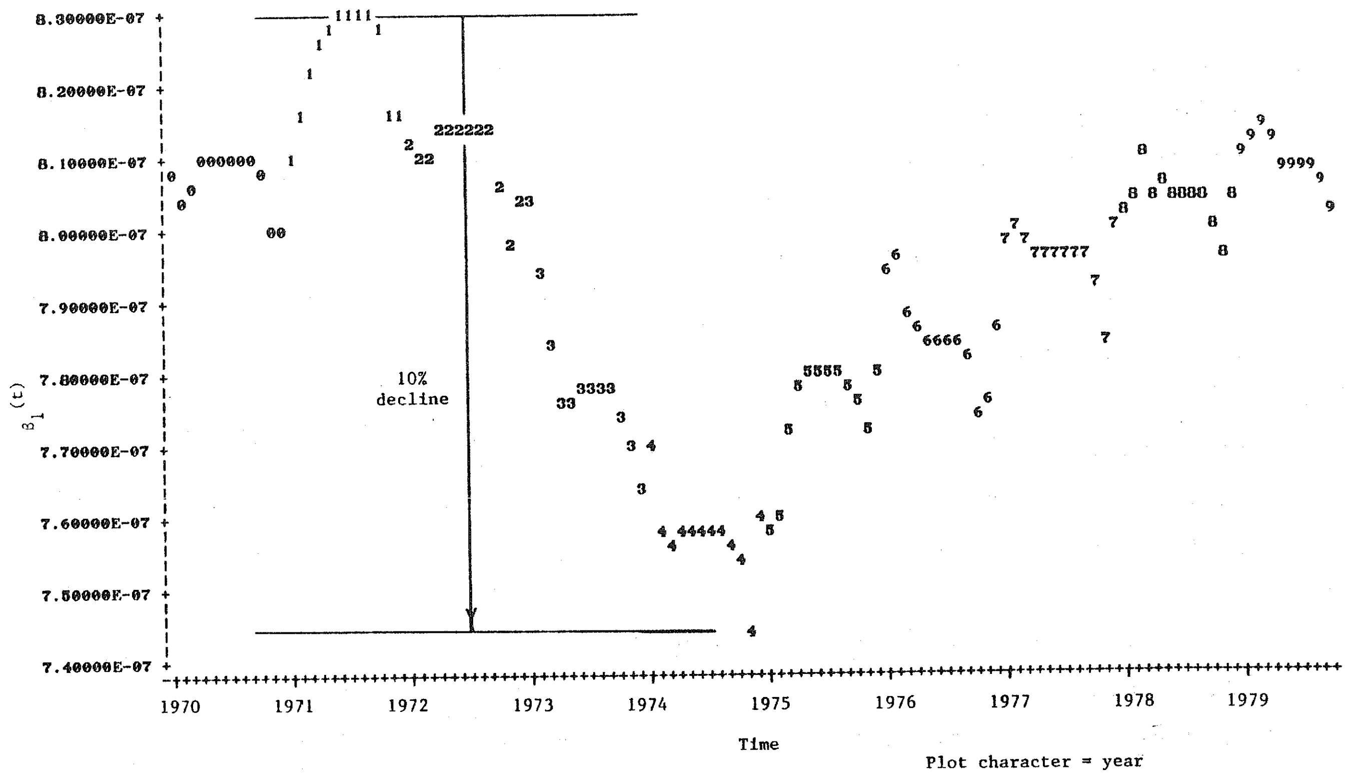


Fig. 16 Parameter path for the $(I/P_1)^{\alpha_2} \cdot D$ term of the expanded model: Cincinnati Gas and Electric

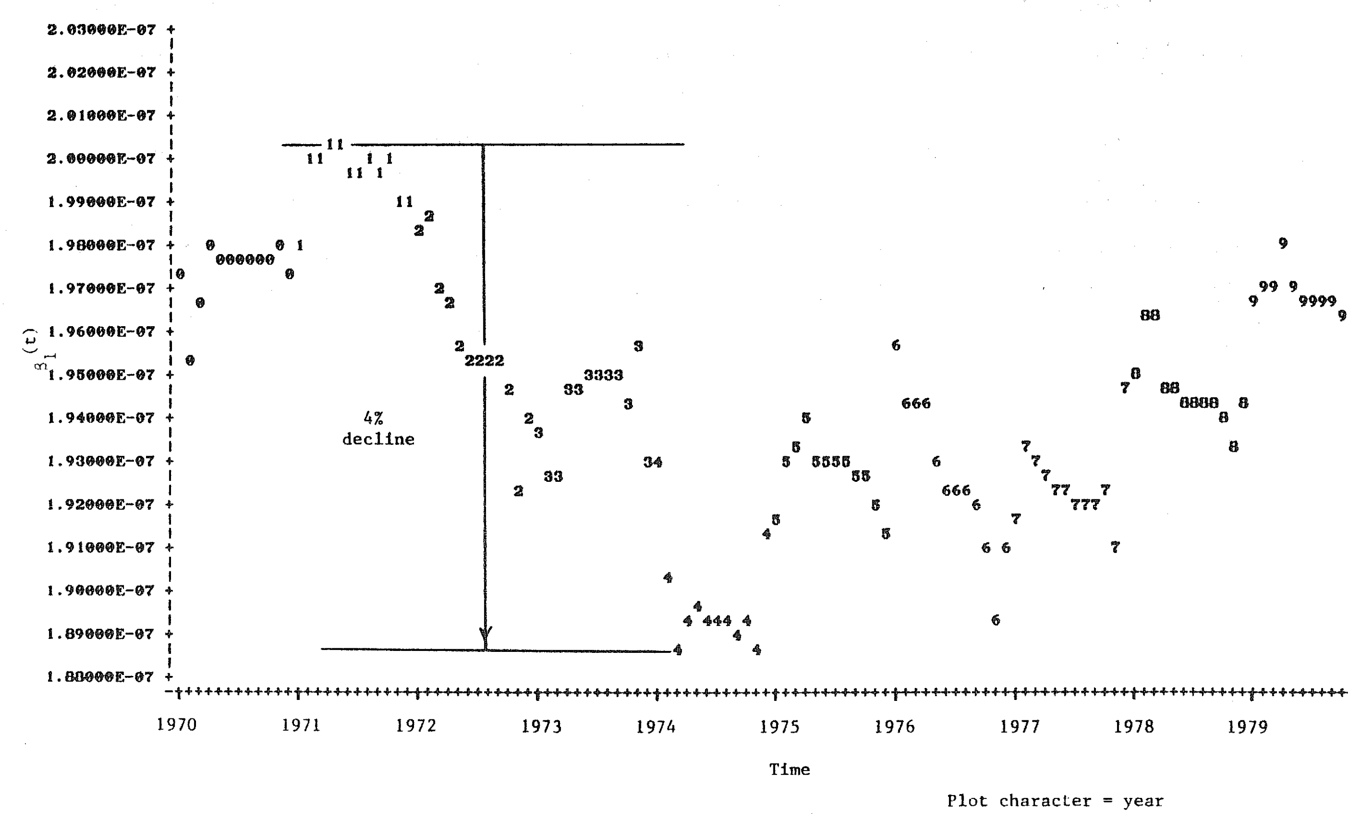


Fig. 17 Parameter path for the $(I/P_1)^{\alpha_2} \cdot D$ term of the expanded model: Columbia Gas of Ohio

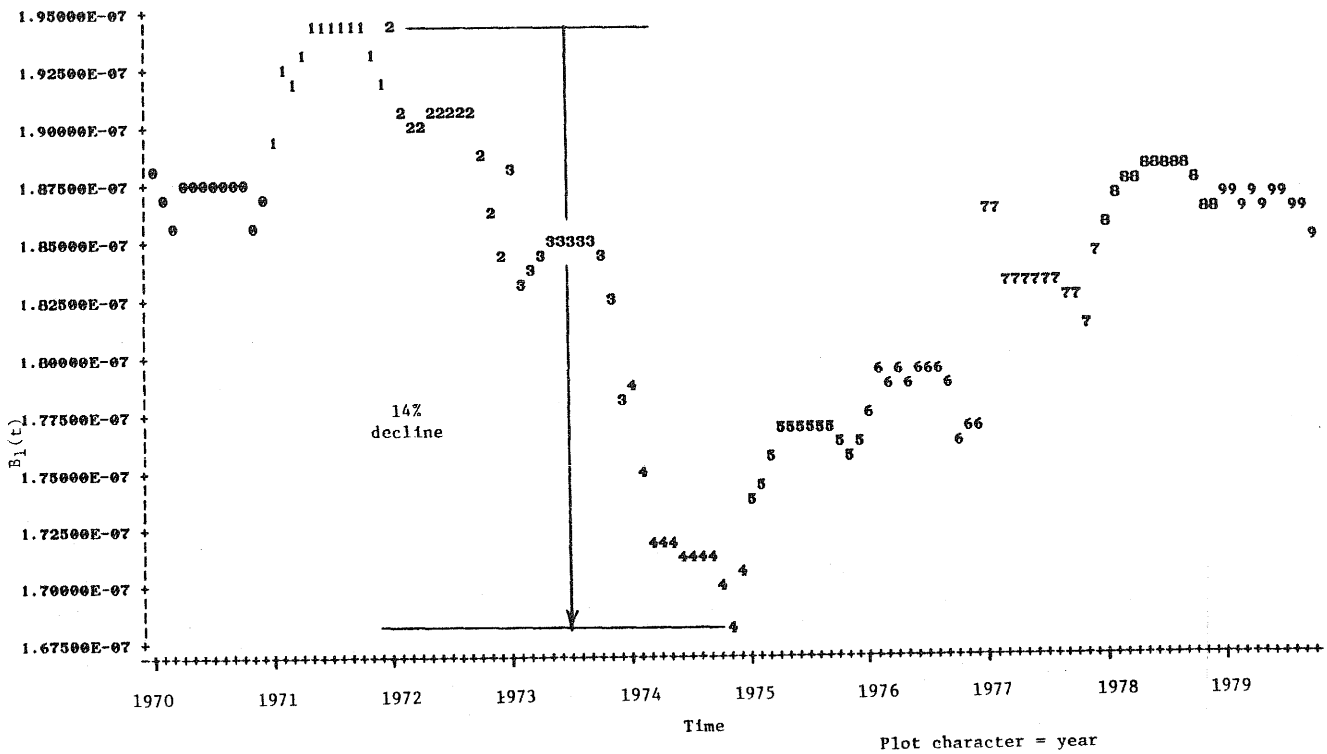


Fig. 18 Parameter path for the $(I/P_1)^{\alpha 2}$ . D term of the expanded model: Dayton Power and Light

