Estimating Regional Short-run and Long-run Price Elasticities of Residential Natural Gas Demand in the U.S[1]*.*

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Fred L Joutz
Professor, Dept. of Economics, George Washington University
Washington DC 20052, 202-994-4899, bmark@gwu.edu
David Shin
Bruce McDowell
American Gas Association
Robert P Trost
Dept of Economics, George Washington University

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Introduction

Demand for natural gas per residential customer has been declining since the 1980's, and in recent years this decline has increased. Between 1980 and 2001, weather adjusted natural gas use per consumer in the US declined almost 1 percent on an annual basis. Since 2000, however, the decline for winter only use has accelerated, decreasing 13.1 percent between 2000 and 2006 for the sample of companies analyzed in this report.

The main objective of this study was to document changes in use per residential customer on a weather normalized basis, particularly since the year 2000, and to identify the reasons for these changes. A second purpose of this study was to test for an increase in the price elasticity[2] of demand for natural gas since the year 2000. A third and equally important purpose of this study was to obtain updated elasticity estimates for all nine US Census Regions and for the US as a whole. Finally, the study attempts to estimate a natural rate of decline in use per customer due to technology induced gains in appliance and shell efficiency that would even occur in an environment of constant real natural gas prices.

There are hundreds of studies on the elasticities of natural gas demand. These studies have generated a range of elasticity estimates. If one goes back to the 1970's and even to the 1960s, these estimates vary over a wide range. Estimates of short-run price elasticity range from as low as –0.05 in Beirlein, Dunn and McConnon (1981) to a high of –0.68 in Barnes, Gillingham & Hagemann (1982). For long-run price elasticity estimates, the range of estimates is even higher, with the low being -0.017 in Hewlett (1977) to a high of –3.42 in Beirlein, Dunn and McConnon (1981). See Dahl and Roman (2004) and Dahl, etc. al. (2005) for recent surveys of energy elasticity demand estimates. Other surveys of energy demand price elasticity estimates are Taylor (1975 and 1977), Bohi (1981), Bohi and Zimmerman (1984), Al-Sahlawi (1989), Dahl (1993), and Espy and Espy (2004). See Appendix C for a brief literature review of price elasticity estimates.

Many of the studies estimated elasticities of natural gas demand with data aggregated at the State and National level and collected by the States themselves; or collected by the Energy Information Administration (EIA). Examples of these are Balestra and Nerlove (1966), Jaskow and Baughman (1976), Berndt and Watkins (1977), and more recently, Maddala, Trost, Li, and Joutz (1997). Other studies use individual micro data to estimate demand elasticities. Examples of these are Hewlett (1977), Barnes, Gillingham and Hagemann (1982), and Green and Gilbert (1983). While the former studies using State and National aggregate data may provide some useful information at the State and National level, and the latter studies may provide good estimates of individual demand elasticities, neither provide adequate estimates at the individual LDC level of aggregation. Most of these studies do not allow for a natural rate of decline in use per customer due to technologically induced efficiency gains in appliances and thermal shells of homes. In addition, there are few, if any, studies that use current data that includes the recent run-up in natural gas prices. This study will fill these gaps in the literature by using high quality data collected and compiled at the individual LDC level and covering the period as recent as March, 2006.

This paper is divided into the following five sections. In Section 1, background information at the regional, as well as the national level, are provided. The information includes residential natural gas consumption, the declining trend of consumption, and price movements. In Section 2, the database constructed from the survey of 41 LDCs is described. Section 3 explains the mathematical equations used to estimate short- and long-run price elasticity of demand. Empirical results of short-run and

[2] The price elasticity of demand is defined as the ratio of the percent change in quantity demanded of a particular good to the percent change in the price of that good, such as natural gas demand in this study.

long-run elasticity and the declining trend in gas usage are presented in Section 4. The report concludes in Section 5 with a summary of the results and policy implications. In addition, there is a list of suggestions for future research. References and technical appendices can be found at the end of the report. The appendices include construction of the weather-normalized series for use per customer, a map of the Census regions, a brief literature review, and a discussion of statistical hypothesis testing.

Section 1: Background

Residential natural gas consumption per customer in the US has been declining. Figure 1 below shows the winter season use per consumption actual and weather normal (in decatherms) from 1996 to 2006 using the data collected from the 41 LDCs. The winter season for this report is defined as the sum of the monthly consumption between October and March.

Figure 1

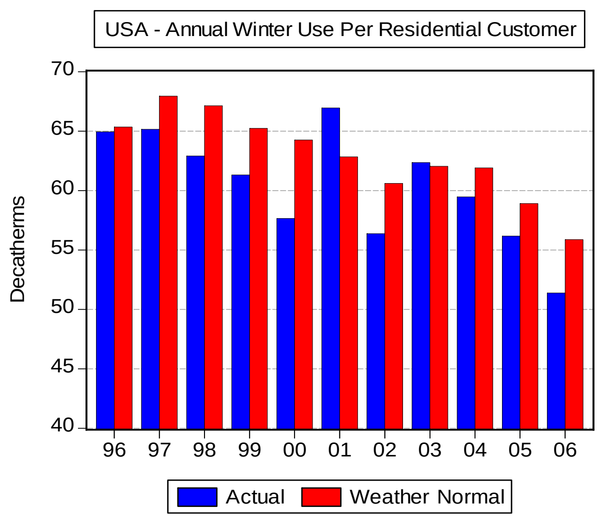


Table 1: US Annual Winter Season Residential Natural Gas Consumption per Household in Decatherms

