

AN ECONOMIC ANALYSIS OF CONSUMER RESPONSE TO NATURAL GAS PRICES

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PREPARED FOR THE AMERICAN GAS ASSOCIATION
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Executive Summary

Introduction and Key Findings

The consumption of natural gas per household has been declining, on a weather-normalized basis, since about 1980. Over time, natural gas consumers have been tightening their homes, purchasing more efficient appliances and turning down their thermostats. Given the significant increase in natural gas prices since 2000, the American Gas Association (AGA) decided to examine whether or not the trend in declining use has changed in this higher-priced environment. The results of this study are based on monthly data submitted by 46 local natural gas distribution companies that serve nearly 30 percent of all residential natural gas customers throughout the U.S. Some companies submitted data as far back as the early 1980's. The key findings of the study are as follows.

- A trend in declining use per residential natural gas customer of 1 percent annually has been documented² back to 1980. This decline rate has accelerated since the year 2000.
 - Weather-adjusted use per residential customer fell by 13.1 percent from 2000 through 2006.
 - The annual rate of decline in this 2000 to 2006 timeframe more than doubled relative to the pre-2000 period, increasing to 2.2 percent annually.
 - Further acceleration was witnessed in the 2004 to 2006 period, as evidenced by a 4.9 percent annual rate of decline.
 - The decline in use per customer has accelerated since 2000 in all 9 geographic regions analyzed.
- No appreciable changes in the price elasticity of demand were observed post-2000. Price elasticity of demand refers to the percentage change in demand for a good relative to a percentage change in price. Although the elasticity has not changed over time, it should be noted that natural gas is an essential product that provides heat, hot water and cooking. Despite the essential nature of natural gas, consumers have continued to reduce their consumption at a relatively constant rate with respect to changing prices. Therefore, the large price increases post-2000 have resulted in the large consumption declines noted above.

² 2004 AGA Energy Analysis: Patterns in Residential Natural Gas Consumption, 1980-2001.

- This study found a short-run price elasticity of -0.09 and a long-run price elasticity of -0.18 . (Long-run elasticity refers to a period of time long enough for consumers to change the capital stock of their energy consuming equipment and the shell efficiency of their homes.)
- These price elasticity estimates are relatively consistent with previous works on this subject.
- The econometric analysis presented in this study predicts a decline of 13.9 percent between 2000 and 2006; the actual decline was 13.1 percent. The decline is attributable to a price effect and the longer-run trend towards tighter homes and more efficient appliances. The price elasticity effect is 7.9 percent - equal to the elasticity estimate of -0.18 times the 44 percent real price increase. The remaining 6.0 percent is explained by the longer-run trend towards tighter homes and more efficient appliances.
- As a general rule of thumb, at the national level we would expect a 10 percent increase in the price of natural gas to result in nearly a 3 percent decline in the average residential use per customer 12 months later – 1 percent attributable to more conservation with existing appliances, 1 percent attributable to the price-induced purchase of more efficient appliances, and 1 percent attributable to the natural turnover of equipment that occurs annually.

Background

Residential natural gas consumption is strongly influenced by three factors: seasonal heating needs; response to price change; and the efficiency changes in appliances and home shells caused by a natural turnover rate to more efficient homes and gas appliances. On a weather-adjusted basis, the price and the long run conservation effects are key determinants of changes in residential natural gas consumption. The price effects can be further decomposed into short-term and long-term effects. Short term effects are decisions made by consumers with the current capital stock. Residential customers “turning down the thermostat” would be considered a short term effect. Long term effects are distinguished from short term effects by the inclusion of the decision to purchase more efficient energy consuming appliances and prematurely retiring less efficient ones. The price elasticity in the long-run is the sum of (1) the short-run demand and (2) the additional changes that occur to quantity demanded one year later because of natural gas price effects on the efficiency of the appliance capital stock and on the shell efficiency of homes³. While the separate efficiency and conservation effects due to