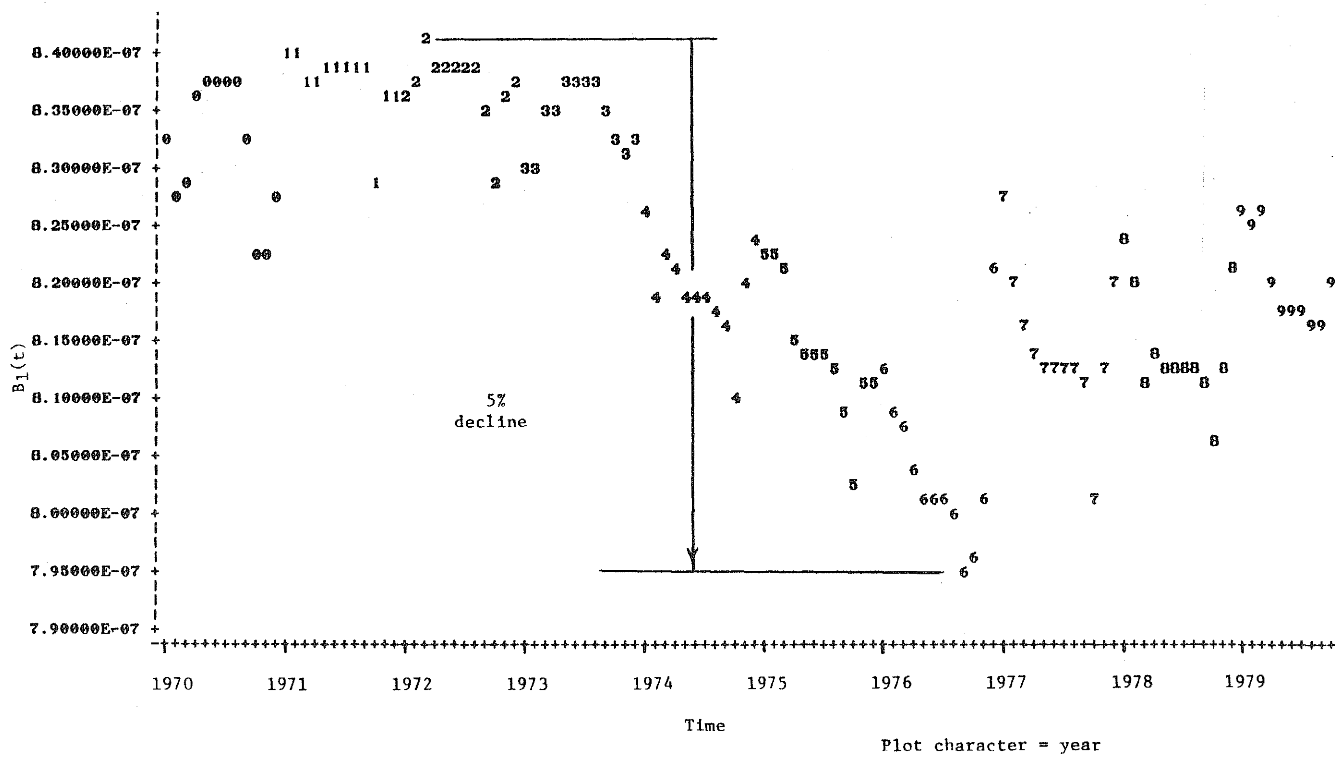


Fig. 19 Parameter path for the $(I/P_1)^{\alpha 2}$ . D term of the expanded model: East Ohio Gas

## 5. Summary

This paper started with a review of long-term trends in space-heat consumption. For a long period until the early 1970s, per capita energy consumption grew strongly as personal income increased faster than the price of space-heat fuel and power. After the October 1973 Arab oil embargo, trends reversed with fuel shortages giving rise to the need for conservation by consumers. Several conservation pressures or incentives were experienced by residential natural gas customers in Ohio including natural gas price hikes starting in 1974, an appeal for emergency conservation during the 1976-77 gas emergency, and the Carter administration's tax credit program that was approved in April of 1977 but probably did not affect consumption, if at all, until late 1977. These conservation pressures were separated nicely over time, and thus, their individual impacts on total conservation should be separable using statistical methods. Intertwined throughout the period of conservation with these conservation measures is the impact of pressures for voluntary conservation. No data on the intensity of voluntarism pressures are available, but even if they were, this component of conservation is not likely to be separable. As a result, conservation impacts due to voluntarism, if any, are mistakenly attributed to the factors for which data are available.

Section 2 of this paper reviewed conventional energy demand models that attempt to explain consumption patterns through price and income effects, and heating (or cooling) degree days. Many researchers notice a limitation in such models that shows up strongly; namely, the behavior of consumers is dynamic and often not accountable through constant-parameter models estimated by ordinary least squares regression. Furthermore, the conventional models failed to produce useful results for the case studies of this paper due to multicollinearity of natural gas price and personal income. Thus, in section 3, this paper introduced the application of time-varying-parameter models estimated by the adaptive estimation procedure as a means to capture dynamic behavior and to identify a new energy demand model. The combination of time-varying-parameter and constant-parameter models leads to a somewhat new approach to modeling that provides new information to the analyst in constructing models.

Section 4 presented comprehensive case studies on natural gas consumption in the residential sectors of Cincinnati Gas and Electric, Columbia Gas of Ohio, Inc., Dayton Power and Light, and East Ohio Gas. Top-level time-varying-parameter models of per customer consumption, using only heating degree days as an explanatory variable, showed from 14% to 20% conservation over the period from January 1974 to January 1978. The preliminary model provided strong evidence that the tax credit program had little impact on total conservation. Perhaps, this program converted temporary behavior, such as reduced thermostat settings, into more permanent conservation measures such as the implementation of weatherization materials.

Section 4 also presented expanded consumption models that included additional explanatory variables. These variables included personal income, marginal natural gas price estimated via a time-varying-parameter model, and dummy variables for the gas emergency and the tax rebate program. Almost all of the total conservation was found to be attributable to income and price effects.

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Appendix A

<u>Listing, Documentation, and Discussion of Raw Data</u>

Tables A-1 through A-4 list data on monthly natural gas consumption in the residential sectors of Cincinnati Gas and Electric Company, Columbia Gas of Ohio, Inc., Dayton Power and Light Company, and the East Ohio Gas Company respectively. The text of this appendix documents and discusses the variables of these tables.

Year and month are self-explanatory. Residential natural gas consumption, labeled "Gas" in the tables, and number of customers were obtained directly from the distribution utilities and from the Public Utilities Commission of Ohio. Consideration must be given to three aspects of these data: (1) they are aggregated from meter reading data, (2) half of each month's data from Columbia Gas are estimated, and (3) many customers are on a budget billing plan. Each aspect is discussed in turn.

First, the so-called "monthly" consumption datum for a month is actually the sum of all meter readings taken within, and a few days after, the month. The total set of customers is partitioned into 21 billing units with 21 different meter reading days in a month. Thus, consumption reported for a given month actually spans a period of two months, the given month and the previous month. Fisch et al. [A.1] have shown that a two-month moving average of heating degree days provides good estimates of such data. The moving average approach compares favorably with the alternative of modeling each billing unit separately, using the exactly corresponding degree days, and then aggregating to the equivalent monthly total. This paper uses a two-month moving average for degree days, but not for any other variables in the model. The income and price variables change slowly on a month-to-month basis so that averaging provides little benefit for these variables.

The second issue is that residential customers of Columbia Gas have meters read every other month. Consider a specific customer and two consecutive months A and B. Suppose that month A does not have a meter reading for the customer, then month A's consumption is estimated from a model determined from recent data on the customer's behavior and measured

