PHILIP BLINN THOMPSON
CURRICULUM VITAE
September, 2009

HOME:
1993 N. Mahonia Pl.
Bellingham, WA 98229
Phone: (360) 656-6334
E-mail: rtconsultingwa@comcast.net
Cell: (989) 944-1950

WORK:
Dept. of Economics, MS 9074
Western Washington University
516High St.
Bellingham, WA 98225
Phone: (360) 650-6326
Fax: (360) 650-6315
E-mail: Philip.Thompson@wwu.edu

EDUCATION

Ph.D., Economics, University of Arizona, May, 1988.
Dissertation: *The Spatial and Temporal Distribution of Risks Associated with Low-Level Radioactive Waste Disposal* (Advisor: David E. Pingry)

B.A., Economics, Magna Cum Laude, Kent State University, June, 1976

EMPLOYMENT EXPERIENCE

September 2009 to present — Assistant Professor of Economics, Western Washington University

August 2006 to August 2009 — Temporary Associate Professor of Economics, Central Michigan University

August 2000 to July 2006 — Temporary Assistant Professor of Economics, Central Michigan University

Courses taught at CMU: Micro Principles, Economics for Entrepreneurs, Economics and Society, Environmental Economics (both undergraduate and graduate level), Intermediate Micro Theory, Government and Business, and Applied Business Statistics

August 1998 to August 2000 — Assistant Professor of Economics, University of Missouri-Rolla

August 1994 to May 1998 — Visiting Assistant Professor of Economics, University of Missouri-Rolla

Courses taught at UMR: Micro Principles, Macro Principles, Intermediate Micro Theory, Energy Economics, Public Utility Regulation, Industrial Organization

August 1994 to present — Principal, RT Associates, consulting on Public Utility, Regulatory, and Antitrust Economics

May 1986 to August 1994 — Chief Public Utility Economist, Office of the Public Counsel, State of Missouri.

May 1984 to May 1986. — Public Utility Economist, Office of the Public Counsel, State of Missouri

August 1982 to May 1984	Visiting Instructor, Department of Economics, Texas A&M University, teaching Principles and Money & Banking.
NATIONAL OFFICES:	Member, Gas Technology Institute Advisory Council, 1993 - 2001, and GRI Advisory Council Science and Technology Committee, 1999 - 2001. National Association of State Utility Consumer Advocates, Chair, Economics and Finance Committee, 1990 - 1994.

PUBLICATIONS

REFEREED PUBLICATIONS

Bailey, Christopher, Gregory Falls, Paul Natke, and Philip Thompson, 2009. "The Determinants of the Local Discretionary Spending Patterns of Students at a Regional State University." Working paper.

Bailey, Christopher, Gregory Falls, Paul Natke, and Philip Thompson, 2008. "Local Spending by Traditional College Students: A Descriptive Case Study." *B-Quest*, 2008. Online journal at: http://www.westga.edu/~bquest/2008/local08.pdf

Bailey, Christopher, Gregory Falls, Paul Natke, and Philip Thompson, 2007. "Measuring the Economic Impact of a Regional Public University." *Midwestern Business and Economic Review.* No. 40: Fall, 2007, 21-31.

Thompson, Philip B., 2002. "Consumer Theory, Home Production, and Energy Efficiency," *Contemporary Economic Policy,* 20(1), 50-59.

Riordan, C.A., L.M. Manning, A. Daniel, S.L. Murray, P.B. Thompson, and E. Cummins, 1999. "If I Knew Then What I Know Now: A Portable Mentor for Women Beginning Professorial Careers in Science and Engineering," *Journal of Women and Minorities in Science and Engineering,* v. 5, 29-52.

Murray, Susan L., L.M. Manning, C.A. Riordan, E. Cummins, and P.B. Thompson, 1998. "A Mentoring Guide for Female Faculty in Engineering," in *1998 American Society for Engineering Education Conference Proceedings.*

Manning, Linda M., and Philip B. Thompson, 1998. "Mentoring Resources for Academic Economists," *Journal of Economics,* XXIV(2), 89-92.

Nystrom, Halvard E., and Philip B. Thompson, 1998. "Refractory Waste Management Financial Decision Model," *Refractories Applications,* 3(2), June, 5-6.

Thompson, Philip B., 1997. "Evaluating energy efficiency investments: Accounting for risk in the discounting process," *Energy Policy,* 25(12), October, 989-996.

Nystrom, Halvard E., and Philip B. Thompson, 1997. "Refractory Recycling Financial Decision Model," in *Proceedings of the 1997 National Conference of the American Society for Engineering Management,* 149-152.

Thompson, Philip B., 1996. "A Cross-Sectional Study of Household Income as a Determinant of Natural Gas Consumption," *Journal of Economics*, XXII(2), 75-82.

TEXTBOOKS

Bryant, R. R., G. M. Gelles, and P. Thompson. *Microeconomics: A Basic Approach.* 1999-2000. Rolla, MO: University of Missouri-Rolla Economics Department.

Bryant, R. R., G. M. Gelles, and P. Thompson. *Microeconomics: A Basic Approach, Student Workbook for Economics 121.* 1999-2000. Rolla, MO: University of Missouri-Rolla Economics Department.

Bryant, R. R., G. M. Gelles, P. Thompson, J. F. Willis, and M. L. Primack. *Explorations in Microeconomics,* 1996-1997, 1997-1998. Redding, CA: CT Publishing.

Bryant, R. R., G. M. Gelles, and P. Thompson, 1996-1997, 1997-1998, 1998-1999. *Explorations in Microeconomics, A Workbook for Economics 121.* Rolla, MO: UMR Bookstore.

OTHER PUBLICATIONS

Thompson, Philip B., contributor. Hill, James, primary author, 2007. *The New Buffalo: A Comparative Examination of Tribal Casino Gaming in Michigan 1993-2003.* Mt. Pleasant, MI: Central Michigan University.

Thompson, Philip B., Various book reviews in *The Journal of Economics*, 1995,1997, 2000, and 2002

Thompson, Philip B., "Writing a Microeconomics Principles Textbook: Process, Problems, and Positives," Proceedings of the 11th Annual Teaching Economics: Instruction and Classroom Based Research, Robert Morris College, Pittsburgh, PA, February, 2000, 245-253.

Thompson, Philip B., 1992. "Appropriate Pricing Policies Toward Bypass: An Application of Natural Monopoly Theory With Spatial Considerations," in *Proceedings of the Eighth National Association of Regulatory Utility Commissioners Biennial Regulatory Information Conference*, National Regulatory Research Institute, The Ohio State University, Columbus, Ohio. Won Honorable Mention (second place) in Conference prize competition.

Thompson, Philip B., 1992. "Accounting for Interruptibility in LDC Cost Allocation and Transportation Rate Design," in *Proceedings of the Eighth National Association of Regulatory Utility Commissioners Biennial Regulatory Information Conference*, National Regulatory Research Institute, The Ohio State University, Columbus, Ohio.

Thompson, Philip B., 1990. "The Allocation of Pipeline Demand Charges to LDC Interruptible Sales Customers: A Consumer Advocate's View," in *Proceedings of the Seventh National Association of Regulatory Utility Commissioners Biennial Regulatory Information Conference*, National Regulatory Research Institute, The Ohio State University, Columbus, Ohio.

