NBER WORKING PAPER SERIES

SHOCK VALUE: BILL SMOOTHING AND ENERGY PRICE PASS-THROUGH

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Working Paper 24558
http://www.nber.org/papers/w24558

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
April 2018

I thank Stephen Holland, Severin Borenstein, Lucas Davis, Joe Shapiro, and workshop and seminar participants at Arizona State University, Colorado School of Mines, the University of Calgary, the University of California Energy Institute, the University of Chicago (EPIC), the University of Michigan, Yale University, and the MSU/UM/WMU EEE Workshop for useful comments. Thanks to Benjamin Rego for assistance collecting pricing data. All errors are my own. The views expressed herein are those of the author and do not necessarily reflect the views of the National Bureau of Economic Research.

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JEL No. L11,L95,Q41

ABSTRACT

Energy price pass-through receives a lot of academic attention, for several reasons: energy prices can be highly volatile, they impact every consumer and every industry in the economy, and they are frequently impacted by regulations including gas taxes and carbon regulations. Like the pass-through literature in general, the energy pass-through literature focuses on pass-through to marginal prices. However, multi-part pricing is common in energy retail pricing. In this paper, I examine pass-through to retail natural gas prices. I show that marginal prices exhibit one-to-one pass-through, but fixed fees exhibit negative pass-through. This is consistent with the stated desire by utilities and price regulators to prevent "bill shock." The results have implications for how pass-through is estimated, as well as for understanding the implications of proposed alternative pricing structures for regulated utilities.

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Energy price pass-through has received much recent attention (Marion and Muehlegger, 2011; Borenstein and Kellogg, 2014; Fabra and Reguant, 2014; Ganapati, Shapiro and Walker, 2016; Stolper, 2016; Knittel, Meiselman and Stock, 2017; Lade and Bushnell, 2017; Muehlegger and Sweeney, 2017; Chu, Holladay and LaRiviere, Forthcoming). Energy prices can be extremely volatile, they impact every consumer and every industry in the economy, and they are frequently impacted by regulations including gasoline taxes and carbon pricing. In this paper, I examine pass-through in the natural gas market. In the last two decades, natural gas prices have seen tremendous variation arising from both supply-side shocks such as the fracking revolution and demand-side shocks such as polar vortex winters. The average year-on-year real upstream change (in absolute value) over 2002-2015 was 20 percent, and more than 10 percent of months saw a year-on-year price change of at least 40 percent. Because gas input costs are observable, the natural gas distribution utility sector provides an ideal setting for understanding firm behavior.

Natural gas distribution firms—which provide the delivery of gas via pipelines through cities to homes and businesses—face high fixed costs and relatively low marginal cost. The distribution sector is thus a natural monopoly, and it is typically regulated by quasi-judicial public utility commissions. Retail prices are determined so that firms can recover costs plus a return for their investors. The textbook model of efficient utility pricing is thus a two-part tariff: a volumetric fee set to recover marginal costs, and a lump-sum customer charge (on, e.g., a monthly basis) set to recover fixed costs (Viscusi, Vernon and Harrington, 2005). As such, multi-part tariffs are common in retail natural gas pricing, as well as in other utility settings such as electricity and water distribution. The energy price pass-through literature, like the pass-through literature in general, typically examines the impact of marginal cost shocks on marginal prices. In this paper, I examine pass-through to both marginal prices and fixed fees, finding that while marginal prices exhibit one-to-one pass-through, fixed fees exhibit *negative* pass-through.

These results are consistent with stated objectives of utilities and their price regulators. Regulators are typically charged not only with setting prices that are cost-based, but that also promote other goals, such as being easily interpretable and not unduly discriminatory. Most importantly for this paper, one of the other objectives frequently stated is something along the lines of avoiding "unnecessary rate shock."[1] A version of this objective comes from a text used by many price regulators, *Principles of Public Utility Rates* (1988), by Bonbright, Danielsen and Kamerschen, which includes as a "desirable attribute" the "[s]tability and predictability of the rates themselves, with a minimum of unexpected changes seriously adverse to rate-payers and with a sense of historical continuity" (p. 383).

[1] Retail prices are usually called "rates" or "tariffs."

I first provide background on retail price structures and on the regulatory process by which prices are set. I next model the regulator's problem when setting retail prices. In a simple two-period framework, I show how fixed fees might be used to smooth bill volatility induced by changes in input prices.

Next, I use survey data on utility fixed fees to show that they are negatively impacted by gas input costs. Then, using a comprehensive dataset on utility input costs, revenues, and volumes transacted, I recover the typical price structure of natural gas distributors in the US. In particular, I estimate the response of both volumetric charges and fixed fees to changes in input costs. Consistent with the anecdotal evidence regarding frequent updating of gas commodity charges,[2] I show essentially full pass-through to volumetric prices. I show that every \$1/mcf (dollar per thousand cubic feet) shock to citygate prices[3] leads to a \$1/mcf change in the volumetric component of retail prices, although around half of the pass-through comes with a lag of at least one month. In addition, I again show that high input prices lead to reduced fixed fees, such that the bill total is smoothed. A positive shock of \$1/mcf at the citygate level leads to a decrease in the fixed fee of \$0.4 per residential customer per month. At the average quantity purchased, this would imply that 6 percent of a price shock is smoothed away, i.e. does not appear in the change to the bill total. That is, bill totals are less volatile than would be expected from input cost volatility. These results are robust to an array of alternative specifications, under which I estimate that 3 to 18 percent of the price shock is smoothed away. Overall, these results are consistent with both the model of the regulator's objective and with the stated objective of lessening "bill shock."

Moreover, I provide evidence that utility expenditures are impacted. Using detailed panel data on the expenditures of over 200 large investor-owned utilities, I show that capital expenditures fall when gas input prices are high. This matches anecdotal evidence from the electricity and natural gas industries that the low gas prices induced by fracking have allowed utilities to engage in more capital investment than they otherwise would have. Recent discussions around aging utility infrastructure have emphasized questions about how to finance infrastructure upgrades (Hausman and Muehlenbachs, 2016), and these results suggest that utilities have looked to raise the necessary funds in ways that protect consumers from bill shock.

The paper contributes to a better understanding of both firm and regulator behavior in natural monopoly settings, an area of interest to the energy economics literature. The most directly related previous work has examined other aspects of retail pricing decisions in the

[2]Gas "commodity charges" are automatically-updated charges designed to reflect gas input costs.

[3]Citygate prices refer to the cost of natural gas at the point at which a utility purchases it. Throughout the paper, I use the terms "citygate price" and "input cost" interchangeably.

natural gas market, particularly the presence of outsized volumetric mark-ups (Davis and Muehlegger, 2010; Borenstein and Davis, 2012). For a discussion of pricing decisions and risk-shifting between utilities and consumers, see Beecher and Kihm (2016). The results are also closely related to work on political pressure on utility regulators (Joskow, 1974; Joskow, Rose and Wolfram, 1996; McRae and Meeks, 2016). For instance, Joskow (1974) writes that the "primary concern of regulatory commissions has been to keep nominal prices from increasing... Consumer groups and their representatives (including politicians) tend to be content if the nominal prices they are charged for services are constant or falling" (pp 298–299). Other work on retail pricing decisions for utilities includes Knittel (2003), which examines cross-subsidization consistent with interest group pressure. More generally, a long literature has examined utility and regulator behavior (Abito, 2016; Lim and Yurukoglu, 2016; Borenstein, Busse and Kellogg, 2012; Guthrie, 2006; Leaver, 2009; Joskow, Rose and Wolfram, 1996). Non-academic papers providing recommendations for utilities and commissions for dealing with rate shock include Graves, Hanser and Basheda (2007); Kolbe, Hanswer and Zhou (2013). This paper's contribution is to examine how multi-part pricing responds to the potential for political pressure.

Also closely related is the large literature on pass-through in energy markets from wholesale to retail prices. A large strand of this literature aims to understand asymmetric pass-through, in which prices rise more rapidly than they fall (Borenstein, Cameron and Gilbert, 1997; Davis and Hamilton, 2004; Johnson, 2002; Lewis, 2011; Tappata, 2009). Other strands of the literature have instead focused on how taxes and other marginal costs are passed through in, for instance, electricity and fuel markets (Marion and Muehlegger, 2011; Borenstein and Kellogg, 2014; Fabra and Reguant, 2014; Stolper, 2016; Knittel, Meiselman and Stock, 2017). Because energy markets are impacted by taxes and other regulatory costs (such as cap and trade markets), understanding pass-through to retail prices is important.

The results on the importance of bill volatility to regulators is currently of additional policy relevance, as it has surfaced in discussions around real-time pricing in electricity (Borenstein, 2005, 2013; Beecher and Kihm, 2016) and around retail choice (Hortacsu, Madanizadeh and Puller, 2017). Policy changes such as real-time pricing could increase bill volatility, and these results suggest that this could be a real concern for price regulators and/or consumers. At the same time, the rise of renewables implies that the welfare gains to real-time pricing are growing (Imelda, Fripp and Roberts, 2018).

The results on pass-through and price setting are also related to the large industrial organization literature on mark-ups. Of most direct relevance is work on bill shock in cellular telephone service (Grubb, 2012, 2015; Grubb and Osborne, 2015). That set of papers examines the welfare implications of cellular pricing plans in which overage charges can substantially increase a customer's bill. A key difference with the natural gas sector that I investigate is that bill shock for cellular service arises not because of exogenous shocks to input costs, but rather because firms use non-linear pricing in which quantity shocks push customers onto a much higher marginal price. In contrast, I investigate a setting in which firms adjust their prices to smooth exogenous cost shocks. More generally, though, two-part tariffs are found in many settings beyond the natural gas industry that I study. Multi-part payment schemes are used in credit card networks, in clubs with membership dues and usage fees, in the royalty and bonus system in mineral extraction, etc. My results suggest that in settings with non-linear prices, pass-through should be evaluated for all price components.