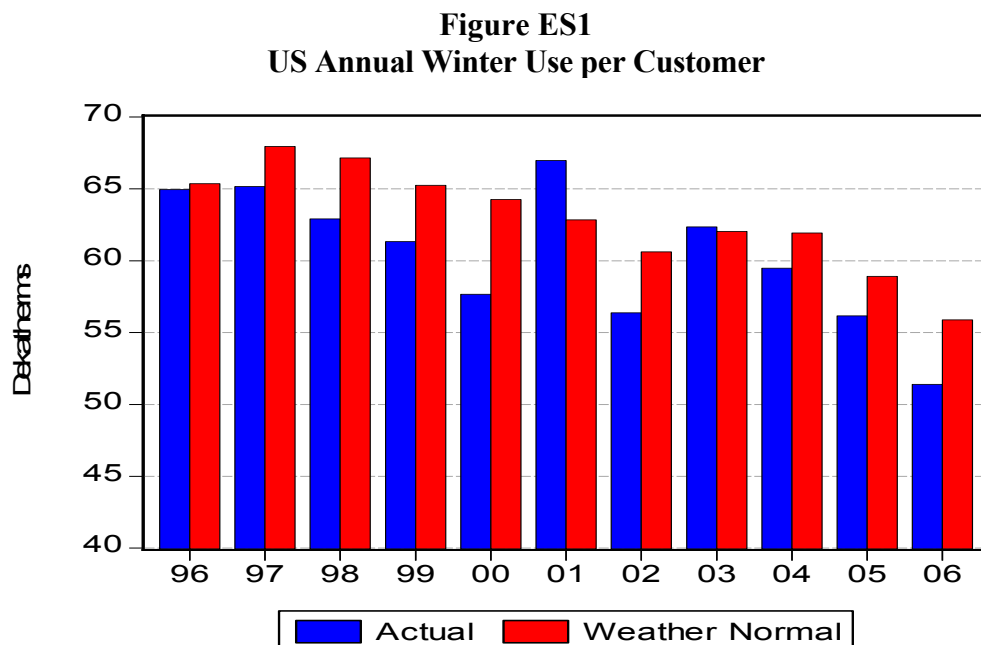
³ It should be noted that if natural gas prices decrease, consumers will not replace recently purchased efficient equipment with less efficient equipment. So there may be asymmetry with respect to the impact of natural gas prices on appliance and shell efficiency. The efficiency gains in appliance equipment that have occurred in the last several years will not disappear if natural gas prices go down. However, declining prices may lead consumers turning up thermostats to increase comfort levels (in the short-run). In the very long-run, a decline in prices could lead to an increase in burner tips per customer.

appliance and housing shell turnover are difficult to disentangle in the current sample, they do appear to be discernable from the long term price effects.

To address these issues, AGA commissioned a study 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. Other objectives of this study were: to obtain updated elasticity estimates for all nine US Census Regions and for the US; to test for an increase in the price elasticity of demand for natural gas since the year 2000; and to estimate a natural rate of decline in use per customer due to technology-induced gains in appliance and shell efficiency and a change in conservation attitudes that would occur even in an environment of constant real natural gas prices.

Decline in Use per Customer

Demand for natural gas per residential customer has been declining since the 1980's, and in recent years this decline has accelerated. 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 nationally between 2000 and 2006 for the sample of companies analyzed in this report. Figure ES1 below shows the winter season use per customer in actual and weather normal dekatherms from 1996-2006 using the data collected by AGA.⁴ It is clear that actual and weather normalized use per customer has been declining since 1997 and this decline has accelerated since 2004.



⁴ The data was collected from 46 Local Distribution Companies (LDCs) in 29 states, representing 28 percent of all residential customers. An LDC is a gas utility that serves a specific rate jurisdiction. Some of the companies in this sample have multiple jurisdictions in their corporate structure. The winter season for this report is defined as the sum of the monthly consumption between October and March.

Table ES1 disaggregates the national winter season weather normal use per residential customer across the nine US Census Regions and for the US. The decline in weather normal use per customer has occurred across all US Census regions. The decline ranges from 5.7 dekatherms per customer for the West South Central region to 10.9 dekatherms for the East North Central region. The percentage decline in use per customer ranged from 9.2 percent for the Middle Atlantic Region to 14.8 percent for the Pacific Region.

Table ES1
Annual Winter Season Weather Normal
Natural Gas Use per Residential Customer,
By Region and for the U.S.
(Dekatherms 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%

Price Elasticity and “Natural” Conservation Estimates

This study found that neither a practical nor statistically significant change in the price elasticity of residential natural gas consumption occurred in the post year 2000 period. The price elasticity of residential natural gas demand appears to have remained relatively constant since the 1990s. This implies the large percentage price increase since 2000 accounted for the decline in natural gas use, rather than an increased sensitivity or greater response by households to a given price change. The study also found that independent of natural gas price increases, the naturally occurring decline due to the technology driven gain in appliance and home thermal shell efficiency, as well as changes in conservation attitudes was 1 percent per year.