TABLE A-1

CINCINNATI GAS AND ELECTRIC:
DATA SET ON RESIDENTIAL NATURAL GAS
CONSUMPTION AND ITS DETERMINANTS

| Year | Month | Gas (mmcf) | Number of Customers | Revenue ($$10^3$) | Marginal Price | National Income ($$10^9$) | Consumer Price Index | Degree Days (°F) |
|---|---|---|---|---|---|---|---|---|
| 70 | 1 | 8145 | 260067 | 7089 | 0.85415 | 778.8 | 113.3 | 1162 |
| 70 | 2 | 7626 | 260544 | 6691 | 0.86095 | 781.5 | 113.9 | 1110 |
| 70 | 3 | 6337 | 260688 | 5597 | 0.85783 | 787.6 | 114.5 | 876 |
| 70 | 4 | 4489 | 260585 | 4044 | 0.86862 | 806.0 | 115.2 | 531 |
| 70 | 5 | 1844 | 260038 | 1800 | 0.87979 | 799.7 | 115.7 | 178 |
| 70 | 6 | 1036 | 259154 | 1101 | 0.88730 | 798.2 | 116.3 | 47 |
| 70 | 7 | 878 | 258022 | 963 | 0.89227 | 803.3 | 116.7 | 3 |
| 70 | 8 | 804 | 258823 | 899 | 0.89580 | 806.4 | 116.9 | 2 |
| 70 | 9 | 815 | 259077 | 910 | 0.89829 | 811.9 | 117.5 | 14 |
| 70 | 10 | 1284 | 260095 | 1312 | 0.89515 | 813.6 | 118.1 | 120 |
| 70 | 11 | 2862 | 261448 | 2663 | 0.87669 | 815.7 | 118.5 | 402 |
| 70 | 12 | 5410 | 262478 | 4804 | 0.84790 | 820.9 | 119.1 | 710 |
| 71 | 1 | 7751 | 263276 | 6781 | 0.86089 | 830.0 | 119.2 | 981 |
| 71 | 2 | 7868 | 263926 | 6919 | 0.85615 | 833.2 | 119.4 | 1007 |
| 71 | 3 | 6695 | 264187 | 5955 | 0.87244 | 839.7 | 119.8 | 820 |
| 71 | 4 | 4711 | 263943 | 4377 | 0.89969 | 844.4 | 120.2 | 555 |
| 71 | 5 | 2674 | 263409 | 2772 | 0.95090 | 850.0 | 120.8 | 254 |
| 71 | 6 | 1430 | 262794 | 1600 | 0.96542 | 870.1 | 121.5 | 79 |
| 71 | 7 | 939 | 262194 | 1116 | 0.97040 | 859.2 | 121.8 | 0 |
| 71 | 8 | 876 | 261982 | 1052 | 0.97275 | 867.6 | 122.2 | 0 |
| 71 | 9 | 896 | 262357 | 1075 | 0.97504 | 871.5 | 122.4 | 16 |
| 71 | 10 | 1096 | 263232 | 1265 | 0.97528 | 874.8 | 122.6 | 80 |
| 71 | 11 | 2419 | 264287 | 2538 | 0.97084 | 879.4 | 122.6 | 389 |
| 71 | 12 | 5455 | 265698 | 5436 | 0.95590 | 890.4 | 123.1 | 690 |
| 72 | 1 | 6455 | 266727 | 6421 | 0.97193 | 898.9 | 123.2 | 902 |
| 72 | 2 | 7687 | 267882 | 7598 | 0.95355 | 908.5 | 123.8 | 1049 |
| 72 | 3 | 6688 | 267789 | 6653 | 0.97599 | 913.6 | 124.0 | 888 |
| 72 | 4 | 4817 | 267500 | 4870 | 0.96904 | 919.4 | 124.3 | 563 |
| 72 | 5 | 2462 | 266774 | 2618 | 0.97891 | 924.0 | 124.7 | 245 |
| 72 | 6 | 1357 | 266161 | 1545 | 0.98376 | 922.9 | 125.0 | 98 |
| 72 | 7 | 1082 | 265601 | 1272 | 0.98573 | 932.9 | 125.5 | 41 |
| 72 | 8 | 841 | 265330 | 1037 | 0.98743 | 940.0 | 125.7 | 3 |
| 72 | 9 | 927 | 265330 | 1123 | 0.98875 | 946.8 | 126.2 | 14 |
| 72 | 10 | 1543 | 266223 | 1753 | 0.99492 | 967.0 | 126.6 | 214 |
| 72 | 11 | 3986 | 267583 | 4179 | 0.99693 | 977.6 | 126.9 | 569 |
| 72 | 12 | 6730 | 268824 | 6850 | 0.97885 | 983.6 | 127.3 | 812 |
| 73 | 1 | 7340 | 269580 | 7442 | 0.99332 | 989.1 | 127.7 | 958 |
| 73 | 2 | 6786 | 270052 | 6868 | 0.97212 | 997.[illegible] | 128.6 | 957 |
| 73 | 3 | 5474 | 270271 | 5618 | 0.99699 | 100[illegible] | 129.8 | 800 |
| 73 | 4 | 4050 | 270288 | 4247 | 0.99760 | 1011.6 | 130.7 | 568 |
| 73 | 5 | 2949 | 269825 | 3173 | 1.003[illegible] | 1018.7 | 131.5 | 320 |
| 73 | 6 | 1543 | 269350 | 1847 | 1.025[illegible] | 1026.[illegible] | 132.4 | 105 |
| 73 | 7 | 887 | 268989 | 1166 | 1.034[illegible] | 1035.[illegible] | 132.7 | 2 |
| 73 | 8 | 834 | 268801 | 1111 | 1.039[illegible] | 1047.3 | 135.1 | 1 |
| 73 | 9 | 900 | 269056 | 1188 | 1.044[illegible] | 1058.5 | 135.5 | 14 |
| 73 | 10 | 1165 | 270081 | 1485 | 1.052[illegible] | 1090.8 | 136.6 | 122 |
| 73 | 11 | 3270 | 271440 | 3728 | 1.064[illegible] | 1100.0 | 137.6 | 400 |
| 73 | 12 | 5316 | 272182 | 5906 | 1.06533 | 1107.1 | 138.5 | 734 |
| 74 | 1 | 7293 | 272531 | 8088 | 1.08532 | 1107.0 | 139.7 | 933 |
| 74 | 2 | 5886 | 272799 | 6690 | 1.10010 | 1113.4 | 141.5 | 882 |
| 74 | 3 | 5326 | 272734 | 6178 | 1.11910 | 1117.1 | 143.1 | 727 |
| 74 | 4 | 4018 | 272291 | 4826 | 1.13987 | 1125.2 | 144.0 | 462 |
| 74 | 5 | 2318 | 271368 | 3064 | 1.18247 | 1135.2 | 145.6 | 247 |
| 74 | 6 | 1291 | 270713 | 1801 | 1.18359 | 1143.5 | 147.1 | 96 |
| 74 | 7 | 971 | 270289 | 1400 | 1.17906 | 1159.5 | 148.3 | 16 |
| 74 | 8 | 878 | 269915 | 1297 | 1.17794 | 1167.2 | 150.2 | 0 |
| 74 | 9 | 1055 | 269951 | 1541 | 1.18568 | 1178.0 | 151.9 | 74 |
| 74 | 10 | 2141 | 270448 | 2965 | 1.22620 | 1185.0 | 153.2 | 259 |
| 74 | 11 | 3078 | 270899 | 4196 | 1.26264 | 1184.5 | 154.3 | 493 |
| 74 | 12 | 6465 | 271391 | 8894 | 1.38320 | 1191.0 | 155.4 | 778 |

TABLE A-1
(continued)

| Year | Month | Gas (mmcf) | Number of Customers | Revenue ($\$10^3$) | Marginal Price | National Income ($\$10^9$) | Consumer Price Index | Degree Days (°F) |
|---|---|---|---|---|---|---|---|---|
| 75 | 1 | 6516 | 271596 | 948 | 1.35731 | 1191.1 | 156.1 | 9230 |
| 75 | 2 | 6197 | 271672 | 864 | 1.35015 | 1193.4 | 157.2 | 8693 |
| 75 | 3 | 6096 | 271571 | 776 | 1.46138 | 1195.7 | 157.8 | 8949 |
| 75 | 4 | 4760 | 271192 | 607 | 1.53563 | 1203.1 | 158.6 | 7556 |
| 75 | 5 | 2367 | 270460 | 243 | 1.55078 | 1214.3 | 159.3 | 4028 |
| 75 | 6 | 1053 | 269731 | 30 | 1.53531 | 1244.1 | 160.6 | 1906 |
| 75 | 7 | 800 | 269203 | 8 | 1.51755 | 1238.9 | 162.3 | 1477 |
| 75 | 8 | 806 | 268775 | 3 | 1.46946 | 1255.9 | 162.8 | 1324 |
| 75 | 9 | 954 | 268687 | 71 | 1.47762 | 1270.9 | 163.3 | 1704 |
| 75 | 10 | 1786 | 269286 | 193 | 1.49553 | 1290.8 | 164.6 | 2981 |
| 75 | 11 | 2626 | 269693 | 359 | 1.51467 | 1300.2 | 165.6 | 4278 |
| 75 | 12 | 5377 | 270074 | 661 | 1.54533 | 1308.2 | 166.3 | 8539 |
| 76 | 1 | 7612 | 270423 | 1008 | 1.64813 | 1320.8 | 166.7 | 12420 |
| 76 | 2 | 6592 | 270456 | 919 | 1.63323 | 1331.4 | 167.1 | 11108 |
| 76 | 3 | 3988 | 270256 | 614 | 1.64585 | 1341.9 | 167.5 | 6856 |
| 76 | 4 | 3233 | 269808 | 440 | 1.62220 | 1352.5 | 168.2 | 5531 |
| 76 | 5 | 2170 | 269395 | 249 | 1.60812 | 1362.9 | 169.2 | 3760 |
| 76 | 6 | 1231 | 268816 | 91 | 1.59890 | 1370.4 | 170.1 | 2232 |
| 76 | 7 | 842 | 268221 | 3 | 1.60084 | 1380.8 | 171.1 | 1639 |
| 76 | 8 | 847 | 267804 | 2 | 1.60950 | 1385.5 | 171.9 | 1678 |
| 76 | 9 | 930 | 267863 | 38 | 1.64474 | 1391.7 | 172.6 | 1933 |
| 76 | 10 | 1730 | 268365 | 285 | 1.79912 | 1414.2 | 173.3 | 3744 |
| 76 | 11 | 4687 | 268940 | 696 | 2.12238 | 1432.1 | 173.8 | 9958 |
| 76 | 12 | 6810 | 269248 | 1025 | 2.26020 | 1450.2 | 174.3 | 15365 |
| 77 | 1 | 8801 | 269466 | 1399 | 2.29157 | 1454.3 | 175.3 | 20441 |
| 77 | 2 | 7951 | 269469 | 1310 | 2.30107 | 1477.0 | 177.1 | 18694 |
| 77 | 3 | 4708 | 269203 | 776 | 2.38664 | 1499.1 | 178.2 | 11590 |
| 77 | 4 | 2837 | 268725 | 424 | 2.39369 | 1510.1 | 179.6 | 7250 |
| 77 | 5 | 1645 | 267886 | 172 | 2.39911 | 1517.3 | 180.6 | 4413 |
| 77 | 6 | 964 | 266875 | 52 | 2.41007 | 1524.3 | 181.8 | 2815 |
| 77 | 7 | 865 | 266111 | 18 | 2.41676 | 1539.2 | 182.6 | 2577 |
| 77 | 8 | 787 | 265514 | 1 | 2.42629 | 1540.7 | 183.3 | 2412 |
| 77 | 9 | 808 | 265365 | 17 | 2.45036 | 1556.9 | 184.0 | 2540 |
| 77 | 10 | 1530 | 266199 | 212 | 2.51410 | 1577.0 | 184.5 | 4492 |
| 77 | 11 | 2617 | 266692 | 489 | 2.56608 | 1592.7 | 185.4 | 7296 |
| 77 | 12 | 5944 | 267203 | 852 | 2.50149 | 1609.2 | 186.1 | 15564 |
| 78 | 1 | 7419 | 267352 | 1279 | 2.50997 | 1615.5 | 187.2 | 19121 |
| 78 | 2 | 8020 | 267494 | 1372 | 2.52217 | 1625.0 | 188.4 | 20707 |
| 78 | 3 | 6690 | 267409 | 1092 | 2.60638 | 1646.3 | 189.8 | 17715 |
| 78 | 4 | 3460 | 266626 | 613 | 2.63284 | 1669.4 | 191.5 | 9661 |
| 78 | 5 | 2301 | 265997 | 277 | 2.62856 | 1682.1 | 193.3 | 6591 |
| 78 | 6 | 1204 | 265369 | 109 | 2.65223 | 1695.7 | 195.3 | 3810 |
| 78 | 7 | 804 | 264557 | 5 | 2.65299 | 1730.0 | 196.7 | 2698 |
| 78 | 8 | 701 | 264128 | 0 | 2.65372 | 1741.3 | 197.8 | 2426 |
| 78 | 9 | 834 | 262571 | 11 | 2.65676 | 1756.1 | 199.3 | 2790 |
| 78 | 10 | 1464 | 264656 | 201 | 2.66910 | 1781.0 | 200.9 | 4504 |
| 78 | 11 | 2892 | 265221 | 467 | 2.68238 | 1891.4 | 202.0 | 8340 |
| 78 | 12 | 4917 | 265865 | 722 | 2.68909 | 1826.8 | 202.9 | 13789 |
| 79 | 1 | 7126 | 266219 | 1120 | 2.65439 | 1834.3 | 204.7 | 19616 |
| 79 | 2 | 7768 | 266429 | 1282 | 2.68488 | 1851.4 | 207.1 | 21302 |
| 79 | 3 | 5703 | 266327 | 890 | 2.66813 | 1872.1 | 209.1 | 15827 |
| 79 | 4 | 3424 | 265822 | 494 | 2.66741 | 1880.7 | 211.5 | 9707 |
| 79 | 5 | 1984 | 265097 | 302 | 2.67000 | 1891.6 | 214.1 | 5876 |
| 79 | 6 | 1159 | 264366 | 97 | 2.67137 | 1905.1 | 216.6 | 3675 |
| 79 | 7 | 855 | 263765 | 8 | 2.66889 | 1933.2 | 218.9 | 2849 |
| 79 | 8 | 760 | 263466 | 8 | 2.65296 | 1946.5 | 221.1 | 2532 |
| 79 | 9 | 843 | 263604 | 37 | 2.69924 | 1960.1 | 223.4 | 2991 |
| 79 | 10 | 1516 | 264336 | 218 | 2.88955 | 1981.2 | 225.4 | 5426 |
| 79 | 11 | 3095 | 265091 | 496 | 3.14004 | 2005.5 | 227.5 | 10545 |
| 79 | 12 | 4845 | 266084 | 752 | 3.19597 | 2028.3 | 229.9 | 16169 |
| 80 | 1 | 6008 | 266752 | 984 | 3.39831 | 2046.5 | 233.2 | 20686 |
| 80 | 2 | 6667 | 267156 | 1131 | 3.45069 | 2055.6 | 236.4 | 23637 |
| 80 | 3 | 6051 | 267423 | 998 | 3.42685 | 2069.6 | 239.8 | 21594 |
| 80 | 4 | . | . | . | . | . | 242.5 | 14077 |