Finally, the results on the stickiness of bill totals relate to the macroeconomic literature on nominal rigidities (Bils and Klenow, 2004; Boivin, Giannoni and Mihov, 2009; Gorodnichenko and Weber, 2016; Kehoe and Midrigan, 2015; Nakamura and Steinsson, 2008), offering support for one of the explanations for sticky prices in that literature. While some models of sticky prices rely on menu costs, another set of models considers the role of consumer antagonism. These papers hypothesize that customers respond negatively to price changes, leading to loss of brand loyalty, search for an alternative product or supplier, boycotts, or other forms of demand decreases (Anderson and Simester, 2010; Rotemberg, 2005, 2011; Sibly, 2002). Similarly, some of the pass-through literature in energy markets has focused on models in which rising prices induce customers to search more or otherwise transfer loyalty (Davis and Hamilton, 2004; Lewis, 2011). The setting I explore is more closely related to these consumer antagonism models than to, e.g. the menu cost models; it is not that menu costs are high for some technological reason (gas input costs are automatically incorporated in bill totals) but rather that firms or price regulators deliberately smooth cost shocks to avoid outcry. A difference from much of the related consumer antagonism literature is that in this setting demand is not directly impacted, as typically no alternative supplier exists and switching to an alternative energy source would be extremely costly. Rather, the setting is consistent with the firm or the commission seeking to avoid negative press, customer complaints to call centers, or some other form of political pressure. It is thus more consistent with the idea of perceived "fairness" in utility pricing, akin to what is described by Zajac (1985). Finally, it is worth noting that while menu costs may decrease with technological change, such as the rise of online retailers, the potential for consumer antagonism as a source of sticky prices is likely to continue to be important.

This paper proceeds as follows. Section 1 provides background on utility pricing. Section 2 provides a model of retail pricing with and without the desire to avoid bill shock. Section 3 shows empirical results for the price structure as well as capital expenditures. Section 4 concludes with thoughts on welfare and policy implications.

1 Background

1.1 Natural Gas Utilities

Natural gas providers in the US primarily face two forms of regulation. The majority of customers are served by investor-owned utilities, companies that face price regulations at the state level and that generally serve a large number of customers. Approximately 300 such companies currently serve US customers. Other customers are served instead by municipal providers. Approximately 900 such municipal providers currently exist, although their service territories are much smaller than those of the investor-owned utilities—overall, investor-owned utilities sell 90 percent of all volume distributed.

Investor-owned utilities are not free to set retail prices nor to determine capital expenditures; instead prices and expenditures are regulated by state-level public utility commissions. Commissions are tasked with ensuring that prices are "just and reasonable." The typical investor-owned utility uses a price structure composed of three parts. The first part is the gas cost recovery charge;[4] this is a volumetric price set equal to the utility's purchasing cost. This price is typically updated frequently (e.g., monthly) via automatic adjustment clauses.[5] In addition, the utility typically charges both a volumetric mark-up, known as a distribution charge,[6] and a fixed charge.[7] These two components of the retail price are not updated automatically; instead the utility must go before regulators and justify any change to these components of the retail prices. A lengthy quasi-judicial regulatory process follows, in which the firm provides evidence relating to its costs, which the utility commission then weighs against evidence provided by interest groups such as rate-payer advocates. Volumetric mark-ups and fixed fees accordingly tend to change only every couple of years.[8]

Time series of these bill components are presented in Figure 1, for two large investor-owned utilities. The monthly fixed charge (thick black line), around 8 to 14 dollars in nominal terms, changes several times for the left-hand utility and just once for the right-hand utility. For these two utilities, fixed fees are rising in nominal terms over this time period. According to a nation-wide survey by the American Gas Association, fixed fees have generally been rising in nominal terms. Historically, this approximately kept pace with inflation. Increases in fixed charges in real terms have only come since around 2010 (American Gas Association, 2015).

[4]The name varies across utilities; it might be called a gas cost recovery charge, the gas cost factor, the cost of gas, or a procurement charge.

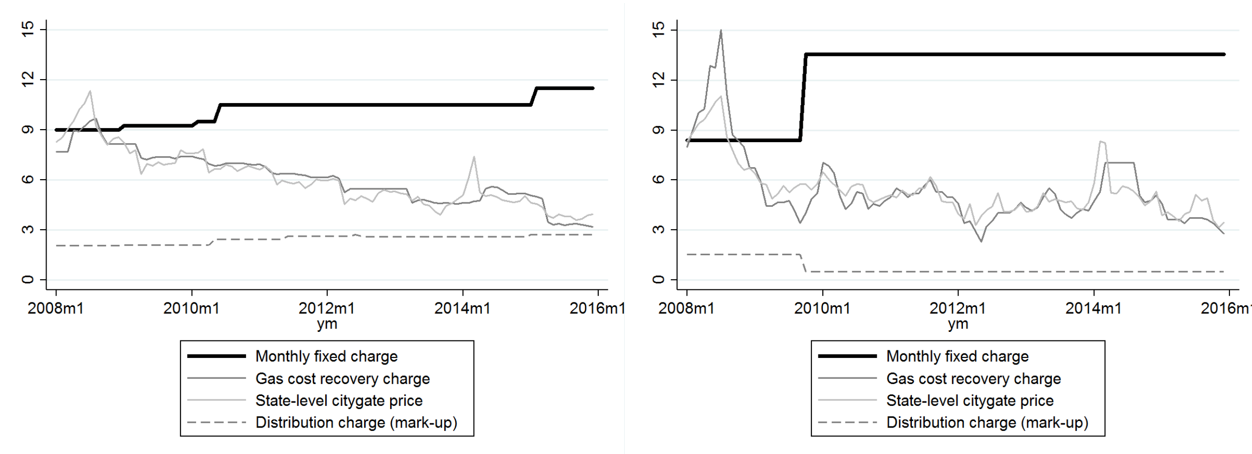
[5]In my data, the median frequency of changes to the observed gas cost recovery charges is one month.

[6]Also sometimes called a delivery charge, transportation charge, or transmission charge.

[7]Also called a customer charge, basic charge, or service charge. Sometimes related to a minimum charge.

[8]In my data, both volumetric mark-ups and fixed fees tend to change only every two to four years.

Figure 1: Bill Components for Two Example Utilities



Note: Each panel shows the nominal prices for three bill components: the monthly fixed charge ($ per customer per month), the commodity charge ($/mcf), and the volumetric mark-up ($/mcf). In addition, state-level average citygate prices from EIA are shown; the commodity charges track these closely. The two panels show two different utilities, both large investor-owned utilities.

The volumetric mark-up in Figure 1 (dashed grey) changes at the same time as the fixed fee. In contrast, the gas cost recovery charge changes approximately monthly and closely matches the state-wide citygate price.

The specifics of how these three price components are implemented vary across utilities, across time, and across customer types (“classes”) within a utility. For instance, some utilities use flat volumetric fees while others use increasing (or decreasing) block prices. Economic theory provides some guidance on these components—namely that marginal price should be set equal to marginal cost—but other aspects are necessarily guided more by distributional and political considerations. For instance, an efficient two-part tariff might use a flat volumetric charge equal to the gas input cost, with a fixed charge set to recover all remaining fixed costs. A remaining distributional question, then, is how to allocate fixed charges across customer types (e.g. residential versus industrial users; or low-income versus high-income groups). Unless elasticities along the extensive margin are large (i.e. customers respond to fixed charges by disconnecting from the service), the latter question has little importance in terms of economic efficiency but can be of great importance politically.

1.2 Stability as a Price-Setting Goal

Both utilities and commissions refer in their documents to a guiding set of principles for price-setting for gas and electric service provision. The principles (Bonbright, Danielsen and Kamerschen, 1988) relate to economic efficiency, but also to equity, revenue adequacy and stability, bill stability, and customer satisfaction. Of particular interest for this paper is

Bonbright's third principle, quoted above, regarding rate stability and predictability. This is sometimes summarized as avoiding "rate shock" or "bill shock" and sometimes as the principle of "gradualism" in implementing price changes.

For instance, testimony in a Maryland rate case stated that a "critical ratemaking goal is continuity with past rates and avoiding rate and bill shocks. This goal is often recognized in Commission decisions that move classes toward more equality in rate of return without imposing very large increases."[9] Similar reasoning appears in rate cases in numerous states. For instance, a New York politician submitted comments to the Public Service Commission to oppose gas and electric price hikes in the wake of energy price hikes caused by hurricanes Katrina and Rita, saying "the 'rate shock' coupled with already skyrocketing energy costs could threaten the health and safety of many families."[10] In addition to opposition to any price increase at all, some documents advocate for under-collection of a utility's cost in the wake of high input prices,[11] or phasing in price increases.[12] While residential users, particularly low-income users, are frequently mentioned, business users are as well,[13] and prior work has suggested that large industrial customers are able to exert pressure (Joskow, Rose and Wolfram, 1996). Sometimes rate shock is mentioned in the context of simply providing additional information to prepare customers, but frequently the timing and magnitude of price changes also adjusts to incorporate concerns about bill stability (Graves, Hanser and Basheda, 2007; Edison Electric Institute, 2016).

Anecdotal evidence from several sources suggests that rate shock avoidance impacts not only retail prices, but also companies' capital expenditures. One trade magazine described an industry analyst's 2012 comments by writing "low-cost natural gas has provided 'headroom' in electricity prices, which has helped utilities pursue 'significant capital spending' plans

[9]Maryland Public Service Commission. Case No 8959. Direct Testimony of William B. Marcus. June 20 2003. Accessed from http://webapp.psc.state.md.us/Intranet/casenum/CaseAction_new.cfm?CaseNumber=8959.

[10]Cahill, Kevin. Re: CASE 05-E-0934 - Proceeding on Motion of the Commission as to the Rates, Charges, Rules and Regulations of Central Hudson Gas & Electric Corporation for Electric Service and CASE 05-G-0935 - Proceeding on Motion of the Commission as to the Rates, Charges, Rules and Regulations of Central Hudson Gas & Electric Corporation for Gas Service. May 24, 2006. Accessed from http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={645401D8-F561-4146-8EFA-1FBB61E9DBAA}.

[11]State of New Hampshire Public Utilities Commission. DG 13-251. Order No 25,633. February 28, 2014. Accessed from http://www.puc.state.nh.us/%5C/Regulatory/Orders/2014orders/25633g.pdf.

[12]Pennsylvania Public Utility Commission. Opinion and Order: Pennsylvania PUC v. Herman Oil & Gas Company, Inc. June 11, 2015. Accessed from http://www.puc.state.pa.us/pcdocs/1365540.docx.