Table ES2 illustrates that for the sample of companies in the study, the short run price elasticity of demand averaged -0.09, while the long run estimated averaged -0.18. Therefore, given a 10 percent increase in the price of natural gas, consumption would decline 2.8 percent; 1.8 percent for price response, added to 1.0 percent decline due to the normal turnover of appliances and other “natural” conservation measures. There is very little regional variation in the total impact of a 10 percent increase in real prices on use per

customer. The impact in all regions was close to the national estimate of 2.8 percent, with the Mountain region being the lowest at 1.9 percent and the South Atlantic region being the highest at 3.7 percent.

The study also found that the elasticity estimates calculated using the sample data were generally consistent with the elasticity estimates found in the energy economics literature.⁵

Table ES2
Summary of National and Regional
Natural Gas Price Elasticity Estimates*

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%

* Estimates obtained from the “fixed effects” pooled regression

** 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.

Implications

These price elasticity estimates and the natural conservation trends are able to explain the post 2000 winter consumption per household per customer actual experience.

Between 2000 and 2006, real natural gas prices for the sample companies in this study rose 44 percent, which according to our analysis would lead to approximately a 7.9 percent (0.18×44 percent) decline in use per customer by the year 2006. In addition to this 7.9 percent price induced decline in weather normal use per household, there would be an additional 6.0 percent (6×1.0 percent) 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 percent over the six-year period, which is very close to the actual decline of 13.1 percent.

⁵ See Appendix C of the main report for a summary of the elasticity estimates found in the energy economics literature.

<i>Overall decline in Winter Gas Use per Customer</i>	=	<i>Price Effect Elasticity with Price Increase</i>	+	<i>Conservation and Turnover to More Efficient Appliances</i>
13.9%	=	0.18 x 44%	+	6 x 1.0%
	=	7.9%	+	6.0%

In the expression above, the left hand term is the overall predicted decline of winter gas use per customer, the first term on the right hand side is the price effect reflecting the elasticity estimate multiplied by the 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 results from analyzing the AGA sample data lead to a general rule of thumb. This rule does not apply to all companies in all situations, but the general rule with its caveats provides valuable insight to the underlying processes governing consumer behavior. This rule appears to capture consumers' winter price sensitive consumption behavior reasonably well across both the LDCs and Census regions. Twelve months after a 10 percent increase in natural gas prices at the national level, there will be nearly a 3 percent decline in natural gas use per customer on a national level. This 3 percent decline is comprised of about a 1 percent drop in gas use with the current capital stock, about a 1 percent drop in use per customer because households respond to the higher gas prices by replacing still functional appliances with more efficient units, and about a 1 percent 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.

Other factors that impacts residential energy use are the many programs that encourage consumers to save energy. These include:

- The federal government encourages conservation through weatherization programs funded by the Low-Income Household Energy Assistance Program (LIHEAP), tax credits for the purchase of efficient appliances and housing 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 conserve energy use. For example, electric and natural gas utilities provided more than \$140 million in 2005 to assist low-income customers to weatherize their homes.⁶

From a planning and policy perspective, even if gas prices do not increase in a given year, there will still be approximately a 1 percent 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

⁶ Source: <http://liheap.ncat.org/tables/FY2005/05stlvtb.htm>

to the more efficient appliances that are available on the market each year. The annual time trend impacts will vary somewhat by LDC, because of regional differences in weather, appliance stocks, housing shell efficiency, demographic and economic characteristics.

There is a caveat. We cannot address whether the phenomenon will continue at the same rate for the long-term. 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 on the efficiency of appliances and housing shells and economic research on the change in conservation habits of consumers for energy use and winter season comfort levels. We would note, however, that legislative and regulatory pressure for greater efficiency is likely to increase as climate change becomes a more pronounced national and international priority.

The policy implications of the 13.1 percent 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 thermal shell efficiency from new construction will result in continued conservation, impacting utility operations. Third, even if future natural gas prices remain constant or even decrease, the appliance and house shell efficiency gains achieved in prior years will not be reversed.

Future Research

As with any study, there is room for future research. Suggestions for future research are the following:

- Obtain data from natural gas companies that did not participate in the initial study.
- Try different specifications of the model.
- Use the Iterative Bayes Shrinkage Estimation Technique to get individual LDC parameter estimates.
- Consider the impact of competition from the electric utility industry.