TABLE A-2

COLUMBIA GAS OF OHIO:
DATA SET ON RESIDENTIAL NATURAL GAS
CONSUMPTION AND ITS DETERMINANTS

| Year | Month | Gas (mmcf) | Number of Customers | Revenue ($\$10^3$) | Marginal Price | National Income ($\$10^9$) | Consumer Price Index | Degree Days (°F) |
|---|---|---|---|---|---|---|---|---|
| 70 | 1 | 31033 | 915609 | 26735 | 0.81437 | 778.8 | 113.3 | 1272 |
| 70 | 2 | 27301 | 916375 | 23955 | 0.82218 | 781.5 | 113.9 | 1193 |
| 70 | 3 | 24851 | 916469 | 21998 | 0.81916 | 787.6 | 114.5 | 939 |
| 70 | 4 | 18418 | 915529 | 16824 | 0.82730 | 806.0 | 115.2 | 613 |
| 70 | 5 | 8007 | 911991 | 8441 | 0.83842 | 799.7 | 115.7 | 242 |
| 70 | 6 | 4367 | 909352 | 5468 | 0.84563 | 798.2 | 116.3 | 66 |
| 70 | 7 | 4052 | 908094 | 5224 | 0.85004 | 803.3 | 116.7 | 12 |
| 70 | 8 | 3516 | 908041 | 4771 | 0.85215 | 806.4 | 116.9 | 5 |
| 70 | 9 | 3556 | 910405 | 4835 | 0.85453 | 811.9 | 117.5 | 29 |
| 70 | 10 | 6963 | 918190 | 7486 | 0.84122 | 813.6 | 118.1 | 178 |
| 70 | 11 | 14492 | 925796 | 13764 | 0.83194 | 815.7 | 118.5 | 436 |
| 70 | 12 | 21190 | 930947 | 19461 | 0.84971 | 820.9 | 119.1 | 809 |
| 71 | 1 | 29278 | 932212 | 26155 | 0.82922 | 830.0 | 119.2 | 1100 |
| 71 | 2 | 30411 | 933347 | 27264 | 0.85227 | 833.2 | 119.4 | 1103 |
| 71 | 3 | 24805 | 933832 | 22681 | 0.84041 | 839.7 | 119.8 | 911 |
| 71 | 4 | 19112 | 932118 | 18139 | 0.86382 | 844.4 | 120.2 | 673 |
| 71 | 5 | 11036 | 930216 | 11760 | 0.89258 | 850.0 | 120.8 | 353 |
| 71 | 6 | 5103 | 927337 | 6589 | 0.90349 | 870.1 | 121.5 | 117 |
| 71 | 7 | 3818 | 925734 | 5409 | 0.90716 | 859.2 | 121.8 | 4 |
| 71 | 8 | 3402 | 926277 | 5015 | 0.90808 | 867.6 | 122.2 | 4 |
| 71 | 9 | 3647 | 929641 | 5124 | 0.90331 | 871.5 | 122.4 | 29 |
| 71 | 10 | 6222 | 936709 | 7627 | 0.91034 | 874.8 | 122.6 | 117 |
| 71 | 11 | 13007 | 945019 | 13702 | 0.90726 | 879.4 | 122.6 | 457 |
| 71 | 12 | 21292 | 950757 | 21167 | 0.90371 | 890.4 | 123.1 | 774 |
| 72 | 1 | 25808 | 952768 | 25384 | 0.91452 | 898.9 | 123.2 | 974 |
| 72 | 2 | 29933 | 954541 | 29227 | 0.91966 | 908.5 | 123.8 | 1105 |
| 72 | 3 | 24562 | 955390 | 24390 | 0.91816 | 913.6 | 124.0 | 969 |
| 72 | 4 | 18830 | 954622 | 19259 | 0.92158 | 919.4 | 124.3 | 671 |
| 72 | 5 | 9122 | 952148 | 10537 | 0.93358 | 924.0 | 124.7 | 314 |
| 72 | 6 | 5232 | 949492 | 6959 | 0.93937 | 922.9 | 125.0 | 124 |
| 72 | 7 | 4954 | 949235 | 6685 | 0.94129 | 932.9 | 125.5 | 62 |
| 72 | 8 | 4130 | 949714 | 5947 | 0.94390 | 940.0 | 125.7 | 20 |
| 72 | 9 | 4190 | 954875 | 6028 | 0.94629 | 946.8 | 126.2 | 48 |
| 72 | 10 | 8930 | 958765 | 10483 | 0.94585 | 967.0 | 126.6 | 275 |
| 72 | 11 | 16128 | 965903 | 16087 | 0.86855 | 977.6 | 126.9 | 600 |
| 72 | 12 | 24028 | 970857 | 24465 | 0.98085 | 983.6 | 127.3 | 808 |
| 73 | 1 | 27516 | 972401 | 27713 | 0.89360 | 989.1 | 127.7 | 965 |
| 73 | 2 | 26192 | 973807 | 26370 | 0.96021 | 997.4 | 128.6 | 988 |
| 73 | 3 | 20508 | 973955 | 21403 | 0.94021 | 1003.3 | 129.8 | 689 |
| 73 | 4 | 16261 | 972622 | 17645 | 0.96271 | 1011.6 | 130.7 | 436 |
| 73 | 5 | 10989 | 970817 | 12885 | 0.97864 | 1018.7 | 131.5 | 306 |
| 73 | 6 | 5847 | 967537 | 7908 | 0.98415 | 1026.6 | 132.4 | 92 |
| 73 | 7 | 4381 | 966705 | 6495 | 0.98776 | 1035.6 | 132.7 | 0 |
| 73 | 8 | 3282 | 966444 | 5367 | 0.98742 | 1047.3 | 135.1 | 2 |
| 73 | 9 | 3632 | 965511 | 5755 | 0.98919 | 1058.5 | 135.5 | 19 |
| 73 | 10 | 5716 | 968962 | 8077 | 1.00392 | 1090.8 | 136.6 | 127 |
| 73 | 11 | 15037 | 973888 | 17559 | 1.01931 | 1100.0 | 137.6 | 404 |
| 73 | 12 | 20386 | 976935 | 22994 | 1.01685 | 1107.1 | 138.5 | 776 |
| 74 | 1 | 27700 | 977750 | 30504 | 1.02277 | 1107.0 | 139.7 | 970 |
| 74 | 2 | 24084 | 977791 | 27519 | 1.06403 | 1113.4 | 141.5 | 959 |
| 74 | 3 | 20349 | 977324 | 23693 | 1.04692 | 1117.1 | 143.1 | 784 |
| 74 | 4 | 15962 | 975101 | 19435 | 1.07448 | 1125.2 | 144.0 | 480 |
| 74 | 5 | 9510 | 972026 | 13109 | 1.10663 | 1135.2 | 145.6 | 255 |
| 74 | 6 | 4958 | 968151 | 7946 | 1.10766 | 1143.5 | 147.1 | 105 |
| 74 | 7 | 4228 | 965461 | 7142 | 1.10831 | 1159.5 | 148.3 | 16 |
| 74 | 8 | 3653 | 961736 | 6501 | 1.10843 | 1167.2 | 150.2 | 0 |
| 74 | 9 | 4424 | 965809 | 7555 | 1.11821 | 1178.0 | 151.9 | 65 |
| 74 | 10 | 9443 | 970579 | 14233 | 1.18667 | 1185.0 | 153.2 | 252 |
| 74 | 11 | 13612 | 973576 | 19888 | 1.24904 | 1184.5 | 154.3 | 492 |
| 74 | 12 | 22763 | 975744 | 32841 | 1.34987 | 1191.0 | 155.4 | 782 |