[13]Michigan Energy Forum Comment. "Joint response from Consumers Energy, DTE Energy, and MEGA." 2013. Accessed from http://www.michigan.gov/documents/energy/Additional_Question_8_response_from_DTE_Consumers_and_MEGA_419053_7.pdf

with little risk of rate shock."[14] While that quote focuses on electric utilities, a press release from the American Gas Association in 2012 stated that "[a]dvances in American technology for natural gas production have unlocked an abundance of this domestic clean energy source which has contributed to huge savings for residential and commercial customers. Americas natural gas utilities are using this opportunity to continue to improve our nations natural gas infrastructure, and they are working with local regulators to develop innovative models for making these capital investments possible."[15] Similarly, slides shown to investors by a major natural gas company, CenterPoint Energy, stated that "[l]low natural gas price environment in the U.S. reduces the potential that increased capital investment will cause customer rate shock."[16]

Overall, the exact way a utility or commission might incorporate rate shock avoidance in its price setting is likely to vary. The goal of this paper is not to provide a comprehensive catalogue or break-down, but rather to investigate how typical retail prices respond to cost changes in ways that are consistent with rate shock avoidance. As such, I leave aside strategies that focus on informational campaigns rather than adjustments to retail prices themselves, although future research on information provision would be of value.[17] I also leave aside the strategic interactions between utilities and commissions related to price setting. That is, I do not take a stand on the extent to which utilities versus commissions drive bill-smoothing behavior. Future work could explicitly model the strategic interactions of these two players, perhaps incorporating the behavior of rate-payer advocates as well, in the spirit of Abito (2016) or Leaver (2009).[18]

[14]Makansi, Jason. July 1 2012. "Innovation Required as Gas Displaces Coal." *Power Magazine.*

[15]American Gas Association. June 28 2012 News Release: "Natural Gas Utilities: Building and Enhancing an Advanced Energy Delivery System." Accessed from https://www.aga.org/news/news-releases/natural-gas-utilities-building-and-enhancing-advanced-energy-delivery-system.

[16]CenterPoint Energy, Inc. Form 8-K. March 26, 2015. Accessed from http://investors.centerpointenergy.com/secfiling.cfm?filingid=1193125-15-106014&cik=1130310.

[17]A related phenomenon is the use of "budget billing," in which a customer's monthly payments are roughly equalized over the year, smoothing shocks associated with cold weather in winter. This price structure frequently targets low-income users. Sexton (2015) empirically investigates this price structure for a utility in South Carolina, finding that customers on budget billing increase their consumption, which the author attributes to a decrease in price salience. Other related work includes Beard, Gropper and Raymond (1998); Borenstein (2013).

[18]A related older literature looked empirically at how commission characteristics impacts regulations (Besley and Coate, 2003; Hagerman and Ratchford, 1978; Primeaux Jr. and Mann, 1986).

1.3 Other Strategies for Reducing Price Volatility

Another strategy for mitigating retail price volatility is hedging to smooth input cost volatility.[19] Utilities use several forms of hedging: physical storage of gas, long-term contracts, and financial instruments. Because of the automatic pass-through clauses in many jurisdictions, utilities may have limited financial incentive to hedge. Instead, hedging is frequently justified by the desire to provide stability for retail prices. However, analysts have noted that regulatory risk limits the amount of hedging actually done by utilities: utilities may be punished by regulators for hedging that ex-post was not in the utility's favor (Borenstein, Busse and Kellogg, 2012; Graves and Levine, 2010).

2 Model

I begin with a simple model of the regulator's behavior, in which the regulator observes all costs faced by the utility, knows the consumer's utility function, and sets prices to maximize social welfare. Suppose there are two periods, in each of which the firm faces input costs, composed of variable costs c and fixed costs G. The regulator sets retail prices in order to maximize social welfare, accounting for the utility that consumers derive from consuming quantity q of gas, and subject to a budget neutrality constraint (over the two periods; i.e. banking and borrowing are assumed to be permitted). The regulator is able to use both variable prices p and fixed fees F. The regulator's problem is then:

$$\max_{p_1,p_2,F_1,F_2} U(q_1) + U(q_2) - c_1 q_1 - c_2 q_2$$

$$\text{s.t.} \quad p_1 q_1 + F_1 + p_2 q_2 + F_2 = c_1 q_1 + c_2 q_2 + G_1 + G_2$$

At the optimum, the regulator simply sets marginal price equal to marginal cost: $p_1 = c_1$ and $p_2 = c_2$. The regulator can select, at the optimum, any F_1 and F_2 such that $F_1 + F_2 = G_1 + G_2$. This is the standard two-part tariff typically seen in utility pricing, in which marginal price is set equal to marginal cost and fixed fees are used to cover all remaining fixed costs.

Now suppose that the regulator faces an additional penalty for volatility in the bill total. To motivate this penalty, suppose that consumers put political pressure on regulators when bills change, as in Joskow, Rose and Wolfram (1996).[20] This could be because consumers

[19] Regressions in the Appendix are suggestive of delayed and incomplete pass-through from the upstream (Henry Hub) price to the reported citygate purchase price, consistent with hedging.

[20] For extreme examples of political pressure, outside the US context, see McRae and Meeks (2016).

face credit constraints, or it could result from consumers judging utility pricing "fairness" by what is most easily observable to them—their bill total; this is related to the models described by Kahneman, Knetsch and Thaler (1986) and Zajac (1985).[21] The regulator's problem then becomes:

$$\max_{p_1,p_2,F_1,F_2} U(q_1) + U(q_2) - c_1 q_1 - c_2 q_2 - f(p_1 q_1 + F_1 - p_2 q_2 - F_2)$$

$$\text{s.t.} \quad p_1 q_1 + F_1 + p_2 q_2 + F_2 = c_1 q_1 + c_2 q_2 + G_1 + G_2$$

Consider a quadratic penalty function: $f = \alpha \left(p_1 q_1 + F_1 - p_2 q_2 - F_2\right)^2$. Here α is a constant denoting how large a penalty the regulator faces; i.e. how much consumer utility is affected by bill volatility. At the optimum, marginal prices are unaffected; $p_1 = c_1$ and $p_2 = c_2$. However, fixed fees are now set at the optimum such that bill totals are equalized:

$$F_1 = G - \frac{1}{2}\left(c_1 q_1 - c_2 q_2\right)$$

$$F_2 = G + \frac{1}{2}\left(c_1 q_1 - c_2 q_2\right)$$

where $G = \frac{1}{2}\left(G_1 + G_2\right)$. Thus the fixed fee will be set lower in the period with higher variable cost.[22]

Several aspects of this model are worth noting. First, the smoothing of the fixed fee when the regulator faces a penalty for bill volatility does not depend on the *magnitude* of that penalty, for this quadratic function. The α parameter drops out and does not impact the fixed fees F. As such, the regulator will engage in this bill smoothing no matter how small the penalty is. Even if only some portion of consumers exert pressure on the regulator,[23] or even if all consumers care only a small amount about volatility, bill smoothing will occur.

Second, in theory it is possible at the optimum that the fixed fee would be need to be negative in one of the two periods. This would occur if the volatility in variable cost is

[21]While the paper has focused conceptually on investor-owned utilities that are regulated by utility commissions, note that similar political pressure from consumers might be expected for municipal utilities.

[22]This model assumes there is no elasticity along the extensive margin, i.e. on the consumer's decision to enter the gas market and incur the fixed customer charge. This simplification is unlikely to matter: total fixed fees across the two periods are at the same level with and without smoothing, and an informed customer will take into account the vector of fixed charges across time. Thus the smoothing may impact *when* a customer enters the market, but is unlikely to affect *whether* the customer enters the market. As such, the extensive margin is not likely to matter much either for the empirical predictions or for welfare analysis. This is explored more below in the empirical analysis.

[23]Note, however, that the simplified model abstracts from heterogeneity across customers. In reality, smoothing via the fixed fee would not protect *all* customers from bill shock if customers are heterogeneous and there is a single pricing structure.

sufficiently large relative to the magnitude of fixed costs G. In practice, this is unlikely to be the case for the natural gas sector analyzed empirically in this paper. The typical quantity sold to a residential household in the US is under 7 mcf per month (shown below, in Table 2). Since the standard deviation of the citygate price is around \$2.5/mcf, a one standard deviation change in the citygate price would lead to a \$17 change in the bill total. The typical utility collects \$35 per month per residential household in fees beyond what is needed to cover gas costs (i.e., to cover fixed costs), indicating that fixed costs are large relative to volatility in variable costs, so negative fees would be unlikely to be needed.

Finally, this presentation uses a symmetric (quadratic) penalty function. One could imagine an asymmetric penalty function, in which there was no welfare loss for *falling* bill totals, but a quadratic penalty for *rising* bill totals. In that case, if cost falls from period 1 to period 2, any combination of fixed fees satisfying $F_1 + F_2 = G_1 + G_2$ can be used, as above, provided that the bill total does not rise.[24] If cost rises from period 1 to period 2, then the combination of fixed fees such that bill totals are equalized (or weakly falling) is used. For this simplified model, straightforward asymmetric *behavior* of fixed fees might not necessarily appear empirically, since the regulator can choose from a large menu of fixed fee combinations without incurring penalty.

3 Empirical Analysis

3.1 Data on Fixed Fees and Input Costs

The typical utility offers multiple pricing plans, some components of which change frequently, and unfortunately there exists no dataset that aggregates this information across the over 1,300 utility providers in the US.[25] However, I begin by leveraging three limited datasets: a survey by the American Gas Association, my own retail pricing search, and a survey by Memphis Light, Gas, and Water (a municipal utility).

The American Gas Association has periodically conducted an unbalanced survey of fixed fees at around 150 to 200 utilities.[26] Survey data are provided in AGA reports at the utility level for the years 2010 and 2015, and averaged to the Census division level (e.g., New

[24] I.e., fixed fees could fall, stay flat, or rise, provided the rise in fixed fees did not outweight the fall in the portion of bill total from the volumetric price.

[25] A typical utility offers a low-income-specific rate, might have differential prices across regions within its service territory, etc. Examples are provided in the Appendix and in Auffhammer and Rubin (2018).

[26] The two most recent surveys are summarized in: American Gas Association, 2010, “Natural Gas Utility Rate Structure: The Customer Charge Component – 2010 Update,” accessed December 2016 from https://www.aga.org/sites/default/files/ea_2010-04_customercharge2010.pdf; and American Gas Association, 2015, “Natural Gas Utility Rate Structure: The Customer Charge Component – 2015 Update,” accessed December 2016 from https://www.aga.org/sites/default/files/ea_2015-03_customercharge2015.pdf.

England, Middle Atlantic, East North Central, etc.) for the years 2006, 2010, and 2015. The average residential fee reported across the three years is $11 per customer per month.