UNPUBLISHED MANUSCRIPTS

Thompson, Philip B., June, 1998. Comments on the Report of the Missouri Public Service Commission's Task Force on Retail Electric Competition, submitted on behalf of the University of Missouri to a Joint Interim Committee of the Missouri General Assembly

OTHER SCHOLARLY ACTIVITIES

RESEARCH GRANTS

Hill, James, Greg Falls, and Philip Thompson, 2006. Central Michigan University Research Excellence Fund. "The White Buffalo Under a Microscope: A Comparative and Longitudinal County Analysis of the Social and Economic Impacts of Tribal Casinos in the State of Michigan: 1994-2004"

CONFERENCE PARTICIPATION

Thompson, Philip B. (presenter) and Gregory Falls, "Casinos and Crime: A Panel Data Analysis of Michigan Counties," Midwest Economic Association International 73rd Annual Meeting, Cleveland, OH, March, 2009.

Thompson, Philip B. "Determinants of Household Natural Gas Demand," United States Association for Energy Economics/International Association for Energy Economics 26th North American Conference, Ann Arbor, MI, September, 2006.

Thompson, Philip B., presenter, and Gary Tan, "Price Asymmetry in the Midwest Retail Gasoline Market Revisited," Midwest Economic Association International 69th Annual Meeting, Milwaukee, WI, March, 2005.

Thompson, Philip B., presenter, "New Faculty Mentoring: Getting a Good Start," Western Economic Association International 75th Annual Conference, Vancouver, BC, July, 2000.

Thompson, Philip B., presenter, "Writing a Microeconomics Principles Textbook: Process, Problems, and Positives," 11th Annual Teaching Economics: Instruction and Classroom Based Research, Robert Morris College, Pittsburgh, PA, February, 2000.

Thompson, Philip B., presenter, "Consumer Theory, Home Production, and Energy Efficiency," Western Economic Association International 74th Annual Conference, San Diego, CA, July, 1999.

Thompson, Philip B., presenter, "Modeling Cost-Risk Tradeoffs Associated With Low-Level Radioactive Waste Disposal Systems," Midwest Economic Association International 63rd Annual Meeting, Nashville, TN, March, 1999.

Thompson, Philip B., presenter, "Low-Level Radioactive Waste Disposal: Cost-Risk Tradeoffs," Western Economic Association International 73rd Annual Conference, Lake Tahoe, July, 1998.

Manning, Linda M., and Philip B. Thompson, presenter, "So You Want to be an Academic Economist: A Complementary Mentor," Missouri Valley Economic Association meetings, Kansas City, Missouri, February, 1998.

Thompson, Philip B., presenter, "A Cross-Section Time-Series Study of the Determinants of Residential Natural Gas Consumption," Midwest Economics Association meetings, Kansas City, Missouri, March, 1997.

Thompson, Philip B., presenter, "Consumer Theory, Discounting, and Energy Conservation," Missouri Valley Economic Association meetings, St. Louis, Missouri, February, 1997.

Thompson, Philip B., presenter, "A Cross-Sectional Study of Household Income as a Determinant of Natural Gas Consumption," Missouri Valley Economic Association meetings, Memphis, Tennessee, March, 1996.

Respondent, Gas Research Institute Energy Seminar, *Electric Utility Restructuring and its Impact on the Gas Industry*, Asheville, North Carolina, August, 1995.

Thompson, Philip B., presenter, "Economists as Government Regulators," First Annual Central Missouri Economics Conference, University of Missouri-Rolla, April, 1993.

Conference participation as a session chair or paper discussant at various conferences.

Various presentations before groups of regulators and other participants in the public utility regulatory process, 1990-1994.

OTHER SCHOLARLY AND PROFESSIONAL ACTIVITIES

ARTICLE REVIEWING/REFEREEING

Energy Journal, Energy Economics, Journal of Economic Education

TESTIMONY

Missouri General Assembly, Joint Interim Committee on Telecommunications and Energy Sources, testimony on behalf of the University of Missouri containing comments on the Public Service Commission Task Force Report on Retail Electric Competition, September, 1998.

Missouri Public Service Commission: Written testimony in over sixty docketed cases before the MPSC between 1984 and 1996, and in 2001 and 2007, and oral cross examination on that testimony in approximately half of those cases.

Missouri Senate, Commerce and Consumer Protection Committee, testimony regarding changes in Missouri law relating to telecommunications, March 1992.

DISSERTATION AND THESIS COMMITTEES

Member of several M.A., M.S., and Ph.D. committees (CMU and UMR); Supervision of two Master's Plan B papers (CMU)

SERVICE ACTIVITIES

Member, Campus Sustainability Advisory Committee, Central Michigan University, 2008-2009
Member, CMU Energy Optimization Committee, Central Michigan University, 2006-2009
Member, Economic Impact Group, Central Michigan University, 2004-2005
Panel Member, Speak Up Speak Out Series, Panel on Election 2004 Environmental Issues, Central Michigan University, Sept. 2004
Discussant, numerous occasions at a variety of professional meetings, 1995-present
Department Representative, various College of Arts and Sciences committees, University of Missouri-Rolla, 1995 - 2000 .
Advisor for Undergraduate Economics Majors, University of Missouri-Rolla, 1995 - 2000.
Member, University Advisory Board, University of Missouri and Network Resources, Inc., Richard L. Wallace, Project Director and Vice President for Academic Affairs, *Study of Missouri's Telecommunications Infrastructure Development*, 1994.