TABLE A-2
(continued)

| Year | Month | Gas (mmcf) | Number of Customers | Revenue ($\$10^3$) | Marginal Price | National Income ($\$10^9$) | Consumer Price Index | Degree Days ($^oF$) |
|---|---|---|---|---|---|---|---|---|
| 75 | 1 | 25279 | 975188 | 36311 | 1.29432 | 1191.1 | 156.1 | 977 |
| 75 | 2 | 25121 | 974895 | 36707 | 1.37547 | 1193.4 | 157.2 | 939 |
| 75 | 3 | 22326 | 973908 | 33619 | 1.36579 | 1195.7 | 157.8 | 864 |
| 75 | 4 | 18558 | 972051 | 29393 | 1.42920 | 1203.1 | 158.6 | 696 |
| 75 | 5 | 8307 | 968193 | 15099 | 1.43332 | 1214.3 | 159.3 | 308 |
| 75 | 6 | 4668 | 963749 | 9690 | 1.42506 | 1244.1 | 160.6 | 46 |
| 75 | 7 | 3800 | 961822 | 8279 | 1.41356 | 1238.9 | 162.3 | 9 |
| 75 | 8 | 3311 | 960882 | 7444 | 1.40209 | 1255.9 | 162.8 | 0 |
| 75 | 9 | 4025 | 963653 | 8630 | 1.40525 | 1270.9 | 163.3 | 55 |
| 75 | 10 | 7928 | 967774 | 14953 | 1.45587 | 1290.8 | 164.6 | 216 |
| 75 | 11 | 11383 | 970772 | 20396 | 1.49926 | 1300.2 | 165.6 | 421 |
| 75 | 12 | 20253 | 973661 | 30405 | 1.28723 | 1308.2 | 166.3 | 747 |
| 76 | 1 | 28092 | 973999 | 49211 | 1.93084 | 1320.8 | 166.7 | 1118 |
| 76 | 2 | 24401 | 973467 | 44737 | 1.52537 | 1331.4 | 167.1 | 1027 |
| 76 | 3 | 16632 | 971487 | 32322 | 1.76176 | 1341.9 | 167.5 | 681 |
| 76 | 4 | 13396 | 968529 | 26770 | 1.73078 | 1352.5 | 168.2 | 505 |
| 76 | 5 | 8339 | 965561 | 17424 | 1.69556 | 1362.9 | 169.2 | 335 |
| 76 | 6 | 4777 | 960988 | 11063 | 1.66935 | 1370.4 | 170.1 | 117 |
| 76 | 7 | 3750 | 958208 | 9234 | 1.65261 | 1380.8 | 171.1 | 3 |
| 76 | 8 | 3341 | 957097 | 8723 | 1.65258 | 1385.5 | 171.9 | 17 |
| 76 | 9 | 3959 | 958923 | 9921 | 1.66139 | 1391.7 | 172.6 | 80 |
| 76 | 10 | 8813 | 963638 | 19077 | 1.73311 | 1414.2 | 173.3 | 340 |
| 76 | 11 | 17940 | 968559 | 31873 | 1.55296 | 1432.1 | 173.8 | 748 |
| 76 | 12 | 24575 | 970618 | 49169 | 2.08383 | 1450.2 | 174.3 | 1099 |
| 77 | 1 | 30958 | 970471 | 66698 | 1.97239 | 1454.3 | 175.3 | 1462 |
| 77 | 2 | 29285 | 970248 | 63512 | 2.10996 | 1477.0 | 177.1 | 1377 |
| 77 | 3 | 19021 | 969074 | 42997 | 2.04601 | 1499.1 | 178.2 | 852 |
| 77 | 4 | 11687 | 966382 | 28005 | 2.06703 | 1510.1 | 179.6 | 476 |
| 77 | 5 | 6343 | 960324 | 16674 | 2.05370 | 1517.3 | 180.6 | 214 |
| 77 | 6 | 4434 | 954783 | 12216 | 2.02085 | 1524.3 | 181.8 | 78 |
| 77 | 7 | 3562 | 951273 | 10251 | 1.99591 | 1539.2 | 182.6 | 33 |
| 77 | 8 | 3137 | 949346 | 9526 | 1.98976 | 1540.7 | 183.3 | 9 |
| 77 | 9 | 3066 | 950853 | 9784 | 2.00588 | 1556.9 | 184.0 | 27 |
| 77 | 10 | 7460 | 957318 | 20668 | 2.14169 | 1577.0 | 184.5 | 215 |
| 77 | 11 | 10662 | 961531 | 28252 | 2.23961 | 1592.7 | 185.4 | 494 |
| 77 | 12 | 21530 | 965316 | 53727 | 2.33553 | 1609.2 | 186.1 | 843 |
| 78 | 1 | 26993 | 965532 | 65915 | 2.24240 | 1615.5 | 187.2 | 1256 |
| 78 | 2 | 29259 | 965339 | 71285 | 2.34792 | 1625.0 | 188.4 | 1383 |
| 78 | 3 | 24320 | 963355 | 60733 | 2.30785 | 1646.3 | 189.8 | 1142 |
| 78 | 4 | 13901 | 959390 | 37099 | 2.36106 | 1669.4 | 191.5 | 681 |
| 78 | 5 | 9154 | 955812 | 25985 | 2.36652 | 1682.1 | 193.3 | 324 |
| 78 | 6 | 4152 | 950415 | 11880 | 2.25252 | 1695.7 | 195.3 | 123 |
| 78 | 7 | 3574 | 946050 | 12123 | 2.27580 | 1730.0 | 196.7 | 12 |
| 78 | 8 | 3042 | 943695 | 10886 | 2.28574 | 1741.3 | 197.8 | 0 |
| 78 | 9 | 3123 | 944643 | 10177 | 2.24728 | 1756.1 | 199.3 | 19 |
| 78 | 10 | 6986 | 951301 | 21715 | 2.39812 | 1781.0 | 200.9 | 225 |
| 78 | 11 | 11560 | 956440 | 33968 | 2.54521 | 1891.4 | 202.0 | 511 |
| 78 | 12 | 18157 | 960680 | 51545 | 2.61663 | 1826.8 | 202.9 | 777 |
| 79 | 1 | 26093 | 961475 | 72302 | 2.59205 | 1834.3 | 204.7 | 1145 |
| 79 | 2 | 27715 | 961711 | 76523 | 2.61469 | 1851.4 | 207.1 | 1308 |
| 79 | 3 | 20585 | 959696 | 58459 | 2.63223 | 1872.1 | 209.1 | 954 |
| 79 | 4 | 14342 | 956267 | 41464 | 2.58753 | 1880.7 | 211.5 | 543 |
| 79 | 5 | 7749 | 951582 | 23491 | 2.53417 | 1891.6 | 214.1 | 312 |
| 79 | 6 | 4615 | 946110 | 14542 | 2.46225 | 1905.1 | 216.6 | 102 |
| 79 | 7 | 3557 | 943636 | 12488 | 2.45755 | 1933.2 | 218.9 | 15 |
| 79 | 8 | 3123 | 942243 | 11452 | 2.45675 | 1946.5 | 221.1 | 14 |
| 79 | 9 | 3432 | 945045 | 12731 | 2.48342 | 1960.1 | 223.4 | 50 |
| 79 | 10 | 7049 | 953017 | 25127 | 2.71103 | 1981.2 | 225.4 | 230 |
| 79 | 11 | 12167 | 960558 | 41078 | 2.94223 | 2005.5 | 227.5 | 504 |
| 79 | 12 | 17498 | 965916 | 58820 | 3.09997 | 2028.3 | 229.9 | 776 |
| 80 | 1 | 23384 | 967620 | 74011 | 2.83854 | 2046.5 | 233.2 | 1010 |
| 80 | 2 | 24994 | 969111 | 82888 | 3.32137 | 2055.6 | 236.4 | 1124 |
| 80 | 3 | 21292 | 968867 | 79540 | 3.55254 | 2069.6 | 239.8 | 1002 |
| 80 | 4 | . | . | 53502 | . | . | 242.5 | . |