Second, the municipal utility of Memphis Light, Gas and Water (MLGW) conducts an annual survey of retail pricing at several dozen utilities, including natural gas (as well as electricity and water).[27] Their annual publication does not report fixed fees per se, but it does report residential bill totals at different quantity levels, such as 1 mcf, 5 mcf, etc. I use the bill totals for the two smallest quantities (1 mcf and 5 mcf) to back out the fixed fee; I also verify that using other quantity points gives similar fixed fee estimates. The mean fixed fee in these data is $13 per customer per month.

Finally, I collect residential fixed fee data for the 40 largest utilities in the US, using a combination of searches of utility and commission websites, contacting utilities directly, and the Internet Archive (archive.org). The resulting dataset is a monthly panel of these utilities; the panel is unbalanced because of differential data availability across utilities. Details on data collection are provided in the Appendix. Roughly matching the AGA survey data, the mean fixed fee in these data is $12 per customer per month.

Reassuringly, the mean fixed fee is roughly comparable across the three datasets. Additionally, while each dataset has limitations, they are likely to be different across the sources, so no systematic error across the datasets is expected in my analysis. While the AGA data are geographically quite aggregated, they at least represent a large sample of utilities. The MLGW survey is not a random sample, but it provides greater disaggregation (both cross-sectionally and temporally) than the AGA data. And while my own cata collection does not yield a balanced panel nor a random sample, it does provide information at the monthly level for the largest utilities, which combined represent half of total residential sales.

I also collect data on gas input costs to utilities. Specifically, I observe citygate prices in dollars per thousand cubic feet ($/mcf).[28] The data are at the monthly state level, covering 1989 to 2015, and are from the Energy Information Administration (EIA) at the US Department of Energy. Recall that this citygate price is the price paid by a utility at the point that natural gas enters the distribution system. The price reported by the EIA is the quantity-weighted average across all utilities in a state. Prices vary because of demand-side shocks like cold winters and supply-side shocks like the fracking boom, with cross-sectional variation arising from pipeline congestion (see, e.g., Marmer, Shapiro and MacAvoy, 2007).

[27]The MLGW survey is not a random sample of utilities, nor is it even a balanced panel. Their 2016 publication reports that they "survey over 50 cities, including many that are geographically close to Memphis, as well as utilities that are similar in size" (Memphis Light, Gas and Water, 2016). It is, of course, possible, that cities are selected specifically based on how their prices compare with MLGW prices.

[28]Note that this citygate price variable is the purchase price paid by the utility, so it is inclusive of the hedging described in Section 1.3. Further interpretation of this is discussed in the Appendix.

I normalize all price variables to 2015 dollars, using the CPI-All Urban Less Energy.

For each of the three datasets, I regress the monthly fixed fee on the citygate price, including fixed effects and a linear trend.[29] The idea is to leverage citygate price shocks, which are generally thought to come from upstream wholesale price shocks, to estimate pass-through to retail fixed fees. One identifying assumption is that fixed fees do not in turn impact citygate prices. Below, I consider instrumental variables specifications to rule out this sort of endogeneity.

Results are presented in Table 1. Column 1 shows a coefficient on citygate price of -0.47, statistically significant at the five percent level. This implies that for every \$1/mcf rise in the citygate price, the monthly fixed fee per customer falls by \$0.47. Recall that in this dataset, the median utility reports a fixed fee of around \$11 per month per customer. For this utility, a \$1/mcf rise in the citygate price (roughly 20 percent of 2015 levels) would translate to a 4 percent fall in the fixed fee. As another way of understanding the magnitude, consider that the average quantity consumed in a month is around 6.6 mcf per residential customer; this would imply that a \$1/mcf rise in the citygate price would, absent smoothing, translate to an increase of \$6.6 in the bill total. However, with smoothing, \$0.47 (or 7 percent) of this increase is muted by the change to the fixed fee. Given the infrequency with which fixed fees adjust (because they require rate case proceedings), it is not surprising that the smoothing is only partial.

Column 2 shows that the magnitude using the MLGW data is -0.11, also statistically significant at the five percent level. Note that this column uses standard errors that are two-way clustered by state and year. Column 3, using the prices I collect at the 40 largest utilities, shows a comparable magnitude (-0.31), albeit with noise (standard errors are again two-way clustered). Instrumental variable specifications, in the Appendix, also show that citygate prices have a negative impact on fixed fees.

3.2 Estimating Price Structures

The previous section demonstrated that across multiple sources of information on utility retail pricing, there is negative pass-through of citygate prices to fixed fees. Two limitations of those results are (1) the data are not a Census of utilities; and (2) only fixed fees are observed, rather than the entire price structure. As such, I next leverage comprehensive information on prices and quantities from the EIA. For 1989-2015, I observe monthly state-level data on retail revenue, quantity sold, and customer counts[30] for four categories of

[29] For the AGA data, I use the citygate price for the year prior to the survey year, since the surveys were conducted in February.

[30] Customer count data are annual.

Table 1: Residential Fixed Fee Smoothing

	(1) Fixed Fee	(2) Fixed Fee	(3) Fixed Fee
Citygate price, $/mcf	-0.47**	-0.11**	-0.31
	(0.21)	(0.05)	(0.22)
Fixed effects	Yes	Yes	Yes
Time trend	Yes	Yes	Yes
Observations	27	5,641	337
R^2	0.92	0.93	0.80

Notes: Column 1 uses observations at the level of a Census division (n=9), covering the years 2005, 2009, and 2014; the data source is AGA surveys. Column 2 uses an unbalanced panel of utility-level monthly observations for the approximately 40 largest utilities in the US for the years 2007 to 2017; the data source is tariff sheets collected by the author. Column 3 uses an unbalanced panel of utility-level observations for 55 cities in the US for the years 2007 and 2009-2016; the data source is a survey conducted annually by Memphis Light Gas and Water. Standard errors are two-way clustered by state and year in Columns 2 and 3. Fixed fees and citygate prices are in 2015 dollars. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

end-users: residential, commercial, industrial, and electric power. The average retail price in these data is not the marginal price; it is calculated simply as total revenue divided by total quantity. In particular, it includes revenue from fixed fees charged to each customer irrespective of their volume purchased.

Industrial and electric power data are observed only for a subset of years (beginning in 2001 for industrial, 2002 for electric power). Moreover, the EIA reports that data used to calculate the state-level average price represents a majority of volume delivered for the residential and commercial sectors (97 percent for residential, 75 percent for commercial) whereas only 20 percent of industrial volumes delivered are represented in the reported industrial price.[31] Throughout my analysis, I focus on the residential and commercial sectors, for which data are more complete.[32]

Table 2 provides summary statistics for these price, revenue, quantity, and customer count variables.

Leveraging these data is not as straightforward as regressing the retail price on the citygate price, since the retail price averages across fixed fees and volumetric prices. As such, I next use an econometric strategy to back out the typical price structure, leveraging

[31] These data do not appear to be available for delivery to the electric power sector.

[32] I use data on the 48 contiguous states. A handful (approximately 0.1 percent) of values are missing; these do not appear to be systematic.

Table 2: Summary Statistics, State by Month Panel

	Mean	Std. Dev.	N
Citygate price	6.48	2.57	15,547
Retail price			
Residential	13.35	4.56	15,543
Commercial	10.05	3.01	15,532
Industrial	8.85	3.14	8,640
Revenue			
Residential	76.68	56.69	15,543
Commercial	477.62	319.08	15,532
Industrial	55,084.89	81,094.80	8,640
Quantity			
Residential	6.61	5.24	15,547
Commercial	48.48	29.18	15,532
Industrial	6,960.17	11,162.80	8,640
Customers			
Residential	1,243,371.36	1,610,016.30	15,552
Commercial	103,205.52	96,291.30	15,552
Industrial	4,336.08	7,113.38	15,552

Notes: A unit of observation is a state in a month. The sample covers 1989 through 2015. Pricing data are available for industrial users only since 2001. Prices are in $ per thousand cubic feet (mcf). Revenue is in $ per customer per month. Quantity is in mcf per customer per month. Prices and revenue are listed in 2015 dollars.

insights from Davis and Muehlegger (2010), hereafter DM. DM note that components of the price structure can be empirically estimated from quantity and revenue data. Their paper is motivatd by a desire to understand how large volumetric mark-ups are in the natural gas sector. They begin by defining net revenue as revenues collected per customer, net of gas input costs. As described in Section 1, a utility's revenues must cover two sets of costs: gas costs, which are determined by citygate prices and by quantities purchased, and costs for the physical infrastructure. They note that under a volumetric mark-up, net revenues are correlated with quantities sold. As a result, changes in net revenues and quantity sold (both observable for all utilities), can be used to empirically estimate the average volumetric mark-up. They implement this insight by regressing net revenues on quantity sold:

$$NR_{it} = \alpha + \beta Q_{it} + \varepsilon_{it}, \tag{1}$$

where net revenue NR is in dollars per month per customer and quantity Q is in mcf per month per customer. Because β gives the amount by which net revenue per customer rises when quantity per customer rises, it provides an estimate of the volumetric mark-up on natural gas purchases. I expand on their equation to estimate additional components of the price structure.

Re-writing Equation 1 using the NR variable's definition:

$$(P_{it} - MC_{it}) \cdot Q_{it} = \alpha + \beta Q_{it} + \varepsilon_{it} \tag{2}$$

where P is the average retail price and MC is the citygate price, both in dollars per mcf. Re-arranging:

$$P_{it}Q_{it} = \alpha + \beta Q_{it} + \gamma MC_{it}Q_{it} + \varepsilon_{it}. \tag{3}$$

That is, one can estimate the same equation as DM in a slightly more flexible form, to be able to directly estimate the pass-through of the input cost to volumetric prices; this pass-through is implicitly assumed to be equal to 1 in the DM specification. In addition to providing a formal test of the pass-through, this allows for the inclusion of, for instance, lagged input prices. Adding in these lagged prices, and noting that the left-hand side $P_{it}Q_{it}$ is simply total revenue, yields:

$$TR_{it} = \alpha + \beta Q_{it} + \sum_{l=0}^{12} \gamma_l MC_{i,t-l}Q_{it} + \varepsilon_{it}. \tag{4}$$

Moreover, by writing out the components of the retail prices, one obtains a formulation that allows for estimating the magnitude of the monthly fixed fee per customer as well as how it varies. Prices are typically set with a volumetric component as well as a fixed fee, such that the total revenue per customer can be written as a combination of volumetric prices and fixed fees: $TR = P^{volumetric}Q + P^{fixedfee}$. Thus the right-hand side of Equation 4 can be conceptually separated into components related to volumetric prices ($\beta Q_{it} + \sum_{l=0}^{12} \gamma_l MC_{i,t-l}Q_{it}$) and components related to the fixed fee (α). In particular, the intercept in the DM estimating equation serves as an estimate of the monthly fixed charge per customer, since it is the portion of revenue that does not vary with quantity.