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.

It is important from a budgeting point of view for Local Distribution Companies (LDCs) to understand the cause of this decline. Was it caused by the recent increases in natural gas prices and customer's response to these price increases? Did customers change their behavior in response to these price increases? Have they become more sensitive to natural gas price movements or has the price induced response behavior remained relatively the same over time? Did customers switch to more efficient gas appliances in response to these natural gas price increases? Is it due to technological innovations which lead to increased efficiencies in appliances and thermal shells of homes? These efficiencies are in some sense passive as older appliances are replaced with more efficient models through natural attrition.

To address these issues, the American Gas Association (AGA) funded a study to re-estimate the price elasticity of natural gas demand by residential households using a sample of data that covers the recent period of large natural gas price increases. 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 elasticity⁷ 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, et. 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.

⁷ 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.

Many of the studies estimated elasticities of natural gas demand with data aggregated at the state and national level and collected by the States; 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, is 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 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 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 dekatherms) from 1996 to 2006 using the data collected from the sample LDCs. The winter season for this report is defined as the sum of the monthly consumption between October and March.

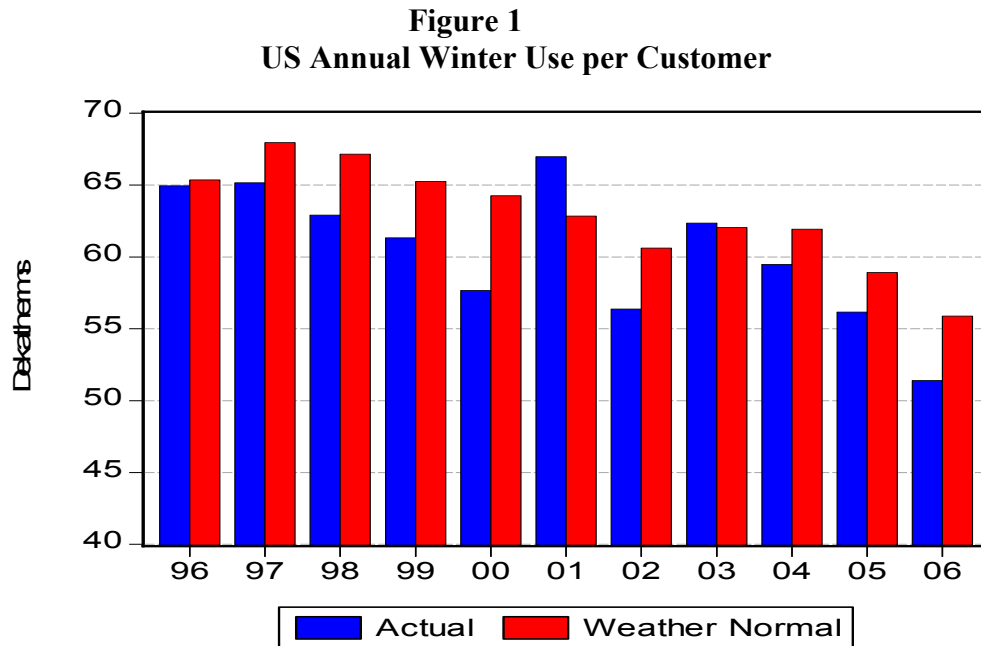


Table 1: US Annual Winter Use per Residential Customer in Dekatherms				
Year	Actual		Winter Normal	
	Level	Percent Change	Level	Percent Change
1996	64.9		65.3	
1997	65.2	0.5	67.9	4.0
1998	62.9	-3.5	67.1	-1.2
1999	61.3	-2.5	65.2	-2.8
2000	57.7	-5.9	64.3	-1.4
2001	67.0	16.1	62.8	-2.3
2002	56.4	-15.8	60.6	-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	

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.

The phenomenon of declining weather normal use per customer is not new⁸. Some even feel it started on February 1, 1977 when then President Jimmy Carter, after only two weeks in office, said in his now famous fireside chat:

“All of us must learn to waste less energy. Simply by keeping our thermostats, for instance, at 65 degrees in the daytime and 55 degrees at night we could save half the current shortage of natural gas.”