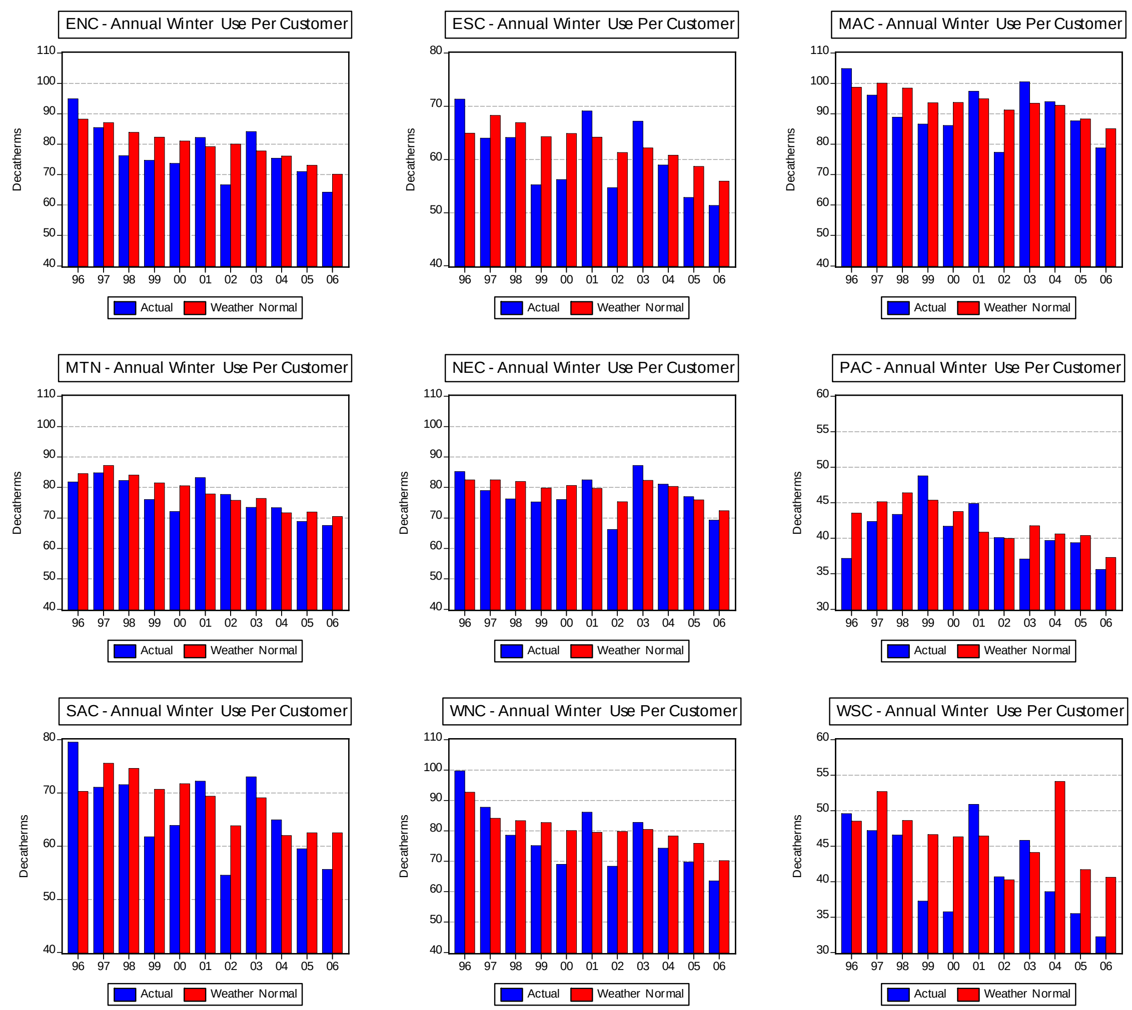
Year	Actual Level	Actual Percent Change	Winter Normal Level	Winter Normal Percent Change
1996	64.9		65.3	
1997	65.2	0.5	67.9	4.0
1998	62.9	-3.5	67.1	-1.2
1999	61.3	-2.5	65.2	-2.8
2000	57.7	-5.9	64.3	-1.4
2001	67.0	16.1	62.8	-2.3
2002	56.4	-15.8	60.6	-3.5
2003	62.3	10.5	62.0	2.3
2004	59.5	-4.5	61.9	-0.2
2005	56.2	-5.6	58.9	-4.9
2006	51.4	-8.5	55.9	-5.1
Annual Percent Change 1996-2000		**-1.64**		**-1.48**

Source: AGA Elasticity Participant Survey 2006

As can be seen from Figure 1 and Table 1, there has been a marked decline in weather normal use per customer. The annual percent change from 1996 to 2006 was -1.64 percent and -1.48 percent respectively, for actual and weather normal consumption. Since 2000, however, the decline for winter only use has accelerated, decreasing 13.1 percent between 2000 and 2006 and by 9.7 percent between 2004 and 2006 for the sample of companies analyzed in this report.

Figure 2 shows the actual and normalized winter season consumption for natural gas per customer by U.S. Census region for the AGA sample. Again, there is a decline over much of the sample in all regions[3]**.** A map of the US Census Regions is shown in Appendix A.

Figure 2
Regional Annual Winter Use per Customer
(Measured in Dth)



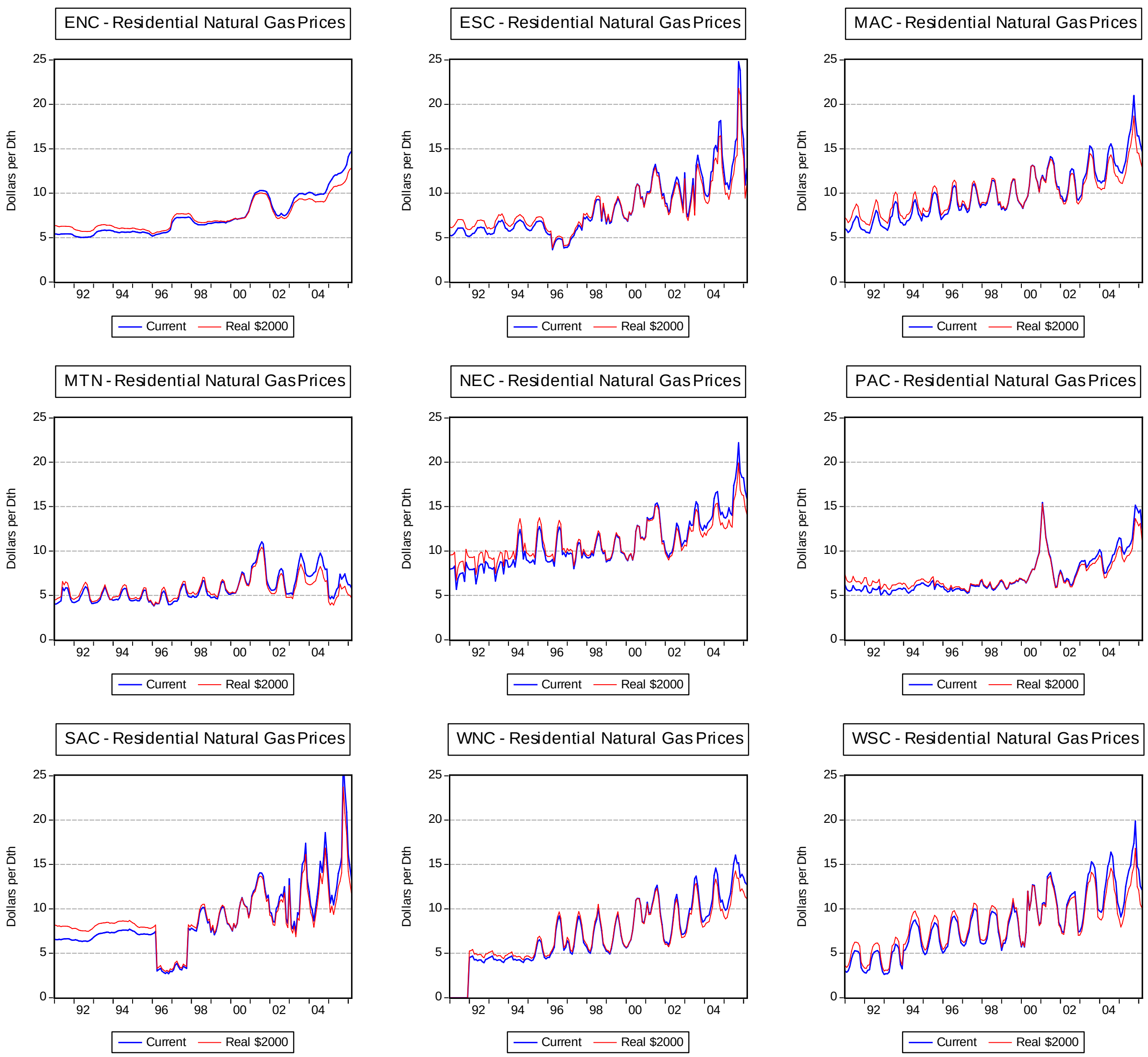
Source: AGA Elasticity Participant Survey 2006

Figure 3 shows the regional natural gas prices nominal and real terms in ($2000)/Dth. Prices were

[3] We compared our winter consumption estimates and prices with those from the U.S. Energy Information Administration; the same patterns emerge.

fairly stable between 1990 and 1997 during the so-called "gas bubble" period. However, they have been increasing, particularly since 2000 due to a variety of factors, including increasing oil prices (Villar and Joutz, October 2006). Nominal prices have risen faster in some regions than in others. The real price has more than doubled to over $12/Dth. Natural gas prices have risen about 35%-40% faster than the general U.S. price level since 1990.

