# The Equity and Efficiency of Two-Part Tariffs in U.S. Natural Gas Markets

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**Abstract**

Residential natural gas customers in the United States face volumetric charges that average about 30 percent more than the marginal cost of gas. This inefficient departure from marginal cost pricing allows gas utilities to cover their fixed infrastructure and operating costs. Proposals for recovering these costs instead through fixed monthly fees are often opposed because of a widespread belief that current rate schedules have desirable distributional consequences. Using nationally representative household-level data, we show that the correlation between household income and natural gas consumption is indeed positive but surprisingly weak, so current rate schedules are only mildly progressive. In part, we argue that this is because poor households tend to have larger families and less energy-efficient homes. We calculate bill impacts under a variety of scenarios and show that even a modest energy assistance program would more than offset the distributional impact of tariff rebalancing for most low-income households.

## 1. Introduction

In regulated markets, policy makers are often tempted to use price schedules to pursue distributional objectives. This is usually in direct conflict with efficiency, which requires that prices be set equal to marginal cost. The trade-off between equity and efficiency is particularly acute in markets with large fixed costs, such as energy, water, transportation, and telecommunications.

Residential sales of natural gas exemplify this issue. A large part of the total cost of household natural gas consumption is the cost of transportation and

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distribution. Local distribution companies (LDCs) in the United States spend billions annually installing and maintaining the distribution grid and metering infrastructure, as well as in processing bills, taking customer service calls, and performing other functions. Many of these costs are fixed with respect to the number of customers served or the volume they consume. As a result, the LDC functions are widely considered to exhibit declining average costs within a geographic region, a classic natural monopoly. Exactly the same issue comes up for markets in electricity, water, and, until recently, wired phone service.

The challenge in regulating markets with declining average costs is that a single price set equal to marginal cost does not provide enough revenue to pay for fixed costs. Coase (1946) was among the first to consider the question of what efficient pricing would look like in such markets. His solution was to use two-part tariffs. In the simplest case, the tariff has two components, a volumetric charge and a fixed monthly fee. The volumetric charge is set equal to marginal cost, and the fixed monthly fee is set equal to each customer's share of the fixed costs.

In practice, natural gas rate schedules in the United States differ substantially from this theoretical ideal. Although the norm is indeed to use two-part tariffs, typically these tariffs take the form of low fixed monthly fees and high volumetric charges. We find that, on average, volumetric charges for residential customers are marked up by about 30 percent above marginal cost. These markups impose deadweight loss by leading existing natural gas customers to consume too little natural gas. They also imply that high-volume customers pay a larger share of fixed costs than low-volume customers.

A natural approach to address these departures from marginal cost pricing would be to reduce the markups and increase fixed monthly fees commensurately. Although it is widely understood that efficiency could be improved by moving closer to marginal cost pricing, attempts at such tariff rebalancing face substantial political opposition because of a widespread perception that the current rate schedules have desirable distributional consequences. Poor people consume less natural gas, it is argued, so rebalancing revenue collection toward the fixed monthly fee would disproportionately harm them. Although this view is widely held by regulators and rate-payer protection groups, we are aware of little direct empirical evidence on the issue.

In this paper, we use a nationally representative household-level data set to calculate the distributional impact of a transition to marginal cost pricing. Our analysis shows that rebalancing rates would indeed cause low-volume customers to pay more and high-volume customers to pay less. We also find, however, that high-volume customers and high-income customers are not synonymous; the correlation between natural gas consumption and household income is positive but surprisingly weak. Consequently, current price schedules deliver only a modest amount of redistribution from high-income to low-income households. For example, we find that under marginal cost pricing, households in the lowest (first) income quintile would pay an average of $44 more per year for natural gas, while households in the fifth quintile would pay an average of $58 less. These impacts are fairly small when viewed as a fraction of household natural gas expenditure or as a fraction of total household income.

Our paper highlights two confounding factors that help explain the weak correlation between natural gas consumption and household income. First, we document a positive correlation between household income and energy efficiency. Controlling for geographic region, we find that low-income households tend to have homes with older furnaces, less insulation, and single-pane windows. These findings may be explained, in part, by the fact that low-income households are more likely to be renters, and the principal-agent problem between landlords and tenants leads to underinvestment in energy efficiency. Second, we show that low-income households are more likely to have children in the home. Households with children are more likely to have people at home during the day and to keep their homes at higher temperatures. With more energy-efficient homes and fewer children, high-income households tend to use less natural gas than would be expected due to the income effect alone.

We use several different measures of household need, beginning with household income, to evaluate the distributional consequences of rate rebalancing. Household composition is an important factor in measuring financial need, so we also measure redistribution by the ratio of income to the poverty line for the specific household's composition of adults, children, and elderly. Using this needs-adjusted measure of household income, we find even smaller distributional impacts. In addition, we focus directly on households with different numbers of children and find that households with children would pay less on average under marginal cost pricing, and households with two or more children would pay substantially less.

We also consider a variety of assumptions about the price elasticity of demand. The first set of results is calculated under the assumption that customers exhibit zero elasticity to this change in prices. Then we expand the analysis to recognize that customers faced with lower volumetric charges will consume more natural gas. Incorporating efficiency gains into the analysis makes the welfare impact of a change to marginal cost pricing more positive (or less negative) for every household. Under the most plausible behavioral responses, we find that the average household in the lowest quintile would see its consumer surplus decline by $21 per year, while the average household in the highest quintile would gain $69 per year.

In addition to estimating the size of the redistribution due to the current rate schedules, we also assess how the distributional consequences of tariff rebalancing could be mitigated by changes in needs-based energy assistance programs. The largest such existing program, the Low Income Home Energy Assistance Program (LIHEAP) operates in all 50 states and had a $4.5 billion budget in 2009. We discuss some of the challenges inherent in administering such programs. We then provide evidence that needs-based programs can substantially mitigate the regressive distributional effects of a transition to marginal cost pricing. We show that even a relatively modest energy assistance program ($10 per month), paid for by increasing the fixed charge on other customers, would more than offset the distributional impact of tariff rebalancing for most low-income households, while still improving total welfare.

This paper is related to a rich existing theoretical literature on the efficiency and equity of two-part tariffs. Coase (1946) is a response to Hotelling (1938), which argues that all prices in an economy should be set equal to marginal cost, with fixed costs paid for with government subsidies from income, inheritance, and property taxes. In cases where it is impractical to pay for fixed costs using government subsidies, Baumol and Bradford (1970) derive elasticity-based conditions following Ramsey (1927) to describe how prices should be marked up above marginal cost.[1] Feldstein (1972) incorporates equity into the analysis, showing how by assuming a functional form for the social welfare function one can derive formulas for the socially optimal two-part tariff. Auerbach and Pellechio (1978) build on the model described by Feldstein, taking into account that prices affect the number of customers in a market and that these changes along the extensive margin may be important for efficiency.

The paper proceeds as follows. Section 2 describes relevant background information about the structure of the residential natural gas distribution market. Section 3 discusses the data used for the analysis. Section 4 describes current natural gas rate schedules in the United States and presents estimates of volumetric charges and fixed monthly fees. Section 5 performs the key counterfactual in the paper, calculating the changes in bills that would be experienced in a transition to marginal cost pricing. Section 6 extends this analysis, incorporating efficiency effects and discussing implications for related markets, including the market for greenhouse gas emissions. Finally, Section 7 concludes by summarizing the key lessons of the analysis.

## 2. The Natural Gas Distribution Market

The natural gas market in the United States consists of gas producers, interstate pipeline operators, and LDCs. Our analysis focuses on LDCs, a segment of the market for which costs are well understood. The main cost for LDCs is the commodity cost of natural gas, which is measured by the city gate price, the price at which the LDC receives natural gas at the entrance to its distribution network. Once the gas enters the distribution network, very small quantities are

[1] Baumol and Bradford (1970) focus broadly on departures from marginal cost pricing in the economy but point out that their main results are applicable for two-part tariffs in regulated markets. Ng and Weisser (1974) make this application explicit, deriving conditions that describe the optimal two-part tariff in the presence of a budget constraint when the number of customers is not fixed. A related literature including Oi (1971) and Schmalensee (1981) examines two-part tariffs in unregulated monopoly markets.

lost to leakage and are used to power the compressors that push the gas through the system, but these losses represent a negligible fraction of the total costs.[2]

Natural gas distribution is a large market that directly affects more than 60 percent of U.S. households. Between 2000 and 2009, the total expenditure on natural gas by residential customers averaged $53 billion annually. Of this, $20 billion on average went to costs incurred by LDCs above and beyond the cost of natural gas itself (U.S. Department of Energy 2010b). The large size of the market suggests that both the efficiency and the equity implications of rate schedule adjustments could be significant. In this section, we briefly describe the organization of the market, highlighting the features that are relevant for the analysis.[3]

In addition to commodity costs, LDCs face the fixed and sunk costs of installing and maintaining the pipeline network, installing and maintaining gas meters, processing bills, and taking customer service calls. These costs are virtually all fixed with respect to the level of consumption of natural gas. Some of these are customer-level fixed costs—such as billing and meter installation and/or maintenance, which scale approximately with the number of customers served—while others are system-level fixed costs, which are largely invariant to the number of customers.

Natural gas LDCs are regulated by state utility commissions, which set rate schedules for each customer class. Using traditional rate-of-return techniques, regulators determine rate schedules to equate total revenues from all customer classes with total costs. A standard result in regulation is that efficiency requires that marginal price be set equal to marginal cost. The availability of two-part tariffs facilitates pricing at marginal cost because the volumetric charge can be set equal to marginal cost, and the fixed monthly fee can be set to cover fixed costs. In natural gas markets, with declining average costs and constant marginal costs, this structure would imply setting the fixed monthly fee equal to each customer's share of the LDC's fixed costs.[4]

In practice, natural gas rate schedules differ substantially from this theoretical ideal. Typically, the volumetric component includes not only a commodity charge

[2] According to the U.S. Department of Energy (2008), in 2005, 44 billion cubic feet of natural gas was used by local distribution companies (LDCs) for pipeline and storage compressors, new pipeline fill, and other processes associated with the operation of the distribution grid. Another 19 billion cubic feet was lost out of the distribution grid from leaks, damage, and accidents. However, together these uses and losses represent only .5 percent of the natural gas transported by LDCs. Therefore, the city gate price is a good approximation of the marginal cost of delivering an additional unit of natural gas. In the empirical analysis, we inflate city gate prices by .5 percent to account for these uses and losses.

[3] For more information about the organization and regulatory history of the U.S. natural gas market, see Viscusi, Harrington, and Vernon (2005) and U.S. Department of Energy (2010a).

[4] Although in theory fixed monthly fees could vary between different types of households, most natural gas LDCs use uniform pricing, in which all households in the utility district face the same price schedule. An important exception is energy assistance for low-income households, an issue to which we return in Section 5.2. Later in the paper, we also address the extensive margin (in Section 6.2) and the idea that increasing fixed monthly fees can inefficiently induce customers to stop using natural gas altogether.

but also an additional per-unit charge for transportation infrastructure, maintenance, billing, and other nonvolumetric costs, which increases the retail price per unit well above marginal cost.[5] To better understand rate schedules in the United States, we examined the residential rate schedules for the 50 largest natural gas LDCs. As of summer 2010, 48 of 50 had some fixed monthly fees in their tariffs, generally ranging from $5 to $15 per month but as high as $26, and two LDCs had no fixed monthly fee. The volumetric charge for natural gas was constant for 30 of the 50 LDCs, with 13 charging decreasing-block prices (a higher volumetric charge for the first units consumed each month and then a lower volumetric charge for all additional units) and the remaining seven charging increasing-block prices. In all 50 cases, the volumetric charge was well above the marginal natural gas acquisition cost for the LDC. This pattern of low fixed monthly fees and high volumetric charges has been a well-known feature of natural gas rate schedules in the United States since the emergence of a national natural gas market in the 1930s.

This combination of low fixed monthly fees and high volumetric charges causes LDC net revenues—net of commodity costs—to be highly seasonal, with LDCs collecting a large share of their total annual net revenue during cold, high-demand winter months. Net revenues for LDCs are highly volatile both across months and across years. For example, a warmer-than-average winter can dramatically reduce an LDCs annual net revenue. This revenue volatility is a major source of concern among natural gas LDCs. Simple time-series forecasting of residential consumption a year in advance has a 95 percent confidence interval of about $\pm 20$ percent of sales, so the annual mismatch between net revenues and the noncommodity costs of the LDC can be quite substantial.[6]

Many utilities have adopted a variety of innovative rate designs that decouple net revenues from consumption levels. The simplest and most efficient approach to reducing this volatility would be to increase the fixed monthly fee and reduce the volumetric charge to more closely reflect the marginal acquisition costs for natural gas. Nonetheless, with few exceptions, natural gas utilities have not gone in that direction. Instead, decoupling typically involves mechanisms by which the volumetric component of the bill is automatically adjusted in response to weather and other factors (for details, see American Gas Association 2010).[7]

[5] Applicable state and local taxes are also typically included in the volumetric component. Among the 20 largest natural gas LDCs, 18 collect some form of tax. The average size of the tax is $.50 per thousand cubic feet. The mean volumetric charge in our data is $11.34, so this tax is a relatively small component. When rebalancing rates in the analyses that follow, we shift taxes, along with nonvolumetric costs, to the fixed monthly fee.

[6] To arrive at this figure, we collected sales data on 1,084 natural gas utilities in the United States from the EIA-176 Query System. We then estimated the regression $\ln(Q_t) = \alpha_0 + \alpha_1 \ln(Q_{t-1}) + \alpha_2 t + \alpha_3 t^2 + \varepsilon$, where $Q_t$ is residential consumption for year $t$. The mean standard error of these regressions was about .1 (the median was about .09). The results are essentially identical when we assume an average usage per customer, which indicates that this volatility is not driven by changes in the number of customers.

[7] As of 2010, 26 utilities in 13 states had adopted mechanisms that adjust volumetric charges in response to weather and other factors.

Distributional considerations are frequently cited as an explanation for this preference for volumetric charges.[8] When LDCs' revenues are overwhelmingly derived from the volumetric charge, high-demand customers are responsible for a larger share of the total revenues than they would be if natural gas was priced at marginal cost. When the fixed monthly fee is zero, for example, a customer consuming 100,000 cubic feet annually pays twice as much as a customer consuming 50,000 cubic feet despite the fact that the cost of providing distribution service to these customers is nearly the same. This discrepancy can have progressive distributional consequences to the extent that natural gas consumption is positively correlated with household income or other measures of need.

This distributional argument features prominently in rate hearings. For example, the attorney general of Arkansas has argued against proposed increases in the fixed monthly fee: "While consumption by individual customers varies, on the average, lower income people use less natural gas than higher income people" (Arkansas Public Service Commission Docket 04-121-U. Revenue Requirement, Cost of Service, and Residential Rate Design for Centerpoint Arkla, May 2005, W. Marcus for the Arkansas Attorney General). Comparing natural gas consumption with average household income at the zip code level, an expert for the attorney general noted a "mild but statistically significant relationship to income" and argued that increases in the fixed monthly fee are "likely to harm low income people" (Arkansas Public Service Commission Docket 06-161-U. Revenue Requirement, Cost of Service, and Residential Rate Design for Centerpoint Arkla, July 2007, W. Marcus for the Arkansas Attorney General [case settled]) (see also Marcus, Ruszovan, and Nahigian 2002; NERA Economic Consulting 2007).[9]

Concerns about the distributional implications of tariff rebalancing persist even though several state and federal programs provide energy assistance for low-income households. How effectively these income-based programs would mitigate the distributional consequences of tariff rebalancing is an empirical question. As we discuss later in the paper, the effectiveness of energy assistance programs depends not only on the overall budget allocated for energy assistance but also on the particular income-eligibility rules, and the participation rate among eligible populations.