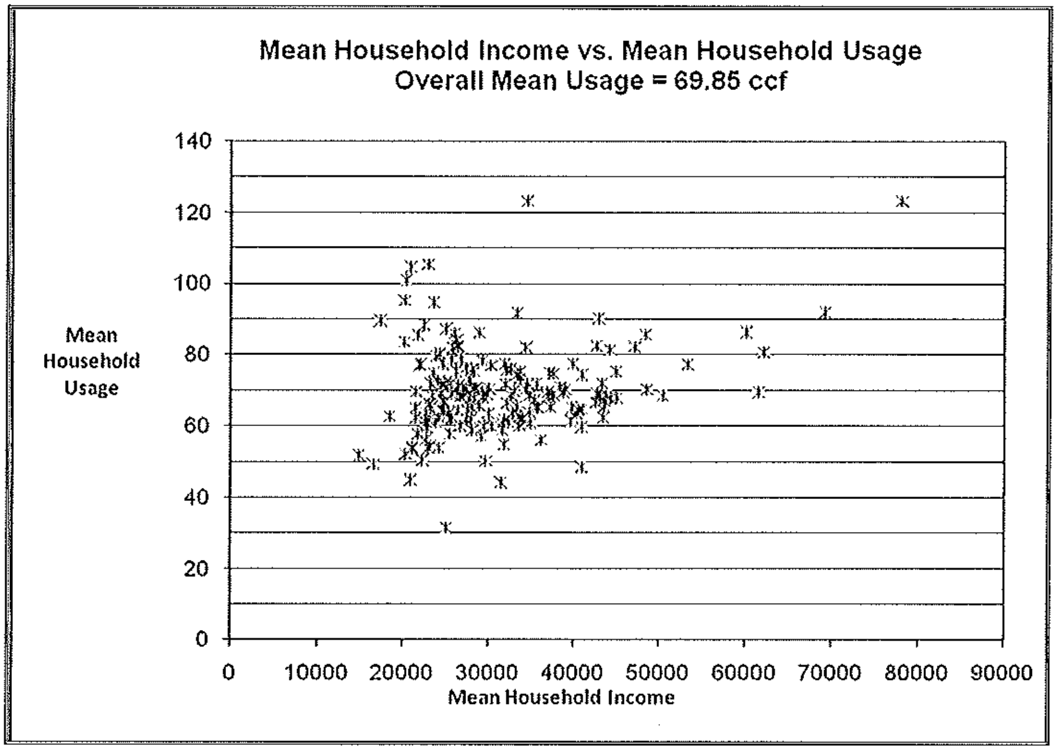
PROFESSIONAL SOCIETY MEMBERSHIPS

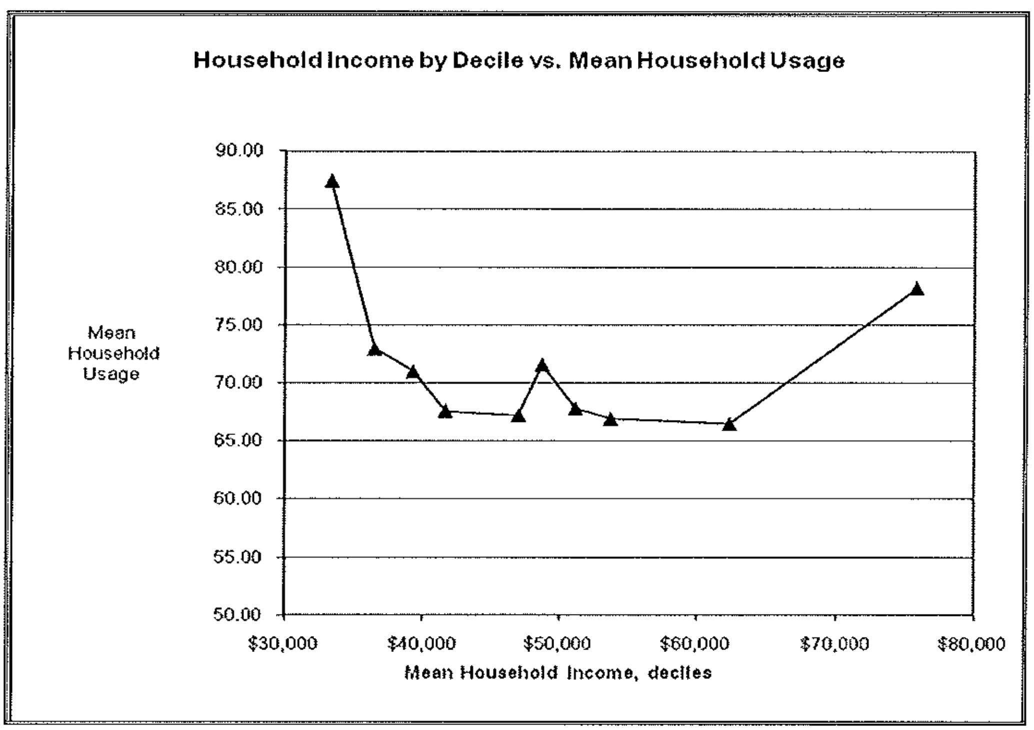
American Economics Association
International Association for Energy Economics
Western Economic Association International