I can additionally include the citygate price as an explanatory variable, to understand how fixed fees vary in response to changes in citygate prices:

$$TR_{it} = \alpha + \psi MC_{it} + \beta Q_{it} + \sum_{l=0}^{12} \gamma_l MC_{i,t-l}Q_{it} + \varepsilon_{it} \tag{5}$$

Thus ψ gives an estimate of how the fixed fee changes with the level of citygate prices, since it is the component of the right-hand side that does not vary with quantity—ψ is capturing just the impact of citygate prices on the fixed fee or non-volumetric component of the bill.[33]

[33]Note that, because quantity sold has been included as an explanatory variable, the estimate of ψ is net of any quantity impact of citygate prices via demand response.

That is, ψ can be used to examine whether a desire to avoid "bill shock" leads to smoothing of the bill total, via adjustment of the fixed fee.[34]

To summarize, the final specification is as follows:

$$TR_{it} = \alpha + \underbrace{\psi MC_{it}}_{\substack{\text{Bill} \\ \text{smoothing:} \\ \text{adj. of} \\ \text{fixed fee}}} + \underbrace{\beta Q_{it}}_{\substack{\text{Volumetric} \\ \text{mark-up}}} + \underbrace{\sum_{l=0}^{12} \gamma_l MC_{i,t-l} Q_{it}}_{\substack{\text{Instantaneous} \\ \text{and lagged} \\ \text{pass-through}}} + X_{it}\Gamma + \varepsilon_{it} \tag{6}$$

Total revenue TR is in dollars per month per customer. The citygate price MC is in dollars per mcf, and quantity Q is in mcf per month per customer. Bill smoothing via adjustment of the fixed fee would show up as a negative estimate of ψ_1. The average volumetric mark-up is estimated by β, as in DM. Pass-through to the volumetric price is estimated in the γ coefficients.

The primary identifying assumption for this equation is that there is no reverse causality from P_{it} (part of total revenue, the dependent variable) to MC_{it}. That is, retail prices do not impact citygate prices. In the related literature, citygate prices are generally thought to be determined by upstream factors. The primary mechanism by which one might worry that retail prices would impact citygate prices would be via demand response. However, note that quantity demanded has been controlled for in this equation. Below, I consider alternative specifications to rule out concerns about endogeneity of the citygate price.

I include controls X_{it}: state-level fixed effects, a time trend, and state by calendar month effects. Because natural gas demand is highly seasonal, with differing seasonal effects across regions based on climate, the related empirical literature has generally found state-specific month effects to be useful for both precision and identification. Below, I show that the results are robust to alternative controls. Standard errors are two-way clustered by state and by year. The results for Equation 6, separated by end-user type, are given in Table 3.

Pass-through to the volumetric price (i.e., the coefficient on cost) is nearly complete, albeit with lags. The instantaneous pass-through rate is 42 to 45 percent, with additional pass-through (of 46 percent for residential, 43 percent for commercial) coming with one to four months lag. The sum of the coefficients on the instantaneous and lagged pass-through is 1.0 for both sectors; for neither sector is it statistically different from 1. This is consistent with the frequent changes to the gas cost recovery charge seen for the largest utilities with retail pricing data available (see Appendix).

[34] Note that one might also be interested in whether the volumetric component of the bill (in practice, composed of the gas cost recovery charge and the volumetric mark-up) responds to citygate prices. That is in fact part of this final specification: it is simply the pass-through coefficient γ.

Table 3: Estimating Rate Structures, by Sector

	(1) Residential	(2) Commercial
Pass-through:		
Cost, $MC_{it}Q_{it}$, in $	0.42***	0.45***
	(0.03)	(0.03)
$MC_{i,t-1}Q_{it}$	0.24***	0.22***
	(0.02)	(0.02)
$MC_{i,t-2}Q_{it}$	0.11***	0.11***
	(0.02)	(0.02)
$MC_{i,t-3}Q_{it}$	0.07***	0.06***
	(0.02)	(0.02)
$MC_{i,t-4}Q_{it}$	0.04***	0.05***
	(0.01)	(0.02)
$MC_{i,t-5}Q_{it}$	0.00	-0.01
	(0.01)	(0.01)
$MC_{i,t-6}Q_{it}$	0.01**	0.01
	(0.01)	(0.01)
$MC_{i,t-7}Q_{it}$	0.01	0.03*
	(0.01)	(0.01)
$MC_{i,t-8}Q_{it}$	0.02	0.03*
	(0.01)	(0.01)
$MC_{i,t-9}Q_{it}$	0.02*	0.01
	(0.01)	(0.01)
$MC_{i,t-10}Q_{it}$	0.03*	0.03**
	(0.01)	(0.01)
$MC_{i,t-11}Q_{it}$	0.02	0.01
	(0.02)	(0.02)
$MC_{i,t-12}Q_{it}$	0.03	0.02
	(0.02)	(0.02)
Volumetric mark-up:		
Quantity, Q_{it}, in mcf	3.03***	2.71***
	(0.26)	(0.37)
Smoothing:		
Citygate price, MC_{it}, in $/mcf	-0.38**	-1.91
	(0.16)	(1.30)
State by month effects	Yes	Yes
Linear trend	Yes	Yes
Observations	14,942	14,931
R^2	0.98	0.96

Notes: A unit of observation is a state in a month. The data cover 1989-2015. The dependent variable is revenue, calculated as the revenue (in $) per customer per month. Prices are in $ per mcf. Quantity is in mcf per customer per month. "Cost per customer" is the commodity cost (in $) per customer per month, calculated as citygate price multipled by quantity per customer. Prices and revenue are in 2015 dollars. Standard errors are two-way clustered by state and by year. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

I estimate a positive volumetric mark-up (the coefficient on quantity). This is similar for residential customers ($3.03/mcf) and commercial customers ($2.71/mcf). This essentially matches DM, who estimate a volumetric mark-up of $3 to $4 for the two sectors (when re-normalizing their 2007 values to 2015 dollars).

The novel result is that I estimate a bill smoothing effect, via the negative coefficient on citygate price. The coefficient on citygate price in the residential equation is -0.38 and is significant at the one percent level. This implies that for every \$1/mcf rise in the citygate price, the monthly fixed fee per customer falls by \$0.38. Recalling that the average quantity consumed in a month is around 6.6 mcf per residential customer, this would imply that a \$1/mcf rise in the citygate price would, absent smoothing, translate to an increase of \$6.6 in the bill total—however with smoothing, \$0.38 (or 6 percent) of this increase is muted by the change to the fixed fee. The portion of a shock that is smoothed for the commercial sector is 4 percent, although it is not statistically significant. Note that the magnitude of this smoothing effect is consistent with the survey evidence presented in Section 3.1, providing reassurance that empirically estimating the price structure is an appropriate strategy where pricing data are limited.[35]

3.3 Robustness of Smoothing Results

In this section, I discuss and test for various potential issues with the empirical specification for the main results. If one were able to directly observe retail price structures for a comprehensive panel, there would be less concern about specification error leading to bias. Because the previous results relied on inferring the price structure from revenue and quantity data, here I evaluate (and rule out) various possibilities that the effects are the mechanical result of the estimation procedure. The estimated smoothing coefficient (on citygate price) is displayed in Table 4. Full estimation results are given in the Appendix.

First I estimate the specification using alternative controls: dropping seasonal controls; including a quadratic, or cubic time trend; including year effects; or including state-specific linear trends. The negative impact of the citygate price is robust to these alternative specifications, and the magnitude is frequently larger than in the main specification (Columns 1 through 5).

Column 6 shows that the results are robust to controlling for GDP growth and for safety regulations taking effect in 2010 that may have impacted utility expenditures (Hausman and Muehlenbachs, 2016). Column 7 demonstrates that the results are robust to controlling for weather. Columns 8 and 9 show that results are similar when weighting by either customer counts or volume sold (time-invariant).

I next separate the sample according to the portion of homes in the state that use natural

[35] The robustness of the results to using either the survey data or the empirically estimated pricing structures is also reassuring regarding the timing of the identifying variation. One might worry that identification in this section's regressions is very short-run, since it is driven by monthly deviations from trend, whereas some of the intuition provided earlier was regarding, for instance, fracking's permanent shift to the supply curve. The survey results are reassuring for this concern, since they use identification driven by longer-run price changes (annual in the case of the MLGW data; multi-year in the case of the AGA data).

Table 4: Residential Bill Smoothing, Alternative Specifications

Panel A: Residential	(1)	(2)	(3)	(4)	(5)	(6)
Citygate price	-1.05***	-0.37**	-0.62***	-1.18***	-0.33**	-0.51***
	(0.28)	(0.16)	(0.18)	(0.24)	(0.15)	(0.16)
	(7)	(8)	(9)	(10)	(11)	(12)
Citygate price	-0.38**	-0.37*	-0.23	-0.33**	-0.47*	-0.86***
	(0.16)	(0.21)	(0.18)	(0.16)	(0.24)	(0.18)
	(13)	(14)	(15)	(16)	(17)	(18)
Citygate price	-0.60**	-0.37*	-0.38**	-0.33**	-0.33**	-0.64***
	(0.26)	(0.18)	(0.16)	(0.16)	(0.13)	(0.20)
Panel B: Commercial	(1)	(2)	(3)	(4)	(5)	(6)
Citygate price	-6.05***	-2.14	-3.96**	-8.88***	-1.97	-3.48**
	(1.98)	(1.40)	(1.57)	(2.02)	(1.38)	(1.42)
	(7)	(8)	(9)	(10)	(11)	(12)
Citygate price	-1.90	-1.01	-0.75	-1.95	-1.53	-4.75***
	(1.31)	(1.66)	(1.51)	(1.76)	(1.73)	(1.57)
	(13)	(14)	(15)	(16)	(17)	(18)
Citygate price	-5.81*	-2.84	-2.31*	-1.59	-1.86*	-3.52***
	(2.78)	(1.92)	(1.19)	(1.38)	(1.02)	(0.95)

Notes: This regressions for this table are identical to those in table 3, but this table displays, for space purposes, only the coefficient on citygate price. Full results are in the Appendix. The primary specification from Table 3 has been modified as follows: Column 1 has no seasonal controls. Column 2 uses a quadratic trend. Column 3 uses a cubic trend. Column 4 uses year effects. Column 5 uses state-specific linear trends. Column 6 controls for GDP growth and for PHMSA safety regulations. Column 7 controls for cooling degree days and heating degree days. Column 8 weights by customer count (time-invariant). Column 9 weights by volume sold (time-invariant). Column 10 restricts the sample to states with less than 50 percent of homes using natural gas for heating. Column 11 restricts to states with more than 50 percent of homes using natural gas for heating. Column 12 is restricted to 1990 through 2004. Column 13 is restricted to 2005 through 2015. Column 14 uses additional lags on the citygate variable. Column 15 controls for third-order polynomials for the quantity variables. Column 16 adds an asymmetric citygate effect (see text for details). Column 17 allows the markup and pass-through coefficients to vary by state and by five-year periods. Column 18 uses first-differences of all variables. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

gas for their home heating.[36] If the elasticity along the extensive margin (i.e., whether or not to have a natural gas hook-up) mattered, one would expect to see differential smoothing across states with low versus high levels of natural gas for home heating usage, since the extensive elasticity is likely to be driven by whether or not homes already have fuel-specific heating capital installed. However, the smoothing effect is comparable across the two types of states (Columns 10 and 11).