[8] An alternative explanation for this preference for volumetric charges is offered by Sherman and Visscher (1982), who argue that rate schedules in electricity and natural gas markets are a manifestation of the Averch-Johnson effect (Averch and Johnson 1962). The argument is that a low fixed monthly fee and a high volumetric charge increase the total number of customers because even customers with a low level of demand for natural gas decide to connect. This outcome increases the total level of capital expenditures and, if the allowed rate of return is above the cost of capital, also increases profits.

[9] Marcus, Ruszovan, and Nahigian (2002) find that lower income households are more likely to live in multiunit buildings, which tend to use less energy for heating than do single-family units of the same size.

## 3. Data

### 3.1. *The Residential Energy Consumption Survey*

The central data set used in this analysis is the 2005 Residential Energy Consumption Survey (RECS), a nationally representative in-home survey of households in the United States conducted every 5 years by the Department of Energy.[10] The RECS provides detailed information about the demographic characteristics of each household, including income, the number of children, and the ages of all household members. In addition, the RECS includes highly detailed information about the housing unit and about the appliances owned by the household.

The 2005 RECS includes 4,382 households. From the complete sample, we exclude households that do not use natural gas. This eliminates 1,690 households, or 39 percent of the sample. In addition, we exclude an additional 137 households that do not directly pay for natural gas. Most of these households live in rental housing units in large multiunit buildings where household-level metering is not available. It makes sense to drop both of these groups of households because neither would be directly affected by changes in natural gas rate schedules. After these exclusions, we are left with a sample that includes 2,555 households, or about 500 per group when we examine households by quintile.

An important feature of the RECS is that it provides, in addition to these household and housing characteristics, high-quality information about natural gas consumption and expenditures. This information is obtained directly from the LDC that provides natural gas to each home. The data collection proceeds as follows. First, during the in-home survey, the household is asked which company supplies natural gas to the home. The surveyor also makes copies of the household's recent bills, if they are available, to make it easier to match households with their billing records. Second, the staff members at the RECS follow up with the LDC, requesting the previous 12 months of bills for the household. Third, the RECS staff members use this information to construct an annual measure of natural gas consumption and expenditures for each household.[11] The RECS is the only nationally representative household-level survey that provides both demographic information and utility-provided energy billing data.

The measure of income in the RECS is the total household income from all sources (employment income, retirement income, cash benefits from public assistance, and noncash benefits) before taxes and deductions. Income is reported in 24 different categories ranging from the annual equivalent of less than $2,500

[10] Interviews for the 2009 Residential Energy Consumption Survey (RECS) started in February 2010, but microdata are not yet available.

[11] In requesting bill information from LDCs, the Department of Energy makes it clear that the reported dollar amounts for expenditures should include all charges, including the fixed monthly fee, taxes, and any other charges. The survey instrument is also clear about how households enrolled in the Low Income Home Energy Assistance Program and other energy assistance programs should be treated. In particular, the LDCs are clearly instructed not to report the amounts on discounted bills but instead to report the dollar amounts of what those households would have paid had they been charged per the regular rate schedule without energy assistance.

to more than $120,000. In the analysis that follows, we use a measure of household income constructed with the midpoint of the income bin reported by each household.[12] For each household, we use TAXSIM version 9.0 to calculate the federal income tax liability.[13] We calculated the tax liability for 2005 using household income, marital status, the number of children, and the age of the household head. We then subtracted the tax liability from the household income to calculate the aftertax annual household income for each household.

### *3.2. Federal Poverty Thresholds*

To gauge the financial stress on a household, many researchers argue that income should be adjusted for household composition. To do so, we examine household income as a percentage of the federal poverty threshold for the specific household's demographics. We use the federal poverty thresholds for 2005, which are based on the total number of household members, the number of children, and whether the household head is 65 or older.[14] Poverty thresholds vary considerably on the basis of household composition, ranging from $9,367 for a single individual 65 years and over to $37,757 for a household with eight or more children. We prefer this measure of needs-adjusted household income to household income per capita because it takes into account that there are differences in needs across household members of different ages and that there are economies of scale within the household.[15]

Table 1 reports covariate means and standard deviations by needs-adjusted household income quintile. Annual household income increases from an average of $16,500 in the first quintile to $129,800 in the fifth quintile. All dollar values in the paper have been adjusted for inflation to reflect year 2010 prices. The large standard deviations for household income reflect that the poverty thresholds vary across households because of household composition. For example, house-

[12] For the top category, we use $200,000, which is based on the conditional mean from more detailed 2005 household annual income data from U.S. Bureau of the Census (2006, table HINC-06). Our results are not sensitive to this assumption, however, because we perform the distributional analysis by quintiles, and even after we adjust for differences in the composition of households, the households in this top income category are always assigned to the top quintile.

[13] For more information about TAXSIM, see Feenberg and Coutts (1993). Created and maintained by the National Bureau of Economic Research, TAXSIM is a tax calculator designed for use with survey data. Based on a database of hundreds of thousands of actual tax returns, the program has been used in hundreds of studies and has been shown to calculate federal income tax liability to a high degree of accuracy.

[14] Except for somewhat higher poverty thresholds established for Alaska and Hawaii, neither the poverty thresholds from the U.S. Census Bureau nor similar poverty guidelines from the U.S. Department of Health and Human Services differ by state (see U.S. Census Bureau, Housing and Household Economic Statistics Division, Poverty Thresholds for 2005 by Size of Family and Number of Related Children under 18 Years [http://www.census.gov/hhes/www/poverty/data/threshld/thresh05.html]). We discuss in Section 3.3 that the RECS data do not identify the state of residence for most households, so even if state-level thresholds were available, they would be difficult to incorporate.

[15] Deaton and Muellbauer (1980, chap. 8) provide a primer on using equivalence scales for comparing welfare across households with different characteristics.

Table 1
Descriptive Statistics by Needs-Adjusted Household Income Quintiles

| | First | Second | Third | Fourth | Fifth |
|---|---|---|---|---|---|
| Percentage of the poverty line | <148 | 148–235 | 236–334 | 335–514 | >514 |
| Household economic and demographic characteristics: | | | | | |
| Mean annual household income ($1,000s) | 16.5 | 32.3 | 46.7 | 65.3 | 129.8 |
| | (8.9) | (12.0) | (15.8) | (20.8) | (44.1) |
| Household members | 2.75 | 2.86 | 2.71 | 2.50 | 2.47 |
| | (1.92) | (1.61) | (1.51) | (1.32) | (1.17) |
| Children | .94 | .85 | .78 | .61 | .52 |
| | (1.38) | (1.14) | (1.08) | (.97) | (.92) |
| Proportion homeowner | .49 | .66 | .77 | .85 | .91 |
| | (.50) | (.47) | (.42) | (.36) | (.29) |
| Proportion receiving energy assistance | .18 | .06 | .00 | .00 | .00 |
| | (.38) | (.24) | (0) | (0) | (0) |
| Natural gas consumption and expenditure: | | | | | |
| Mean annual consumption (1,000s of cubic feet) | 61.1 | 68.2 | 66.7 | 67.9 | 80.9 |
| | (47.8) | (44.1) | (40.7) | (41.6) | (47.9) |
| Mean annual expenditure ($) | 743 | 823 | 807 | 854 | 993 |
| | (588) | (533) | (476) | (550) | (586) |
| Expenditure as a fraction of income | .06 | .03 | .02 | .01 | .01 |
| | (.09) | (.02) | (.01) | (.01) | (.01) |
| Energy efficiency: | | | | | |
| Main heating system < 10 years old | .34 | .38 | .41 | .48 | .50 |
| | (.47) | (.49) | (.49) | (.50) | (.50) |
| Well insulated | .30 | .39 | .38 | .37 | .45 |
| | (.46) | (.49) | (.49) | (.48) | (.50) |
| Double-pane windows | .38 | .51 | .62 | .60 | .70 |
| | (.49) | (.50) | (.49) | (.49) | (.46) |

**Source.** The data are from the 2005 Residential Energy Consumption Survey (RECS).
**Note.** The sample includes all households with a natural gas connection excluding renters living in housing units in which utility costs are included in the rent. The resulting sample includes 2,555 households, or approximately 500 households per quintile. Means and standard deviations (in parentheses) are calculated using RECS sampling weights.

holds with several children can have a relatively high level of household income yet appear in one of the bottom quintiles for needs-adjusted household income.

Household economic and demographic characteristics differ substantially across quintiles. The average number of children decreases from .94 in the poorest quintile to .52 in the wealthiest quintile, and the proportion of households that own a home increases steadily across quintiles from .49 to .91. The proportion of households that receive energy assistance declines across the quintiles as one would expect. Whereas 18 percent and 6 percent of households in the two lowest quintiles received some form of energy assistance in 2005, no households in the highest three quintiles received energy assistance.

Natural gas consumption and expenditures increase across quintiles. The mean annual expenditure on natural gas increases from $743 to $993, and the fraction of income dedicated to natural gas expenditures decreases from 6 percent to less than 1 percent. In our sample, the simple correlation between natural gas con-

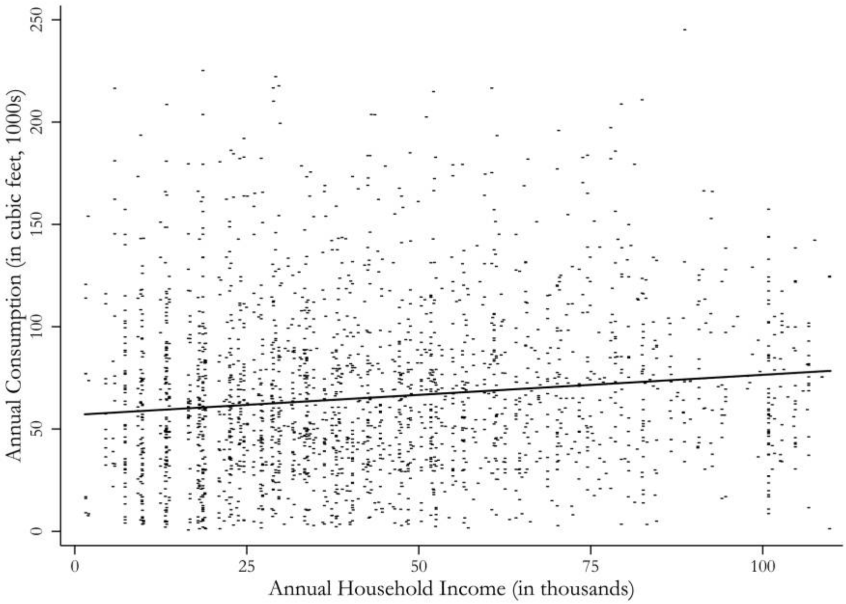



**Figure 1.** Natural gas consumption and household income

sumption and household income is .19, and the correlation between natural gas consumption and needs-adjusted household income is .13.[16]

Figure 1 is a scatterplot of natural gas consumption against household income. Each observation is a household, and the figure includes a fitted least squares regression line.[17] The figure illustrates that whereas the correlation between consumption and income is positive, little of the variation in natural gas consumption is explained by the variation in household income. Part of this lack of correlation can be explained by systematic differences in natural gas consumption across climate zones. However, even within geographic divisions, household income explains only a small fraction of the variation in natural gas consumption. Figure 2 plots residuals from a regression of natural gas consumption on indicator variables for each of the nine census divisions against household income. Again, the correlation between higher consumption and higher income is positive but weak. Across census divisions, the average $R^2$-value

[16] This low correlation reflects, in part, the fact that household income is measured with error. Misreporting by households, the binning of income into 24 categories, and errors in the tax imputation will all tend to reduce the correlation between household income and natural gas consumption.

[17] For presentation purposes, we exclude from Figure 1 households for which annual aftertax household income exceeds $120,000 or annual natural gas consumption exceeds 250,000 cubic feet. These households are included in all statistical analyses.

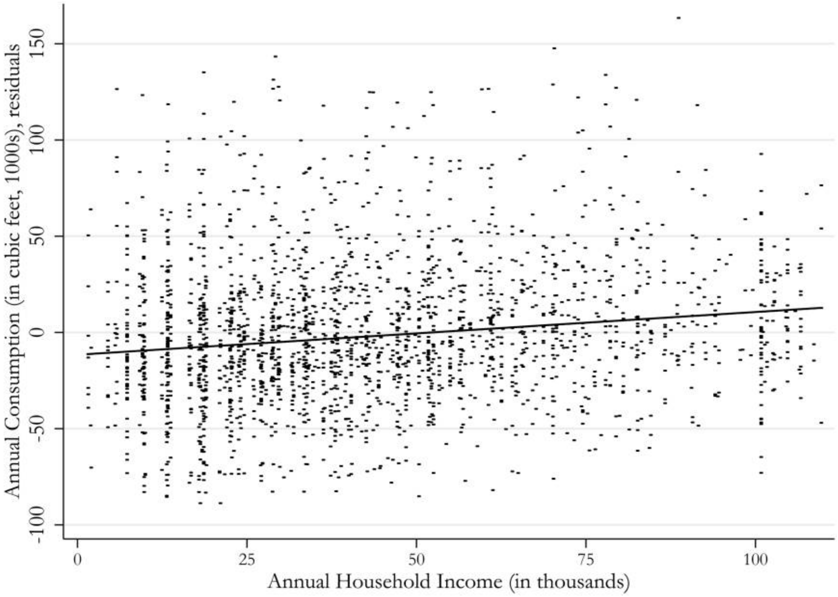



**Figure 2.** Natural gas consumption and household income, controlling for census division

from a regression of natural gas consumption on household income is .09.[18] This weak correlation illustrates the challenge of using natural gas price schedules for redistribution and highlights that only very large changes in the price schedule will have substantial distributional effects and that any price reform will impact different types of households differently.

Finally, Table 1 shows three measures of residential energy efficiency. The proportion of households that report having a heating system that is less than 10 years old increases across quintiles from 34 to 50 percent. Similarly, the proportion of the houses that are well insulated and the proportion that have double-pane windows both also exhibit a strong positive correlation with needs-adjusted household income. This positive relationship between energy efficiency and needs-adjusted household income remains after controlling for geographic division. In alternative results (not reported), we regressed energy efficiency on needs-adjusted household income and indicator variables for each census division. For all three measures of energy efficiency, the coefficient on needs-

[18] It would be preferable to examine the within-utility correlation between natural gas consumption and income. Although this analysis is not possible with the RECS data, in additional results described in Appendix A, we use an alternative data set to examine the within-utility correlation for California utilities. Across the three major natural gas LDCs in California, the average $R^2$-value from a regression of natural gas consumption on household income is .04.

adjusted household income is positive and statistically significant, with $t$-statistics ranging from 5.4 to 9.9.

One potential explanation for this pattern is the landlord-tenant problem. Several studies have pointed out that landlords may underinvest in energy efficiency when their tenants pay for utilities.[19] Although investments in energy efficiency could, in theory, be passed on in the form of higher rents, it may be difficult for landlords to credibly convey information about energy efficiency. In the higher quintiles, households are considerably more likely to be homeowners and so the landlord-tenant problem is less important. When we restrict the sample to exclude renters, the correlation between energy efficiency and needs-adjusted household income is positive but weaker. In additional alternative results (also not reported), we used this smaller sample to perform the same regressions. For all three measures of energy efficiency, the coefficient on needs-adjusted household income was positive and statistically significant. However, the magnitudes of the coefficient estimates were 23.8, 25.2, and 15.1 percent smaller, which is consistent with the landlord-tenant problem providing some but not all of the explanation for the observed correlation. Other potential explanations include capital constraints, a negative correlation between income and discount rates (see, for example, Hausman 1979; Dubin and McFadden 1984), and the idea that the comfort provided by energy efficiency is a normal good.