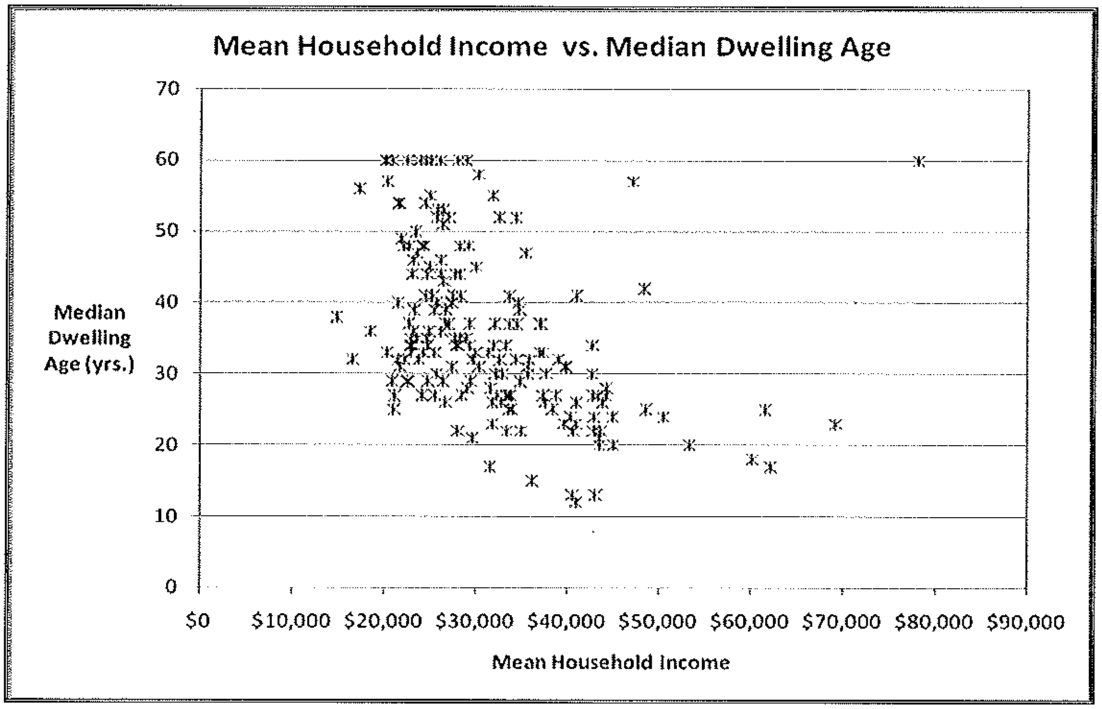
REFERENCES

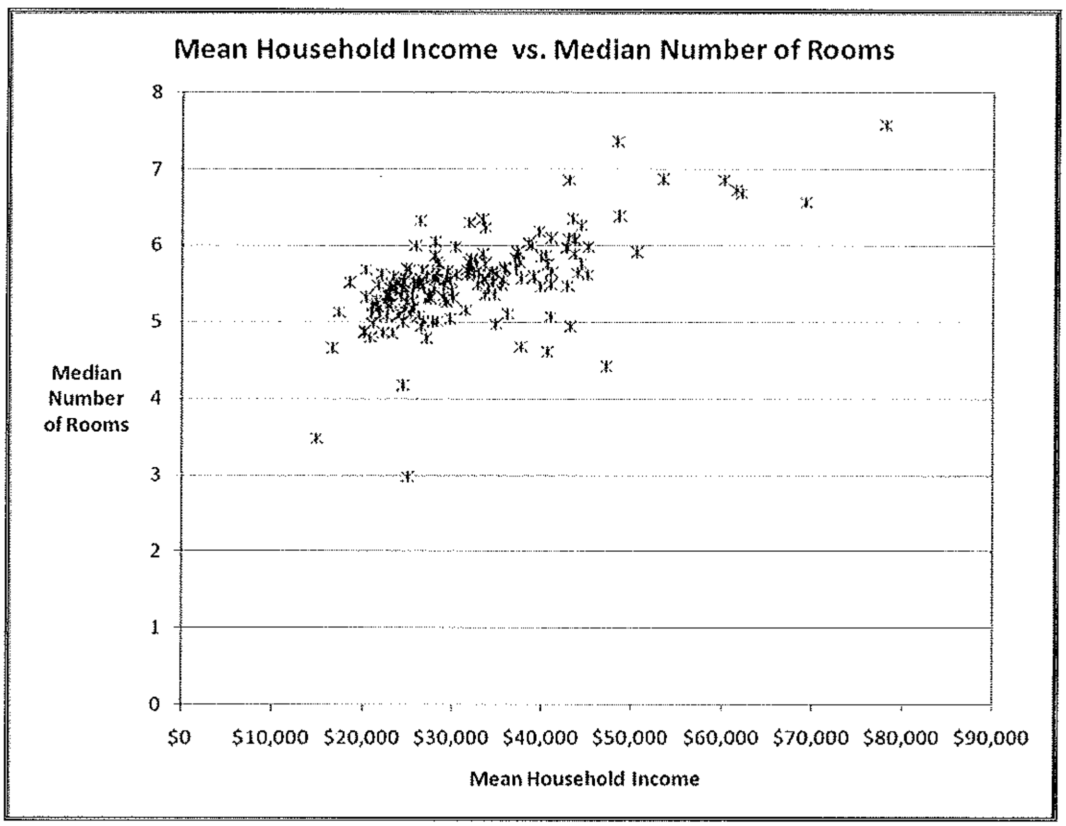
Available on Request

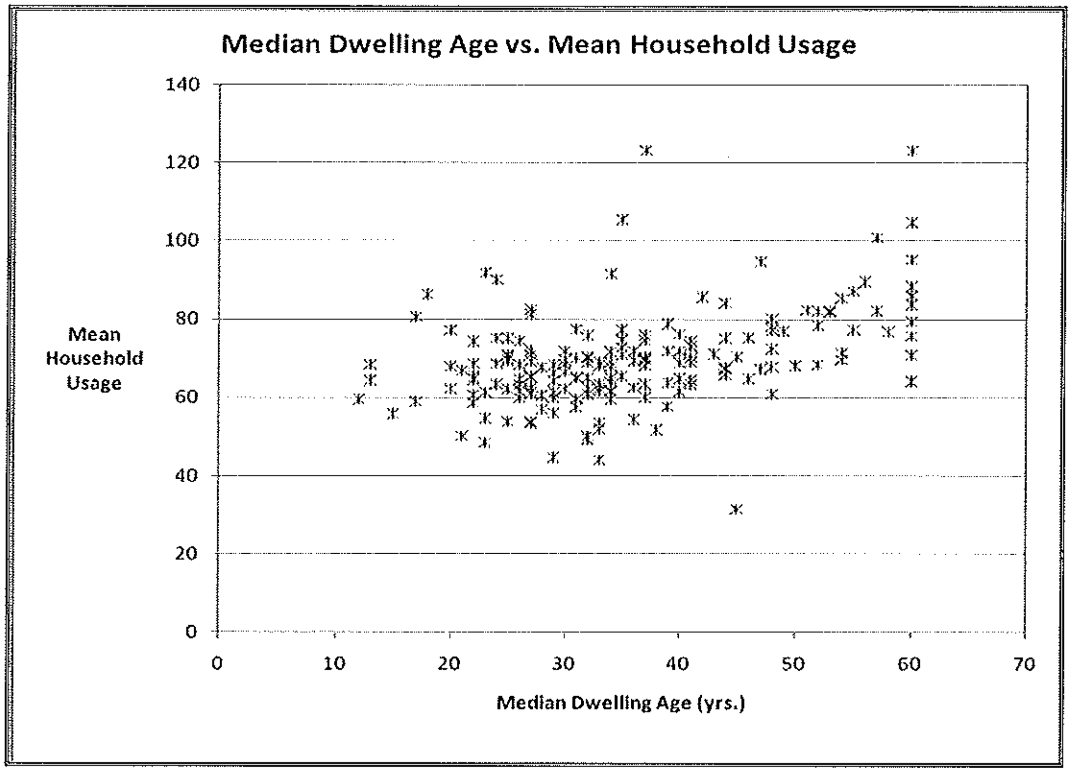
Schedule PBT-2
Some Relationships Between Household Income, Average Gas Usage, Dwelling Age, and Dwelling Size






Mean Household Income vs. Median Dwelling Age
Median Dwelling Age (yrs.)
0
10
20
30
40
50
60
70
$0
$10,000
$20,000
$30,000
$40,000
$50,000
$60,000
$70,000
$80,000
$90,000
Mean Household Income


Mean Household Income vs. Median Number of Rooms
Median Number of Rooms
0
1
2
3
4
5
6
7
8
$0
$10,000
$20,000
$30,000
$40,000
$50,000
$60,000
$70,000
$80,000
$90,000
Mean Household Income



Median Dwelling Age vs. Mean Household Usage
Mean Household Usage
Median Dwelling Age (yrs.)
0
20
40
60
80
100
120
140
0
10
20
30
40
50
60
70

The Relationship Between Household Income and Natural Gas Consumption in Missouri Gas Energy's Service Territory: A Report to MGE

Philip B. Thompson, Ph.D., Bellingham, WA

I. Introduction

An important consideration in deciding how to apportion a given residential margin revenue requirement between the fixed monthly customer charge and the volumetric rate is how the apportionment will affect customers at various income levels. Collecting more revenue through the volumetric rate and less through the customer charge leads to higher bills for above-average users and lower bills for those whose usage is below the average. The impact on customers in different income groups therefore depends on the relationship between household income and natural gas consumption.

There are four distinct theoretical possibilities regarding this relationship. The first is that there is no significant connection between usage levels and income; this is essentially the null hypothesis for the study. The second is that natural gas usage is positively related to income: as household income rises, so does gas consumption, as households add more gas-using appliances such as gas hearths and swimming pool heaters. A third possibility is that consumption may increase as income decreases below a certain level because of the tendency for lower income families to live in older homes that are less well insulated and that have less efficient heating equipment. In addition, families at the low end of the income spectrum are more likely to live in rental housing, which yields fewer incentives for efficiency. Landlords are less likely to invest in energy efficiency measures such as efficient furnaces and windows and doors because they typically do not pay tenants' utility bills. Renters are less likely than homeowners to invest in such measures because their tenure in a given housing unit tends to be shorter than the payback period for those investments. Furthermore, low-income homeowners may find it difficult to afford the up-front costs associated with efficiency investments and would be unable to find lenders willing to help.

The final possibility is a combination of the second and third. At lower income levels consumption decreases as income rises because households' ability to pay for efficiency retrofits and to afford newer, better-insulated housing rises. Then at some income level usage reaches a minimum and begins to increase as more appliances are added and as families come to afford higher levels of comfort. This possible outcome is depicted graphically as a "U"-shaped curve, with income on the horizontal axis and usage per month on the vertical. As will be discussed in greater detail below, this study finds a high likelihood that the income-consumption relationship for Missouri Gas Energy's (MGE's) service territory is of this type.

The purpose of this report is to present the results of a study I performed to investigate the income-consumption relationship in MGE's service territory. In the next section I provide a general overview of the results, and the third section consists of a discussion of the more technical aspects of the study. The report ends with a summary and conclusions.