I also separate the sample into early (1989-2004) and late (2005-2015) periods. The smoothing effect appears in both periods (Columns 12 and 13).

I next verify that the results are not driven by various mechanical features of the main specification. I include two lags of the citygate price (Column 14). The coefficients on lagged citygate are not statistically significant (see Appendix), and the contemporaneous smoothing effect remains. Thus the results do not appear to be driven by misspecification arising from omitted lags in the main specification. I also verify that results are not driven by the linearity imposed on the quantity variable. Since some utilities use either increasing or decreasing block prices, imposing linearity on this mark-up coefficient could introduce mis-specification. I include third-order polynomials for the quantity variables in Column 15; results for the smoothing coefficient remain similar.

I next allow for an asymmetric smoothing effect by including a dummy for whether citygate prices have risen year-on-year. The estimated coefficient (see Appendix) is negative, suggestive that utilities, regulators, or customers are more concerned with rising bill totals than with falling bill totals. The negative and significant coefficient on citygate price remains, however, indicating that the bill smoothing effect is not solely present when citygate prices are rising (Column 16).

I next allow for heterogeneity in the pass-through and mark-up coefficients to vary by state and by five-year blocks (Column 17). Finally, I estimate the specification in first differences rather than levels (Column 18).

In the Appendix, I also use the survey data to rule out the possibility of price endogeneity. In the main regression, finding an instrument for the price variable is complicated by the fact that the cost variable, and its twelve lags, would also require an instrument. However, in the more straightforward regressions using surveys of fixed fees, I can easily instrument for the citygate price variable. In particular, I use the average citygate price in the Census region (West, Midwest, Northeast, and South). Table A2 presents IV results, which are essentially unchanged from the OLS results shown in Table 1.

Overall, while I have considered a very wide range of potential empirical issues, I con-

[36]These data come from the 2000 Census, which tabulates whether an occupied housing unit uses utility gas, bottled gas, electricity, no heating fuel, etc.

sistently find a negative impact of the citygate price on the component of revenue that is not correlated with quantity, i.e. on the fixed fee. This is consistent with the theoretical model as well as with anecdotal evidence from the utility industry. The magnitude of the coefficient on the citygate price ranges in these alternative specifications from -0.23 to -1.18 for the residential sector, implying that around 3 to 18 percent of the impact of a cost shock on a customer's bill total would be smoothed away. For the commercial sector, the coefficient on the citygate price ranges in these alternative specifications from -0.75 to -8.88, implying smoothing of 1 to 17 percent at the typical quantity purchased.

3.4 Expenditures and Citygate Prices

In addition to the possibility of welfare loss on the consumer side, it is possible that the price structures estimated in this paper have implications for utility operations. One of the biggest expense categories for the typical utility is capital expenditures to either upgrade or expand infrastructure. Other expenditures include administrative expenses, meter reading, advertising, etc.

The previous sections showed that fixed fees, and therefore net revenues, respond in unexpected ways to input costs. In this section, I examine whether expenditures similarly respond to unrelated input costs. In particular, I estimate the impact of citygate prices on capital expenditures. There is no economic reason to a priori expect citygate prices to affect these expenditures—gas purchasing costs are a separate line-item, and gas is not an input into infrastructure-related activities. As such, evidence of an impact of citygate prices on these expenditures would be more consistent with bill smoothing impacting the utilities' ability to engage in pipeline network replacement and expansion activities. Several of the anecdotes in Section 1 suggest that this might be the case in the wake of price decreases from the fracking revolution.

To answer this question, I use an annual utility-level dataset on expenditures for large investor-owned utilities. For this subset ($n = 207$) of investor-owned utilities, I observe data on capital expenditures[37] at an annual level for 1998-2013 in addition to quantity sold and average price by sector.[38] While only available for some utilities, these tend to be the largest firms; as such, this panel accounts for around 80 percent of the residential and commercial volume distributed in the US over this time frame. These data are reported to state-level public utility commissions, and they have been assembled across state-level records by SNL,

[37]Additional categories of expenditures, such as administrative examples, are explored in the Appendix.

[38]In principle, one could use this utility-by-year panel to estimate price structures at the utility, rather than state, level. In practice, having only annual data makes identification of the separate price components (pass-through, volumetric mark-up, and fixed fee smoothing) very difficult.

a provider of industry data. Summary statistics are provided in the Appendix. I winsorize the right tail (the upper one percent) because the raw data show extreme outliers.

With these data, I regress capital expenditures on the citygate price, including as controls utility effects and a linear trend. I additionally control for the quantity sold across various sectors to control for territory expansions. I control for heating degree days (HDDs),[39] because cold weather is likely to impact both citygate prices and the need for repairs. In particular, a severe cold snap increases demand for natural gas, which combined with supply constraints can lead to spikes in prices. At the same time, cold snaps can contribute to corrosion of pipelines as well as inhibit pipeline repair.

Table 5 provides results. Expenditures are per customer and per month, so the coefficient on citygate price can be interpreted in the same way as the citygate coefficient in Table 3. Recall that for every $1/mcf increase in the citygate price, fixed fees fall by $0.38 for residential customers and by $1.91 for commercial customers. According to the results in Table 5, capital spending falls by $0.13 per customer (statistically significant at the five percent level). The magnitude is smaller than the smoothing of fixed fees; this is not surprising if utilities are able to save or borrow funds. It appears that utility capital expenditures are indeed lower when natural gas input prices are high, consistent with the anecdotes given in Section 1. The fracking supply boom lowered natural gas prices by $3.45/mcf from 2007 to 2013 (Hausman and Kellogg, 2015); the coefficient in Table 5 implies that utilities in this sample increased capital expenditures by five percent as a result. Robustness checks are shown in the Appendix; the result is somewhat sensitive to the time series controls used.

4 Conclusion

The standard theoretical utility pricing structure involves a two-part tariff, in which volumetric prices are set equal to marginal cost and fixed fees are ued to cover fixed costs. In this paper, I show that fixed fees are actually tied in part to marginal cost: they fall when marginal cost is high, consistent with utilities' and price regulators' stated objective of preventing customers from experiencing bill shock. While fixed fees are not directly observable for the entirety of natural gas firms, I use revenue and quantity data to back out the average impact of natural gas wholesale prices on residential and commercial fixed fees. I estimate that, at the average quantity consumed, 6 percent of a cost shock is smoothed away, i.e. not reflected in bill totals.

In a model where price regulators face a penalty for volatility of bill totals, smoothing cost shocks by varying fixed fees is welfare improving. Since marginal prices are not impacted,

[39] Defined as the sum over a year of daily degree days, defined as $min(0, 65 - T)$.

Table 5: The Impact of Gas Input Prices on Capital Expenditures

	Capital
Citygate	-0.13**
	(0.06)
Utility effects	Yes
Linear trend	Yes
Observations	2,434
R^2	0.63

Notes: Expenditures are in $ per customer per month, and citygate prices are in $ per mcf. All variables are normalized to 2015 dollars. Controls include quantity per customer, by end-user type, and heating degree days. Coefficients on controls are displayed in the Appendix. Standard errors are clustered by state. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

quantity consumed remains at the socially optimal level. Note that in contrast, hedging as a strategy to reduce bill volatility impacts marginal prices—potentially impacting consumption decisions and thus welfare.

In the simple model presented in this paper, fixed fees would be used to smooth 100 percent of input cost shocks. That only a portion of cost shocks are smoothed could reflect adjustment costs on the part of firms. For instance, firms typically enter rate cases only every several years; in the intervening periods, prices are not fully adjustable.

Although not modeled here, it is possible that welfare could decrease with fixed fee smoothing. If consumers respond to average, rather than marginal, prices (as in Ito, 2014), smoothing of fixed fees distorts consumption decisions. However, in a setting where consumers respond to average prices, *all* two-part tariffs lead to distorted consumption decisions, since average price is always greater than marginal cost.

It is also possible that fixed fee smoothing could decrease welfare if capital expenditures are distorted away from the socially-optimal investment decision. Anecdotes suggest that utilities do indeed adjust capital expenditures in response to wholesale gas prices, and I estimate a small but statistically significant relationship. Thus it appears that the timing of capital expenditures are distorted; whether the overall *level* of expenditures is distorted remains an open question.

Several implications emerge from the results on fixed fees. First, these results suggest that in settings with multi-part pricing, pass-through analysis should take into account the entire price structure, not just the marginal price. The incidence of a tax, for instance, will depend on not just on how volumetric prices change, but also on whether fixed fees adjust. Second, the natural gas industry shows evidence of a form of price stickiness (in average prices rather than marginal prices) that is consistent with the previous literature on consumer antagonism. Finally, the results suggest that price regulators, consumers, or firms value predictability of bill totals, consistent with anecdotal evidence. Proposals to reform utility pricing by, for instance, tying marginal prices more tightly to marginal cost (as in real-time pricing proposals for the electricity sector) are likely to face resistance if bill volatility will increase. On the other hand, proposals to reduce or eliminate volumetric mark-ups (and increase fixed fees accordingly) could take into account the benefit brought about by *reduced* volatility (from quantity shocks) that this would imply for bill totals.