TABLE A-3

DAYTON POWER AND LIGHT:
DATA SET ON RESIDENTIAL NATURAL GAS
CONSUMPTION AND ITS DETERMINANTS

| Year | Month | Gas (mmcf) | Number of Customers | Revenue ($\$10^3$) | Marginal Price | National Income ($\$10^9$) | Consumer Price Index | Degree Days (°F) |
|---|---|---|---|---|---|---|---|---|
| 70 | 1 | 8140 | 235883 | 6116 | 0.70493 | 778.8 | 113.3 | 1242 |
| 70 | 2 | 7027 | 236114 | 5385 | 0.76672 | 781.5 | 113.9 | 1182 |
| 70 | 3 | 5846 | 236255 | 4542 | 0.71933 | 787.6 | 114.5 | 919 |
| 70 | 4 | 4661 | 236261 | 3683 | 0.75061 | 806.0 | 115.2 | 590 |
| 70 | 5 | 2008 | 235969 | 1785 | 0.76430 | 799.7 | 115.7 | 226 |
| 70 | 6 | 1099 | 235780 | 1116 | 0.77468 | 798.2 | 116.3 | 63 |
| 70 | 7 | 837 | 235745 | 912 | 0.77956 | 803.3 | 116.7 | 8 |
| 70 | 8 | 779 | 235899 | 866 | 0.78199 | 806.4 | 116.9 | 3 |
| 70 | 9 | 775 | 236232 | 864 | 0.78356 | 811.9 | 117.5 | 24 |
| 70 | 10 | 1477 | 236827 | 1394 | 0.77945 | 813.6 | 118.1 | 163 |
| 70 | 11 | 3018 | 237763 | 2700 | 0.80680 | 815.7 | 118.5 | 482 |
| 70 | 12 | 5178 | 238824 | 4671 | 0.87466 | 820.9 | 119.1 | 796 |
| 71 | 1 | 7636 | 239603 | 6744 | 0.81397 | 830.0 | 119.2 | 1086 |
| 71 | 2 | 7551 | 240032 | 6710 | 0.89991 | 833.2 | 119.4 | 1120 |
| 71 | 3 | 5869 | 240151 | 5341 | 0.83831 | 839.7 | 119.8 | 906 |
| 71 | 4 | 4593 | 240098 | 4295 | 0.88777 | 844.4 | 120.2 | 620 |
| 71 | 5 | 2656 | 239734 | 2815 | 0.93542 | 850.0 | 120.8 | 298 |
| 71 | 6 | 1417 | 239578 | 1669 | 0.94684 | 870.1 | 121.5 | 97 |
| 71 | 7 | 793 | 239392 | 1066 | 0.94894 | 859.2 | 121.8 | 1 |
| 71 | 8 | 761 | 239553 | 1034 | 0.94973 | 867.6 | 122.2 | 0 |
| 71 | 9 | 827 | 240011 | 1101 | 0.95111 | 871.5 | 122.4 | 25 |
| 71 | 10 | 1332 | 240778 | 1589 | 0.95385 | 874.8 | 122.6 | 74 |
| 71 | 11 | 2396 | 241876 | 2571 | 0.94634 | 879.4 | 122.6 | 379 |
| 71 | 12 | 5022 | 243479 | 4682 | 0.83676 | 890.4 | 123.1 | 734 |
| 72 | 1 | 6622 | 244184 | 6440 | 1.01359 | 898.9 | 123.2 | 981 |
| 72 | 2 | 6937 | 244835 | 6716 | 0.83194 | 908.5 | 123.8 | 1107 |
| 72 | 3 | 5857 | 245233 | 5760 | 1.00017 | 913.6 | 124.0 | 964 |
| 72 | 4 | 4629 | 245138 | 4669 | 0.92138 | 919.4 | 124.3 | 654 |
| 72 | 5 | 2465 | 244697 | 2697 | 0.95323 | 924.0 | 124.7 | 284 |
| 72 | 6 | 1350 | 244234 | 1643 | 0.96218 | 922.9 | 125.0 | 99 |
| 72 | 7 | 1109 | 243991 | 1405 | 0.96488 | 932.9 | 125.5 | 41 |
| 72 | 8 | 817 | 244190 | 1118 | 0.96503 | 940.0 | 125.7 | 11 |
| 72 | 9 | 837 | 244498 | 1139 | 0.96548 | 946.8 | 126.2 | 35 |
| 72 | 10 | 1525 | 245044 | 1814 | 0.96846 | 967.0 | 126.6 | 253 |
| 72 | 11 | 3711 | 246487 | 3842 | 0.94485 | 977.6 | 126.9 | 607 |
| 72 | 12 | 6161 | 247901 | 5586 | 0.78325 | 983.6 | 127.3 | 869 |
| 73 | 1 | 7119 | 248524 | 6947 | 1.09090 | 989.1 | 127.7 | 1003 |
| 73 | 2 | 6199 | 248870 | 6121 | 0.80963 | 997.4 | 128.6 | 990 |
| 73 | 3 | 4999 | 249008 | 5035 | 0.99960 | 1003.3 | 129.8 | 722 |
| 73 | 4 | 3933 | 248649 | 4102 | 0.95121 | 1011.6 | 130.7 | 473 |
| 73 | 5 | 2712 | 248037 | 2960 | 0.96346 | 1018.7 | 131.5 | 324 |
| 73 | 6 | 1521 | 247572 | 1823 | 0.96795 | 1026.6 | 132.4 | 102 |
| 73 | 7 | 864 | 247198 | 1177 | 0.96755 | 1035.6 | 132.7 | 0 |
| 73 | 8 | 741 | 246809 | 1045 | 0.96468 | 1047.3 | 135.1 | 1 |
| 73 | 9 | 812 | 246642 | 1119 | 0.96429 | 1058.5 | 135.5 | 17 |
| 73 | 10 | 1125 | 246735 | 1468 | 0.97514 | 1090.8 | 136.6 | 129 |
| 73 | 11 | 2777 | 247076 | 3091 | 0.98473 | 1100.0 | 137.6 | 410 |
| 73 | 12 | 4633 | 247473 | 4905 | 0.98212 | 1107.1 | 138.5 | 819 |
| 74 | 1 | 7222 | 247696 | 7347 | 0.95407 | 1107.0 | 139.7 | 1025 |
| 74 | 2 | 5541 | 247722 | 5870 | 1.02099 | 1113.4 | 141.5 | 995 |
| 74 | 3 | 4750 | 247617 | 5101 | 0.99031 | 1117.1 | 143.1 | 839 |
| 74 | 4 | 3894 | 247356 | 4313 | 1.01858 | 1125.2 | 144.0 | 535 |
| 74 | 5 | 2240 | 245777 | 2797 | 1.05826 | 1135.2 | 145.6 | 289 |
| 74 | 6 | 1236 | 245129 | 1704 | 1.06123 | 1143.5 | 147.1 | 120 |
| 74 | 7 | 907 | 244555 | 1350 | 1.06152 | 1159.5 | 148.3 | 21 |
| 74 | 8 | 746 | 244344 | 1162 | 1.05814 | 1167.2 | 150.2 | 0 |
| 74 | 9 | 924 | 244289 | 1402 | 1.06773 | 1178.0 | 151.9 | 82 |
| 74 | 10 | 1879 | 244559 | 2614 | 1.12338 | 1185.0 | 153.2 | 274 |
| 74 | 11 | 2743 | 245069 | 3749 | 1.18864 | 1184.5 | 154.3 | 499 |
| 74 | 12 | 5279 | 245608 | 7174 | 1.31573 | 1191.0 | 155.4 | 801 |

TABLE A-3
(continued)

| Year | Month | Gas (MMCF) | Number of Customers | Revenue ($10^3$) | Marginal Price | National Income ($\$10^9$) | CP Index | Degree Days ($^oF$) |
|---|---|---|---|---|---|---|---|---|
| 75 | 1 | 6488 | 245865 | 8714 | 1.22606 | 1191.1 | 156.1 | 983 |
| 75 | 2 | 5659 | 245930 | 7725 | 1.31584 | 1193.4 | 157.2 | 923 |
| 75 | 3 | 5273 | 245927 | 7472 | 1.32786 | 1195.7 | 157.8 | 852 |
| 75 | 4 | 4421 | 245635 | 6641 | 1.40463 | 1203.1 | 158.6 | 683 |
| 75 | 5 | 2153 | 245142 | 3599 | 1.42000 | 1214.3 | 159.3 | 307 |
| 75 | 6 | 979 | 244609 | 1932 | 1.42396 | 1244.1 | 160.6 | 53 |
| 75 | 7 | 768 | 244238 | 1610 | 1.42140 | 1238.9 | 162.3 | 12 |
| 75 | 8 | 735 | 243930 | 1561 | 1.41966 | 1255.9 | 162.8 | 1 |
| 75 | 9 | 868 | 243884 | 1813 | 1.43259 | 1270.9 | 163.3 | 65 |
| 75 | 10 | 1673 | 244070 | 3086 | 1.47075 | 1290.8 | 164.6 | 211 |
| 75 | 11 | 2345 | 244459 | 4194 | 1.51867 | 1300.2 | 165.6 | 392 |
| 75 | 12 | 4386 | 244939 | 7433 | 1.57026 | 1308.2 | 166.3 | 725 |
| 76 | 1 | 6074 | 245234 | 10448 | 1.65850 | 1320.8 | 166.7 | 1198 |
| 76 | 2 | 6007 | 245320 | 10602 | 1.66266 | 1331.4 | 167.1 | 1010 |
| 76 | 3 | 3746 | 245242 | 6870 | 1.66707 | 1341.9 | 167.5 | 665 |
| 76 | 4 | 3106 | 244583 | 5758 | 1.65418 | 1352.5 | 168.2 | 487 |
| 76 | 5 | 2090 | 244337 | 3935 | 1.61655 | 1362.9 | 169.2 | 303 |
| 76 | 6 | 1242 | 243827 | 2534 | 1.59895 | 1370.4 | 170.1 | 103 |
| 76 | 7 | 789 | 243438 | 1782 | 1.58558 | 1380.8 | 171.1 | 2 |
| 76 | 8 | 716 | 243190 | 1687 | 1.58314 | 1385.5 | 171.9 | 15 |
| 76 | 9 | 794 | 243044 | 1868 | 1.59443 | 1391.7 | 172.6 | 79 |
| 76 | 10 | 1575 | 243345 | 3241 | 1.63440 | 1414.2 | 173.3 | 329 |
| 76 | 11 | 4184 | 244032 | 8020 | 1.80268 | 1432.1 | 173.8 | 726 |
| 76 | 12 | 5766 | 244481 | 10628 | 1.67919 | 1450.2 | 174.3 | 1053 |
| 77 | 1 | 7542 | 244559 | 15734 | 2.40144 | 1454.3 | 175.3 | 1371 |
| 77 | 2 | 7706 | 244584 | 15953 | 1.43233 | 1477.0 | 177.1 | 1299 |
| 77 | 3 | 3480 | 244445 | 7727 | 2.01158 | 1499.1 | 178.2 | 834 |
| 77 | 4 | 2861 | 244118 | 6455 | 1.97199 | 1510.1 | 179.6 | 465 |
| 77 | 5 | 1513 | 243906 | 3646 | 1.93181 | 1517.3 | 180.6 | 193 |
| 77 | 6 | 833 | 243582 | 2229 | 1.89585 | 1524.3 | 181.8 | 50 |
| 77 | 7 | 715 | 243048 | 1994 | 1.87614 | 1539.2 | 182.6 | 18 |
| 77 | 8 | 638 | 242782 | 1834 | 1.86332 | 1540.7 | 183.3 | 4 |
| 77 | 9 | 737 | 242512 | 2139 | 1.88204 | 1556.9 | 184.0 | 26 |
| 77 | 10 | 1480 | 242407 | 4089 | 2.03399 | 1577.0 | 184.5 | 206 |
| 77 | 11 | 2393 | 242758 | 6486 | 2.25033 | 1592.7 | 185.4 | 486 |
| 77 | 12 | 4845 | 243379 | 12403 | 2.41366 | 1609.2 | 186.1 | 857 |
| 78 | 1 | 6414 | 243630 | 16099 | 2.30438 | 1615.5 | 187.2 | 1268 |
| 78 | 2 | 6848 | 243657 | 17129 | 2.41709 | 1625.0 | 188.4 | 1384 |
| 78 | 3 | 5766 | 243695 | 14575 | 2.31653 | 1646.3 | 189.8 | 1133 |
| 78 | 4 | 3495 | 243309 | 9320 | 2.38320 | 1669.4 | 191.5 | 661 |
| 78 | 5 | 2349 | 242840 | 6499 | 2.36127 | 1682.1 | 193.3 | 300 |
| 78 | 6 | 1062 | 242336 | 3292 | 2.31825 | 1695.7 | 195.3 | 110 |
| 78 | 7 | 734 | 241820 | 2465 | 2.28588 | 1730.0 | 196.7 | 8 |
| 78 | 8 | 654 | 241333 | 2282 | 2.26996 | 1741.3 | 197.8 | 6 |
| 78 | 9 | 688 | 241139 | 2400 | 2.27015 | 1756.1 | 199.3 | 29 |
| 78 | 10 | 1427 | 241107 | 4253 | 2.31496 | 1781.0 | 200.9 | 222 |
| 78 | 11 | 2532 | 241322 | 7055 | 2.40438 | 1801.4 | 202.0 | 497 |
| 78 | 12 | 4087 | 241601 | 10994 | 2.47824 | 1826.8 | 202.9 | 770 |
| 79 | 1 | 5990 | 242042 | 15751 | 2.46916 | 1834.3 | 204.7 | 1157 |
| 79 | 2 | 6745 | 242508 | 17619 | 2.47795 | 1851.4 | 207.1 | 1327 |
| 79 | 3 | 4921 | 242499 | 13082 | 2.46389 | 1872.1 | 209.1 | 958 |
| 79 | 4 | 3264 | 242122 | 8918 | 2.44790 | 1880.7 | 211.5 | 540 |
| 79 | 5 | 1949 | 241723 | 5599 | 2.42191 | 1891.6 | 214.1 | 306 |
| 79 | 6 | 1128 | 241290 | 3502 | 2.38858 | 1905.1 | 216.6 | 91 |
| 79 | 7 | 751 | 241017 | 2516 | 2.35579 | 1933.2 | 218.9 | 11 |
| 79 | 8 | 672 | 240812 | 2277 | 2.32811 | 1946.5 | 221.1 | 15 |
| 79 | 9 | 753 | 240753 | 2570 | 2.33629 | 1960.1 | 223.4 | 57 |
| 79 | 10 | 1387 | 241010 | 4755 | 2.52487 | 1981.2 | 225.4 | 244 |
| 79 | 11 | 2775 | 241437 | 8919 | 2.80552 | 2005.5 | 227.5 | 523 |
| 79 | 12 | 4028 | 241828 | 12183 | 2.75624 | 2028.3 | 229.9 | 786 |
| 80 | 1 | 4965 | 242023 | 14797 | 2.77951 | 2046.5 | 233.2 | 1034 |
| 80 | 2 | 5822 | 242236 | 17189 | 2.76953 | 2055.6 | 236.4 | 1181 |
| 80 | 3 | 5126 | 242239 | 16605 | 3.17450 | 2069.6 | 239.8 | 1059 |
| 80 | 4 | . | . | 11469 | . | . | 242.5 | . |