II. General Overview of Models and Results

This study is based on data from two sources. MGE provided me with monthly total usage figures and bill numbers for its residential customers in each zip code it serves, for the entire 24-month (October 1998 through September 2000) period of the study. In the most detailed analysis performed for this study (which I call the monthly analysis) I used this data as given, in its monthly form: I divided total usage in each zip code in each month by the corresponding number of bills to obtain the average usage per bill, which I call CCF. (Variable names as used in the regression analysis appear in all capital letters throughout this report.) There are therefore 4,344 observations (181 zip codes X 24 months) in the monthly dataset. MGE also gave me weather and price data that I used to calculate appropriate weather and price variables for each of the zip code-months. My other data source, from which I obtained demographic, economic, and housing data, is the 2000 U.S. Census. I used the statistical method known as regression analysis in this portion of the study to determine the most important factors affecting the quantity of natural gas consumed.

Based on the simple graphical presentations of the data in Schedule PBT-2 of this rebuttal testimony, one could reasonably conclude that MGE's low income customers use above-average amounts of gas, but it is nevertheless of interest to ask what may be behind these results. Are there other factors associated with income that are the real determinants of gas usage? If so, what are these? The answers are not only of interest for their rate design implications, but for broader public policy goals such as energy efficiency and helping low-income users pay their heating bills. The best way to examine the roles of potential household natural gas usage determinants is through a well-established statistical technique known as regression analysis. In this approach the goal is to find what the contribution is of each potential determinant (the "independent" variables) of natural gas usage (the "dependent" variable).

The independent variables discussed below in connection with either the annual or monthly model groups were selected initially because of their theoretical roles as determinants of residential gas consumption. Several other variables were used in some trial models but are not discussed because they turned out not to be significant determinants of gas usage, or because some other, similar variable performs just a bit better in the models. For example, the number of persons per household was used instead of the average number of rooms as representing the "size" of a home, and while the former did help explain gas usage, it did not do so as well as the latter. Similarly, the proportion of homes built before a particular year was used in place of median home age, but the latter appeared to work a little better. The proportion of homes occupied by the owner did not seem to explain gas usage in the models as well as theory would predict (a discussion of the results appears below). These similarities in performance between two related variables (e.g., the age of homes versus the proportion of homes older than some preselected limit) are largely due to similar patterns of variation (in the statistical sense) across zip codes. The remaining discussions are largely confined to those model specifications that performed better, but in many cases the improvement in model performance offered by a particular independent variable was modest.

Returning to the annual model, the independent variable HDD, or heating degree-days, is derived in a manner slightly similar to CCF. That is, monthly HDD are calculated for each month and zip code, using a bill-cycle weighting process described in the technical section below, and then are summed across months to get the total HDD over the period. It is reasonable to expect the regression coefficient on HDD to be positive—colder weather (higher HDD) leads to increased gas consumption.

Other independent variables used in the annual models are taken from or calculated using 2000 U.S. Census of Population data. The variable AGEMED is the median age of housing units in a zip code, and is calculated by subtracting the census data's "Median Year Built" from 1999. Median age of housing is used as a proxy variable for the energy efficiency of homes (degree of insulation, quality of windows, efficiency of heating equipment, etc.). Theory predicts that the regression coefficient on AGEMED will be positive—that older homes consume more gas, all else equal. The independent variable RMSMED is the median number of rooms in a zip code's housing units and is a proxy for home size. The coefficient on this variable is also expected to be positive, because heating larger homes requires more gas.

Another factor that would tend to affect gas usage is whether someone is at home during normal working hours. Many homes are kept at lower temperatures when nobody is home for several hours. The variable UNEMP is the unemployment rate for persons aged 16 and over and is a proxy for the proportion of households in which someone is at home during the day. The regression coefficient on this variable is expected to be positive since it is unlikely that the thermostat in such a home would be lowered during the day.

Two income variables were used. One is mean (average) household income for a zip code (AY) and the other is median household income (MY), which is the "middle" income value for the zip code: 50% of households have higher incomes than the median. These two variables have substantially different values for most zip codes; on average, the mean income is 21.4% higher than the median, and in only two of the 181 zip codes is the median larger (by only 0.5% and 0.3%). This means that the income distribution is skewed, so that a few high income earners in each zip code have a large impact on the average. The argument for using the mean income is that it picks up the impact of a few large income earners on the average consumption of natural gas. On the other hand, the median is a better indicator of "central tendency," since very large incomes have no more impact than slightly large incomes. To illustrate this, imagine a student who has scored 2/100 on 9 quizzes and 82/100 on the tenth. The average score is 10, but since the student scores 2/100 nine times out of ten, we would probably conclude that 2/100 is the most likely score. Both income variables were used (but not in the same regression) and in most of the results, including the ones given in Tables 1 and 2 below, they performed about the same.

To test for the existence of a "U"-shaped income-consumption relationship, the square of the income variable, denoted AY2 or MY2, is also included. If the relationship is in fact "U"-shaped, adding the square of income will improve the performance of a model, measured by its R^2 coefficient. In addition, the coefficient on the income variable will be negative and statistically significant, and the coefficient on its squared value will be positive and statistically significant.

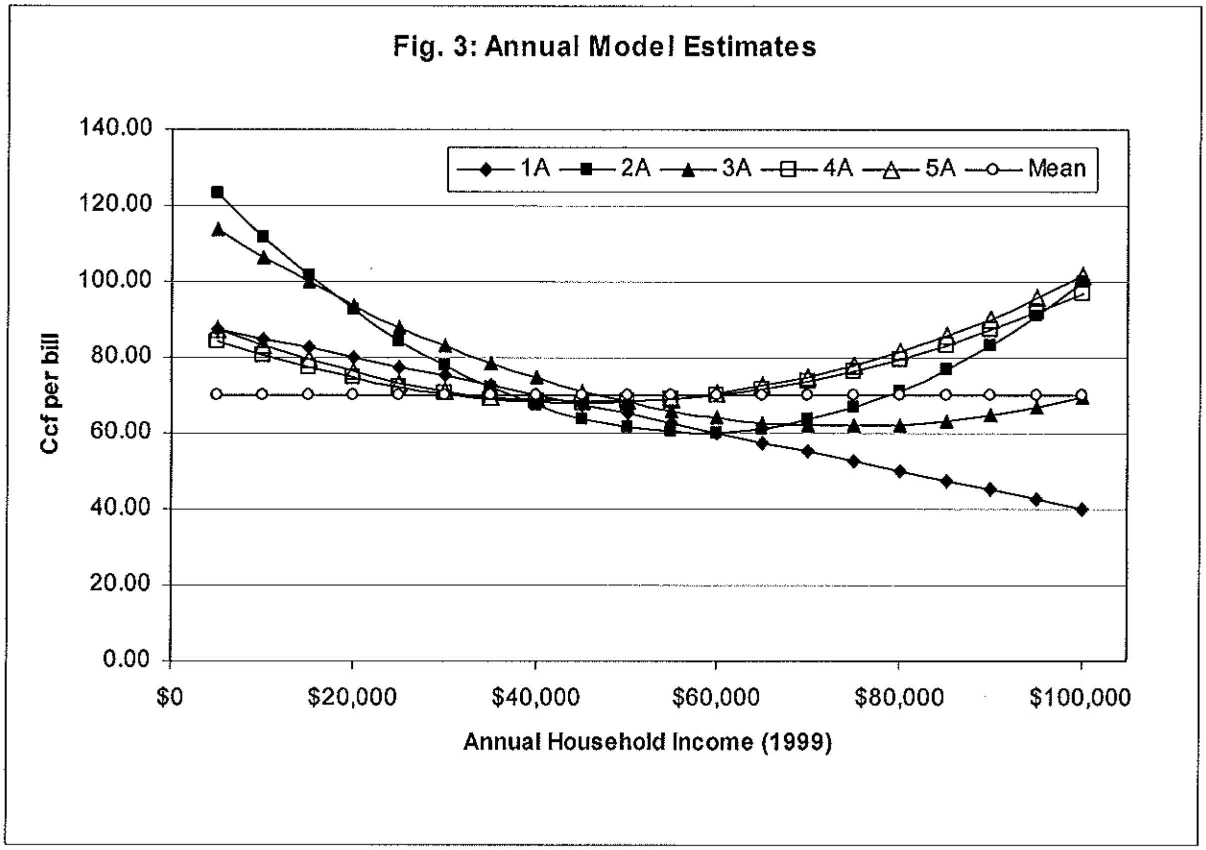
Estimation of the annual models employs a technique known as weighted ordinary least squares. The results of the models that generally perform the best are presented in Table 1. In each model the dependent variable is CCF. Each model is designated with a number along with the letter A to signify the annual set of models. (More complete information about each model, including t-statistics, is presented in the technical section of this report.) If a cell in the table is blank, the corresponding independent variable was not used in that model. A graph of the income-consumption relationships derived from Table 1 appears in Figure 3.