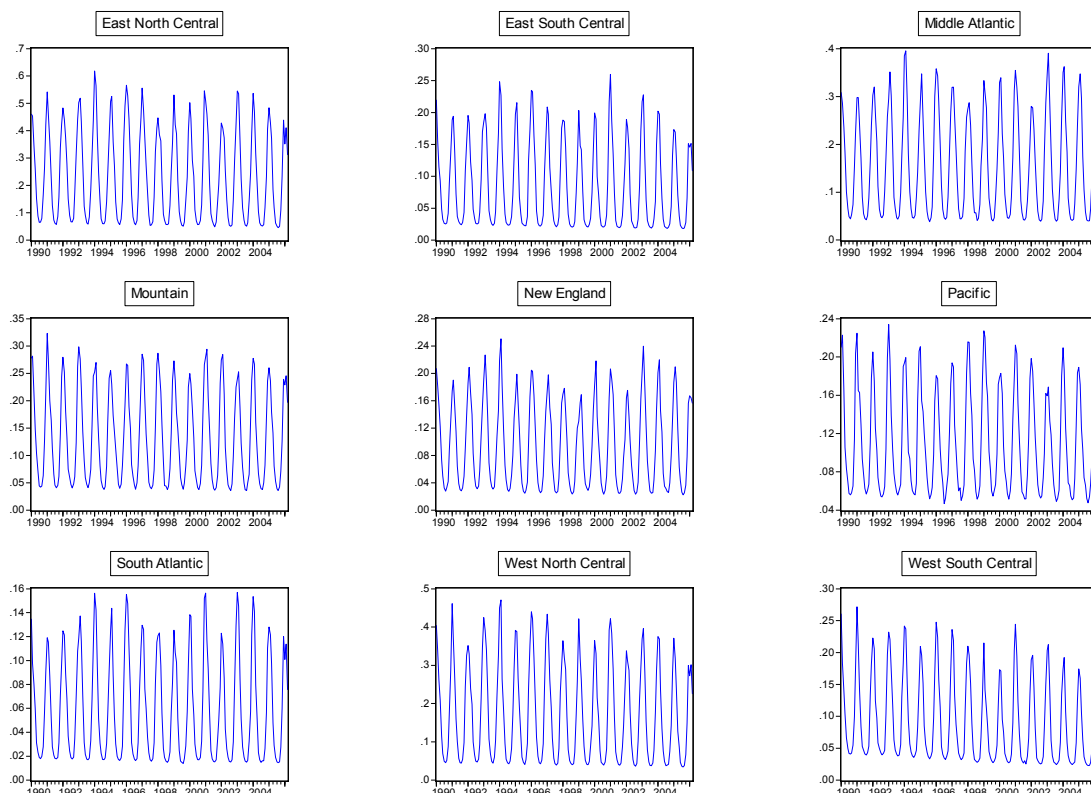
In the years since, the first President Bush established the first National Energy Strategy in June of 1989, and the government has imposed efficiency standards, subsidized technological improvements in both shell and appliance efficiency, and generally encouraged its citizenry to conserve on energy. Efficiency improvements are sure to continue, and if natural gas prices stay high, it will most certainly encourage natural gas

⁸ Between 1978 and 1982, energy consumption per household actually decreased by 26%. See EIA’s Annual Energy Review, URL http://www.eia.doe.gov/emeu/aer/ep/ep_frame.html.

customers to trade in old inefficient appliances for newer more efficient ones. The impact on the natural gas industry will be an obvious decrease in revenue accruing to natural gas LDC's.

This study will examine the reasons for this decline in use per customer, with particular emphasis on estimating the short-run and long-run price elasticity of natural gas demand since the year 2000. It will also analyze and measure the rate of decline caused by the natural turnover rate of old inefficient appliances with newer more efficient ones. The trends in the AGA sample are validated from trends in other data. The U.S. Energy Information Administration (EIA) reports aggregate estimates of residential consumption in BCF/day and residential prices in \$/MCF on a monthly basis from 1990 to the present. The EIA sample data covers all LDCs in the US. These series are plotted by US Census Region in residential consumption per household per day in Figure 2 and in nominal and real terms in Figure 3 below. A map of the US Census Regions is shown in Appendix B. These figures provide a comparison with the subsequent figures from the AGA survey database. They demonstrate that the trends and patterns in the survey are consistent with a recognized national source of data even before adjusting for normal weather.