Figure 3
Regional Residential Natural Gas Prices
(Nominal and Real $ / Dth)



Real disposable income per capita has risen across the U.S. by about 33% from $21,000 to $28,000 in the sample. While income is important in any economic analysis of demand, income was not included in our final model for several reasons. First, estimates of real disposable income (per customer, household, or person) were not available for all the LDCs. We constructed estimates using state level data from the U.S. Bureau of Economic Analysis. Second, the services from natural gas is a normal good, one would expect a positive income effect, which should has been reflected in a positive trend in natural gas use per household. However, in our sample and specification, we observe a negative trend in use per household. The income series are highly positively autocorrelated and trend-like. The income coefficient(s) were erratic and even negative. This is consistent with the declining use per household due to a naturally occurring and non-natural gas price-induced replacement of old inefficient appliances with new more efficient appliances. At present, we believe a time trend appropriately captures this new technology-induced naturally occurring adoption of more energy efficient appliances and improvements in housing shell efficiency or conservation. Third, our findings are similar to surveys of natural gas demand by Bohi (1981), Dahl (1993, and personal discussions about preliminary results regarding an update to her previous study.) In a number of papers, Bohi found that dismisses the large income elasticities from some static cross section estimates and concluded that income is an important variable in natural gas demand. Dahl found that income effects in residential demand models are consistently small in both aggregate and disaggregate data. Both authors suggest that representing the income effect in residential is problematic and sensitive to the particular study.

Table 2 shows the cumulative decline of winter weather normal use per customer between 2000 and 2006. The fall, on average, is greater than two per cent per year for six of the nine Census Regions and for the U.S. as a whole. Our analysis will try to explain this phenomenon via the large increases in natural gas prices and (possible) conservation activities by consumers.[4]

Table 2
Annual Winter Season Weather Normal Natural Gas Use per Residential Customer.
By Region and for the U.S. in the AGA Sample of 41 LDCs
(Decatherms per Customer)

Census Region	2000	2001	2002	2003	2004	2005	2006	Percent Change
National	64.3	62.8	60.6	62.0	61.9	58.9	55.9	-13.1%
East North Central	81.1	79.2	80.1	77.8	76.1	73.1	70.2	-13.4%
East South Central	64.9	64.2	61.3	62.2	60.8	58.7	55.9	-13.9%
Middle Atlantic	93.7	95.0	91.2	93.5	92.8	88.3	85.1	-9.2%
Mountain	80.6	77.9	75.8	76.4	71.8	72.0	70.5	-12.5%
New England	80.7	79.8	75.3	82.3	80.3	75.9	72.4	-10.3%
Pacific	43.8	40.9	40.0	41.8	40.6	40.4	37.3	-14.8%
South Atlantic	71.7	69.4	63.8	69.1	62.0	62.5	62.5	-12.8%
West North Central	80.1	79.5	79.8	80.4	78.3	75.9	70.2	-12.4%
West South Central	46.3	46.4	40.2	44.1	54.1	41.7	40.6	-12.3%

Source: AGA Elasticity Participant Survey 2006

Table 2 shows the overall decline between 2000 and 2006 for the AGA sample of 41 LDCs. As shown in Table 2, the decline in weather normal use per customer for the National sample is from 64.3 decatherms in 2000 to 55.9 decatherms per household in 2006. This represents a cumulative decline of 13.1% or an average decline of 2.2% per year. The decline since 2004 is even more dramatic, going from 61.9 decatherms per household in 2004 to 55.9 decatherms in 2006, nearly a 6% decline

[4] The pre-2000 period will be addressed in the statistical modeling sections.

per year. As shown in this table, every region in the US experienced a decline in use per residential customer.

Section 2: Data

Sixteen AGA member companies provided data for this study. The companies supplied monthly data on residential consumption, average prices, number of customers, heating-degree data, and economic data. Most companies were able to provide a time series of data starting in 1992 and in some cases even into the 1980s. Three firms were unable to contribute data prior to 1999 for accounting or reorganization reasons. The remaining fifteen corporations comprise 41 local distribution companies. This represents more than sixteen million customers and 28%of all residential customers nationwide.

But data on a single LDC is often not enough information. The problem with using current data from only one LDC is that the number of observations will be quite small, and statistical reliability will be compromised. Instead of tens of thousands of observations on individual consumers, one may be left with 50 or 60 observations for any given LDC during the important winter season months. From a statistical reliability point of view then, it is important to obtain data from many different individual LDCs, data that is collected by each individual LDCs, rather than using survey data collected by government agencies such as the EIA.

In this study, the breadth and depth of the data collected by the AGA has not to our knowledge been done before. The breadth of the data spans the entire US, covering 41 different LDCs. The depth of the data covers almost a decade or more for most of the companies. Therefore, this is a data set that is uniquely suited for the analysis of residential natural gas consumption in the US.

The number of LDCs in each the nine Census Regions and the percent of total customers the sample covers for each Region is given in Table 3 below.

Table 3
Percent of Total Residential Customers Covered by the AGA Sample by Regions

Census Regions	Census Abbreviation	Number of participating LDCs	Coverage
East North Central	ENC	3	8%
East South Central	ESC	3	11%
Mid-Atlantic	MAC	6	45%
Mountain	MTN	4	42%
New England	NEC	8	50%
Pacific	PAC	4	39%
South Atlantic	SAC	4	17%
West North Central	WNC	3	20%
West South Central	WSC	6	32%

Section 3: Approaches to Estimating Short- and Long-run Price Elasticity of Demand

Economists often distinguish between a short-run response and long-run response when referring to how a household changes its natural gas usage when faced with price and income changes,. The short-run response is defined as a household's natural gas demand response to natural gas price and income changes given their current capital stock of natural gas-using appliances and shell efficiency of the house. The long-run response is defined as a household's response to natural gas prices changes and income changes after the household has had time to change their stock of gas using appliances and house shell efficiency.

The idea behind the short-run and long-run responses to price changes is that when natural gas prices change, a household's short-run response is to alter the intensity with which they use their current stock of natural gas-using appliances. The long-run response to a change in natural gas prices is to alter the number and efficiency of natural gas using appliances, while at the same time changing the shell efficiency of the house.

A household's percentage change in natural gas demand per one percent change in natural gas price is called the price elasticity of natural gas demand. When this percentage change is computed for a household with a given stock of natural gas-using appliances and house shell efficiency, it is termed the short-run price elasticity of natural gas demand for that household. When this percentage change is computed over a time period long enough to allow a household to change it's stock and efficiencies of house and natural gas using appliances, it is termed the long-run price elasticity of natural gas demand for that household. A similar definition is given to short-run and long-run income elasticities of natural gas demand. If the natural gas demand equation is specified in logarithmic form, the price and income coefficients in a regression equation can be interpreted as the price and income elasticities.

A Dynamic Model of Capital Stock Choice and Natural Gas Demand

For a typical household, natural gas is demanded not for its own sake but for use in furnaces, appliances and the like. The household's accumulated energy saving "capital stock" is determined by income, habits, and past prices of fuels. Consequently, in any period, the household's demand for natural gas is a function of the current price, which influences how intensively the stock of equipment is used, and past prices, which influences the size and composition of that stock. A very simple structural model (Fisher and Kaysen, 1962) of these effects for a given household might be

$$\begin{aligned} Demand: &\quad Y_t = \alpha + \beta_1 X_{t-1} + \lambda Z_{t-1} + \delta\left(K_t + E_t\right) + \varepsilon_t \quad (1) \\ Equipment: &\quad K_t = \gamma_1 X_{t-12} + \gamma_2 Z_t \quad (2) \\ Efficiency: &\quad E_t = \gamma_3 T_t \quad (3) \end{aligned}$$

where Y_t is use per household of weather normalized Natural gas at time t, X_{t-1} is the real (base = \$2000) price of natural gas at time t - 1, Z_t is real (base = \$2000) household income at time t, K_t is capital stock with a given efficiency E_t at time t, T_t is a annual time trend to capture technological improvements in the efficiency of the capital stock, and ε_t is a random error term. We use the real price lagged one period to capture the short-run response to a price change since the current price is not known until the gas bill arrives in the next billing period. Hence, a household's price-induced consumption adjustment during this period is based on last period's real gas price.