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Appendix

This appendix provides additional tables and figures.

Pass-Through from Henry Hub to Citygate

Another form of price smoothing is via hedging, including physical storage of gas, signing long-term contracts, or the use of financial instruments. To get a sense of how this impacts the purchasing price that utilities report, I regress purchasing cost on the Henry Hub price. Across various specifications (Table A1), pass-through is estimated to be at most 0.9, suggestive of some form of hedging. Column 1 shows the immediate pass-through (0.76). Column 2 shows that much of this comes with one-month lag. Column 3 shows that the pass-through after one year is 0.87; Column 4 includes additional time-series controls and shows a one-year pass-through of 0.79. Column 5 shows that, with an AR(1) process, the long-run pass-through is estimated to be 0.91 (calculated as 0.26 / (1-0.72)). Column 6 shows that instrumenting for the Henry Hub price does not change the results; the instrument, in the spirit of Hausman and Kellogg (2015), is the national average heating degree days over twelve months. Across these six specifications, the largest estimated long-run pass-through is 0.91 (Column 5). All specifications except the long-run pass-through in Column 5 are statistically different from one. This delayed (and possibly incomplete) pass-through is consistent with some hedging on the part of utilities.

Allowing for Price Endogeneity

Table A2 presents IV results for the residential fixed fee smoothing using the survey data on fixed fees. All three columns instrument for the citygate price with the average price at the Census region level. Results are essentially unchanged from the OLS results shown in Table 1.

Price Data Collection

While no comprehensive dataset on utility retail prices exists, some price documentation is publicly available online or by request from utilities and commissions. I searched for a time-series of rate documents for the largest utilities in the US.[40] Information was collected via a combination of web searches for utility and commission websites, contacting utilities directly, and the Internet Archive (archive.org). I searched for data on fixed charges for

[40]Largest according to the number of residential customers in 2013, the last year for which I have SNL data.

the 40 largest utilities, finding both current and historical information for 30, and current information only for an additional 9. I additionally searched for data on variable mark-ups and on gas cost recovery charges for the 15 largest utilities. I found current mark-up data for 14 and historical mark-up data for 8; and gas cost recovery data for 15.

The typical utility or commission provides two types of documentation: a table of changes in gas commodity charges over time, and a "tariff book" in pdf form detailing the other components of the prices, which tend to change less often. For instance, Con Edison (New York) provides the information for March 2017 displayed in Figure A1. The left image shows the "gas cost factors," or volumetric commodity charge, for Con Edison, which change monthly. The right image shows the "minimum charge (per month)" (in practice, akin to a fixed charge) and "base rate... per therm" (volumetric mark-up), which tend to change every 1-3 years. Other utilities tend to show comparable documentation.

The Con Edison documentation also shows some of the complications that arise when collecting price data. The right panel of Figure A1 shows the pricing for "Service Classification No. 3: Residential and Religious - Heating Firm Sales Service." Numerous other price plans are available, including "general firm sales service," "residential and religious firm sales service," "seasonal off-peak firm sales service," "interruptible" rates, etc. Moreover, a comprehensive dataset would also need to account for additional fees and charges (frequently called "riders"), including the "merchant function charge," "revenue decoupling mechanism," "system benefits charge," and "temporary state assessment surcharge," each of which carries its own time series of changes. These additional charges are widespread across utilities, and they can appear as either volumetric or fixed charges. Finally, for the case of Con Edison (and some other utilities), what is loosely described here as a two-part tariff with a fixed and a volumetric charge is actually a minimum charge with an increasing block pricing structure: that is, there is a fixed charge, then zero mark-up (but a commodity charge) for the first three units sold, and a volumetric charge (both commodity cost and a mark-up) for additional units rising with usage. In practice, the typical customer is likely to use between 3 and 87 units, so I have elided the non-linear aspect of the volumetric fee.

Additional complications that arise include multiple service territories (in general, I collected pricing data for the largest service territory) and additional service classifications (e.g. low-income pricing).

A comprehensive dataset would require tracking, for all utilities, changes in (1) fixed charges, (2) volumetric mark-ups, (3) commodity costs, (4) additional temporary fixed and volumetric surcharges, (5) non-linear volumetric prices—these would need to be tracked for each service classification and each service territory, and one would need data on the number of customers subject to each service classification. Each of these components could be structured and reported differently across utilities, and across time within a utility.

Estimating Price Structures

Tables A3 through A8 provide full results for the tests of potential threats to identification (matching the condensed results presented in Table 4). Tables A3 through A5 provide residential sector results; Tables A6 through A8 are for the commercial sector. Descriptions are given in the main text.

Expenditures

Table A9 provides summary statistics for the firm-level panel used in the capital expenditures regression. While the data are annual, quantity and expenditure variables have been divided by 12, to be comparable with the monthly summary statistics in Table 2.[41] Summary statistics are displayed for the 229 companies in the raw data; the regressions results in the main text use fewer companies because of missing data.

Tables A10 shows the robustness of the expenditures and input cost results to alternative specifications: alternative controls (Columns 1-3), using the region-level price as an instrument (Column 4), and weighting (Column 5). The results are sensitive to the time series controls (Columns 2 and 3); the coefficient is approximately zero if a quadratic trend is used, but the coefficient is larger in absolute value when year effects are used. Results are qualitatively similar when instrumenting for the citygate price (Column 4), but statistical significance is lost.

Table A11 shows the same specification as in Table 5, but with alternative expenditures categories. The expenditures data are broken out into multiple categories: distribution operations and maintenance (O&M); customer accounts, sales, and information; administrative expenses; and capital. Distribution O&M includes, for instance, repairs at citygate stations, repairs to customer meters, etc. Customer accounts, sales, and information includes such spending as meter reading, customer accounts maintenance, uncollectible expenses, low-income assistance, etc. I subtract uncollectible accounts from this category, since its value is mechanically linked to the citygate price. As a result, this category missing values—data on uncollectible accounts contain missing values. Administrative expenses include salaries, office supplies, etc. While negative impacts are estimated for capital, impacts for distribution expenditures; customer accounts, information, and sales; and administrative expenditures

[41]The only variable not directly comparable with Table 2 is the customer count variable; in the state-by-month panel, this is a count of customers per state, whereas in the utility-by-year panel, it is a count of customers per utility.

are small and not statistically different from zero.

Note that control coefficients (not displayed in the main text's Table 5) are also displayed in this table, in Column 2. The positive coefficients on quantity consumed, although not statistically significant, are consistent with two possibilities: (1) service territory expansions increase the number of customers and require capital expenditures; (2) a positive mark-up means that additional sales will lead to additional revenue, which can then be used for capital expenditures. The negative coefficient on heating degree days is also consistent with two possibilities: (1) cold weather might inhibit pipeline repair; (2) "weather normalization" clauses in some jurisdictions are designed to undo the quantity/revenue tie previously mentioned. In these jurisdictions, additional HDDs would lead to additional consumption and therefore additional revenue, but some of this additional revenue would be removed via the normalization clause. To the extent these revenue changes impact capital expenditures, it would imply a positive coefficient on quantity but a negative coefficient on HDDs.

Figure A1: Sample Price Documentation, Con Edison (NY)

CON EDISON
Gas Cost Factors and Monthly Rate Adjustments
Applicable to SC Nos. 1, 2, 3 and 13

	Gas Cost Factor			Monthly Rate Adjustment	
Effective Date	SC 1 (cents per therm)	SC 2 Rate II and SC 3 (cents per therm)	SC 2 Rate I, SC 2 and SC 3 A/C, SC 13 (cents per therm)	NYC Customers (cents per therm)	Westchester Customers (cents per therm)
03/01/17	47.4896	47.7475	41.1678	0.6789	0.6991
02/01/17	54.6189	54.9069	47.5616	0.6155	0.6357
01/01/17	40.9488	41.2122	34.4936	0.6114	0.6316
12/01/16	36.1429	36.4060	29.6956	0.2917	0.3119
11/01/16	28.4883	28.9471	21.7925	0.2757	0.2959
10/01/16	28.6842	29.0308	23.6280	3.7925	3.8127
09/01/16	26.3109	26.6613	21.1971	3.5188	3.5390
08/01/16	26.9068	27.2596	21.7584	3.6004	3.6528
07/01/16	31.1158	31.4730	25.9033	4.1176	4.1700
06/01/16	27.1375	27.5000	21.8491	3.9981	4.0505
05/01/16	27.7819	28.1392	22.5683	3.3876	3.4749
04/01/16	24.2405	24.5786	19.3075	3.3233	3.4106
03/01/16	26.6120	26.9182	22.1445	3.2974	3.3847
02/01/16	29.5427	29.8925	24.4379	3.3090	3.3963
01/01/16	28.3872	28.6847	24.7763	3.3931	3.4804
12/01/15	25.9941	26.2975	22.3117	3.1847	3.2720
11/01/15	21.4644	21.7678	17.7823	2.9954	3.0827
10/01/15	19.5212	19.8025	16.1055	4.7488	5.1024
09/01/15	12.2822	16.5840	13.6272	4.7895	5.1431
08/01/15	12.7915	17.5172	14.2691	4.7810	5.0822
07/01/15	14.0138	18.6705	15.4699	4.7627	5.0639
06/01/15	25.5320	28.9314	26.5949	4.7088	5.0100
05/01/15	26.1760	31.1958	27.7455	4.6229	4.8892
04/01/15	23.9616	30.8762	28.5226	4.3955	4.6618

CON EDISON
Service Classification No. 3
Residential and Religious - Heating Firm Sales Service

Date Effective: **March 1, 2017**

Rate (per month)

A. Base Rate:

For the First	3 therms	(or less):	$20.40
For the next	87 therms		80.54 cents per therm
For the next	2,910 therms		61.26 cents per therm
For excess over	3,000 therms		47.16 cents per therm

B. Low Income Base Rate:

For the First	3 therms	(or less):	$13.15
For the next	87 therms		31.74 cents per therm
For the next	2,910 therms		61.26 cents per therm
For excess over	3,000 therms		47.16 cents per therm

C. Minimum Charge (per month):

Applicable to All Customers Except Low Income (per month):	$20.40
Applicable to Low Income Customers (per month):	$13.15

D. Air-Conditioning Rate:

Customers who use gas for the operation of gas air-conditioning equipment which is permanently installed will be billed for gas used during the period June 14 to October 14th as follows (per meter per month):

(1) The total quantity of gas supplied, less the quantity of gas billed at the air-conditioning rate set forth below, will be billed at the above rates;

(2) The quantity of gas (if any) exceeding 12 therms, and up to a maximum of 62 therms per ton of rated capacity of the Customer's air-conditioning equipment, will be billed at the rate set forth below.