Model 1A is presented to show what happens when no squared income term is included. Although in my opinion the correct specification includes the squared income variable, which is not in Model 1A, it is interesting to note that median income (MY) has a negative and statistically significant influence on consumption in Model 1A (see Section III below for t-statistics). This means that if the income-consumption relationship is linear rather than U-shaped, low income customers use more gas than high income users. The addition of the squared income variable MY2 in equations 2A, 4A, and 5A improves the fit of the regression to the data. This can be seen from the slight improvement in the R^2 statistic, which measures how well the model fits the data; R^2 must lie between 0 and 1, and a higher value indicates a better fit. In addition and more importantly, both income variables are statistically significant. The conclusion from these annual models is therefore that the income-consumption relationship is indeed U-shaped. This conclusion in turn implies that a larger customer charge would result in lower bills for customers at the lowest income levels than they would receive if the *volumetric* rate were made larger. Table 1 also includes two lines that show 1) the household income level (1999 dollars) at which monthly usage is at a minimum, and 2) the income level at which usage equals the average, and below which usage is above average.

TABLE 1: Regression Results from Annual Models

Dependent variable = CCF (mean = 69.83)	Coefficients on Variables in Model No.:				
Variable Names	1A	2A	3A	4A	5A
HDD	0.002037	0.004647	0.003041	0.002126	0.002677
AGEMED	0.735	0.379	0.538	0.548	0.556
RMSMED	20.046	15.361	13.953	12.529	9.628
MY	-0.0005	-0.0026		-0.000892	-0.001052
MY2		2.25×10^{-8}		9.77×10^{-9}	1.14×10^{-8}
AY			-0.001612		
AY2			1.09×10^{-8}		
UNEMP				1.3652	1.4277
PCTOWNOC					0.1704
CONSTANT	-61.38	-0.625	1.765	-23.01	-20.54
R^2	.990	.994	.991	.995	.995
Income level at bottom of "U"	N.A.	\$57,867	\$73,945	\$45,650	\$46,140
Income level below which usage exceeds the average	N.A.	\$37,135	\$47,005	\$32,203	\$34,613

The coefficients listed in Table 1 are interpreted as follows, using model 4A as an example. The coefficient on AGEMED is 0.548, which implies that a 10-year increase in the age of a housing unit increases gas consumption by approximately 5.5 Ccf per month, about 8% of the average consumption level of 69.83 Ccf per month. Similarly, we see that the coefficient on RMSMED equals roughly 12.53, which means that a house with one more room will use an additional 12.53 Ccf per month, on average, all else held constant. The impacts of other variables can be similarly calculated. See Table 3 in Section III below for a list of the mean values for all variables to get an idea of how large each variable is, and therefore what can be thought of as a reasonable change in its size.



The estimation of the monthly models is carried out using a technique known as panel data analysis, which accounts for variations across both zip codes and months. There are a total of 4,344 (24 months x 181 zip codes) observations. The dependent variable CCF varies both across zip codes and months. HDD varies across months, and because different zip codes are on different (combinations of) bill cycles and are in different geographic regions (3 in total), HDD also varies to some extent across zip codes. The same can be said about the price variable PRICE (current month's non-gas margin plus gas cost). Data taken from the U.S. Census (all variables except for CCF, HDD, and the price variables) vary across zip codes but not across months. That is, a given zip code is assigned the same income (or AGEMED, RMSMED, etc.) value for each of the 24 months in the study period. Table 2 below presents the results of five monthly models. Figure 4 on page PBT-2-9 graphically depicts the estimated income-consumption relationships for these models.

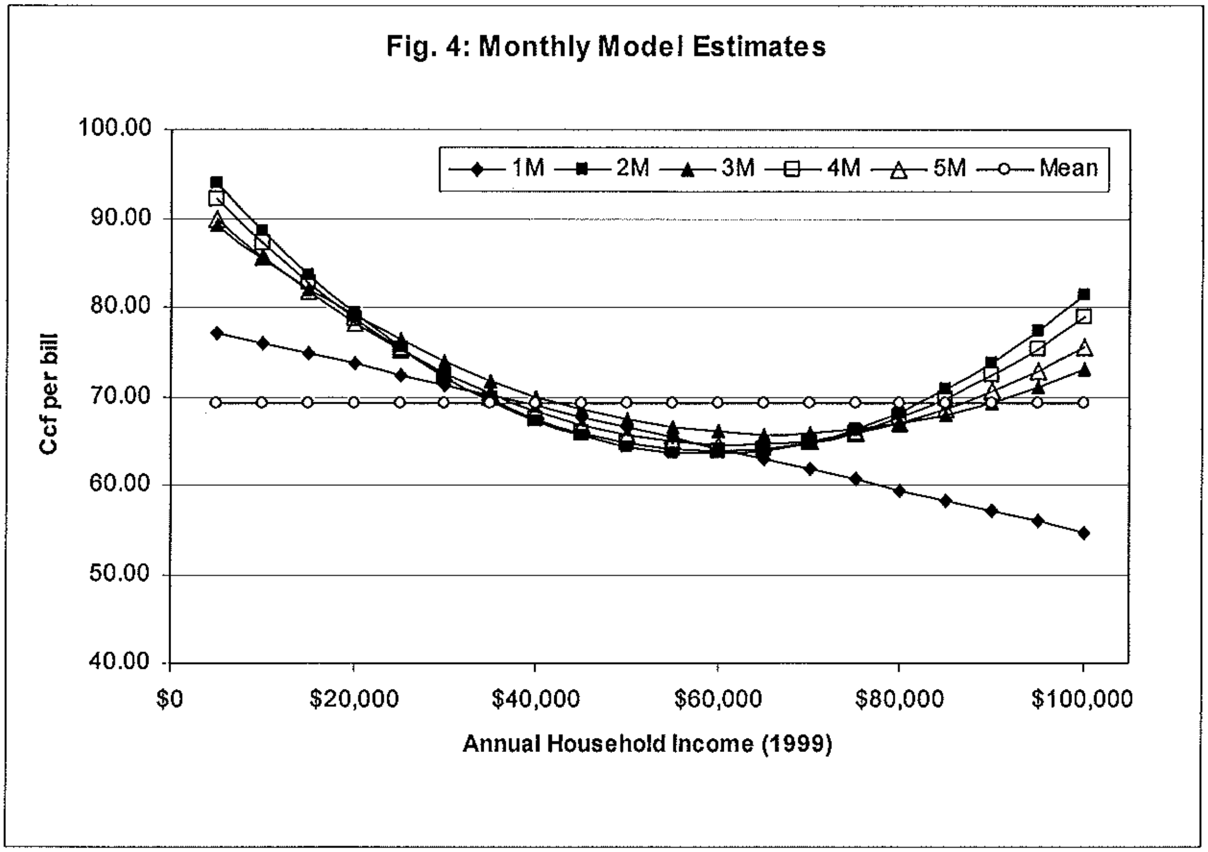
There are several explanatory variables used in the annual models that are also used in the monthly models: HDD, AGEMED, RMSMED, and UNEMP. The variation in consumption within a zip code across months is considerably greater than the variation across zip codes either within a given month, or, with reference to the annual models discussed above, across zip codes for the entire study period. The vast majority of the *monthly* variation in usage is driven by HDD. Indeed, a trial model including only HDD as an explanatory variable performed very well, and adding the other independent variables increased the performance of the models only marginally.