### *3.3. Wholesale Natural Gas Prices*

To be able to evaluate the impact of tariff rebalancing, we augment the household-level data from the RECS with natural gas city gate prices from the Platts GASdat database. Our measure of wholesale prices is the city gate price, the price paid by LDCs at the entrance to the distribution network. We focus on city gate prices because they accurately reflect the marginal cost of the LDC acquiring additional natural gas. Most LDCs purchase some natural gas on short-term, fixed-price, fixed-quantity contracts 30–120 days in advance. Some LDCs also purchase on longer term contracts. However, because these contracts are for fixed quantities at fixed prices, and because there are active daily spot markets, the contracts do not change the LDCs' marginal opportunity cost of providing additional natural gas.[20]

The Platts data describe daily natural gas spot prices from 131 locations throughout the continental United States, obtained by Platts via surveys of trades made at each location. We aggregate daily city gate prices to the monthly level and then calculate state averages across all locations in a given state. For states without Platts survey locations, prices from the closest available location are used. Next we aggregate these data to the annual level by taking consumption-weighted averages over the year. Data on total residential consumption by state and month come from the U.S. Department of Energy (2010b). The Department

[19] For a recent investigation of this relationship, see Davis (2012).

[20] See Borenstein, Busse, and Kellogg (2012) for a detailed description of natural gas procurement.

of Energy constructs these data using a monthly survey (EIA Form-857) of natural gas distribution companies. This consumption weighting accounts for the fact that city gate prices tend to be somewhat higher than usual during winter months when consumption rises, although seasonal variation in natural gas prices is mitigated by the ability of natural gas suppliers to store natural gas.[21]

For the main analysis, we use city gate prices for the period 2003–5. The RECS data report residential consumption for 12-month periods ending at different times during 2005, so the relevant wholesale prices would be from 2004 and 2005 if residential tariffs adjusted immediately to wholesale price changes. To account for the fact that there is frequently a lag in adjustment, we include 2003 prices as well. Results are qualitatively similar when we use only 2005 data, although they differ somewhat because there was an unusually sharp increase in natural gas prices during that year. Many utilities do not have mechanisms that allow them to immediately pass on price increases to consumers, so the LDC net revenue for 2005 was substantially below average. Using average city gate prices for the period 2003 to 2005 provides a more reasonable representation of typical LDC net revenues.

The RECS identifies the census division of residence for all households. In addition, the RECS identifies the state of residence for households in Texas, California, New York, and Florida. We assign wholesale prices to households using the most highly disaggregated geographic unit available, separating households in Texas, California, and New York from their census divisions. Because there are few households in Florida with natural gas connections, we do not attempt to separate these households from their census division (South Atlantic). Also, we drop the Pacific census division (Alaska, Hawaii, Oregon, and Washington) because Platts city gate prices are not available for Alaska and Hawaii and because even if some city gate prices could be constructed for these states, this census division is extremely heterogeneous with regard to proximity to natural gas producers, weather, and other factors. Thus, the resulting set of geographic units includes eight census divisions and three individual states.[22] For brevity, in the rest of the paper, these geographic units are referred to simply as divisions. In calculating city gate prices by division, we use consumption weights across states.

[21] According to U.S. Department of Energy (2010a, table 14), as of December 2008, the working natural gas storage in the lower 48 states was 4.2 trillion cubic feet, enough to meet total consumption for about 2 months.

[22] Thus, in addition to the three individual states (California, New York, and Texas), our modified divisions include New England (Connecticut, Maine, Massachusetts, New Hampshire, and Rhode Island), Middle Atlantic (New Jersey and Pennsylvania), East North Central (Indiana, Illinois, Michigan, Ohio, and Wisconsin), West North Central (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota), South Atlantic (Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia), East South Central (Alabama, Kentucky, Mississippi, and Tennessee), West South Central (Arkansas, Louisiana, and Oklahoma), and Mountain (Arizona, Colorado, Idaho, New Mexico, Montana, Utah, Nevada, and Wyoming).

## 4. Current Natural Gas Rate Schedules

### *4.1. Graphical Evidence*

In this section, we use household-level natural gas consumption and expenditures to describe the natural gas rate schedules faced by residential customers in the United States. Figure 3 plots annual consumption and expenditure by division. Each observation is a household, and a fitted least squares regression line (the dashed line) is included.[23] Within divisions, there is large variation across households in annual natural gas consumption. As we expected, the data reveal a strong positive correlation between consumption and expenditure. In fact, in most divisions there is a group of households (and, in some cases, more than one group) for whom the relationship is almost exactly linear. This finding is consistent with these observations all coming from the same utility and linear rate schedule.

There is also, however, a large degree of heterogeneity in expenditure in all divisions. In many cases, different households consuming the exact same amount of natural gas in the same division pay considerably different amounts. This heterogeneity in rate schedules is at first surprising. After all, natural gas can be easily transported, so wholesale prices do not vary much within a division. Instead, these differences are driven by differences in the cost of local distribution and other costs that are recovered in the LDCs' volumetric charge. Within each division, there are several different LDCs, and costs vary across LDCs on the basis of the mix of residential, commercial, and industrial customers; average consumption levels; the population density; the age of the distribution grid; and other factors.[24] In addition, the heterogeneity in rate schedules reflects the fact that households differ in the timing of their consumption. Many utilities charge rates that vary seasonally, so a household that consumes proportionately more during winter months pays more on average per unit. A limitation of the RECS data is that monthly consumption data are not supplied, and it is therefore impossible to distinguish these seasonal differences in consumption from differences in price schedules across households.

Another factor that creates differences in rate schedules within divisions is retail choice. Several states—including Georgia, Maryland, New York, Ohio, Pennsylvania, and Virginia—have active retail choice programs for residential natural gas customers. In these states, customers have a choice between buying natural gas from an LDC or from independent natural gas marketers who set their own rate schedules. If the customer buys from an independent marketer,

[23] For presentation purposes, in these figures we dropped households with annual consumption above 250,000 cubic feet or annual expenditures above $2,500. These outliers represent less than 2 percent of the total sample. All subsequent analyses in the paper include these observations. We also tested the sensitivity of our results to excluding these outliers, and the results were essentially identical.

[24] Local distribution companies also differ in the longer term natural gas contracts that they sign and the gains and losses these contracts yield relative to the city gate prices. Those gains and losses are part of why rates differ across LDCs in the same division.

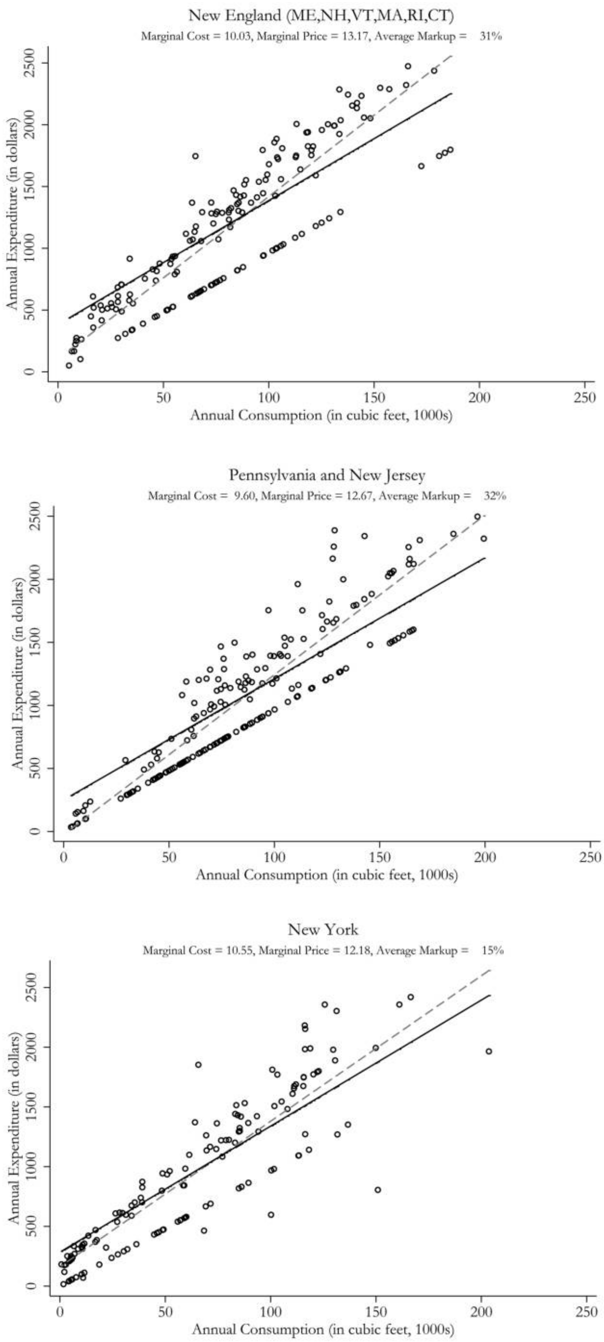



**Figure 3.** Residential natural gas rate schedules for 2005, by geographic division

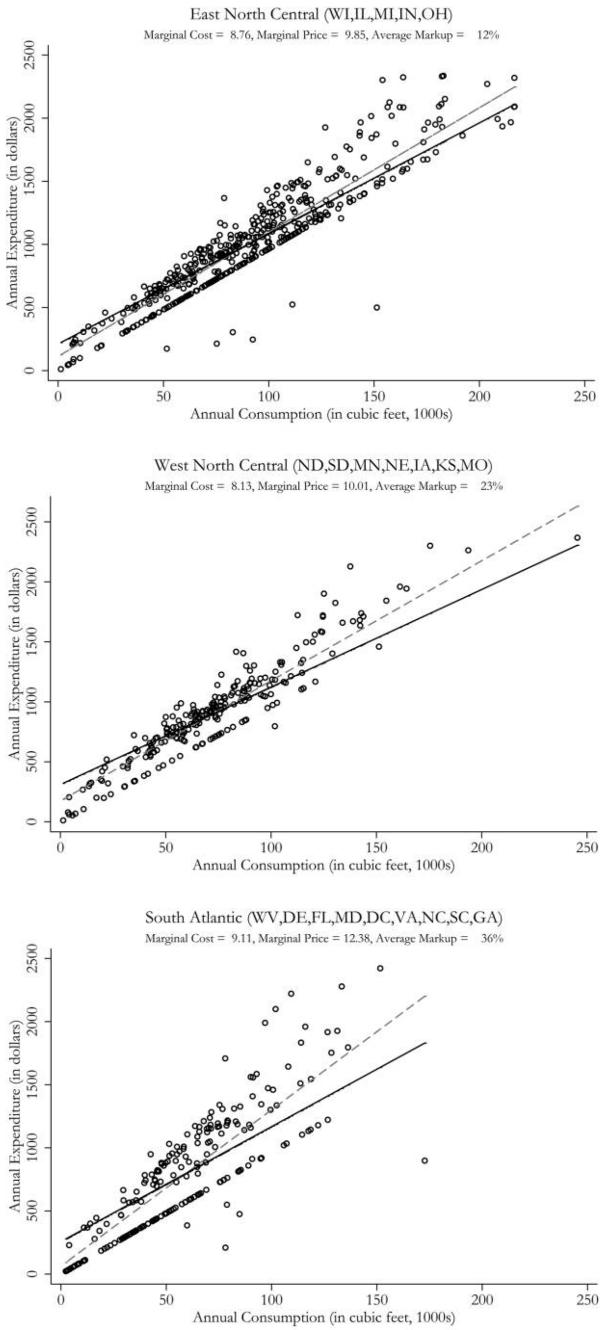



**Figure 3.** *Continued*

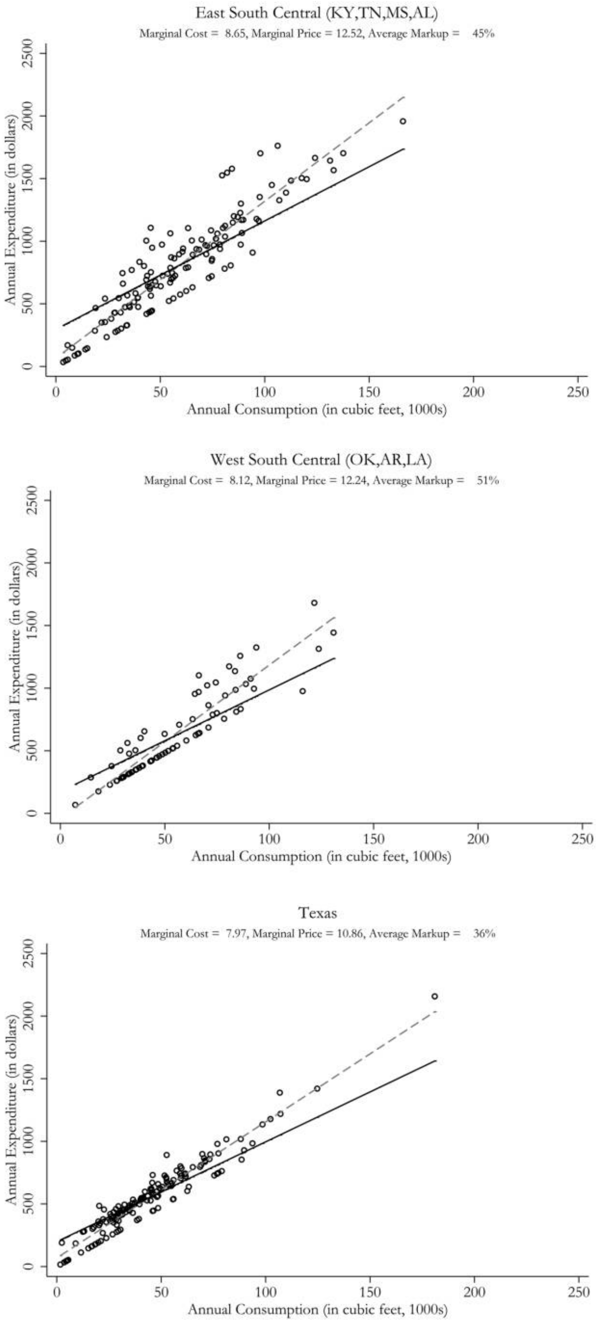
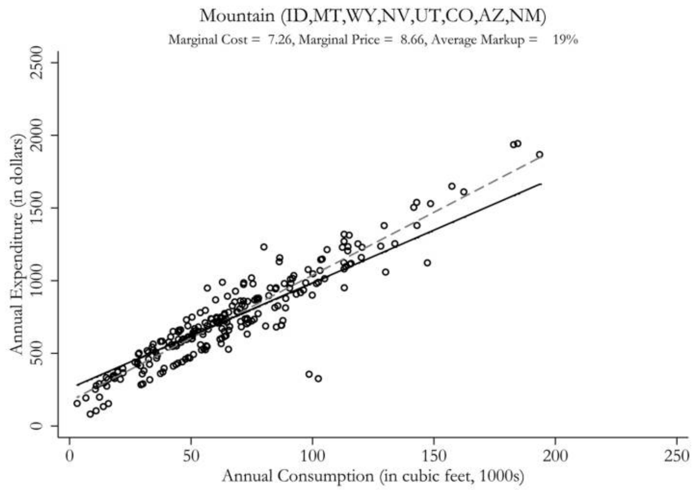



**Figure 3.** *Continued*



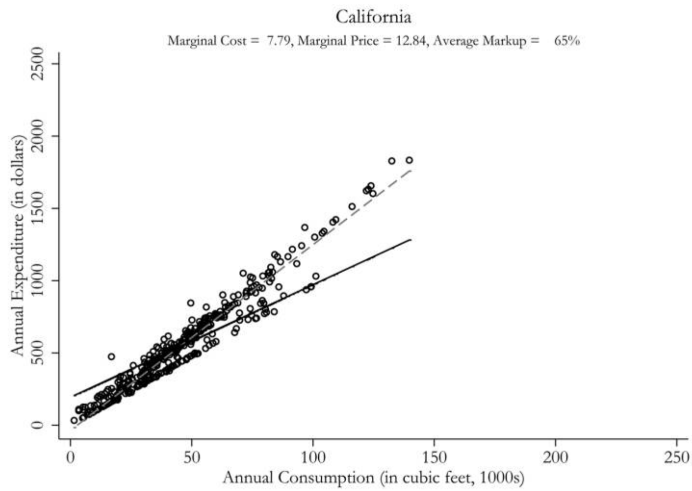




**Figure 3.** *Continued*

the LDC provides and is reimbursed for transportation services—for the most part on a volumetric basis—but marketers set the rate schedules, procure natural gas in the wholesale market, and bill customers directly.[25] Despite the fact that most of an LDC's costs of providing services to retail choice customers do not vary with volume, most of an LDC's revenues from these customers are collected on a volumetric basis.