If equation (1) is in natural logarithms for Y_t, X_{t-1} and Z_t, the coefficient β_1 can be interpreted at the short-run price elasticity of natural gas demand. It measures the responsiveness of natural gas demand at time t to a change in natural gas price at time t-1 for a fixed capital stock of natural gas appliances K_t. In order to derive the long-run price elasticity of natural gas demand, we need to substitute equations (2) and (3) into equation (1) to get

$$Y_t = \alpha + \beta_1 X_{t-1} + \beta_2 X_{t-12} + \beta_3 Z_t + \beta_4 T_t + \varepsilon_t \quad (4)$$

If all variables except the time trend are in logarithms, then the coefficient on X_{t-1} is an estimate of the short-run price elasticity, the sum of the coefficients on all price variables is an estimate of the long-run price elasticity, and a negative coefficient (β_4) on the annual time trend is the decline in use per household of natural gas demand due to the adoption of newer and more efficient capital equipment.

Although the length of the lag (t-12) on price in equation (2) to capture the capital stock adjustment process is somewhat arbitrary in this formulation, one can put other restrictions on the shape and length of the price and lagged price coefficients by using models such as the Koyck(1954) or Almon(1965) lag.

The coefficient β_1 in equation (4) gives the short-run price elasticity of natural gas demand. In equation (4) the coefficient β_2 captures capital stock adjustments that depend on past natural gas prices, while still allowing for an annual decline in use per customer that occurs because of a non-gas price induced rate of turnover of the capital stock to more energy efficient equipment. The sum of the coefficients $\beta_1 + \beta_2$ represents the long-run elasticity of natural gas demand. The coefficient β_4 on the time trend variable represents the pure turnover to newer more efficient capital equipment after subtracting out the gas price effect on this turnover rate captured by β_2. A negative coefficient (β_4) on the annual time trend is the annual decline in use per household of natural gas demand due to the natural adoption of newer and more efficient capital equipment.

Section 4: Empirical Results by Region

The AGA study is interested in answering the following five questions:

(a) What are the changes in natural gas use per residential customer on a weather normalized basis since the year 2000?
(b) What is the short-run price elasticity of demand for natural gas for its member's customers?
(c) Has this short-run price elasticity of natural gas demand changed since 2000?
(d) What is the long-run price elasticity of natural gas demand for its member's customers?
(e) What is the annual reduction in natural gas usage per customer due to the natural replacement of old inefficient natural gas appliances with more energy efficient appliances; and the building of new homes with greater shell efficiencies compared to existing homes?

To answer these questions we estimated two variants of equations[5] (1) to (3). The first variant assumes the short-run price elasticity has a structural shift in the year 2000 and the second model assumes there is no shift in the short-run price elasticity in the year 2000 and beyond. These two equations are given below as (4a) and (4b), respectively:

$$Y_t = \alpha + \beta_1 X_{t-1} + \delta_{2000} X_{t-1} \bullet D2000 + \beta_2 X_{t-12} + \beta_4 t_t + \varepsilon_t \qquad (4a)$$

$$Y_t = \alpha + \beta_1 X_{t-1} + \beta_2 X_{t-12} + \beta_4 T_t + \varepsilon_t \qquad (4b)$$

where all variables except the time trend are in natural logarithms and D2000 is a 0,1 indicator variable, equal to 0 if the time period is pre year 2000, and equal to 1 if the time period is the year 2000 or greater. The dependent variable Y_t in equations (4a) and (4b) is daily natural gas use per customer in month t.

In equation (4a), the coefficient δ_{2000} is a shift coefficient on the price elasticity given by β_1. The interpretation of δ_{2000} is that β_1 represents the price elasticity of natural gas demand for the period prior to the year 2000, and $\beta_1 + \delta_{2000}$ gives the price elasticity of natural gas demand for the year 2000 and beyond. So a negative δ_{2000} in equation (4a) would indicate that demand has become more elastic since

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[5] We omitted the income variable Z_t for the reasons outlined the Background Section of the paper. First, estimates of real disposable income (per customer, household, or person) are difficult to obtain at the LDC level, which is the building block of this research. Second, the services from natural gas is a normal good, one would expect a positive income effect, which should has been reflected in a positive trend in natural gas use per household. However, in our sample and specification, we observe a negative trend in use per household. The income series are highly positively autocorrelated and trend-like; see Figure 4. The income coefficient(s) were erratic and even negative. This is consistent with the declining use per household due to a naturally occurring and non-natural gas price-induced replacement of old inefficient appliances with new more efficient appliances. At present, we believe a time trend appropriately captures this new technology-induced naturally occurring adoption of more energy efficient appliances and improvements in housing shell efficiency or conservation.

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The sum of the coefficients $\beta_1 + \delta_{2000}$ in equation (4a) gives the short-run price elasticity of natural gas demand in the post-2000 period, the sum of the coefficients $\beta_1 + \delta_{2000} + \beta_2$ represents the long-run elasticity of natural gas demand in the post-2000 period, and the coefficient β_4 on the time trend variable represents the pure turnover to newer more efficient capital equipment after subtracting out the gas price effect on this turnover rate captured by β_2.

The interpretation of the coefficients for equation (4b) is similar, except in equation (4b) the slope shift coefficient δ_{2000} for the short-run elasticity is constrained to zero.

Shrinkage Estimators

With a panel data set such at the one used in this study, there is always the question of whether to pool the data and obtain a single estimate of the parameters from the whole sample, or to estimate the equations separately for each cross-section. The implicit assumption in the fixed effects model is that the intercepts are different for each cross-section, but the slope coefficients are the same for all cross sections. This may not be a tenable assumption. Indeed, in practice the constancy of slope coefficients across different cross-section units is often rejected. This implies that the equations should be estimated separately for each cross-section rather than obtaining an overall pooled estimate.

The problem with the two usual estimation methods of either pooling the data or obtaining separate estimates for each cross section is that both are based on extreme assumptions. If the data are pooled as in the fixed effects model, it is assumed the coefficients are all the same. If separate estimates are obtained for each cross section, it is assumed that the coefficients are all different for each cross section. The truth probably lies somewhere in-between. The coefficients are not exactly the same, but there is some similarity between them.

One way to allow for some similarity among the slope coefficients without constraining them to be exactly the same is to assume the coefficients all come from a joint distribution with a common mean and non-zero covariance matrix. This suggests that the resulting coefficient estimates should be a weighted average of the overall pooled estimate and the separate time series estimates based on each cross section. Thus, each cross-section estimate is “shrunk” towards the overall pooled estimate. For example, consider the model given by equation (4b) and using aggregate data on the nine census Regions to estimate the coefficients. This model is:

$$Y_{i,t} = \alpha + \beta_1 X_{i,t-1} + \beta_2 X_{i,t-12} + \beta_3 Z_{i,t} + \beta_4 T_{i,t} + \varepsilon_{i,t}$$

$$where\ i = 1,2,3,...,N\ (N = 9, BEA\ Census\ Regions); t = 1,2,3,...,T;\ (T = observations)$$

The implicit assumption in the fixed effects model is that we retain the i subscript on α but remove the subscript on the β’s. The implicit assumption if we run separate regressions for each cross section is that the i subscript is retained on both α and all the β’s.