TABLE 2: Regression Results from Monthly Models

Dependent variable = CCF (mean = 69.17)	Coefficients on Variables in Model No.:				
Variable Names	1M	2M	3M	4M	5M
HDD	0.146	0.1465	0.1464	0.1465	0.1245
CCF(-1)					0.3266
AGEMED	0.447	0.3892	0.412	0.3735	0.2173
RMSMED	13.477	13.175	11.319	13.607	9.745
MY	-0.0002	-0.0012		-0.0011	-0.0010
MY2		1.05×10^{-8}		9.42×10^{-9}	7.73×10^{-9}
AY			-0.0008		
AY2			6.72×10^{-9}		
UNEMP				0.2779	0.1444
CONSTANT	-61.47	-36.65	-33.76	-42.32	-34.08
R^2	0.6522	0.6531	0.6526	0.6532	0.7224
Income level at bottom of "U"	N.A.	$58,857	$66,108	$59,873	$62,160
Income level below which usage exceeds the average	N.A.	$35,624	$42,656	$35,925	$37,701

This does not mean that the other variables are not important determinants of gas usage. Regression analysis allows us to answer the question, "What is the impact of a particular variable, assuming all of the other variables are held constant?" By including HDD in the regression equation, we effectively examine the impacts of the other variables after extracting the impact of weather. Even though variations in these other factors do not cause as much variation in usage per customer as weather over the study period, regression analysis allows us to isolate the separate impacts of the other variables in terms of usage variations across zip codes. Put another way, weather is the most important determinant of month-to-month variations in usage, while the other variables are important in explaining usage variations across zip codes.

As was the case in the annual models, the coefficients on weather (HDD), housing age (AGEMED), housing size (RMSMED), and unemployment (UNEMP) all have the expected signs and are statistically significant. In addition, both the income variables are statistically significant and each has the sign that yields a "U"-shaped income-consumption relationship: negative for MY (AY in Model 3M) and positive for MY2 (AY2 in Model 3M). And as was the case for the annual models, the equation that omits the squared income variable (1M) indicates that a hypothesized linear income-consumption relationship (if correct) is downward-sloping—low-income customers use more gas than high income consumers.



Results of models including the price variable PRICE, which are not presented here, are at first somewhat puzzling. In all of the models I examined that included PRICE, the price variable had a positive and statistically significant coefficient. While this is somewhat troubling from the standpoint of pure microeconomic theory–the price variable should have a negative coefficient, to comport with the theory that higher prices reduce consumption—the rather unique case of utility pricing in which consumers are rarely aware of the marginal price of an additional unit of consumption helps explain it. Indeed, while consumers should reasonably be expected to be are aware that they use more gas in cold weather, they generally cannot determine *how much* more until they receive a bill, by which time they are already halfway into the next billing month. In addition, increases in price (which more frequently result from gas cost increases rather than margin rate increases) tend to occur during colder weather periods, which is in fact the case for this dataset. That is, higher winter demand causes higher prices, but not vice versa.

What conclusions can be reached from the annual and monthly models? First, that the income-consumption relationship in MGE's service territory is very likely "U"-shaped, and that larger fixed customer charges are *not* regressive. Second, as would be expected, older, larger homes use more gas than newer, smaller ones. Third, the presence of non-working adults in a household tends to increase gas consumption. While it can be argued that the models of household natural gas consumption examined in this study do not allow us to precisely state the extent to which usage increases at low income levels, I have seen no evidence whatsoever to indicate that low-income customers as a group use a <u>lower</u> than average quantity of natural gas.

III. Technical Details: Variable Calculations and Regression Techniques

This section describes the data used and provides additional discussion of the regression analyses. An initial issue was determining the zip codes to include in the analysis. MGE provided me with a list of 226 zip codes. Forty-five of these could be eliminated because either 1) usage in the zip was either 0 in all 24 months or fewer than 24 months of data were available; or 2) they do not appear in the 2000 census. The eliminated zip codes accounted for less than 2% of MGE volume sales over the study period. After eliminating these 45, there were 181 zip codes remaining.

Table 3 lists the names of variables used in the study, their respective mean values, and a brief definition of each. Some are discussed at greater length following the table. Note that all variables with monthly values that vary by month (CCF, HDD, PRICE) cover the period October 1998 through September 2000. If two numbers appear under "Mean," the first is for the annual models, and the second is for the monthly models. See Tables 1 and 2 to determine which variables were used in each model.

Table 3: Variable Means and Definitions

Name	Mean	Description
CCF	69.83/69.17	Usage per bill, MGE residential class
HDD	8389.5/349.56	Bill-cycle weighted heating degree-days, 65° basis
AGEMED	31.011	Median age of housing in zip, 1999
RMAVG	5.56	Mean number of rooms per housing unit
PRICE	0.48784	MGE's residential non-gas margin plus volumetric gas rate
MY	39,389	1999 median household income
MY2	1.71×10^9	MY x MY
AY	47,183	1999 mean household income
AY2	2.42×10^9	AY x AY
UNEMP	5.08	Unemployment rate, percent
PCTOWNOC	74.14	Percentage of housing units that are owner-occupied

Values for CCF were computed from data provided by MGE on total volumes recorded by month and zip code and the corresponding number of bills. For annual data, the mean shown is the 24 month total of usage divided by the 24 month total bills. For monthly data, that same calculation is carried out using individual CCFs for each month, and the mean is the sum of these monthly figures divided by 4,344, the number of observations. The difference between the two values is explained by the variation in the number of bills across months in a given zip code.

Values for HDD were calculated in a standard way. First, HDD for each month, billing cycle, and weather region in MGE's service territory were calculated. This yielded 1,512 HDD values (24 months x 21 billing cycles x 3 weather stations–Kansas City, Joplin, and St. Joseph). This calculation involved summing the daily HDD figures across the days in a month/billing cycle/weather region. Then, if a given zip code had only one bill cycle, the simple sum was used. But if a zip code had multiple billing cycles, the monthly HDD figure for that zip code is a weighted sum of the bill cycle HDD, with the weights equal to the proportion of total monthly volumes for a zip code recorded for each bill cycle.

AGEMED was calculated from the Census data, equal to 1999 minus the median year built as recorded in the census data. RMSMED was taken directly from the census data.