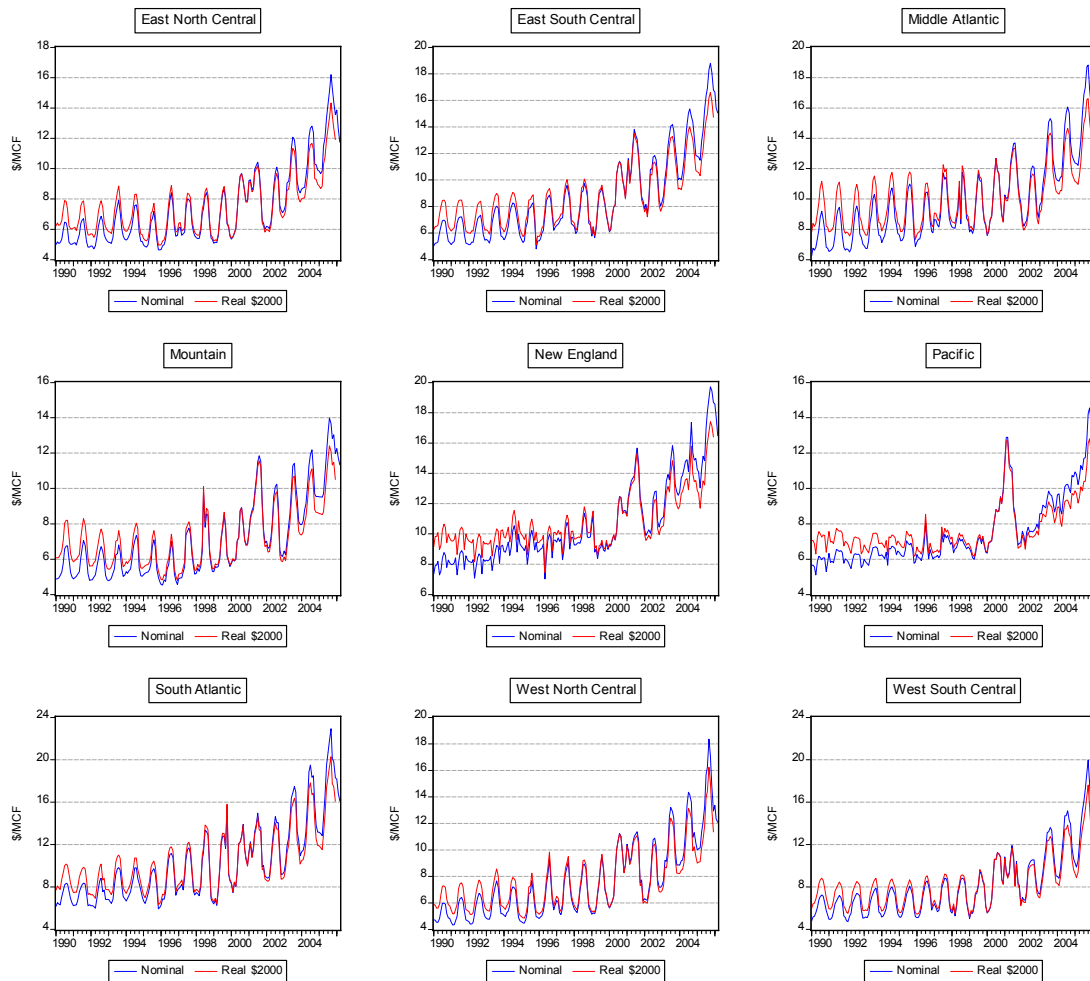
Figure 2
Regional Consumption per Customer per Day
Mcf per Day



Source: U.S. Energy Information Administration

Regional consumption per customer appears to decline for every region for most of the period and particularly after 2000. This has occurred while residential natural gas prices have more than doubled over the same period.

Figure 3
Nominal and Real (\$2000) Delivered Natural Gas Prices



Source: U.S. Energy Information Administration

Residential natural gas prices were 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 spread in nominal terms has been between \$12/MCF to almost \$20/MCF. The real price has more than doubled to over \$12/MCF. Natural gas prices have risen about 35 percent to 40 percent faster than the general U.S. price level since 1990. Figure 3 shows the monthly residential natural gas prices per MCF according to the EIA. Figure 4 shows U.S. real disposable income per capita has risen about 33 percent from \$21,000 to \$28,000 today.

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) 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 have 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. 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 Dahl's previous study). In a number of papers, Bohi dismisses the large income elasticities from some static cross section estimates and concluded that income is not found to be 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.