A shrinkage estimator sometimes suggested is the Stein rule estimator defined by:

$$\tilde{\beta}_i = \left(1 - \frac{c}{F}\right)\hat{\beta}_i + \left(\frac{c}{F}\right)\hat{\beta}_p \qquad (5)$$

where $\tilde{\beta}_i$ is the shrinkage estimator, $\hat{\beta}_i$ is the separate OLS estimate from each time series, $\hat{\beta}_p$ is the fixed effects pooled estimator. The F is the F-test statistic used to test the null hypothesis that all the β's are equal across each cross-section. The constant c is given by

$$c = \frac{(N-1)K-2}{NT-NK+2}, \tag{6}$$

We will present the shrinkage estimates for the nine Census Regions below when we discuss the regional results.

Regional OLS Estimates

Tables 4A and 4B to Tables 12A and 12B give the estimates of equations (4a) and (4b) for each of the nine census Regions using data on the individual LDCs in each of the respective Regions. For the most part, the Regional results are similar to the national results, with some differences noted below.

East North Central Region

The regression output for the ENC Region is given in Tables 4A and 4B. In Table 4A, we estimate neither a practical nor a statistically significant shift in the short-run elasticity in post 2000 and beyond. According to equation (4b) in Table 6B, the short-run elasticity is between -0.08 and –0.12, and is statistically significantly different from zero in the pooled model. The long-run elasticity is between –0.22 and –0.27. In the pooled regression, we observe a statistically significant annual declining rate of weather normal use per household demand of 1.0%. From Table 4B we see the total annual percent decline in use per customer one year after a ten percent price increase is between 2.8% and 3.2%, which is close to the annual percent decline in the national sample.

Table 4A
ENC Regional Elasticity Model Estimates for Equation (4a)
(t-stats in parentheses)

Variable	Pooled With LDC Fixed Effects Dummies	Average of 41 Individual LDC OLS Estimates
$\ln(\text{Price}_{t-1})$	-0.09 (-3.02)	-0.12
$\ln(\text{Price}_{t-1})$*D2000	0.005 (0.51)	-0.006
$\ln(\text{Price}_{t-12})$	-0.14 (-3.63)	-0.16
Annual Time Trend	-0.011 (-3.92)	0.0013
Rbar^2	0.99	
Std. Error of Regression	0.064	
Mean of the Dependent Variable	1.319	
AIC	-2.569	
Schwarz Criterion	-2.200	
Number of Observations	195	3

Table 4B
ENC Regional Elasticity Model Estimates for Equation (4b)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
Ln($Price_{t-1}$)	-0.08 (-3.02)	-0.12
Ln($Price_{t-12}$)	-0.14 (-3.66)	-0.15
Annual Time Trend	-0.010 (-4.57)	-0.001
$Rbar^2$	0.99	
Std. Error of Regression	0.063	
Mean of the Dependent Variable	1.319	
AIC	-2.578	
Schwarz Criterion	-2.225	
Number of Observations	195	3

East South Central Region

The regression output for the ESC Region is given in Tables 5A and 5B. In Table 5A, we estimate neither a practical nor a statistically significant shift in the short-run elasticity in post 2000 and beyond. According to equation (4b) in Table 5B, the short-run elasticity is
-0.06 when computed from the average of the individual LDC results and for all practical purposes is zero in the pooled regression. The long-run elasticity is between –0.01 and
–0.12. In the pooled regression, we observe a statistically significant annual declining rate of weather normal use per household demand of 2.0%. From Table5B we see the total annual percent decline in use per customer one year after a ten percent price increase is between 2.0% and 2.1%, which is slightly lower than the annual percent decline in the national sample.

Table 5A
ESC Regional Elasticity Model Estimates for Equation (4a)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
Ln($Price_{t-1}$)	-0.007 (-0.12)	-0.08
Ln($Price_{t-1}$)*D2000	0.0169 (1.09)	0.02
Ln($Price_{t-12}$)	-0.03 (-0.47)	-0.06
Annual Time Trend	-0.023 (-4.92)	-0.016
$Rbar^2$	0.97	
Std. Error of Regression	0.129	
Mean of the Dependent Variable	1.013	
AIC	-1.167	
Schwarz Criterion	-0.835	
Number of Observations	227	3

Table 5B
ESC Regional Elasticity Model Estimates for Equation (4b)
(t-stats in parentheses)

Variable	Pooled With LDC Fixed Effects Dummies	Average of 41 Individual LDC OLS Estimates
Ln($Price_{t-1}$)	0.012 (0.23)	-0.06
Ln($Price_{t-12}$)	-0.026 (-0.44)	-0.06
Annual Time Trend	-0.020 (-5.33)	-0.012
$Rbar^2$	0.97	
Std. Error of Regression	0.129	
Mean of the Dependent Variable	1.013	
AIC	-1.170	
Schwarz Criterion	-0.853	
Number of Observations	227	3

Middle Atlantic Region

The regression output for the MAC Region is given in Tables 6A and 6B. In Table 6A, we estimate neither a practical nor a statistically significant shift in the short-run elasticity in post 2000 and beyond. According to equation (4b) in Table 6B, the short-run elasticity is -0.13 when computed from the average of the individual LDC results, and is –0.10 in the pooled regression. The long-run elasticity is between –0.18 and –0.20. In the pooled regression we observe a statistically significant annual declining rate of weather normal use per household demand of 1.3%. Table 6B we see the total annual percent decline in use per customer one year after a ten percent price increase is between 2.5% and 3.3%, which is close to the annual percent decline in the national sample.

Table 6A
MAC Regional Elasticity Model Estimates for Equation (4a)
(t-stats in parentheses)

Variable	Pooled With LDC Fixed Effects Dummies	Average of 41 Individual LDC OLS Estimates
Ln($Price_{t-1}$)	-0.11 (-2.35)	-0.12
Ln($Price_{t-1}$)*D2000	0.01 (1.21)	0.005
Ln($Price_{t-12}$)	-0.09 (-1.70)	-0.04
Annual Time Trend	-0.015 (-5.21)	-0.009
$Rbar^2$	0.97	
Std. Error of Regression	0.100	
Mean of the Dependent Variable	1.508	
AIC	-1.681	
Schwarz Criterion	-1.325	
Number of Observations	465	6

Table 6B
MAC Regional Elasticity Model Estimates for Equation (4b)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
Ln($Price_{t-1}$)	-0.10 (-2.24)	-0.13
Ln($Price_{t-12}$)	-0.10 (-1.77)	-0.05
Annual Time Trend	-0.013 (-5.80)	-0.007
$Rbar^2$	0.97	
Std. Error of Regression	0.100	
Mean of the Dependent Variable	1.508	
AIC	-1.682	
Schwarz Criterion	-1.335	
Number of Observations	465	6

Mountain Region

The regression output for the MTN Region is given in Tables 7A and 7B. In Table 7A, we estimate shift of –0.035 in the short-run elasticity in post 2000 and beyond. According to equation (4b) in Table 7B, the short-run elasticity is -0.11 when computed from the average of the individual LDC results and is –0.07 and statistically significant in the pooled regression. The long-run elasticity is between –0.10 and –0.19. In the pooled regression we observe a statistically significant annual declining rate of weather normal use per household demand of 0.9%. Table 7B we see the total annual percent decline in use per customer one year after a ten percent price increase is between 1.9% and 2.8%, which in the pooled regression (1.9%) is slightly lower than the annual percent decline in the national sample.