[25] In December 2005, 3.9 out of 62.5 million residential natural gas customers in the United States purchased natural gas from a marketer rather than an LDC (see U.S. Department of Energy 2005).

In the calculations that follow, we compare households' actual expenditures on natural gas with how much they would have spent under marginal cost pricing. Because rate schedules vary within divisions, however, and because we do not observe the exact rate schedules for each household, our counterfactual also implicitly imposes a uniform retail tariff for all customers within a division. Under these counterfactual tariffs, all customers within a division pay the same fixed monthly fee and the same volumetric charge. An alternative approach is to perform this harmonization for both the current tariffs and the counterfactual tariffs. We do this by using the fitted values from equation (1) to predict each household's expenditure under the average rate schedule for that division. These predictions can then be compared with expenditures under the marginal-cost-based alternative tariff. We prefer the former approach because it does not require any assumptions about the structure of the current rate schedules. Nonetheless, it is reassuring that when we instead use this alternative approach, the results are quite similar.

Moreover, the results are also similar when we repeat the analysis with a completely different data set, the Residential Appliance Saturation Survey (RASS). A household-level survey conducted in 2003 by the California Energy Commission, the RASS identifies the exact utility that serves each household, which allows us to perform the counterfactual bill analysis separately by utility. As we describe in detail in the Appendix, the general pattern of results is very similar with these alternative data. Together with the results from the alternative harmonization for both the actual and the counterfactual approach above, this analysis suggests that our results are not driven by that fact that we create the counterfactual at the geographic division, rather than utility, level. In retrospect, this outcome is not surprising because there is no reason ex ante for there to be a substantial correlation between within-division departures from average rate schedules and our measures of household well-being.

### *4.2. Volumetric Charges*

Table 2 describes natural gas rate schedules by region and how schedules would change after tariff rebalancing. For clarity, we present results for the four geographic census regions in the continental United States (Northeast, Midwest, South, and West) that aggregate the areas reported in the RECS data.[26] Columns 1 and 2 describe average features of natural gas rate schedules. These estimates are derived from the following regression:

$$\text{Expenditure}_{ij} = \alpha_{0j} + \alpha_{1j}\text{Consumption}_{ij} + \varepsilon_{ij}, \tag{1}$$

where $\text{Expenditure}_{ij}$ is the annual expenditure for household $i$ in division $j$, $\text{Consumption}_{ij}$ is the annual natural gas consumption, and $\varepsilon_{ij}$ is an error term

[26] Northeast includes New York and the Middle Atlantic and New England divisions; Midwest includes the West North Central and East North Central divisions; South includes Texas and the West South Central, East South Central, and South Atlantic divisions; and West includes California and the Mountain division.

Table 2
Natural Gas Rate Schedules by Region

| | Current Rate Schedule | | Rate Schedule after Rebalancing | |
|---|---|---|---|---|
| | Volumetric Charge (1) | Fixed Monthly Fee (2) | Volumetric Charge (Marginal Cost) (3) | Fixed Monthly Fee (4) |
| Northeast | 12.60 | 5.82 | 10.04 | 24.20 |
| | (.38) | (2.10) | | (1.37) |
| Midwest | 9.90 | 10.90 | 8.57 | 20.03 |
| | (.44) | (2.75) | | (.68) |
| South | 11.97 | 4.22 | 8.58 | 19.67 |
| | (.46) | (1.90) | | (.93) |
| West | 11.47 | 2.69 | 7.61 | 17.92 |
| | (.26) | (.96) | | (.58) |
| Average | 11.34 | 6.20 | 8.63 | 20.24 |
| | (.20) | (1.05) | | (.44) |

**Note.** Column 1 reports mean volumetric charges for current rate schedules in the Residential Energy Consumption Survey (RECS) per 1,000 cubic feet. Column 2 reports mean fixed monthly fees for current rate schedules in the RECS. Column 3 reports the mean city gate prices from the Platts GASdat database per 1,000 cubic feet. Column 4 reports the fixed monthly fees required to maintain the same level of revenue if the volumetric charges were decreased to marginal cost. Amounts are expressed in year 2010 dollars. Bootstraped standard errors based on 1,000 replications are in parentheses. All calculations use RECS sampling weights.

that captures unmodeled differences in the rate structure across households. We estimate equation (1) separately for the 11 different divisions.[27] The parameters in this regression have a direct economic interpretation. The intercept, $\alpha_{0j}$, is the mean amount paid annually in fixed monthly fees or, equivalently, the level of expenditure implied by the regression equation for a household that consumes no gas. The slope, $\alpha_{1j}$, is the mean volumetric charge for natural gas.

Table 2 reports average parameter estimates (weighted by households). On average, across all regions households faced a volumetric charge of $11.34 compared with a city gate price of $8.63, for an average markup of 32.1 percent. Wholesale prices were somewhat higher on average in the Northeast and somewhat lower on average in the West during this period. These differences reflect differences in transportation costs across regions. Most natural gas in the United States is produced in gas fields concentrated in the south-central United States, and wholesale prices tend to increase as one moves farther away from these producing areas. Markups vary somewhat across regions, but in all regions the volumetric charge is marked up considerably above marginal cost.

Our approach uses within-division, across-household variation to infer the average rate schedule in each geographic division. An alternative to this regression-

[27] We have also tried a more flexible specification that allows $\alpha_0$ and $\alpha_1$ to vary both across division and across urban, suburban, town, and rural locations. Although utilities typically do not use different rate schedules for these different groups, such a specification would make sense to the extent that different utilities in each census division tend to serve predominantly households in one particular group. The results with this more flexible specification are essentially unchanged from those in our original analysis, and for parsimony we prefer the baseline specification.

based approach would be to match households with their exact rate schedules. With the RECS this process is not feasible, however, because it does not identify exactly where households are or from which utility they obtain natural gas. Given this indirect method for inferring average rate schedules, it is important to cross-check our estimates with measures of rate schedules from other sources. Davis and Muehlegger (2010) use aggregate data and a different empirical approach to estimate residential natural gas schedules in the United States during the period 2002–7. They find an average markup of $3.38 per thousand cubic feet, compared with our average markup of $2.71. Although we continue to recognize that our estimates are only an approximation, it is reassuring that this important feature of the rate schedules is similar to this existing estimate in the literature.[28]

### *4.3. Fixed Monthly Fees*

The other key feature of natural gas rate schedules is the fixed monthly fee. We estimate that, under current rate schedules, households in the United States pay an average fixed monthly fee of $6.20. The estimates vary somewhat across regions from $2.69 in the West to $10.90 in the Midwest. Under the assumption of zero demand elasticity and revenue neutrality, column 4 shows how the fixed monthly fee would increase if the volumetric charge were set equal to marginal cost: the fixed monthly fee would need to increase substantially to offset the decrease in revenue. Across regions, the increase in the fixed monthly fee ranges from $17.92 to $24.20. These fees assure that total LDC revenue from residential customers would not change under the counterfactual. This calculation assumes no change in any cross subsidization across customer classes (residential, commercial, and industrial) or across energy products for utilities that sell both electricity and natural gas.[29]

The transition to marginal cost pricing is illustrated graphically in Figure 3. The black line in each scatterplot denotes the marginal cost price schedule. The slope of the line is the estimated mean city gate price for each division, and the vertical intercept is the mean fixed monthly fee under marginal cost pricing. Notice that the line is considerably flatter than the line describing the current rate schedules. With the marginal cost schedule, the LDC pays all operating and capital expenses through revenue from the fixed monthly fee. Comparing each observation to the marginal cost schedule illustrates how the total expenditure would change under marginal cost pricing. Households with low levels of annual consumption would tend to pay more, and households with high levels of annual

[28] In related work, Naughton (1986) evaluates the efficiency and equity of electricity price schedules for a sample of U.S. electric utilities in 1980. Estimating costs using a translog function, he finds that per-unit prices exceed marginal cost by approximately 50 percent for residential, commercial, and industrial customers. The study then examines the equity of electricity prices across customer classes, finding no evidence of cross subsidization.

[29] In related research, Knittel (2003) compares prices of single- and dual-product electricity and natural gas utilities and finds evidence that the price markups of residential and commercial electricity consumers are used to subsidize industrial natural gas consumers.

Table 3
The Distributional Impact of a Change to Marginal Cost Pricing

| | Mean Annual Change ($) | Experiencing Bill Increase (%) | Mean Bill Change (%) |
|---|---|---|---|
| By household income quintile: | | | |
| First | 44.39 (9.79) | 66.7 (2.3) | 6.1 (1.5) |
| Second | 23.26 (9.69) | 60.2 (2.5) | 2.9 (1.3) |
| Third | 8.20 (10.19) | 53.7 (2.4) | 1.0 (1.3) |
| Fourth | −19.04 (11.37) | 49.2 (2.6) | −2.1 (1.2) |
| Fifth | −58.45 (10.93) | 39.0 (2.4) | −5.9 (1.0) |
| By needs-adjusted household income quintile: | | | |
| First | 29.70 (10.05) | 64.7 (2.3) | 4.0 (1.4) |
| Second | 28.16 (9.73) | 59.9 (2.4) | 3.5 (1.3) |
| Third | 12.44 (9.70) | 54.8 (2.5) | 1.5 (1.2) |
| Fourth | −16.47 (11.07) | 50.4 (2.6) | −1.9 (1.3) |
| Fifth | −54.97 (10.52) | 39.2 (2.4) | −5.6 (1.0) |
| Households with children: | | | |
| All | −21.19 (6.20) | 52.1 (1.5) | −2.3 (.7) |
| With one child | −1.34 (10.94) | 53.9 (2.7) | −.2 (1.3) |
| With two children | −33.63 (12.17) | 53.5 (2.6) | −3.6 (1.2) |
| With three or more children | −33.72 (16.37) | 46.4 (3.6) | −3.5 (1.6) |
| Low-income households with children: | | | |
| All | 2.80 (18.47) | 65.5 (3.4) | .3 (2.2) |
| With one child | 65.68 (21.68) | 73.7 (6.0) | 10.1 (3.8) |
| With two children | −24.96 (36.58) | 64.3 (5.9) | −2.7 (3.8) |
| With three or more children | −29.94 (32.31) | 58.2 (6.4) | −3.2 (3.3) |

**Note.** Values indicate changes in household expenditures on natural gas under marginal cost pricing. Bootstraped standard errors based on 1,000 replications are in parentheses. All calculations use Residential Energy Consumption Survey sampling weights. Dollar amounts are expressed in year 2010 dollars. Low-income households are defined as households in the lowest quintile by needs-adjusted household income.

consumption would tend to pay less. With our sample, 46 percent of households would pay less under marginal cost pricing, and 54 percent would pay more. In Section 5, we examine these distributional consequences in detail, comparing the characteristics of households with different levels of natural gas consumption and determining how particular types of households would fare under a change to marginal cost pricing.

## 5. A Transition to Marginal Cost Pricing

### 5.1. *Counterfactual Bills*

Table 3 presents evidence on the distributional impact of a change to marginal cost pricing and the associated increase in the fixed monthly fee. These estimates assume that the price elasticity of demand is zero. Later in the paper, we incorporate the potential efficiency gains from tariff rebalancing by considering alternative price elasticities. The complete analysis allows us to characterize the overall trade-off between efficiency and redistribution by, for example, quantifying the amount of deadweight loss that is incurred in order to achieve a particular level of redistribution.

Table 3 reports bill impacts by household income quintile. Households in the first quintile would pay $44 more on average annually under marginal cost pricing, and 67 percent of the households in this quintile would experience some increase in their annual bills. This result reflects the fact that these households tend to consume less natural gas, so the savings experienced from the lower volumetric charge is too small to offset the increased fixed monthly fee. Households in the fourth and fifth income quintiles would pay less under marginal cost pricing because they tend to have relatively high consumption levels and thus benefit more from the decrease in the volumetric charge. A majority of the households in the top two quintiles would experience a decline in expenditures on natural gas.

The results by needs-adjusted household income quintile are similar but somewhat attenuated when compared with the results by household income quintile. Households in the first quintile would pay $30 more on average annually under marginal cost pricing, whereas households in the fifth quintile would pay $55 less on average. The smaller changes in cost for the first quintile reflect the fact that the needs-adjusted measure accounts for differences in household composition and is less correlated with natural gas consumption than is household income. In particular, households with children have higher poverty thresholds and also tend to consume more natural gas.

Households with children are also examined specifically. On average, households with children would experience decreases in natural gas expenditures under marginal cost pricing. The effect is greater for large households; customers with two or more children would pay $34 less on average annually on natural gas. Low-income households with children, on average, would experience essentially no change in costs under marginal cost pricing. Low-income households with only one child would see their bills increase on average, while low-income households with two or more children would see their bills decline on average.

To put these results into perspective, Table 4 reports natural gas expenditures as a share of household income. Natural gas expenditure as a share of income decreases from about 7 percent for the lowest income quintile to less than 1 percent for the highest quintile. Under marginal cost pricing, low-income households would pay more and high-income households would pay less. These differences, however, are incremental when compared with the existing differences across quintiles. Table 4 also shows expenditure shares by needs-adjusted household income quintile. Compared with the results by household income quintile, the households in the first quintile have somewhat higher average household income levels but also somewhat higher average natural gas consumption levels. These two effects are roughly offsetting, so the natural gas expenditure as a share of income across quintiles is similar to the results by household income quintile. A transition to marginal cost pricing causes shares to change in the same direction

Table 4
**Natural Gas Expenditures as a Percentage of Household Income**

| | Under Current Price Schedules (1) | Under Marginal Cost Pricing (2) | *p*-Value (3) |
|---|---|---|---|
| By household income quintile: | | | |
| First | 6.7 | 7.1 | .00 |
| Second | 2.8 | 2.9 | .02 |
| Third | 1.8 | 1.8 | .46 |
| Fourth | 1.4 | 1.3 | .24 |
| Fifth | .8 | .7 | .00 |
| By needs-adjusted household income quintile: | | | |
| First | 6.5 | 6.8 | .01 |
| Second | 2.8 | 2.9 | .00 |
| Third | 1.9 | 1.9 | .09 |
| Fourth | 1.4 | 1.4 | .34 |
| Fifth | .9 | .8 | .00 |

**Note.** Column 3 presents *p*-values from tests that the means in columns 1 and 2 are equal. All calculations use Residential Energy Consumption Survey sampling weights.

and with roughly the same magnitude as in the results by household income quintile.