The price variables were calculated in a manner similar to HDD and were based on the prices (residential non-gas margin plus volumetric gas price) in effect for MGE on each day of the study period. PLAG1 is simply PRICE lagged one month.

The remaining variables were calculated as described in Table 3.

The regressions were done using E-Views version 5.0. The annual regressions used the software's ordinary least squares weighted regression option, with the weights being the number of bills in each zip code. The monthly regressions were done using the random effects panel data specification.

The regression results and some calculations based thereon are presented below in Table 4 (annual models) and Table 5 (monthly models). The additional calculations include usage at various income levels based on a particular model and on the overall means of all other variables; these are the numbers that appear graphically in Figures 3 and 4 above. For those models including the squared income term, the value of income at the minimum of the "U" is also shown, along with the income level below which predicted usage is above average.

Table 4: Annual Model Results (t-statistics in italics below coefficients)

Model No. and Estimated Coefficients (t-statistic in italics)					
Variable name	1A	2A	3A	4A	5A
HDD	0.002037 *2.21*	0.004647 *6.34*	0.003041 *3.35*	0.002126 *2.66*	0.002677 *3.33*
AGEMED	0.735073 *13.20*	0.378578 *7.26*	0.537519 *8.06*	0.548467 *9.80*	0.556374 *10.15*
RMSMED	20.04573 *12.00*	15.36074 *11.59*	13.95276 *8.84*	12.5293 *9.58*	9.627645 *5.95*
MY	-0.0005 *-6.00*	-0.0026 *-13.51*		-0.000892 *-2.61*	-0.001052 *-3.10*
MY2		2.25E-08 *11.55*		9.77E-09 *3.48*	1.14E-08 *4.07*
AY			-0.001612 *-7.61*		
AY2			1.09E-08 *6.95*		
UNEMP				1.3652 *5.85*	1.4277 *6.22*
PCTOWNOC					0.1704 *2.93*
CONSTANT	-61.37712 *-6.17*	-0.624673 *-0.07*	1.764664 *0.16*	-23.0128 *-2.49*	-20.53606 *-2.26*
ADJ. WTD. RSQ.	0.989556	0.99404	0.990556	0.994991	0.9952
F	111.561	183.0926	102.6354	187.2284	168.6933
Income at minimum CCF		$57,867	$73,945	$45,650	$46,140
Income where predicted usage equals average		$37,135	$47,005	$32,203	$34,613

Table 4, Continued

Predicted usage by income level, evaluated at the means of other variables

Model Number	1A	2A	3A	4A	5A
$5,000	87.47	123.04	113.73	84.21	87.61
$10,000	84.98	111.71	106.49	80.48	83.21
$15,000	82.49	101.50	99.79	77.24	79.37
$20,000	80.00	92.42	93.64	74.49	76.11
$25,000	77.51	84.46	88.03	72.23	73.41
$30,000	75.02	77.63	82.97	70.46	71.29
$35,000	72.53	71.92	78.45	69.17	69.73
$40,000	70.04	67.34	74.48	68.38	68.75
$45,000	67.55	63.88	71.05	68.07	68.33
$50,000	65.06	61.55	68.17	68.25	68.49
$55,000	62.57	60.34	65.83	68.92	69.21
$60,000	60.08	60.26	64.04	70.08	70.51
$65,000	57.59	61.30	62.79	71.72	72.37
$70,000	55.10	63.47	62.09	73.86	74.81
$75,000	52.61	66.76	61.93	76.48	77.81
$80,000	50.12	71.18	62.32	79.59	81.39
$85,000	47.63	76.72	63.25	83.19	85.53
$90,000	45.14	83.39	64.73	87.28	90.25
$95,000	42.65	91.18	66.75	91.86	95.53
$100,000	40.16	100.10	69.32	96.92	101.39

Table 5: Monthly Model Results (t-statistics in italics below coefficients)

Model Numbers and regression coefficients (t-statistics in parentheses)					
Variable name	1M	2M	3M	4M	5M
HDD	0.146 *89.24*	0.1465 *89.38*	0.1464 *89.28*	0.1465 *89.30*	0.124486 *70.64*
CCF(-1)					0.326629 *35.03*
AGEMED	0.447 *7.69*	0.3892 *6.57*	0.412 *6.93*	0.3735 *6.32*	0.217301 *11.01*
RMSMED	13.4770 *8.18*	13.1750 *8.12*	11.3190 *7.67*	13.6070 *8.41*	9.7447 *18.24*
MY	-0.0002 *-2.61*	-0.0012 *-4.40*		-0.0011 *-3.98*	-0.0010 *-10.46*
MY2		1.05E-08 *3.75*		9.42E-09 *3.33*	7.73E-09 *8.45*
AY			-0.0008 *-3.66*		
AY2			6.27E-09 *3.51*		
UNEMP				0.2779 *1.72*	0.1444 *2.78*
CONSTANT	-61.468 *-8.02*	-36.653 *-3.66*	-33.759 *-3.42*	-42.319 *-4.06*	-34.08478 *-9.84*
ADJ. WTD. RSQ.	0.6522	0.6531	0.6526	0.6532	0.722485
F	2037.471	1636.528	1632.697	1364.146	1548.91
Income at minimum CCF	N.A.	$58,857	$66,108	$59,873	$62,160
Income where predicted usage equals average	N.A.	$35,624	$42,656	$35,925	$37,701

Table 5, continued

Predicted usage by income level, evaluated at the means of other variables

Model Number	1M	2M	3M	4M	5M
$5,000	77.17	93.96	89.14	92.13	89.80
$10,000	75.99	88.57	85.46	87.20	85.58
$15,000	74.80	83.70	82.10	82.74	81.74
$20,000	73.62	79.36	79.05	78.74	78.29
$25,000	72.43	75.54	76.32	75.22	75.22
$30,000	71.25	72.25	73.90	72.17	72.54
$35,000	70.06	69.48	71.79	69.60	70.25
$40,000	68.88	67.24	70.00	67.49	68.34
$45,000	67.69	65.52	68.52	65.85	66.82
$50,000	66.51	64.33	67.35	64.69	65.69
$55,000	65.32	63.66	66.50	63.99	64.94
$60,000	64.14	63.52	65.96	63.77	64.58
$65,000	62.95	63.90	65.73	64.02	64.61
$70,000	61.77	64.81	65.82	64.73	65.02
$75,000	60.58	66.24	66.22	65.92	65.82
$80,000	59.40	68.20	66.93	67.58	67.01
$85,000	58.21	70.68	67.96	69.72	68.58
$90,000	57.03	73.69	69.30	72.32	70.54
$95,000	55.84	77.22	70.96	75.39	72.88
$100,000	54.66	81.28	72.92	78.94	75.61

IV. Summary and Conclusions

This study has used two approaches (weighted cross section and random-effects panel data) to investigate the relationship between usage and a number of independent explanatory variables. Regression coefficients with few exceptions are statistically significant and of the correct (i.e., predicted or expected) sign. Most important, there is no evidence that usage and household income are positively related through all levels of income. Rather, the relationship between usage and income has a "U"-shape. At lower income levels, usage increases as income falls, and at the lowest income levels is greater than the overall average usage. The relationship becomes positive at higher income levels—beyond some income level, usage increases with income. The implication for ratemaking is that larger proportional increases in the fixed monthly customer charge are not regressive. That is, increases in the customer charge do not harm low income users as a group. In fact, effecting a residential rate increase by disproportionately increasing the volumetric charge would likely have a greater harmful impact on such customers.