Table 7A
MTN Regional Elasticity Model Estimates for Equation (4a)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
Ln($Price_{t-1}$)	-0.014 (-0.52)	-0.08
Ln($Price_{t-1}$)*D2000	-0.035 (-4.19)	-0.02
Ln($Price_{t-12}$)	-0.018 (-0.75)	-0.07
Annual Time Trend	-0.004 (-2.47)	-0.007
$Rbar^2$	0.99	
Std. Error of Regression	0.060	
Mean of the Dependent Variable	1.262	
AIC	-2.700	
Schwarz Criterion	-2.353	
Number of Observations	298	4

Table 7B
MTN Regional Elasticity Model Estimates for Equation (4b)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
$Ln(Price_{t-1})$	-0.07 (-2.73)	-0.11
$Ln(Price_{t-12})$	-0.03 (-1.33)	-0.08
Annual Time Trend	-0.009 (-6.22)	-0.009
$Rbar^2$	0.99	
Std. Error of Regression	0.060	
Mean of the Dependent Variable	1.262	
AIC	-2.644	
Schwarz Criterion	-2.309	
Number of Observations	298	4

New England Region

The regression output for the NEC Region is given in Tables 8A and 8B. In Table 8A, we do estimate a statistically significant shift in the short-run price elasticity in year 2000 and beyond in Table 8A, although in this case it is a shift that lowers the short-run price elasticity and is not practically significant with only 0.015 decrease. According to equation (4b) in Table 8B, the short-run elasticity is -0.08 when computed from the average of the individual LDC results and is also –0.08 and statistically significant in the pooled regression. The long-run elasticity is between –0.25 and –0.28. In the pooled regression we observe a statistically significant annual declining rate of weather normal use per customer demand of 0.4%. Table 8B we see the total annual percent decline in use per customer one year after a ten percent price increase is between 2.9% and 3.0%, which is close to the annual percent decline in the national sample.

Table 8A
NEC Regional Elasticity Model Estimates for Equation (4a)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
$Ln(Price_{t-1})$	-0.09 (-3.34)	-0.09
$Ln(Price_{t-1})*D2000$	0.015 (2.44)	0.01
$Ln(Price_{t-12})$	-0.17 (-5.06)	-0.20
Annual Time Trend	-0.008 (-4.24)	-0.005
$Rbar^2$	0.97	
Std. Error of Regression	0.096	
Mean of the Dependent Variable	1.307	
AIC	-1.767	
Schwarz Criterion	-1.413	
Number of Observations	660	8

Table 8B
NEC Regional Elasticity Model Estimates for Equation (4b)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
$Ln(Price_{t-1})$	-0.08 (-2.86)	-0.08
$Ln(Price_{t-12})$	-0.17 (-5.00)	-0.20
Annual Time Trend	-0.004 (-3.73)	-0.002
$Rbar^2$	0.97	
Std. Error of Regression	0.097	
Mean of the Dependent Variable	1.307	
AIC	-1.760	
Schwarz Criterion	-1.412	
Number of Observations	660	8

Pacific Region

The regression output for the PAC Region is given in Tables 9A and 9B. In Table 9A, we do estimate a statistically significant shift in the short-run price elasticity in year 2000 and beyond, although from a practical point of view this decline is small with an impact of only 0.02. According to equation (4b) in Table 9B, the short-run elasticity is -0.07 when computed from the average of the individual LDC results and is also –0.07 and statistically significant in the pooled regression. The long-run elasticity is between –0.12 and –0.15. In the pooled regression we observe a statistically significant annual declining rate of weather normal use per customer demand of 0.8%. In Table 9B, we see the total annual percent decline in use per customer one year after a ten percent price increase is 2.0%, which is lower than the annual percent decline in the national sample.

Table 9A
PAC Regional Elasticity Model Estimates for Equation (4a)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
$Ln(Price_{t-1})$	-0.04 (-1.29)	-0.03
$Ln(Price_{t-1})$*D2000	-0.02 (-2.13)	-0.02
$Ln(Price_{t-12})$	-0.05 (-1.66)	-0.07
Annual Time Trend	-0.005 (-1.96)	-0.004
$Rbar^2$	0.98	
Std. Error of Regression	0.072	
Mean of the Dependent Variable	0.910	
AIC	-2.314	
Schwarz Criterion	-1.929	
Number of Observations	258	4

Table 9B
PAC Regional Elasticity Model Estimates for Equation (4b)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
Ln(Price$_{t-1}$)	-0.07 (-2.61)	-0.07
Ln(Price$_{t-12}$)	-0.05 (-1.83)	-0.08
Annual Time Trend	-0.008 (-3.87)	-0.005
Rbar^2	0.98	
Std. Error of Regression	0.073	
Mean of the Dependent Variable	0.910	
AIC	-2.302	
Schwarz Criterion	-1.931	
Number of Observations	258	4

South Atlantic Region

The regression output for the SAC Region is given in Tables 10B and 10B. In Table 10A, we estimate neither a practical nor a statistically significant shift in the short-run elasticity in post 2000 and beyond. According to equation (4b) in Table 10B, the short-run elasticity is -0.11 when computed from the average of the individual LDC results and is –0.12 and statistically significant in the pooled regression. The long-run elasticity is between -0.24 and -0.29. In the pooled regression we observe a statistically significant annual declining rate of weather normal use per customer of 0.8%. Table 10B, we see the total annual percent decline in use per customer one year after a ten percent price increase is between 3.4% to 3.7%, which is higher than the annual percent decline in the national sample.

Table 10A
SAC Regional Elasticity Model Estimates for Equation (4a)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
Ln(Price$_{t-1}$)	-0.115 (-3.09)	-0.10
Ln(Price$_{t-1}$)*D2000	-0.002 (-0.15)	-0.005
Ln(Price$_{t-12}$)	-0.17 (-4.16)	-0.13
Annual Time Trend	-0.008 (-2.58)	-0.009
Rbar^2	0.97	
Std. Error of Regression	0.109	
Mean of the Dependent Variable	1.218	
AIC	-1.509	
Schwarz Criterion	-1.146	
Number of Observations	280	4

Table 10B
SAC Regional Elasticity Model Estimates for Equation (4b)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
Ln($Price_{t-1}$)	-0.12 (-3.30)	-0.11
Ln($Price_{t-12}$)	-0.17 (-4.18)	-0.13
Annual Time Trend	-0.008 (-3.76)	-0.010
$Rbar^2$	0.97	
Std. Error of Regression	0.108	
Mean of the Dependent Variable	1.218	
AIC	-1.516	
Schwarz Criterion	-1.166	
Number of Observations	280	4

West North Central Region

The regression output for the WNC Region is given in Tables 11A and 11B. In Table 11B, We do estimate a statistically significant shift in the short-run price elasticity in year 2000 and beyond in Table 11A, although in this case it is a shift that lowers the short-run price elasticity and from a practical point of view is not significant with an impact of only –0.014. According to equation (4b) in Table 11B, the short-run elasticity is -0.08 when computed from the average of the individual LDC results and is –0.09 and statistically significant in the pooled regression. The long-run elasticity is between -0.13 and -0.15. In the pooled regression we observe a statistically significant annual declining rate of weather normal use per customer demand of 1.1%. Table 11B we see the total annual percent decline in use per customer one year after a ten percent price increase is between 2.5% and 2.6%, which is close to the annual percent decline in the national sample.