Of course, it has been widely recognized that household income may not be a very good indicator of the sorts of vulnerable populations or financial needs that are of more direct interest to policy makers, who are likely more concerned with financial stress on families, permanent income, or total wealth (see, for example, Poterba 1989, 1991; Cutler and Katz 1992). Ideally, we would like to compare the results in Tables 3 and 4 to alternative results constructed with a measure of permanent income or household wealth. Although the RECS data do not provide multiple years of household income or any measure of financial wealth, they do include highly detailed information about the appliances owned by the household. In Borenstein and Davis (2010), we explain how we used this information together with 20 years of articles from *Consumer Reports* to construct a measure of appliance wealth for each household based on the number, age, characteristics, and original cost of the major appliances used by the household. As we discuss, this approach is not a panacea, and there are important limitations to appliance wealth as a long-term measure of household well-being. Nevertheless, we find it reassuring that with this alternative measure, we find results that are generally similar to the results above.

### *5.2. Energy Assistance Programs*

The estimated impacts on bills reported in Section 5.1 are consistent with the conventional wisdom about two-part tariffs, which indicates that marginal cost pricing would tend to increase bills on average for low-income households while decreasing bills on average for high-income households. However, these estimated impacts assume that no energy assistance is available for low-income households. In practice, means-tested energy assistance programs are widely available. For example, LIHEAP distributes funds to all 50 states. Many states and local governments offer additional energy assistance, and some LDCs offer alternative rate schedules for low-income households. It is important to consider how these programs could mitigate the distributional impact of a change to marginal cost pricing. Suppose, for example, that marginal cost pricing was implemented simultaneously with increased funding for an energy assistance program. This funding could come from public programs like LIHEAP or a surcharge on natural gas customers with income (or needs-adjusted income) levels above a particular level.

Table 5 reports the baseline results along with results from five alternative scenarios. For each scenario, the table reports the impact of a change to marginal cost pricing on households in the first quintile by needs-adjusted household income (approximately 150 percent of the poverty line). With no energy assistance whatsoever, households in the first quintile experience on average about a $30 annual increase in natural gas bills. This finding corresponds exactly to the first quintile results shown in Table 3. Results are also shown for an energy assistance program that waives the fixed monthly fee for all households below 150 percent of the poverty line. The advantage of this lump-sum approach is that it leaves the volumetric charge equal to marginal cost for households receiving assistance. Under this scenario, the mean impact for the quintile becomes large and negative, a $210 average annual bill decrease for households below 150 percent of the poverty line. If the program were internally funded, the other 80 percent of households would experience annual bill increases of $60 in order to pay for the program. The third row shows that under a less generous program, the mean impact for households below 150 percent of the poverty line is still negative. In this scenario, the 20 percent of households that are below 150 percent of the poverty line receive a $10 per month lump-sum transfer. A program of this size could be self-financed by increasing the fixed monthly fee for the other 80 percent of households by $30 annually.

These results suggest that it may be possible for energy assistance programs to substantially offset the distributional impacts of marginal cost pricing for low-income households. Still, it is important to point out that energy assistance programs have limitations. For example, it has been shown to be difficult to identify and enroll eligible households. Casual evidence of this comes from Table 1, which shows for each quintile the percentage of households who report having received energy assistance in the previous year. Even though most households in the first quintile would typically be eligible for LIHEAP or state-level energy assistance programs, only 18 percent report receiving energy assistance in the previous year. This is a self-reported measure, and one might be concerned that stigma or some other factor would result in underestimation of true participation levels. Still, it seems clear that not all eligible households participate in energy assistance programs, and noneligible households may attempt to participate

**Table 5**

**Changes in Expenditures for Households below 150 Percent of the Poverty Line**

| | Mean Annual Change ($) | Mean Change (%) | Share Who Receive Benefits (%) | Annual Cost per Nonrecipient ($) |
|---|---|---|---|---|
| No energy assistance program | 29.70 | 4.0 | 0 | 0 |
| | (10.05) | (1.4) | (.0) | (.0) |
| No fixed monthly fee (100 percent participation) | −210.14 | −28.0 | 20.0 | 60.07 |
| | (11.41) | (1.0) | (.1) | (1.52) |
| $10 Monthly lump-sum payment: | | | | |
| 100 Percent participation | −90.30 | −12.0 | 20.0 | 30.06 |
| | (10.05) | (1.1) | (.1) | (.23) |
| 50 Percent participation | −30.30 | −4.0 | 10.0 | 13.36 |
| | (10.05) | (1.2) | (.1) | (.09) |
| 20 Percent participation | 5.70 | .8 | 4.0 | 5.01 |
| | (10.05) | (1.4) | (.0) | (.03) |
| For those in multiunit buildings | −24.25 | −3.2 | 27.6 | 45.65 |
| | (10.19) | (1.3) | (1.0) | (2.34) |

**Note.** Bootstraped standard errors based on 1,000 replications are in parentheses. All calculations use Residential Energy Consumption Survey sampling weights. Dollar amounts are expressed in year 2010 dollars.

fraudulently. Effective screening of program applicants is expensive and imperfect.[30] Table 5 also shows data for how incomplete participation affects mean annual bill impacts for the first quintile. With 50 percent participation, households below 150 percent of the poverty line experience a $30 decrease in bills on average. With 20 percent participation, the lump-sum payments are similar in size to the bill increases, so the net impact is positive but small. The annual cost per nonrecipient is lower for these programs because of the lower participation rate.

It is also worth highlighting that these mean impacts for the first quintile obscure substantial heterogeneity across households. Because households differ substantially in their levels of natural gas consumption, the $10 monthly lump-sum transfer is not enough to ensure net bill decreases for all households in this group. Most at risk of bill increases are households that consume very low levels of natural gas. Increasing the fixed monthly fee makes these households considerably worse off because they enjoy relatively little benefit from the decreased volumetric charge. More generous energy assistance could prevent bill increases for these households. For example, one could waive the entire fixed monthly fee for households below 150 percent of the poverty line. The tension here is that there are real economic costs of maintaining natural gas connections, and eliminating the fixed monthly fee entirely for these households would induce an inefficiently large number of these households to consume natural gas.

Finally, Table 5 considers the impact of an energy assistance program based on an important characteristic, not of the household but of the housing unit itself. In particular, we examine the results for a policy that would provide a $10 lump-sum transfer to households living in multiunit buildings. In our sample, 45 percent of households below 150 percent of the poverty line live in multiunit buildings, compared with 28 percent of households overall. Consequently, the policy is reasonably effective at targeting low-income households, and the program has about the same mean impact as a conventional program with 50 percent participation. This type of program is expensive because a large number of households above 150 percent of the poverty line receive the credit. In addition, one would expect multiunit discounts to be at least partially capitalized into rents, which means that some of the transfer would be received by landlords rather than tenants. Nonetheless, such a program would also offer a number of potential advantages. First, whereas traditional programs suffer from low enrollment, households in multiunit buildings could be automatically enrolled. Second, screening for the multiunit discount is low cost and highly accurate, and therefore it is very difficult for noneligible households to participate fraudulently.

Energy assistance programs based on multiunit discounts would be most effective in utility districts where the housing type is highly correlated with income.

[30] Borenstein (2012) discusses this problem in administering means-tested low-income electricity rates for three California electric utilities.

In high-density utility districts where all households live in multiunit buildings or in low-density utility districts where no households live in multiunit buildings, there is little scope for redistribution. Alternatively, discounts could be based on a richer set of housing characteristics, such as square footage or the number of rooms, or even on neighborhood characteristics, such as the mean of the household income by zip code. There is little precedent for natural gas LDCs using this kind of differentiation, and these policies would likely face political challenges, but these more flexible approaches would also allow for better targeting of needy households.

## 6. Efficiency Effects of Changing Retail Prices

While the distributional impact of changing marginal retail prices of natural gas to reflect marginal cost appears to be fairly modest, the regressive impact is still contrary to the general goal of helping low-income households. The argument in favor of such a change rests on improving economic efficiency, which requires that consumers change their behavior in response to the price changes. The efficiency impact, however, is complex for two distinct reasons. First, because natural gas is priced in a two-part tariff and the fixed monthly fee as well as the volumetric charge would have to be adjusted, the change has the potential to cause some consumers to make nonmarginal adjustments: some current consumers of natural gas may decide to exit the market, and some who have not previously been in the market might choose to enter. Second, the current distortions in the residential market for natural gas are part of a larger set of distortions in energy pricing. Therefore, a broader analysis of the welfare impact—one that accounts for distortions in closely related markets, such as for other energy products—is relevant.

In the simplest setting, we could focus only on the deadweight loss from nonmarginal cost pricing of marginal gas consumption, which is a straightforward exercise for any given assumed demand elasticity. We begin with this calculation. We then expand the analysis to consider potential welfare changes from changes at the extensive margin: customers entering and leaving the natural gas market. We cannot derive convincing estimates of these changes on the extensive margin from our data. Instead, we create a simple demand model based on calculations of the cost differential between natural gas and other residential energy sources in order to establish the size of the population that might find it economic to drop or add natural gas service in response to the tariff rebalancing. From these calculations, we derive bounds on the size of adjustment along the extensive margin.

We then discuss further impacts of rebalancing natural gas tariffs that result from the fact that related products are not priced efficiently. We first consider other energy sources, particularly electricity and heating oil. We then consider one of the most pressing distortions in energy, the failure to price greenhouse

Table 6
Consumer Surplus Impact of a Change to Marginal Cost Pricing

| | $\varepsilon = 0$ | $\varepsilon = -.2$ | $\varepsilon = -.4$ | $\varepsilon = -.6$ |
|---|---|---|---|---|
| By needs-adjusted household income quintile: | | | | |
| First | −29.70 | −25.54 | −21.17 | −16.60 |
| | (10.05) | (10.10) | (10.32) | (10.11) |
| Second | −28.16 | −23.66 | −18.94 | −14.01 |
| | (9.73) | (9.97) | (10.16) | (9.89) |
| Third | −12.44 | −7.88 | −3.10 | 1.91 |
| | (9.70) | (9.81) | (9.92) | (9.71) |
| Fourth | 16.47 | 21.46 | 26.68 | 32.15 |
| | (11.07) | (11.12) | (11.20) | (11.61) |
| Fifth | 54.97 | 61.72 | 68.82 | 76.28 |
| | (10.52) | (11.24) | (11.75) | (11.90) |
| Average across quintiles | .00 | 4.99 | 10.21 | 15.69 |
| | (.00) | (.59) | (1.21) | (1.87) |
| Percentage better off | 46.2 | 47.5 | 48.5 | 49.6 |
| | (.9) | (.8) | (.8) | (.8) |
| National annual change in welfare ($millions) | .0 | 314 | 644 | 989 |
| | (0) | (37) | (76) | (118) |

**Note.** Values presented are the change in mean annual consumer surplus under a change to marginal cost pricing. Results are reported for four alternative assumptions about the price elasticity of demand for natural gas. Amounts are expressed in year 2010 dollars. Bootstraped standard errors based on 1,000 replications are in parentheses. All calculations use Residential Energy Consumption Survey sampling weights.

gases. In the analysis thus far, we have assumed that emission of greenhouse gases is not socially costly and is not priced. We consider two alternative scenarios, one in which carbon dioxide emissions are socially costly but are still not priced and one in which carbon dioxide emissions are socially costly and emitters must pay a price that reflects that cost. Finally, we consider recent research that suggests that consumers may not carry out the somewhat sophisticated optimization that would lead them to respond to the marginal price. Instead, consumers might focus on the total bill in relation to consumption, that is, the average price. If consumers engage in this sort of suboptimizing behavior, we show that the efficiency analysis changes substantially.

### *6.1. Efficiency Effects of Marginal Quantity Changes*

The counterfactuals we have considered thus far show how household expenditures on natural gas would change under marginal cost pricing if the demand elasticity were zero, which implies no efficiency consequences of the change. With nonzero elasticity, volumetric charges above marginal cost impose a deadweight loss, as customers consume too little natural gas. We first address this issue under the assumption that the tariff change does not cause any consumers to enter or exit the market.

Table 6 reports estimates by needs-adjusted household income quintile of the average annual change in consumer surplus resulting from a switch to marginal cost pricing. The table reports consumer surplus change estimates under a range of different plausible price elasticities of demand, ranging from 0 to $-.6$. The relevant elasticity for these calculations is the long-run demand elasticity for which empirical estimates in the literature are rare and not very convincing.[31] Rather than take a strong stand on the magnitude, we report estimates for this relatively broad range.

To calculate the consumer surplus gain for each household, we assume a constant elasticity form of demand, $D(p) = A_i p^{\varepsilon}$, in which all households have identical demand up to a scale parameter, $A_i$. On average in our sample, lowering the volumetric charge to equal marginal cost implies a 32 percent decrease. With a price elasticity of $-.2$, for example, this yields an average increase in natural gas consumption of 3.5 units (in thousands of cubic feet) annually, compared with a baseline level of 68.7 units. We calculate the change in consumer surplus as the area to the left of the demand curve from the original volumetric charge to the price that reflects marginal cost, and then we subtract the difference between the fixed monthly fees shown in Table 3.[32]

The magnitude of the efficiency impact varies predictably with the assumed elasticity, with larger increases in consumer surplus for larger elasticities. The results for $\varepsilon = 0$ correspond exactly to the results in Table 3, which were calculated with an assumption of zero elasticity. For a price elasticity of $-.2$, households are better off across quintiles by about $5 per year on average. Consumer surplus continues to increase with larger price elasticities. Changing the assumed elasticity from 0 to $-.6$ raises the average consumer surplus of customers in the population by about $16 per year.

These estimates assume that the price elasticity is the same across income classes. Natural gas expenditures represent a smaller share of the total household expenditures for high-income households, so one might expect the price elasticity to be smaller for these households. Although we are not aware of any direct evidence from the natural gas market, this is consistent with evidence from Reiss and White (2005) and Ito (2010), who find that the short-run price elasticity of demand for electricity is smaller for high-income households.[33] Redoing the exercise with heterogeneous price elasticities would increase the welfare gains

[31] As a point of comparison, the U.S. Department of Energy (2003) adopts for natural gas a long-run price elasticity of demand of $-.41$ for residential customers. Long-run elasticities are difficult to estimate credibly because it may take several years for agents to fully respond to price changes. For example, in the long run, consumers may respond to a decrease in natural gas prices by purchasing a less efficient furnace than they would have otherwise. Because the stock of equipment turns over slowly, the full long-run impact of a price change may not be realized for many years, and estimating such long-run effects from historical data is extremely challenging.

[32] We ignore income effects and calculate surplus changes along the constant-elasticity Marshallian demand curve. The change in wealth for the vast majority of households is an extremely small share of the annual income, as is shown in Table 4. Combined with the fact that the income elasticity of demand for natural gas is generally estimated to be well below one, this finding implies that the cost of omitting income effects is not material.

[33] Ito (2010), for example, finds a short-run price elasticity of $-.13$ for households with incomes below the median, compared with $-.09$ for households with incomes above the median, a difference that is statistically significant but small in magnitude.

for households in the lower quintiles and decrease the welfare gains for households in the upper quintiles but would not change the qualitative pattern. In particular, even with a considerably larger price elasticity for low-income households, the efficiency gains would still be too small to offset the direct bill impact.

Because these calculations hold the LDC's profits constant, by construction, the sum of the changes in consumer surplus reflects the entire welfare change. Table 6 also reports the overall average change in consumer surplus across all households in the data set. Multiplying this number by the 65 million households[34] that consume natural gas in the United States implies that the total inefficiency from nonmarginal cost pricing of natural gas to residential customers is \$314 million per year with an elasticity of $-.2$ and \$989 million per year with an elasticity of $-.6$.

Using a different data set and empirical methodology, Davis and Muehlegger (2010) find that with an elasticity of $-.2$ the annual deadweight loss borne by residential natural gas customers between 2001 and 2007 from nonmarginal cost pricing was \$968 million. Our considerably lower estimate (\$314 million) reflects the fact that in 2005 natural gas prices were unusually high, retail prices did not fully adjust to reflect this increased commodity cost, and a lower markup resulted. Moreover, because the level of prices was much higher in 2005, we estimate a considerably lower percentage markup that (with a constant elasticity demand function) implies a smaller change in the quantity consumed.