TABLE A-4

EAST OHIO GAS COMPANY:
DATA ON RESIDENTIAL NATURAL GAS
CONSUMPTION AND ITS DETERMINANTS

| Year | Month | Gas (mmcf) | Number of Customers | Revenue ($10^3$) | Marginal Price | National Income (\$$10^9$) | Consumer Price Index | Degree Days (°F) |
|---|---|---|---|---|---|---|---|---|
| 70 | 1 | 33498 | 883448 | 27223 | 0.77107 | 778.8 | 113.3 | 1296 |
| 70 | 2 | 30823 | 884069 | 25262 | 0.79244 | 781.5 | 113.9 | 1239 |
| 70 | 3 | 27381 | 883890 | 22789 | 0.78829 | 787.6 | 114.5 | 1006 |
| 70 | 4 | 22036 | 882286 | 18841 | 0.80682 | 806.0 | 115.2 | 711 |
| 70 | 5 | . | . | 9701 | 0.80342 | 799.7 | 115.7 | . |
| 70 | 6 | 6313 | 876865 | 6204 | 0.80770 | 798.2 | 116.3 | 97 |
| 70 | 7 | 4754 | 874930 | 5071 | 0.83908 | 803.3 | 116.7 | 24 |
| 70 | 8 | 4108 | 873367 | 5164 | 0.85975 | 806.4 | 116.9 | 11 |
| 70 | 9 | 4181 | 873855 | 5309 | 0.87258 | 811.9 | 117.5 | 49 |
| 70 | 10 | 6542 | 878093 | 7355 | 0.88235 | 813.6 | 118.1 | 209 |
| 70 | 11 | 11761 | 882495 | 11968 | 0.89127 | 815.7 | 118.5 | 514 |
| 70 | 12 | 22397 | 886905 | 21466 | 0.89471 | 820.9 | 119.1 | 853 |
| 71 | 1 | 30528 | 888718 | 28832 | 0.92022 | 830.0 | 119.2 | 1177 |
| 71 | 2 | 33777 | 889504 | 32212 | 0.89821 | 833.2 | 119.4 | 1188 |
| 71 | 3 | 26854 | 889322 | 25932 | 0.92196 | 839.7 | 119.8 | 1032 |
| 71 | 4 | 21942 | 887607 | 21684 | 0.91456 | 844.4 | 120.2 | 841 |
| 71 | 5 | 13871 | 884821 | 14255 | 0.91707 | 850.0 | 120.8 | 464 |
| 71 | 6 | 7277 | 882113 | 8288 | 0.91899 | 870.1 | 121.5 | 147 |
| 71 | 7 | 4407 | 879209 | 5673 | 0.91724 | 859.2 | 121.8 | 13 |
| 71 | 8 | 4518 | 878291 | 5721 | 0.92105 | 867.6 | 122.2 | 11 |
| 71 | 9 | 3942 | 878901 | 5295 | 0.92349 | 871.5 | 122.4 | 38 |
| 71 | 10 | 6697 | 882588 | 7836 | 0.92111 | 874.8 | 122.6 | 116 |
| 71 | 11 | 10505 | 887766 | 11289 | 0.92705 | 879.4 | 122.6 | 436 |
| 71 | 12 | 23037 | 892955 | 22942 | 0.93603 | 890.4 | 123.1 | 766 |
| 72 | 1 | 26571 | 895156 | 26412 | 0.95726 | 898.9 | 123.2 | 994 |
| 72 | 2 | 30861 | 896486 | 30878 | 0.91111 | 908.5 | 123.8 | 1147 |
| 72 | 3 | 27882 | 896400 | 27577 | 0.96049 | 913.6 | 124.0 | 1032 |
| 72 | 4 | 22028 | 894923 | 22528 | 0.95917 | 919.4 | 124.3 | 747 |
| 72 | 5 | 11842 | 892417 | 12864 | 0.94894 | 924.0 | 124.7 | 380 |
| 72 | 6 | 6996 | 889640 | 8276 | 0.95469 | 922.9 | 125.0 | 160 |
| 72 | 7 | 5359 | 887287 | 6852 | 0.95268 | 932.9 | 125.5 | 78 |
| 72 | 8 | 4824 | 886161 | 6240 | 0.95163 | 940.0 | 125.7 | 30 |
| 72 | 9 | 4735 | 886962 | 6142 | 0.95907 | 946.8 | 126.2 | 61 |
| 72 | 10 | 9106 | 888563 | 10463 | 0.97392 | 967.0 | 126.6 | 290 |
| 72 | 11 | 16295 | 896281 | 17560 | 0.98582 | 977.6 | 126.9 | 619 |
| 72 | 12 | 26122 | 900099 | 27341 | 0.95839 | 983.6 | 127.3 | 845 |
| 73 | 1 | 27657 | 902268 | 28528 | 0.99547 | 989.1 | 127.7 | 1002 |
| 73 | 2 | 27052 | 903707 | 28235 | 0.97348 | 997.4 | 128.6 | 1050 |
| 73 | 3 | 22785 | 903681 | 24037 | 0.97941 | 1003.3 | 129.8 | 801 |
| 73 | 4 | 17386 | 901652 | 18729 | 0.98044 | 1011.6 | 130.7 | 510 |
| 73 | 5 | 12443 | 899512 | 13916 | 0.97703 | 1018.7 | 131.5 | 352 |
| 73 | 6 | 7634 | 897336 | 9132 | 0.97948 | 1026.6 | 132.4 | 129 |
| 73 | 7 | 4583 | 894700 | 6231 | 0.97426 | 1035.6 | 132.7 | 3 |
| 73 | 8 | 4115 | 893132 | 5631 | 0.96675 | 1047.3 | 135.1 | 6 |
| 73 | 9 | 4693 | 893897 | 6096 | 0.96461 | 1058.5 | 135.5 | 41 |
| 73 | 10 | 6579 | 895588 | 7958 | 0.96337 | 1090.8 | 136.6 | 154 |
| 73 | 11 | 13624 | 901436 | 14751 | 0.97997 | 1100.0 | 137.6 | 429 |
| 73 | 12 | 22511 | 905375 | 23587 | 0.53440 | 1107.1 | 138.5 | 776 |
| 74 | 1 | 28999 | 907723 | 22798 | 0.80160 | 1107.0 | 139.7 | 981 |
| 74 | 2 | 26689 | 908315 | 28141 | 1.09131 | 1113.4 | 141.5 | 1025 |
| 74 | 3 | 23928 | 908237 | 26019 | 1.01850 | 1117.1 | 143.1 | 906 |
| 74 | 4 | 19210 | 906435 | 22014 | 1.08686 | 1125.2 | 144.0 | 598 |
| 74 | 5 | 11728 | 903781 | 15397 | 1.07839 | 1135.2 | 145.6 | 350 |
| 74 | 6 | 6472 | 901314 | 9243 | 1.06966 | 1143.5 | 147.1 | 165 |
| 74 | 7 | 4535 | 899688 | 7032 | 1.07046 | 1159.5 | 148.3 | 26 |
| 74 | 8 | 4113 | 898687 | 6694 | 1.08238 | 1167.2 | 150.2 | 4 |
| 74 | 9 | 4892 | 899995 | 7779 | 1.13052 | 1178.0 | 151.9 | 91 |
| 74 | 10 | 10165 | 905626 | 14249 | 1.16515 | 1185.0 | 153.2 | 300 |
| 74 | 11 | 13204 | 909685 | 18057 | 1.42479 | 1184.5 | 154.3 | 542 |
| 74 | 12 | 24921 | 913248 | 35949 | 0.90517 | 1191.0 | 155.4 | 843 |