Table 11A
WNC Regional Elasticity Model Estimates for Equation (4a)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
Ln($Price_{t-1}$)	-0.10 (-5.19)	-0.09
Ln($Price_{t-1}$)*D2000	0.014 (1.98)	0.01
Ln($Price_{t-12}$)	-0.06 (-2.62)	-0.05
Annual Time Trend	-0.014 (-5.48)	-0.014
$Rbar^2$	0.99	
Std. Error of Regression	0.048	
Mean of the Dependent Variable	1.314	
AIC	-3.141	
Schwarz Criterion	-2.765	
Number of Observations	190	3

Table 11B
WNC Regional Elasticity Model Estimates for Equation (4b)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
Ln($Price_{t-1}$)	-0.09 (-4.78)	-0.08
Ln($Price_{t-12}$)	-0.06 (-2.69)	-0.05
Annual Time Trend	-0.011 (-5.35)	-0.012
$Rbar^2$	0.99	
Std. Error of Regression	0.048	
Mean of the Dependent Variable	1.314	
AIC	-3.129	
Schwarz Criterion	-2.770	
Number of Observations	190	3

West South Central Region

The regression output for the WSC Region is given in Tables 12A and 12B. In Table 12A, we estimate neither a practical nor a statistically significant shift in the short-run elasticity in post 2000 and beyond. According to equation (4b) in Table 12B, the short-run elasticity is -0.14 when computed from the average of the individual LDC results and is –0.13 and statistically significant in the pooled regression. The long-run elasticity is -0.16 in both the pooled regression and when computed as the average of the individual LDC OLS estimates. In the pooled regression we observe a statistically significant annual declining rate of weather normal use per customer demand of 1.6%. Table 12B, we see the total annual percent decline in use per customer one year after a ten percent price increase is between 2.9% and 3.2%, which is close to the annual percent decline in the national sample.

Table 12A
WSC Regional Elasticity Model Estimates for Equation (4a)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
Ln($Price_{t-1}$)	-0.12 (-1.71)	-0.13
Ln($Price_{t-1}$)*D2000	-0.008 (-0.48)	-0.009
Ln($Price_{t-12}$)	-0.03 (-0.40)	-0.02
Annual Time Trend	-0.015 (-2.52)	-0.01
$Rbar^2$	0.92	
Std. Error of Regression	0.198	
Mean of the Dependent Variable	0.722	
AIC	-0.318	
Schwarz Criterion	0.048	
Number of Observations	450	6

Table 12B
WSC Regional Elasticity Model Estimates for Equation (4b)
(t-stats in parentheses)

Variable	**Pooled With LDC Fixed Effects Dummies**	**Average of 41 Individual LDC OLS Estimates**
$\ln(\text{Price}_{t-1})$	-0.13 (-1.87)	-0.14
$\ln(\text{Price}_{t-12})$	-0.03 (-0.40)	-0.02
Annual Time Trend	-0.016 (-3.79)	-0.013
Rbar^2	0.92	
Std. Error of Regression	0.198	
Mean of the Dependent Variable	0.722	
AIC	-0.322	
Schwarz Criterion	0.034	
Number of Observations	450	6

Shrinkage Estimates

We also estimate equation (4a) and (4b) with a type of shrinkage estimator, time series data on the Nine Census Regions, aggregated over the respective LDCs in each region. We will apply the Stein rule estimator discussed above in the sub-section on Shrinkage Estimators. The advantage of shrinkage estimators is that they allow for some similarity among the slope coefficients without constraining them to be exactly the same as in the case of pooled estimates.

Using aggregate regional data, Table 13 below gives the pooled fixed effects estimates of equation (4b) and the average of the individual regional coefficient estimates. Using regional aggregate data we see from Table 13 the impact of a ten percent price increase is a similar 2.9 percent decline in use per customer one year later.

Table 13
Regional Elasticity Model Estimates using aggregate data for Equation (4b)
(t-stats in parentheses)

Variable	**Pooled With Regional Dummies**	**Average of Individual Regions**
$\ln(\text{Price}_{t-1})$	-0.12 (-3.4)	-0.10
$\ln(\text{Price}_{t-12})$	-0.06 (-1.63)	-0.08
Annual Time Trend	-0.011 (-3.72)	-0.011
Rbar^2	0.98	
Std. Error of Regression	0.094	
Mean of the Dependent Variable	12.14	
AIC	-1.79	
Schwarz Criterion	-1.34	
Number of Observations	540	9

Section 5: Summary of Results and Policy Implications

This research project was initiated to examine the decline in residential natural gas consumption since 2000 and to determine whether there had been a change in the response by residential consumers to higher (and more volatile) natural gas prices. The data that was collected and the analysis conducted support two important findings and a general rule of thumb, with caveats, for forecasting residential natural gas consumption under normal weather conditions.

First, the results from analyzing the AGA sample data leads to the following rule of thumb. This rule appears to capture consumers' winter price sensitive consumption behavior reasonably well across the LDCs and Census regions.

$$Consumption = Monthly\,Weather + Price\ Effect + Efficiency\ \&\ Conservation$$

Consumption is strongly influenced by seasonal heating needs, response to price change, and the efficiency changes in appliances and home shell efficiency coupled with conservation behavior by consumers. While the separate efficiency and conservation effects due to appliance and housing shell turnover are difficult to disentangle in the current sample, they appear to be discernable from the price effects. Table 14 gives a summary of the national and separate regional price and naturally occurring time trend effects found in this study.

Second, we could not find evidence supporting an appreciable change in the short-run price elasticity of natural gas consumption in the post year 2000 period.

Table 14
Summary of National and Regional
Natural Gas Price and New Technology Elasticity Estimates[6]

Region	Short-run elasticity	Long-run elasticity*	Annual Time Trend	Total Response to a 10% Price Increase**
National	-0.09	-0.18	-1.0%	-2.8%
East North Central	-0.08	-0.22	-1.0%	-3.2%
East South Central	0.01	-0.01	-2.0%	-2.1%
Middle Atlantic	-0.10	-0.20	-1.3%	-3.3%
Mountain	-0.07	-0.10	-0.9%	-1.9%
New England	-0.08	-0.25	-0.4%	-2.9%
Pacific	-0.07	-0.12	-0.8%	-2.0%
South Atlantic	-0.12	-0.29	-0.8%	-3.7%
West North Central	-0.09	-0.15	-1.1 %	-2.6%
West South Central	-0.13	-0.16	-1.6%	-3.2%

* Cumulative: includes impacts of short-run elasticities
** The total response to a 10% price increase is the sum of the long-run elasticity and the annual time trend effect.

The results from the price elasticity estimates and the combination of efficiency and conservation estimates are able to explain the post 2000 winter consumption per customer actual experience. Normal winter season natural gas use per household in the US has declined about 13.1% since the year

[6] Estimates obtained from the "fixed effects" pooled regression.

2000. There has been an increase in real natural gas prices of 44% since the year 2000, which according to our analysis would lead to approximately a 7.9% (0.18 x 44%) decline in use per customer by the year 2006. In addition to this 7.9% price induced decline in weather normal use per household, there would be an additional 6.0% (6 x 1.0%) decline because of the natural annual rate of turnover of old gas appliances to newer more efficient appliances. Hence, our analysis predicts a decline of 13.9% over the six-year period, which is very close to the actual decline of 13.1%.

$$\begin{array}{lclcl} \textit{Overall decline} & & \textit{Price Effect} & & \textit{Conservation and} \\ \textit{in Winter Gas Use} & = & \textit{Elasticity with} & + & \textit{Turnover to More} \\ \textit{per Customer} & & \textit{Price Increase} & & \textit{Efficient Appliances} \\ \quad 13.9\% & = & 0.18\,x\,44\% & + & \quad 6\,x\,1.0\% \\ & = & \quad 7.9\% & + & \quad\; 6.0\% \end{array}$$

In the expression above the left hand term is the overall declining rate of winter gas use per customer, the first term on the right hand side is the price effect reflecting elasticity with price increase, and the second term the effect from conservation and turnover to more efficient appliances that occurs naturally every year with or without a price increase.