These results help clarify the overall trade-off between efficiency and redistribution. For the long-run elasticity of $-.4$, the efficiency cost of nonmarginal cost pricing is \$644 million per year, and the redistribution impact is to transfer about \$520 million per year to households in the two lowest needs-adjusted household income quintiles. Thus, for this price elasticity of demand, the deadweight loss from transferring these funds is estimated to be more than 100 percent of the transfer. This result is higher than the cost of public funds ratios generally referenced for tax-funded expenditures, which are generally less than 50 percent (see Ballard and Fullerton 1992; Snow and Warren 1996). This apparently strong case against nonmarginal cost pricing of natural gas, however, seems less strong when we consider other potential distortions in the following sections.

### 6.2. *Efficiency Effects of Changes on the Extensive Margin*

Balancing the revenue lost from lower volumetric charges by raising the fixed monthly fees would also have implications for efficiency. In theory, this process could have two types of efficiency effects: current customers might leave the market (leavers), and current noncustomers might choose to enter the market (arrivers). The degree of efficiency effects resulting from these changes on the

[34] The RECS sampling weights imply that in 2005 there were 65.1 million households in the United States with natural gas connections. As a point of comparison, the U.S. Department of Energy (2010b), using aggregate data reported by utilities, notes that there were 63.6 million residential customers in 2005.

extensive margin depends in part on the degree to which the fixed monthly fee departs from the monthly customer-level fixed costs—the marginal cost of adding an additional customer to the system—beyond the direct commodity cost. With the volumetric charge set to reflect only the commodity cost, all other utility costs must be captured through the fixed monthly fee. Some of those costs vary with the number of residential customers served, and some are system fixed costs that are mostly unchanged by the addition of one more residential customer. The distinction between these costs is not always completely clear, particularly in the long run, but the former category would probably include monthly paperwork and billing of the customer, meter and other household-level maintenance, and call center staffing. The latter category would include maintenance of the main gas pipelines in the service territory, recovery of past investments in building the pipeline infrastructure, and some portion of the management budget if there are any scale economies in managing the LDC, which seems likely.

If the customer-level fixed costs were equal to the LDC's full noncommodity expenses divided by the number of customers, then the move to marginal cost pricing of natural gas would also reset the fixed monthly fee to the efficient level, and all in- and out-migration of customers would be efficient. Unfortunately, this is not the case; in fact, the monthly incremental cost to the LDC of managing an additional customer is likely much lower than the fixed monthly fees under marginal cost pricing that are shown in column 4 of Table 2. Data shared with us by one California utility indicate that somewhat less than half of the noncommodity costs vary significantly with the number of subscribing customers within the service territory, although that information probably overstates the marginal cost per customer, because the customer-specific fixed costs probably exhibit some economies of scale. As a result, some customers might leave the market even though they receive a net surplus in excess of the monthly incremental (noncommodity) cost they impose on the system.

A complete empirical investigation of changes on the extensive margin is beyond the scope of this paper. Still, it could be an important input in the analysis of a switch to marginal cost pricing. And incorporation of changes on the extensive margin could reduce the estimated efficiency gains from a switch to marginal cost pricing.

To investigate the potential impact of incorporating the extensive margin, we focus first on leavers, customers who use natural gas under the current tariff but would leave the market under a rebalancing that substantially increased the fixed monthly fee. Low-consumption customers are the ones who lose surplus under the rebalanced tariff. For them, the alternative energy source for all current natural gas services would almost certainly be electricity, which is generally sold with a small or no fixed monthly fee.

To evaluate the impact of leavers on the welfare analysis, we consider first the customer's energy cost if he or she switched to electricity to provide the energy services received from natural gas under the current tariff. This method ignores

Table 7
**Evaluating Potential Leavers under Marginal Cost Pricing**

| | Gas Space Heating | No Gas Space Heating |
|---|---|---|
| Assumption: | | |
| Cost of electricity ($/kWh) | .10 | .10 |
| kWh per thousand cubic feet | 293 | 293 |
| Efficiency of natural gas appliances | .80 | .80 |
| Choke-off price for gas ($/1,000 cubic feet) | 23.44 | 23.44 |
| Current volumetric charge for natural gas ($) | 10.00 | 10.00 |
| Volumetric charge under marginal cost pricing ($) | 7.00 | 7.00 |
| Current fixed annual fee ($) | 72.00 | 72.00 |
| Fixed annual fee under marginal cost pricing ($) | 240.00 | 240.00 |
| Annual fixed cost of natural gas furnace ($) | 100.00 | .00 |
| Annual fixed cost of electric heat ($) | 20.00 | .00 |
| Elasticity of demand | −.40 | −.40 |
| Result: | | |
| Break-even consumption under current tariff | 14 | 6 |
| Break-even consumption under marginal cost pricing | 22 | 17 |
| Proportion of households with natural gas consumption levels between two break-even levels | .03 | .26 |
| Implied total number of households in the United States (millions) | 1.65 | 2.41 |

**Note.** Consumption is annual consumption of natural gas in thousands of cubic feet. Dollar amounts are expressed in year 2010 dollars.

the fact that cooking, space heating, water heating, and clothes drying are not exactly the same services when provided with natural gas as when provided with electricity. That product differentiation will almost surely reduce the level of switching in comparison to what would result from a strict cost comparison. This differentiation explains why we observe some households consuming very small quantities of natural gas.

The customers who would leave the natural gas market under the rebalanced tariff are those who receive positive consumer surplus from the current tariff but negative consumer surplus under the rebalanced tariff. To analyze who these customers would be, we constructed a simple model of demand for natural gas that assumes that a customer consumes gas along a demand curve of a given constant elasticity until the price per unit of heat (adjusting for combustion efficiency) with natural gas exceeds the cost of using electricity, at which price the household's demand drops discontinuously to zero. The energy services cost includes the volumetric charge, the fixed monthly fee, and any differences in the cost of appliances that use the energy. The most important difference in the appliance cost is that a natural gas furnace is substantially more expensive than electric space heaters. The assumptions we make are shown in Table 7. We show two scenarios, one in which the households heat with space heaters and natural gas and another in which they do not. Because natural gas furnaces are more expensive than electric space heaters, many households in mild climates choose not to use natural gas heating even though they either face a very low fixed monthly fee or already pay the fixed monthly fee to use natural gas for other purposes.[35] The range of natural gas usage for which the tariff switch would make natural gas consumption cost-inefficient is fairly small, so many affected households will be ones that already do not use space heaters and natural gas and will not save on the capital cost of a furnace versus the costs for electric space heating. Table 7 indicates that for such households, the consumer surplus increases from dropping natural gas completely if consumption was between 6 and 17 units (thousands of cubic feet) of natural gas per year. If the household was consuming less than 6 units per year, it should have already dropped natural gas under the current tariff, while if it is consuming more than 17 units per year, natural gas is still cost-effective. If the household is space heating with natural gas, presumably in a very mild climate, it would also save on the capital cost of the furnace, as is shown. In that case, the range for dropping natural gas moves to 14–22 units per year.

These calculations are obviously rough, but they give an idea of the range of consumption that might lead a household to consider dropping natural gas in response to the tariff change. The table also shows the implied number of households based on the RECS data that do and do not use natural gas for space heating. To infer the potential deadweight loss from changes on the extensive margin, one would need to know the share of these customers who would actually choose to drop natural gas—presumably some would not do so because of a preference for using natural gas in cooking or other activities. The deadweight loss would also depend on the share of fixed costs that are customer specific rather than system level.

We do not attempt to analyze these parameters further, but it is clear from the data in Table 7 that the impact of changes on the extensive margin could be important. If half of the 4.1 million potential leavers did actually drop natural gas service and if the customer-specific fixed costs were a small share of the fixed monthly fee that covers all noncommodity costs, then these changes would result in deadweight loss of over \$100 million per year.[36] It is not clear that this

[35] In addition, some households do not have access to natural gas because they live in rural or other areas with no natural gas distribution pipeline systems. From RECS data, it appears that 72 percent of U.S. households have access to natural gas, and 85 percent of those with access to natural gas consume it.

[36] As an example, assume that customer-specific fixed costs are equal to the current fixed annual fee of \$72. Also assume that there are no distortions in other markets. Since all leavers are choosing to consume natural gas under the current tariff, and since the higher fixed annual fee under marginal cost pricing does not reflect the costs that actually change if the customer leaves, then all leavers are exiting inefficiently. The deadweight loss of one leaver's departure is the consumer surplus that he or she would have received had the volumetric charge been \$7 and the fixed annual charge been \$72. For a leaver who had been consuming almost no natural gas, that lost consumer surplus is bounded between zero and \$168, because he or she would not leave under the rebalanced tariff if he or she would receive more than \$168 in surplus. For a leaver with a natural gas demand of $Q(P)$, that lost consumer surplus is bounded between $\$3 \times Q(10)$ (below which he or she would have already left under the current tariff) and approximately $\$168 - \$3 \times Q(10) + 1/2 \times \$3 \times [Q(7) - Q(10)]$. The equations essentially demarcate a narrower range centered between zero and

loss would reverse the result of the analysis that ignored the extensive margin, but it could reduce the gains substantially.

The other side of the extensive margin is arrivers, customers who would choose to enter the market if the tariff changed. We consider, in turn, households substituting away from electric and heating oil heating systems. A straightforward analysis suggests that the number of households switching from electricity to natural gas is likely to be extremely small. Such a household must have chosen not to enter the natural gas market under the current tariff, so it receives negative consumer surplus under the current tariff. Yet the lower volumetric charge creates so much more consumer surplus that it more than offsets the higher fixed monthly fee. As is shown in Table 7, fixed fees increase by $168 per year, and the volumetric charge decreases by $3 per thousand cubic feet. Thus, a household switching from electricity to natural gas would have to receive at least an additional $168 per year in consumer surplus due to the price drop. It is possible to derive a demand curve that satisfies both of these conditions—not entering under the current tariff but entering under the alternative tariff—but it would have to demonstrate very high elasticity around the current volumetric charge. For instance, a linear demand curve that exactly satisfies this condition would have a price elasticity of nearly $-3$ at the current marginal tariff price, which is far larger than any estimates of the price elasticities of residential demand for natural gas. While there is probably a nonzero set of customers who meet these criteria, it seems likely to be a very small set.

In contrast, there may be scope for substitution from heating oil to natural gas. Although only 7 percent of the households in our data set use heating oil as the primary source of home heating, the fraction among households in the Northeast region is 30 percent. Heating oil and natural gas heating systems are similar in that both use a central furnace that is connected to the rest of the house with air ducts. The capital cost and the installation costs are substantial, so these systems are favored by households with relatively high demand for heat. In most locations and time periods, the price per British thermal unit (Btu) of heating oil exceeds the price per Btu of natural gas. This lower price, combined with the cleanliness and convenience of natural gas, has made it the popular choice for most households. The one exception is the Northeast, where natural gas prices are the highest in the continental United States, and during some years the price per Btu of natural gas has exceeded the price per Btu of heating oil. Tariff rebalancing would decrease the volumetric charges enough that it would be very unusual to observe this inversion in prices. Because the market for heating oil is essentially perfectly competitive, substitutions away from heating oil toward natural gas would represent efficiency gains.[37]

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$168. Taking the midpoint of $84 per year and multiplying by (4.1)(.5) million leavers yields approximately $170 million per year in deadweight loss.

[37] Here we are implicitly assuming that the marginal cost remains equal to the city gate price and that there is no capacity constraint or need to upgrade the LDC's distribution grid or other infrastructure in order to accommodate the additional natural gas demand.

### 6.3. *The Impact of Distortions in Related Markets*

The analysis thus far rests on the assumption that prices in the rest of the economy are set efficiently. This is of particular concern if the prices of complementary and substitute products are also distorted. The three markets that are of greatest potential concern are heating oil and electricity, both of which are substitutes, and greenhouse gases, which is a complement in the consumption of natural gas. We consider the first two in the absence of considering greenhouse gas externalities and then turn specifically to greenhouse gases.

While 7 percent of all households use heating oil as their primary home heating fuel, this is a reasonably competitive market in which the price reflects marginal cost quite closely.[38] Thus, substitution to or from heating oil in response to a rebalancing of natural gas rates is unlikely to impose additional distortions. Electricity use is a more complex issue, as prices around the country differ from marginal cost, in some cases substantially. Residential prices for electricity are generally established through a regulatory process that sets rates in order to allow the utility to recover its historical costs, and, thus, prices reflect historical average cost.[39] In some areas of the country, the price is below marginal cost, as the utilities are able to average in cheap sources that would be a small share of a marginal expansion—such as large hydroelectric projects—or older fossil fuel sources that have been depreciated in the accounting sense, so they are assigned a very low cost in the rate-making process—such as older coal and natural gas plants. In other parts of the country, prices are well above marginal cost, as the rates are being set to cover mistakes of the past, such as cost overruns on nuclear (and other) power plants, and costs incurred from unsuccessful deregulation plans or poorly designed attempts at competitive procurement. In addition, throughout the country, residential rates are set to cover the costs of transmission and distribution systems, much of which do not vary with marginal consumption. A complete analysis of the distortion from substitution between electricity and natural gas, on both the intensive and the extensive margin, is beyond the scope of this paper. Still, it seems likely that prices are generally above the marginal cost of electricity, so to the extent that rebalancing natural gas rates causes substitution from electricity to natural gas, our estimates of efficiency gains would need to be adjusted downward.

Perhaps the most significant related distortion is the fact that greenhouse gas emissions are currently free. Rates for natural gas do not reflect the negative

[38] One might argue that the Organization of Petroleum Exporting Countries, or, more exactly, Saudi Arabia, exercises market power and raises oil prices above competitive levels. Nonetheless, if the goal is to maximize the U.S. surplus, then it probably makes sense to treat these producers as exogenous quantity constraints, with all other producers acting as price takers in the oil market. Downstream from oil producers, in the refining and distribution sectors, sellers are generally thought to be quite competitive.

[39] This description is not entirely accurate in areas where there is competition among retail providers, but even in those areas, transmission and distribution costs are still recovered through regulated charges that are set to cover the average cost, and adjustments to retail prices are made to allow for recovery of revenues that are necessary to cover other historical costs.

Table 8
**Alternative Assumptions about Greenhouse Gases**

| | Mean Annual Efficiency Gain by Quintile | | | | | Average across Quintiles |
|---|---|---|---|---|---|---|
| | First | Second | Third | Fourth | Fifth | |
| No externalities or greenhouse gas policy | 8.53 | 9.22 | 9.33 | 10.21 | 13.86 | 10.21 |
| | (1.15) | (1.14) | (1.13) | (1.29) | (1.90) | (1.21) |
| External cost of $CO_2$ emissions of $22 and no greenhouse gas policy | 3.34 | 3.50 | 3.68 | 4.01 | 5.86 | 4.07 |
| | (.67) | (.65) | (.65) | (.77) | (1.20) | (.73) |
| External cost of $CO_2$ emissions of $22 and $CO_2$ tax (or permit) of $22 | 7.64 | 8.26 | 8.36 | 9.14 | 12.42 | 9.15 |
| | (1.04) | (1.03) | (1.02) | (1.17) | (1.72) | (1.09) |

**Note.** Efficiency gains are per household under a transition to marginal cost pricing. Quintiles are by needs-adjusted household income. External damages of $22 per ton of carbon dioxide are adopted following the Interagency Working Group on Social Cost of Carbon (2010). All results assume that the price elasticity of demand is −.4. Bootstraped standard errors based on 1,000 replications are in parentheses. All calculations use Residential Energy Consumption Survey sampling weights. Efficiency gains are expressed in year 2010 dollars.

externality that burning the gas creates. It is interesting to compare the average markup on natural gas that we have calculated with the price increase that would be implied by a carbon tax. Table 2 reports an average markup in the United States in 2005 of $2.71 per thousand cubic feet. There are .0543 metric tons of carbon dioxide per thousand cubic feet of natural gas, so this average markup is equivalent to a tax of about $50 per ton of carbon dioxide. This is higher than the level of a carbon tax envisioned by most economists and policy makers. As a point of comparison, the Interagency Working Group on Social Cost of Carbon (2010) adopts a central social cost of carbon dioxide of $22 per ton of carbon dioxide.[40] Compared to this measure, current markups exceed the external cost of natural gas consumption, so residential customers may already face a volumetric charge that exceeds social marginal cost.