TABLE A-4
(continued)

| Year | Month | Gas (mmcf) | Number of Customers | Revenue ($\$10^3$) | Marginal Price | National Income ($\$10^9$) | Consumer Price Index | Degree Days (°F) |
|---|---|---|---|---|---|---|---|---|
| 75 | 1 | 27553 | 914619 | 33644 | 1.35776 | 1191.1 | 156.1 | 1024 |
| 75 | 2 | 26895 | 915590 | 36303 | 1.19101 | 1193.4 | 157.2 | 992 |
| 75 | 3 | 25797 | 916315 | 35401 | 1.26314 | 1195.7 | 157.8 | 948 |
| 75 | 4 | 22194 | 915057 | 30657 | 1.25590 | 1203.1 | 158.6 | 813 |
| 75 | 5 | 11392 | 912059 | 17349 | 1.22733 | 1214.3 | 159.3 | 423 |
| 75 | 6 | 5447 | 908777 | 9272 | 1.20828 | 1244.1 | 160.6 | 96 |
| 75 | 7 | 4286 | 906047 | 7681 | 1.19258 | 1238.9 | 162.3 | 22 |
| 75 | 8 | 3948 | 904283 | 7108 | 1.18808 | 1255.9 | 162.8 | 5 |
| 75 | 9 | 4841 | 905301 | 8252 | 1.23034 | 1270.9 | 163.3 | 96 |
| 75 | 10 | 8388 | 908935 | 13313 | 1.27745 | 1290.8 | 164.6 | 266 |
| 75 | 11 | 11150 | 913183 | 17277 | 1.52938 | 1300.2 | 165.6 | 439 |
| 75 | 12 | 24461 | 917819 | 38260 | 1.23692 | 1308.2 | 166.3 | 774 |
| 76 | 1 | 29034 | 920456 | 42811 | 1.57296 | 1320.8 | 166.7 | 1176 |
| 76 | 2 | 28837 | 921639 | 44143 | 1.40593 | 1331.4 | 167.1 | 1086 |
| 76 | 3 | 19175 | 920657 | 30592 | 1.42722 | 1341.9 | 167.5 | 725 |
| 76 | 4 | 16008 | 918436 | 25891 | 1.38885 | 1352.5 | 168.2 | 554 |
| 76 | 5 | 11562 | 916060 | 18856 | 1.36888 | 1362.9 | 169.2 | 401 |
| 76 | 6 | 6543 | 913000 | 11628 | 1.36263 | 1370.4 | 170.1 | 167 |
| 76 | 7 | 4361 | 910116 | 8676 | 1.36163 | 1380.8 | 171.1 | 14 |
| 76 | 8 | 4032 | 908314 | 8273 | 1.36837 | 1385.5 | 171.9 | 17 |
| 76 | 9 | 4752 | 908585 | 9409 | 1.49373 | 1391.7 | 172.6 | 97 |
| 76 | 10 | 9086 | 911904 | 17572 | 1.74489 | 1414.2 | 173.3 | 349 |
| 76 | 11 | 18673 | 915729 | 35360 | 1.90562 | 1432.1 | 173.8 | 741 |
| 76 | 12 | 28292 | 917739 | 55683 | 1.74129 | 1450.2 | 174.3 | 1125 |
| 77 | 1 | 35653 | 918607 | 69167 | 2.04696 | 1454.3 | 175.3 | 1398 |
| 77 | 2 | 32222 | 918481 | 64903 | 1.91160 | 1477.0 | 177.1 | 1311 |
| 77 | 3 | 20566 | 917410 | 43851 | 1.89231 | 1499.1 | 178.2 | 915 |
| 77 | 4 | 14476 | 915272 | 31188 | 1.86163 | 1510.1 | 179.6 | 568 |
| 77 | 5 | 8920 | 910813 | 20113 | 1.83397 | 1517.3 | 180.6 | 304 |
| 77 | 6 | 5662 | 905007 | 13674 | 1.76685 | 1524.3 | 181.8 | 141 |
| 77 | 7 | 4388 | 901031 | 10129 | 1.82240 | 1539.2 | 182.6 | 60 |
| 77 | 8 | 4644 | 900696 | 12471 | 1.80859 | 1540.7 | 183.3 | 15 |
| 77 | 9 | 4205 | 900845 | 10787 | 1.81768 | 1556.9 | 184.0 | 43 |
| 77 | 10 | 7180 | 902917 | 16488 | 1.85906 | 1577.0 | 184.5 | 219 |
| 77 | 11 | 10189 | 904830 | 22616 | 2.49461 | 1592.7 | 185.4 | 485 |
| 77 | 12 | 23420 | 909189 | 57313 | 1.24730 | 1609.2 | 186.1 | 848 |
| 78 | 1 | 30718 | 911450 | 56402 | 1.87095 | 1615.5 | 187.2 | 1245 |
| 78 | 2 | 31673 | 912160 | 65903 | 1.98929 | 1625.0 | 188.4 | 1365 |
| 78 | 3 | 26464 | 911487 | 55939 | 1.91824 | 1646.3 | 189.8 | 1174 |
| 78 | 4 | 17142 | 908261 | 37454 | 1.89750 | 1669.4 | 191.5 | 770 |
| 78 | 5 | 11868 | 905234 | 26835 | 1.84552 | 1682.1 | 193.3 | 376 |
| 78 | 6 | 5663 | 901693 | 14013 | 1.78001 | 1695.7 | 195.3 | 131 |
| 78 | 7 | 4298 | 898137 | 10489 | 1.76897 | 1730.0 | 196.7 | 25 |
| 78 | 8 | 3862 | 895858 | 10175 | 1.78140 | 1741.3 | 197.8 | 5 |
| 78 | 9 | 3658 | 894576 | 10224 | 1.82411 | 1756.1 | 199.3 | 23 |
| 78 | 10 | 7095 | 899243 | 17022 | 1.92435 | 1781.0 | 200.9 | 203 |
| 78 | 11 | 12030 | 905410 | 27436 | 2.62971 | 1801.4 | 202.0 | 491 |
| 78 | 12 | 21378 | 910752 | 56701 | 1.34724 | 1826.8 | 202.9 | 793 |
| 79 | 1 | 29799 | 913992 | 62800 | 2.02986 | 1834.3 | 204.7 | 1147 |
| 79 | 2 | 31085 | 915094 | 73287 | 2.23556 | 1851.4 | 207.1 | 1305 |
| 79 | 3 | 23147 | 914220 | 56144 | 2.22032 | 1872.1 | 209.1 | 981 |
| 79 | 4 | 16789 | 911563 | 43338 | 2.15392 | 1880.7 | 211.5 | 616 |
| 79 | 5 | 10264 | 912389 | 27544 | 2.08864 | 1891.6 | 214.1 | 421 |
| 79 | 6 | 6225 | 904709 | 17759 | 2.06390 | 1905.1 | 216.6 | 175 |
| 79 | 7 | 4182 | 901702 | 13476 | 2.05436 | 1933.2 | 218.9 | 40 |
| 79 | 8 | 4567 | 897481 | 14320 | 2.04459 | 1946.5 | 221.1 | 16 |
| 79 | 9 | 3556 | 900801 | 12097 | 2.16502 | 1960.1 | 223.4 | 49 |
| 79 | 10 | 7557 | 906674 | 22739 | 2.76281 | 1981.2 | 225.4 | 245 |
| 79 | 11 | 13777 | 913363 | 45804 | 3.37236 | 2005.5 | 227.5 | 537 |
| 79 | 12 | 19747 | 918222 | 71921 | 2.32729 | 2028.3 | 229.9 | 819 |
| 80 | 1 | 24612 | 921701 | 74151 | 3.49093 | 2046.5 | 233.2 | 1093 |
| 80 | 2 | 27723 | 923145 | 91427 | 2.71666 | 2055.6 | 236.4 | 1231 |
| 80 | 3 | 23638 | 922689 | 78226 | . | 2069.6 | 239.8 | 1106 |

degree days from the billing period. Then in month B a meter reading is taken that covers consumption in both months A and B. Any error made in the estimate of consumption in month A is eliminated in the month B billing. Month B's bill is calculated as the meter reading minus month A's estimate. Of course, meter readers work every month, so that half of the residential customers have meters read in month A and the other half in month B. The error or bias caused by this billing procedure on the monthly data of table A.2 is judged to be negligible. The primary reason is that estimates are made for hundreds of thousands of customers so that errors tend to cancel out between months A and B.

The third consideration of the billing data is that many customers, as many as a third, are on a budget plan so that equal payments are made every month in a year. This tends to make consumer response to price increases sluggish, suggesting that the income and price variables be lagged in modeling natural gas consumption. Preliminary analysis of the case studies suggested that this would not provide substantial improvements in models, so these data are not lagged.

Revenue data were obtained directly from the distribution utilities. These data are the sum of all billings for a particular month. Marginal prices were estimated using the AEP model of section 4.2.1 of this paper.

The national personal income data were obtained from Survey of Current Business, U.S. Department of Commerce. As mentioned in Section 4, monthly national income data are used, since state and city-level income data were not available on a monthly basis. The simple correlation between national income data and state of Ohio income data, compared on an annual basis, is 0.99 so that the national income data provide valuable information. The Consumer Price Index data were obtained from CPI Detailed Report, U.S. Department of Labor.

Finally, heating degree day data were obtained from Climatological Data, National Climatic Center, Asheville, North Carolina. Data from airports in or near Cincinnati, Columbus, Dayton, and Cleveland are included for the four distribution utilities.