The proposed rule of thumb suggests that twelve months after a 10% increase in natural gas prices at the national level, there will be nearly a 3% decline in natural gas use per customer. This 3% decline is comprised of about a 1 % drop in gas use with the current capital stock, about a 1% drop in use per customer because households respond to the higher gas prices by buying more efficient appliances, and a 1% drop in gas usage per customer due to the natural turnover of old gas appliances to the more efficient gas appliances that are available in the market each year. This rule of thumb will vary by LDC; because they are heterogeneous in terms of weather, housing stocks, and standards of living.

The heightened conservation behavior by consumers is partly due to the many government and utility programs that currently exist to encourage residential consumers to save energy:

- The federal government encourages conservation through weatherization programs funded by the Low-Income Household Energy Assistance Program (LIHEAP), tax credits for purchase of efficient appliances and shell improvements, and consumer education on the importance of saving energy.
- State and local governments also encourage efficiency through similar programs
- Many utilities provide rebates, incentives, and assistance to their customers to improve use of energy. For example, electric and natural gas utilities provided more than $140 million in 2005 to assist low-income customers to weatherize their homes {Source: http://liheap.ncat.org/tables/FY2005/05stlvtb.htm }

Finally, there is a natural turnover of old gas appliances every year that has nothing to do with changes in the price of natural gas. It occurs when old appliances wear out and need to be replaced. It also occurs as new housing stock is built. This results in an additional 1% per year reduction in gas use, even if gas prices remain constant over the period; and occurs because of increased gas appliance efficiency and increase shell efficiency of new homes. These effects will vary somewhat by LDC, because of regional differences in weather, appliance stocks, housing shell efficiency, demographic and economic characteristics.

From a planning and policy perspective, even if gas prices do not increase in a given year, there will still be approximately a 1% fall in gas usage per household in the following year. This is driven by the historical forces related to the natural turnover of old appliances to the more efficient appliances that are available on the market each year. There is a caveat. We cannot address whether the phenomenon will continue for the long-term. The gains in efficiency since the 1980s and 1990s have occurred during a period of significant technological change in the efficiency of furnaces, hot water heaters, and other natural gas using appliances. Further, gains in efficiency in absolute and relative terms may or may not have the same impact as they did previously. This is an issue for more detailed engineering studies and research on a change in conservation habits of consumers for energy use and winter season comfort levels.

The policy implications of the 13.1% decline since 2000 are significant. First, regulators must recognize these trends and allow rate structures to incorporate these variations. Second, the natural turnover of appliances and increases in shell efficiency from new construction will result in continued conservation, regardless of price changes, impacting utility operations. Third, even if future gas prices remain constant or even decrease, the appliance and home shell efficiency gains achieved in prior years will not be reversed.

We do note that there are some societal benefits from this annual reduction in gas use per household. There will be a better use of society's non-renewable natural resources. There will be reduced environmental impact from energy use, and there will be lower gas utility bills for natural gas customers.

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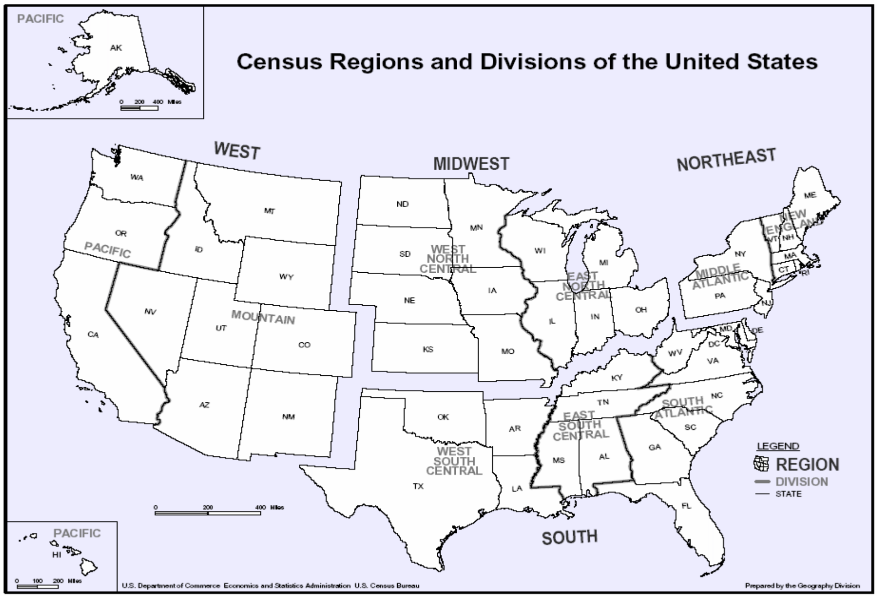
Appendix B: U.S. Census Regions

Figure 1: RSTEM 13 Electricity Demand and Supply Regions



Division 1
New England

Connecticut
Maine
Massachusetts
New Hampshire
Rhode Island
Vermont

Division 2
Middle Atlantic

New Jersey
New York
Pennsylvania

Division 3
East North Central

Illinois
Indiana
Michigan
Ohio
Wisconsin

Division 4
West North Central

Iowa
Kansas
Minnesota
Missouri
Nebraska
North Dakota
South Dakota

Division 5
South Atlantic

Delaware
District of Columbia
Florida
Georgia
Maryland
North Carolina
South Carolina
Virginia
West Virginia

Division 6
East South Central

Alabama
Kentucky
Mississippi
Tennessee

Division 7
West South Central

Arkansas
Louisiana
Oklahoma
Texas

Division 8
Mountain

Arizona
Colorado
Idaho
Montana
Nevada
New Mexico
Utah
Wyoming

Division 9
Pacific

Alaska
California
Hawaii
Oregon
Washington

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Table C.1
Sample of Residential Gas Demand Study Elasticity Estimates

Authors	Data	Estimation Method	Short Run	Long Run
Balestra & Nerlove (1966)	Pooled: 36 States for 1957-62)	GLS(EC)	NA	-0.63
Jaskow & Baughman (1976)	Pooled: 48 States for 1968-72	OLS	-0.15	-1.01
Berndt & Watkins (1977)	Pooled: Ontario and British Columbia for 1959-74	Maximum Likelihood	-0.15	-0.69
Hewlett (1977)	Cross Section: New York State household survey	OLS	NA	-0.45
Hewlett (1977)	Pooled: New York State customer survey for 1976 and 1977.	OLS	NA	-0.17
Beirlein, Dunn & McConnon (1981)	Pooled: 9 States for 1967-77	OLS	-0.23	-2.90
		GLS (EC)	-0.23	-2.96
		GLS (EC-SUR)	-0.05	-3.42
Barnes, Gillingham & Hagemann (1982)	Pooled: 10,000 households in 23 US cities. Quarterly data for 1972-73.	IV	-0.68	NA
Green & Gilbert (1983)	Cross-Sectional: non-poverty homeowners and poverty homeowners	OLS	NA	-1.25
		OLS	NA	-1.09
Blattenberger, Taylor, & Rennhack (1983)	Pooled: 48 states for 1961-74	GLS (EC)	-0.32	-0.39
Green, Salley, Grass & Osei (1986)	Pooled: between 6 and 7 thousand households for 1974 to 1979.	OLS	-0.16	NA

This appendix benefited from discussions and on-going research by Professor Carol Dahl, the Colorado School of Mines, Golden, Colorado. All errors are ours.