Table 8 reports efficiency gains under three assumptions about greenhouse gas emissions and policy. Our calculations until this point have implicitly assumed that there are no externalities from the production or consumption of natural gas and that there is no policy in place, such as a carbon tax or a cap-

[40] The Interagency Working Group on Social Cost of Carbon (2010) presents a range of values for the social cost of carbon dioxide in accordance with different discount rates and for different time periods that is intended to capture changes in net agricultural productivity, human health, property damages from increased flood risk, and other factors. In table 15A.1.1 with a 3 percent discount rate (its central value) for 2010, it finds a social cost of carbon dioxide of $21.40 (in 2007 dollars) per metric ton of carbon dioxide. In 2010 dollars, this is approximately $22. To avoid confusion, we refer to carbon dioxide, rather than carbon, throughout. Because the atomic weight of carbon is 12 atomic mass units, while the weight of carbon dioxide is 44, 1 ton of carbon equals 44/12 tons of carbon dioxide. The average markup of $2.71 is equivalent to a tax of $50 per ton of carbon dioxide or $183 per ton of carbon.

and-trade program, that places an implicit price on these emissions. The first assumption is the mean annual efficiency gains by needs-adjusted household income quintile under this baseline scenario for a price elasticity of demand of $-.4$. These efficiency gains are identical to the implied gains when the data for $\varepsilon = 0$ and $\varepsilon = -.4$ in Table 6 are compared.

For the second assumption, we see that if we assume that carbon dioxide emissions remain unpriced but are truly costly to society, the potential efficiency gains from marginal cost pricing are reduced by about 60 percent. In this scenario, volumetric charges are set equal to social marginal cost, which is the private marginal cost plus external damages that we assume are equal to $22 per ton of carbon dioxide. Here the welfare gains from tariff rebalancing or, equivalently, the inefficiency of current price schedules are considerably smaller because incorporating marginal damages reduces the wedge between current volumetric charges and the proper measure of marginal cost. Of course, if the true social cost of carbon dioxide is more than $50 per ton, then even the current rate structure places a marginal price on natural gas consumption that is too low.

The third assumption is a scenario in which carbon dioxide emissions are assumed to impose external damages of $22 per ton of carbon dioxide but there is also assumed to be a carbon tax or cap-and-trade program in place that puts a price of $22 per ton on carbon dioxide emissions. We assume that this policy increases the volumetric charge faced by residential customers by the equivalent of $22 per ton of carbon dioxide. Here the efficiency gains from marginal cost pricing are very similar in magnitude to the gains observed under the baseline assumption. This scenario illustrates that the distortion we have addressed in this paper would still be present if carbon dioxide emissions were priced to reflect the negative externality. The fixed costs of operating a natural gas distribution system would still have to be recovered, and the policy argument over whether to recover them through fixed or volumetric charges would be essentially the same as if there were no negative externality.

### *6.4. To Which Price Do Customers Respond?*

The discussion and analysis thus far maintain the implicit assumption that households have perfect information and respond optimally in response to two-part tariffs. These may not be reasonable assumptions. Although natural gas bills typically are reasonably clear about the distinction between the fixed monthly fee and the volumetric charge, many customers have not thought much about the distinction.

Customers who are not aware of or do not understand the two-part tariff might instead respond to the total bill rather than the volumetric charge. Recent empirical evidence from the electricity market provides some evidence for this alternative hypothesis. Focusing on the California electricity market, Ito (2010) finds evidence consistent with households responding to average, rather than marginal, prices. Although these results are compelling, it is important to point out that in the market examined by Ito (2010), households face four- and five-part increasing block tariffs. In comparison, the typical natural gas schedule is substantially less complex, with most natural gas LDCs using only a fixed monthly fee and a single, constant volumetric charge. Given this considerably simpler structure, it seems likely that households would be better able to distinguish between average prices and marginal prices. This simplicity lends some support to our baseline estimates, which assume that households respond to marginal prices.

Nonetheless, it is interesting to consider how the welfare implications would change under the alternative hypothesis that households respond to average prices. Under tariff rebalancing, households with high consumption levels would experience decreases in both average and marginal prices, which implies welfare gains regardless of how well the customer understands the tariff. In contrast, households with low consumption levels would see decreases in marginal prices but increases in average prices, which would potentially move consumption in the wrong direction. The total change in welfare could, in theory, be positive or negative.[41]

Repeating the analysis in Section 6.1 under the assumption that households respond to average prices rather than marginal prices, we find that the overall change in welfare under marginal cost pricing is still positive but considerably smaller in magnitude. With a price elasticity of demand of $-.4$, we find an increase in total welfare nationally of $223 million annually, compared with $644 million annually in the original analysis. About half of all households experience a decrease in average prices under marginal cost pricing, but the net welfare change is positive because we find that the increases in welfare for households experiencing average price decreases (high-consumption households) tend to be larger than the decreases in welfare for households experiencing average price increases (low-consumption households).

Overall, it seems clear that if customers indeed respond to average prices rather than marginal prices, then the welfare gain from rebalancing natural gas rates could be substantially smaller than the baseline estimates given in Section 6.1. This finding raises the question of customer education and whether changes in the way that bills are designed could have impacts on household welfare. In particular, after a transition to marginal cost pricing, it would be important for natural gas LDCs to make every effort to describe the reform to the public as clearly as possible and to strive to make bills as transparent as possible by distinguishing between marginal and average prices with easy-to-understand language, figures, and examples.

[41] We assume in this analysis that the customer's demand curve is still well defined and appropriate for welfare analysis but that cognitive or attention constraints cause the customer to make choices that are privately suboptimal compared with the choices they would make without these constraints.

## 7. Conclusion

In this paper, we used nationally representative microdata to characterize the effect of a transition to marginal cost pricing in the U.S. residential natural gas market. The results confirm a widespread perception in the industry and among regulators and consumer protection groups that tariff rebalancing would have regressive distributional consequences. However, our results indicate that the magnitude of these effects is relatively small. What matters for distributional consequences is the correlation between household income and natural gas consumption. We show that this relationship is positive but weak, so current price schedules deliver a modest amount of redistribution. And needs-based programs, such as LIHEAP, could reduce the negative impacts to vulnerable subgroups substantially.

Our analysis highlights a number of confounding factors that weaken the relationship between energy consumption and income and complicate attempts to accomplish distributional goals through price schedules. For example, we show that household income is positively correlated with energy efficiency. Part of this correlation is likely driven by the landlord-tenant problem, which leads to suboptimal energy efficiency investment in rental properties, although the correlation holds in owner-occupied housing units as well. In addition, households in the lowest income quintiles and the lowest needs-adjusted income quintiles tend to have more children, and we show that, in particular, low-income households with two or more children tend to have high levels of natural gas consumption and thus would tend to benefit from marginal cost pricing.

The broader conclusion of our paper is that it is important for policy makers to keep in mind this trade-off between efficiency and equity when implementing rate structures. The reality is that whenever policy makers can influence prices, there is a temptation to use these prices to accomplish distributional goals. This temptation lingers despite the fact that economists generally view optimal tariff design as separate from redistribution, particularly when there are broader redistributive tools in place, such as the income tax. Striking a balance between these two objectives is perhaps the biggest challenge faced by utility regulators, and it is surprising that there is so little empirical evidence on the topic. Studies like this one are important because they move us closer to understanding the sometimes complex distribution and efficiency implications of price schedules and because they demonstrate that analyses using real-world data can reveal important evidence about the magnitude of these effects.

## Appendix A

### Results for California with Alternative Data

Here we present results of calculations using an alternative data set. The RASS provides household-level demographics, natural gas consumption, and the exact utility district for a representative sample of households in California. We collected actual utility rate schedules for Pacific Gas and Electric, San Diego Gas and Electric, and the Southern California Gas Company by contacting the utilities directly. These three utilities represent 97 percent of the residential sales of natural gas in California. (Table A1 provides descriptive statistics.) We then calculated the revenue-neutral, marginal cost price schedule for each utility. Table A2 reports price schedules separately by utility and for the state as a whole. Markups in California are considerably higher than the national average, which reflects relatively low city gate prices in 2003 and the fact that the typical household in California uses less natural gas than the typical household nationwide. The rest of the tables show the distributional impacts of a change to marginal cost pricing. The general pattern of the results is similar to our main results in Table 3. Under marginal cost pricing, low-income households would tend to pay somewhat more, and high-income households and households with children would tend to pay somewhat less. This pattern holds for the state as a whole, as shown in Table A3, and for each utility separately, as shown in Tables A4, A5, and A6. Figures A1 and A2 present scatterplots of natural gas consumption against household income for all California households and separately by utility, respectively. Figure A3 presents scatterplots of natural gas expenditure against consumption by utility with a fitted least squares regression line (dashed gray line) and the marginal cost price schedule (black line).

**Table A1**

**Descriptive Statistics from the Residential Appliance Saturation Study by Percentage of the Poverty Line Quintiles**

| | First | Second | Third | Fourth | Fifth |
|---|---|---|---|---|---|
| Percentage of the poverty line | <190 | 190–307 | 308–426 | 427–612 | >612 |
| Household economic and demographic characteristic: | | | | | |
| Mean annual household income ($1,000s) | 26.88 | 47.54 | 66.35 | 86.47 | 136.78 |
| | (13.51) | (17.22) | (19.78) | (28.06) | (30.01) |
| Household members | 3.90 | 3.24 | 2.92 | 2.55 | 2.45 |
| | (2.33) | (1.65) | (1.33) | (1.34) | (1.01) |
| Children | 1.45 | 1.03 | .78 | .55 | .44 |
| | (1.61) | (1.26) | (.98) | (1.01) | (.79) |
| Proportion homeowners | .46 | .70 | .81 | .90 | .92 |
| | (.50) | (.46) | (.39) | (.30) | (.26) |
| Natural gas consumption and expenditure: | | | | | |
| Mean annual consumption (1,000s of cubic feet) | 42.00 | 46.03 | 46.96 | 50.46 | 61.52 |
| | (29.49) | (23.78) | (26.22) | (30.79) | (40.91) |
| Mean annual expenditure ($) | 361.20 | 397.23 | 408.31 | 442.24 | 544.81 |
| | (267.17) | (215.03) | (240.69) | (297.13) | (394.06) |
| Expenditure as a fraction of income | .02 | .009 | .006 | .005 | .004 |
| | (.02) | (.01) | (.00) | (.00) | (.00) |
| Energy efficiency: | | | | | |
| Main heating system < 9 years old | .28 | .33 | .35 | .37 | .38 |
| | (.45) | (.47) | (.48) | (.48) | (.49) |
| All exterior walls insulated | .43 | .51 | .52 | .61 | .63 |
| | (.50) | (.50) | (.50) | (.49) | (.48) |
| Some or all exterior walls insulated | .58 | .69 | .70 | .77 | .80 |
| | (.49) | (.46) | (.46) | (.42) | (.40) |
| Ceiling and attic insulated | .52 | .70 | .74 | .82 | .83 |
| | (.50) | (.46) | (.44) | (.38) | (.37) |
| All windows double pane | .25 | .32 | .36 | .46 | .48 |
| | (.43) | (.47) | (.48) | (.50) | (.50) |
| Some or all windows double pane | .34 | .42 | .50 | .56 | .60 |
| | (.47) | (.49) | (.50) | (.50) | (.49) |

**Note.** The data are from the 2003 Residential Appliance Saturation Study (RASS). Summary statistics are reported only for those households that answered every question of interest ($N$ = 11,722). Means and standard deviations (in parentheses) are calculated with RASS sampling weights. Dollar amounts are expressed in year 2010 dollars.

**Table A2**

**Natural Gas Rate Schedules in California by Utility**

| | Current Rate Schedule | | | Rate Schedule after Rebalancing | |
|---|---|---|---|---|---|
| | Volumetric Charge below Baseline (1) | Volumetric Charge above Baseline (2) | Fixed Monthly Fee (3) | Volumetric Charge (Marginal Cost) (4) | Fixed Monthly Fee (5) |
| Pacific Gas and Electric ($N$ = 6,745) | 7.71 | 10.08 | 0 | 4.31 | 15.45 |
| San Diego Gas and Electric ($N$ = 1,670) | 9.30 | 11.29 | 0 | 4.31 | 17.97 |
| Southern California Gas Company ($N$ = 7,582) | 6.94 | 9.14 | 6.05 | 4.31 | 18.22 |
| Consumption-weighted average | 7.50 | 9.74 | 2.97 | 4.31 | 17.06 |

**Note.** Columns 1 and 2 show the mean volumetric charge per 1,000 cubic feet as reported by the local distribution companies (LDCs). Fees in column 3 are reported by the LDCs. Column 4 is the mean city gate price from the Platts GASdat database, calculated as the consumption-weighted mean of monthly California prices. Column 5 shows the fixed monthly fee that would be required to maintain the same level of revenue if volumetric charges were decreased to marginal cost. The calculations in column 5 ignore that Pacific Gas and Electric currently offers a discount of approximately 10 cents per day to multifamily homes. All calculations use Residential Appliance Saturation Study sampling weights. Amounts are expressed in year 2010 dollars.

**Table A3**
**The Distributional Impact of Marginal Cost Pricing on All California Utilities**

| | Mean Annual Change ($) | Share Experiencing Bill Increase (%) | Mean Bill Change (%) |
|---|---|---|---|
| By household income quintile: | | | |
| First (<$32,000) | 40.46 (4.68) | 73.1 (1.7) | 12.3 (1.8) |
| Second ($32,000–$47,000) | 34.90 (4.42) | 73.3 (1.8) | 10.3 (1.6) |
| Third ($47,001–$68,000) | 15.05 (5.26) | 67.6 (1.9) | 4.0 (1.5) |
| Fourth ($68,001–$92,000) | −15.42 (4.71) | 54.2 (1.9) | −3.5 (1.0) |
| Fifth (>$92,000) | −77.03 (6.43) | 43.8 (2.0) | −14.1 (.9) |
| By percentage of the poverty line quintile: | | | |
| First (<165%) | 31.68 (5.00) | 70.5 (1.8) | 9.1 (1.7) |
| Second (165%–281%) | 21.77 (4.44) | 67.8 (1.8) | 6.0 (1.4) |
| Third (282%–412%) | 11.60 (4.96) | 64.4 (2.0) | 3.0 (1.4) |
| Fourth (413%–587%) | −11.31 (5.41) | 58.4 (1.9) | −2.7 (1.2) |
| Fifth (>587%) | −61.64 (7.40) | 49.3 (2.1) | −11.9 (1.1) |
| Households with children: | | | |
| All | −10.70 (2.94) | 58.1 (1.2) | −2.5 (.7) |
| With one child | 2.40 (6.04) | 64.9 (2.0) | .6 (1.5) |
| With two children | −17.78 (5.69) | 53.6 (2.3) | −4.0 (1.2) |
| With three or more children | −20.58 (7.45) | 54.3 (2.6) | −4.6 (1.5) |
| Low-income households with children: | | | |
| All | 28.26 (6.17) | 68.1 (2.5) | 8.0 (2.0) |
| With one child | 49.58 (10.54) | 74.4 (4.5) | 15.8 (4.4) |
| With two children | 37.85 (9.98) | 70.3 (4.7) | 11.3 (3.6) |
| With three or more children | 8.54 (10.18) | 62.8 (3.9) | 2.2 (2.7) |

**Note.** Values indicate changes in household expenditures on natural gas under marginal cost pricing. The sample includes all households in the 2003 Residential Appliance Saturation Survey (RASS) who use natural gas. A small number of households for whom demographic information was not available were dropped. Bootstraped standard errors based on 1,000 replications are in parentheses. All calculations use RASS sampling weights. Dollar amounts are expressed in year 2010 dollars. Low-income households are defined as households in the lowest quintile by percentage of the poverty line.

**Table A4**
**The Distributional Impact of Marginal Cost Pricing by Pacific Gas and Electric**

| | Mean Annual Change ($) | Share Experiencing Bill Increase (%) | Mean Bill Change (%) |
|---|---|---|---|
| By household income quintile: | | | |
| First (<$32,000) | 57.39 (6.88) | 74.1 (2.6) | 19.4 (3.1) |
| Second ($32,000–$47,000) | 43.02 (6.88) | 75.7 (2.7) | 13.2 (2.6) |
| Third ($47,001–$68,000) | 20.72 (7.77) | 64.4 (2.8) | 5.7 (2.3) |
| Fourth ($68,001–$92,000) | −28.20 (8.76) | 51.8 (2.8) | −6.2 (1.7) |
| Fifth (>$92,000) | −82.24 (9.01) | 43.7 (2.5) | −15.0 (1.2) |
| By percentage of the poverty line quintile: | | | |
| First (<165%) | 55.75 (7.33) | 74.0 (2.9) | 18.6 (3.2) |
| Second (165%–281%) | 21.90 (7.39) | 67.9 (2.9) | 6.0 (2.3) |
| Third (282%–412%) | 10.12 (9.48) | 63.4 (2.9) | 2.7 (2.5) |
| Fourth (413%–587%) | −16.28 (8.81) | 53.7 (2.9) | −3.8 (1.9) |
| Fifth (>587%) | −68.54 (10.65) | 49.1 (2.6) | −13.1 (1.6) |
| Households with children: | | | |
| All | −8.80 (4.70) | 56.5 (1.9) | −2.1 (1.1) |
| With one child | 5.34 (10.48) | 64.0 (3.1) | 1.4 (2.8) |
| With two children | −17.51 (7.84) | 51.0 (3.4) | −4.0 (1.7) |
| With three or more children | −17.91 (11.95) | 52.9 (4.4) | −4.1 (2.6) |
| Low-income households with children: | | | |
| All | 52.95 (9.35) | 72.6 (3.9) | 17.2 (4.0) |
| With one child | 102.16 (11.77) | 87.7 (4.8) | 48.3 (11.0) |
| With two children | 47.86 (16.02) | 70.8 (7.5) | 14.8 (6.5) |
| With three or more children | 19.21 (16.44) | 62.4 (7.0) | 5.2 (5.0) |

**Note.** Values indicate changes in household expenditures on natural gas under marginal cost pricing. The sample includes all Pacific Gas and Electric customers in the 2003 Residential Appliance Saturation Survey (RASS) who use natural gas. A small number of households for whom demographic information was not available were dropped. Bootstraped standard errors based on 1,000 replications are in parentheses. All calculations use RASS sampling weights. Dollar amounts are expressed in year 2010 dollars. Low-income households are defined as households in the lowest quintile by percentage of the poverty line.

Table A5

**The Distributional Impact of Marginal Cost Pricing by San Diego Gas and Electric**

| | Mean Annual Change ($) | Share Experiencing Bill Increase (%) | Mean Bill Change (%) |
|---|---|---|---|
| By household income quintile: | | | |
| First (<$32,000) | 70.06 (16.81) | 79.8 (6.0) | 26.5 (8.8) |
| Second ($32,000–$47,000) | 59.70 (16.37) | 74.6 (5.8) | 21.2 (7.6) |
| Third ($47,001–$68,000) | 10.37 (33.22) | 74.3 (5.1) | 2.8 (9.1) |
| Fourth ($68,001–$92,000) | 6.81 (14.76) | 62.0 (6.5) | 1.8 (4.0) |
| Fifth (>$92,000) | −109.22 (24.70) | 43.7 (5.1) | −19.3 (2.8) |
| By percentage of the poverty line quintile: | | | |
| First (<165%) | 66.22 (20.15) | 78.2 (6.4) | 24.6 (10.6) |
| Second (165%–281%) | 44.23 (17.42) | 69.5 (6.1) | 14.4 (6.9) |
| Third (282%–412%) | 41.71 (13.03) | 72.1 (6.6) | 13.2 (4.5) |
| Fourth (413%–587%) | −5.34 (19.37) | 67.8 (5.1) | −1.4 (4.6) |
| Fifth (>587%) | −103.13 (26.83) | 44.3 (5.4) | −18.6 (3.2) |
| Households with children: | | | |
| All | −22.00 (14.85) | 62.3 (3.7) | −5.2 (3.2) |
| With one child | 3.05 (31.77) | 74.6 (6.1) | .8 (8.4) |
| With two children | −28.32 (21.20) | 53.1 (7.1) | −6.6 (4.5) |
| With three or more children | −58.92 (56.19) | 55.5 (9.3) | −12.3 (9.8) |
| Low-income households with children: | | | |
| All | 40.34 (33.23) | 67.2 (11.0) | 12.9 (14.0) |
| With one child | 99.02 (39.50) | 83.7 (11.3) | 47.0 (27.6) |
| With two children | 21.44 (49.36) | 65.4 (18.7) | 6.2 (19.9) |
| With three or more children | 29.27 (60.85) | 59.7 (18.2) | 8.9 (27.8) |

**Note.** Values indicate changes in household expenditures on natural gas under marginal cost pricing. The sample includes all San Diego Gas and Electric customers in the 2003 Residential Appliance Saturation Survey (RASS) who use natural gas. A small number of households for whom demographic information was not available were dropped. Bootstraped standard errors based on 1,000 replications are in parentheses. All calculations use RASS sampling weights. Dollar amounts are expressed in year 2010 dollars. Low-income households are defined as households in the lowest quintile by percentage of the poverty line.

Table A6

**The Distributional Impact of Marginal Cost Pricing by Southern California Gas Company**

| | Mean Annual Change ($) | Share Experiencing Bill Increase (%) | Mean Bill Change (%) |
|---|---|---|---|
| By household income quintile: | | | |
| First (<$32,000) | 22.71 (6.47) | 71.3 (2.3) | 6.2 (2.0) |
| Second ($32,000–$47,000) | 23.83 (6.10) | 71.1 (2.6) | 6.6 (1.9) |
| Third ($47,001–$68,000) | 11.83 (6.07) | 68.8 (2.6) | 3.0 (1.6) |
| Fourth ($68,001–$92,000) | −9.93 (4.93) | 54.3 (2.8) | −2.3 (1.1) |
| Fifth (>$92,000) | −62.01 (8.52) | 44.0 (3.3) | −11.5 (1.2) |
| By percentage of the poverty line quintile: | | | |
| First (<165%) | 11.46 (6.80) | 67.4 (2.4) | 3.0 (1.9) |
| Second (165%–281%) | 17.44 (5.52) | 67.4 (2.6) | 4.6 (1.6) |
| Third (282%–412%) | 7.55 (5.43) | 63.8 (2.5) | 1.9 (1.4) |
| Fourth (413%–587%) | −8.19 (6.35) | 60.3 (2.9) | −1.9 (1.4) |
| Fifth (>587%) | −43.05 (8.09) | 50.9 (3.1) | −8.6 (1.3) |
| Households with children: | | | |
| All | −10.17 (3.34) | 58.7 (1.7) | −2.3 (.7) |
| With one child | .03 (6.44) | 63.8 (2.8) | .0 (1.6) |
| With two children | −15.78 (8.52) | 56.0 (3.1) | −3.6 (1.8) |
| With three or more children | −17.46 (7.88) | 54.9 (3.3) | −3.9 (1.6) |
| Low-income households with children: | | | |
| All | 11.32 (7.50) | 65.4 (3.2) | 2.9 (2.0) |
| With one child | 8.96 (13.41) | 64.3 (6.5) | 2.3 (3.6) |
| With two children | 32.69 (10.73) | 70.8 (6.0) | 9.5 (3.8) |
| With three or more children | 1.51 (12.73) | 63.2 (4.8) | .4 (3.1) |

**Note.** Values indicate changes in household expenditures on natural gas under marginal cost pricing. The sample includes all Southern California Gas Company customers in the 2003 Residential Appliance Saturation Survey (RASS) who use natural gas. A small number of households for whom demographic information was not available were dropped. Bootstraped standard errors based on 1,000 replications are in parentheses. All calculations use RASS sampling weights. Dollar amounts are expressed in year 2010 dollars. Low-income households are defined as households in the lowest quintile by percentage of the poverty line.

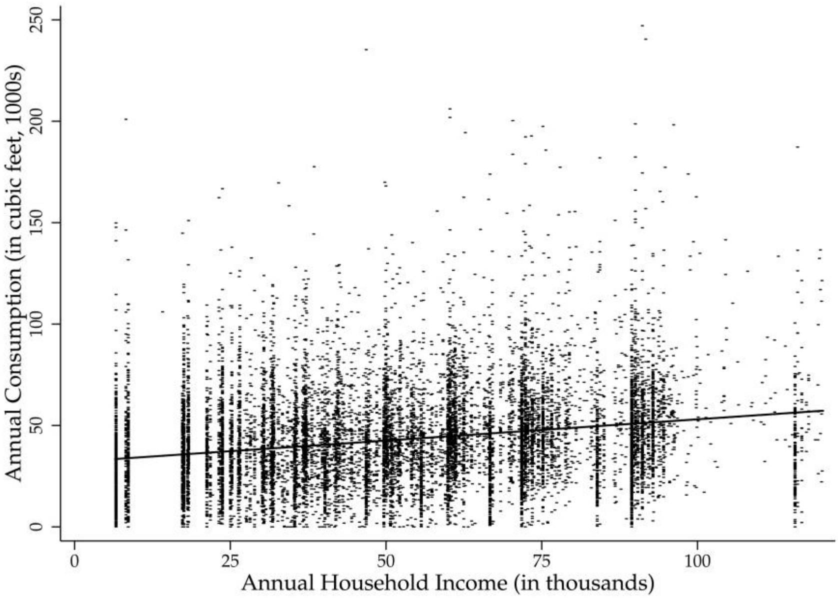


**Figure A1.** Natural gas consumption and household income for California households

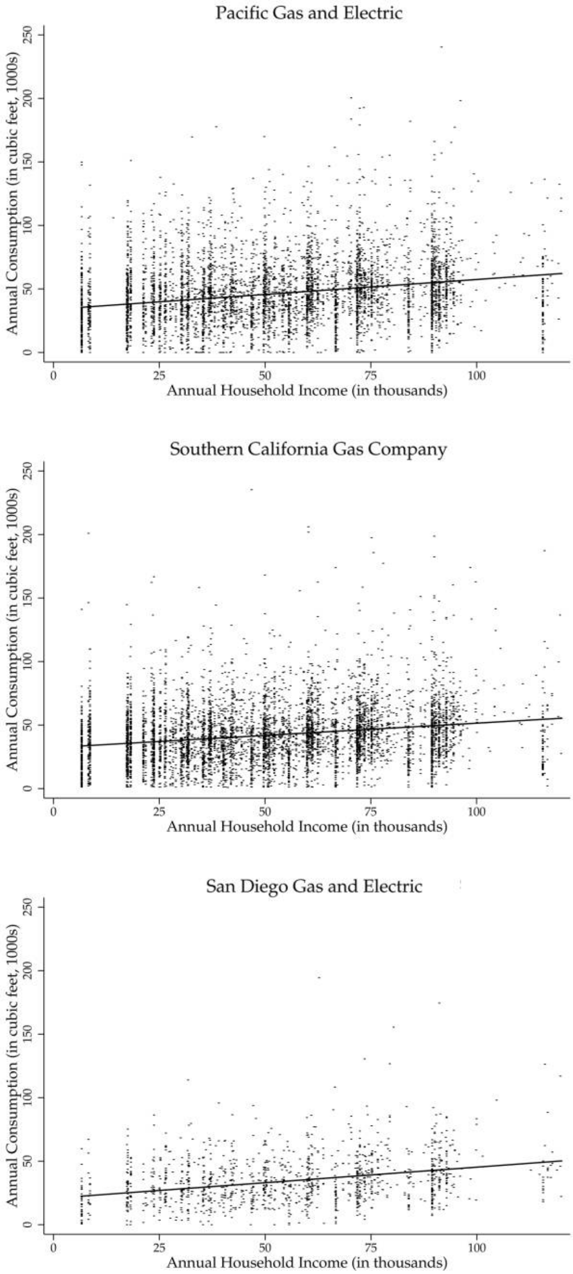


**Figure A2.** Natural gas consumption and household income by utility

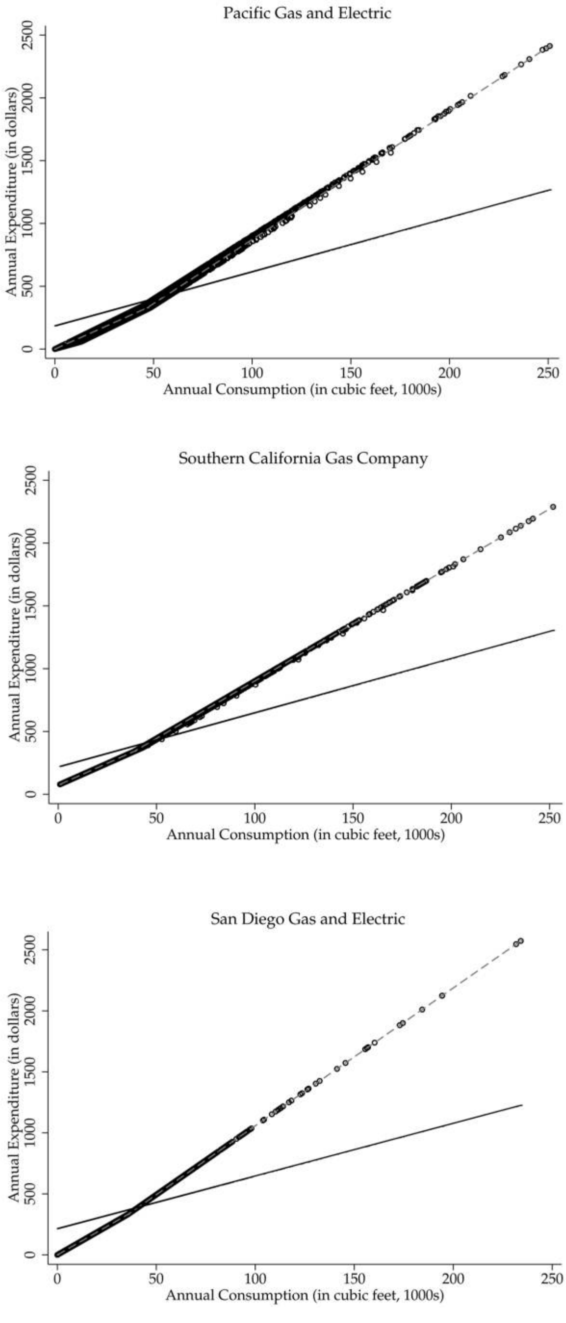


**Figure A3.** Residential natural gas rate schedules for 2002 by California utility

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