For the First	1,200 therms:	25.71 cents per therm
For excess over	1,200 therms:	21.99 cents per therm

When a bill includes periods during both the Air-Conditioning Billing Period (June 14th to October 14th) and the Standard Billing Period (balance of the year), the rates and charges applicable will be prorated based on the number of days in the Air-Conditioning Billing Period and the number of days in the Standard Billing Period related to the total number of days in the billing period.

E. Other Rate Provisions

1. **Minimum charge applicable to Large Dual Fuel Customers (per month)**- The monthly minimum charge shall be determined by applying the base rates set forth in A, B, and/or D above, to two-thirds of 100,000 therms divided by 365 days multiplied by the number of days (approximately 30) in the billing period.

2. **Merchant Function, System Benefits, and Billing and Payment Processing Charges, Revenue Decoupling Mechanism Adjustment, and Temporary State Assessment Surcharge:** A Firm Sales Customer taking service under this rate is also subject to the Merchant Function Charge, Revenue Decoupling Mechanism Adjustment, System Benefits Charge ("SBC") , the Billing and Payment Processing ("BPP") Charge, and Temporary State Assessment Surcharge ("TSAS"), depending on billing arrangements. Current and historical Merchant Function Charges can be found in the "Merchant Function Charge" table (See Page 13), and Temporary State Assessment Surcharge can be found on the Table "TSAS" (See Page 16).

3. **Gas Cost Factor and Monthly Rate Adjustment (per month):** The rates for gas service under Service Classification No. 3 shall be increased each month by a Gas Cost Factor per therm to reflect the average cost of gas and certain other supply related adjustments, and shall be adjusted each month by a Monthly Rate Adjustment per therm to reflect items not directly related to gas costs. Current and historical months' Gas Cost Factors and Monthly Rate Adjustments can be found in the "Gas Cost Factors and Monthly Rate Adjustments" table (See page 12) .

4. **Increase in Rates and Charges:** The rates and charges in A to E above are increased by the applicable percentage found in the "Gross Receipts Tax" table to recover local and state gross receipts taxes (See pages 7 and 8).

Note: The left image shows the "gas cost factors," or volumetric commodity charge, for Con Edison, which change monthly. The right image shows the "minimum charge (per month)" (in practice, akin to a fixed charge) and "base rate... per therm" (volumetric mark-up), which tend to change every 1-3 years.

Table A1: Pass-Through of Henry Hub to Citygate

	(1)	(2)	(3)	(4)	(5)	(6)
Henry Hub price	0.76***	0.26***	0.25***	0.24***	0.26***	0.71***
	(0.03)	(0.05)	(0.04)	(0.03)	(0.02)	(0.15)
Henry Hub, lag 1		0.48***	0.48***	0.48***		
		(0.07)	(0.05)	(0.05)		
Henry Hub, lag 2		0.06	-0.05	-0.05*		
		(0.04)	(0.05)	(0.03)		
Henry Hub, lag 3			0.01	-0.00		
			(0.04)	(0.03)		
Henry Hub, lag 4			0.02	0.04		
			(0.03)	(0.03)		
Henry Hub, lag 5			-0.02	-0.03*		
			(0.02)	(0.02)		
Henry Hub, lag 6			0.06**	0.05**		
			(0.02)	(0.02)		
Henry Hub, lag 7			0.02	-0.01		
			(0.03)	(0.02)		
Henry Hub, lag 8			0.04	0.04*		
			(0.03)	(0.02)		
Henry Hub, lag 9			-0.03	-0.04		
			(0.03)	(0.03)		
Henry Hub, lag 10			-0.02	0.00		
			(0.04)	(0.04)		
Henry Hub, lag 11			0.07	0.07		
			(0.04)	(0.04)		
Henry Hub, lag 12			0.03	0.01		
			(0.03)	(0.03)		
Citygate price, lag 1					0.72***	
					(0.02)	
Linear trend	Yes	Yes	Yes	Yes	Yes	Yes
Quadratic trend	No	No	No	Yes	No	No
State by month effects	No	No	No	Yes	No	No
Observations	10,943	10,847	10,367	10,367	10,942	10,943
R^2	0.59	0.63	0.64	0.80	0.84	0.59
F-stat						6.29

Notes: This table regresses citygate purchasing costs reported by utilities on the Henry Hub price. The Henry Hub price, originally reported in dollars per mmBtu, has been rescaled to dollars per mcf using a conversion factor of 1.037. Column 6 instruments for the Henry Hub price using the national average heating degree days over 12 months. Standard errors are clustered by sample month. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

Table A2: Residential Fixed Fee Smoothing, IV Specifications

	(1) Fixed Fee	(2) Fixed Fee	(3) Fixed Fee
Citygate price, $/mcf	-0.43**	-0.17**	-0.41
	(0.17)	(0.07)	(0.27)
Fixed effects	Yes	Yes	Yes
Time trend	Yes	Yes	Yes
Observations	27	5,641	337
R^2	0.92	0.93	0.80
F-stat	245.90	1452.36	221.17

Notes: Column 1 uses observations at the level of a Census division (n=9), covering the years 2005, 2009, and 2014; the data source is AGA surveys. Column 2 uses an unbalanced panel of utility-level monthly observations for the approximately 40 largest utilities in the US for the years 2007 to 2017; the data source is tariff sheets collected by the author. Column 3 uses an unbalanced panel of utility-level observations for 55 cities in the US for the years 2007 and 2009-2016; the data source is a survey conducted annually by Memphis Light Gas and Water. Standard errors are two-way clustered by state and year in Columns 2 and 3. The citygate price is instrumented with the Census region level (West, Midwest, Northeast, and South) average price. Fixed fees and citygate prices are in 2015 dollars. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

Table A3: Estimating Residential Rate Structures, Alternative Specifications

	(1)	(2)	(3)	(4)	(5)	(6)
Cost, $MC_{it}Q_{it}$, in $	0.47***	0.42***	0.44***	0.47***	0.42***	0.43***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
$MC_{i,t-1}Q_{it}$	0.23***	0.24***	0.24***	0.23***	0.24***	0.24***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
$MC_{i,t-2}Q_{it}$	0.10***	0.12***	0.12***	0.11***	0.11***	0.12***
	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
$MC_{i,t-3}Q_{it}$	0.08***	0.07***	0.07***	0.06**	0.07***	0.07***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Quantity	2.62***	3.03***	3.14***	3.21***	3.13***	3.08***
	(0.23)	(0.26)	(0.26)	(0.30)	(0.26)	(0.26)
Citygate price	-1.05***	-0.37**	-0.62***	-1.18***	-0.33**	-0.51***
	(0.28)	(0.16)	(0.18)	(0.24)	(0.15)	(0.16)
CDD						
HDD						
Citygate, lag 1						
Citygate, lag 2						
Quantity, quadratic						
Quantity, cubic						
Rising citygate indicator						
Observations	14,942	14,942	14,942	14,942	14,942	14,942
R^2	0.96	0.98	0.98	0.98	0.98	0.98

Notes: This table is identical to table 3 in the main text, with the following exceptions. Additional lags (4-12) on cost are included as controls, as in table 3, but are not shown here for space. All columns use fixed effects and a linear trend with the following exceptions. Column 1 has no seasonal controls. Column 2 uses a quadratic trend. Column 3 uses a cubic trend. Column 4 uses year effects. Column 5 uses state-specific linear trends. Column 6 controls for GDP growth and for PHMSA safety regulations. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

Table A4: Estimating Residential Rate Structures, Alternative Specifications

	(7)	(8)	(9)	(10)	(11)	(12)
Cost, $MC_{it}Q_{it}$, in $	0.42***	0.42***	0.43***	0.38***	0.47***	0.45***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)
$MC_{i,t-1}Q_{it}$	0.24***	0.27***	0.26***	0.23***	0.24***	0.22***
	(0.02)	(0.04)	(0.04)	(0.03)	(0.03)	(0.02)
$MC_{i,t-2}Q_{it}$	0.11***	0.13***	0.13***	0.11***	0.12***	0.10***
	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)
$MC_{i,t-3}Q_{it}$	0.07***	0.05**	0.06**	0.10***	0.03	0.07**
	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.03)
Quantity	2.98***	2.85***	2.94***	3.59***	2.35***	3.11***
	(0.29)	(0.33)	(0.30)	(0.37)	(0.26)	(0.41)
Citygate price	-0.38**	-0.37*	-0.23	-0.33**	-0.47*	-0.86***
	(0.16)	(0.21)	(0.18)	(0.16)	(0.24)	(0.18)
CDD	-0.04					
	(0.05)					
HDD	0.04					
	(0.10)					
Citygate, lag 1						
Citygate, lag 2						
Quantity, quadratic						
Quantity, cubic						
Rising citygate indicator						
Observations	14,942	14,942	14,942	8,411	6,531	8,606
R^2	0.98	0.98	0.98	0.98	0.98	0.98

Notes: This table is identical to table 3 in the main text, with the following exceptions. Additional lags (4-12) on cost are included as controls, as in table 3, but are not shown here for space. All columns use fixed effects and a linear trend with the following exceptions. Column 7 controls for cooling degree days and heating degree days. Column 8 weights by customer count (time-invariant). Column 9 weights by volume sold (time-invariant). Column 10 restricts the sample to states with less than 50 percent of homes using natural gas for heating. Column 11 restricts to states with more than 50 percent of homes using natural gas for heating. Column 12 is restricted to 1990 through 2004. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

Table A5: Estimating Residential Rate Structures, Alternative Specifications

	(13)	(14)	(15)	(16)	(17)	(18)
Cost, $MC_{it}Q_{it}$, in $	0.45***	0.42***	0.42***	0.43***		
	(0.04)	(0.03)	(0.03)	(0.03)		
$MC_{i,t-1}Q_{it}$	0.26***	0.25***	0.24***	0.24***		
	(0.03)	(0.03)	(0.02)	(0.02)		
$MC_{i,t-2}Q_{it}$	0.11***	0.10***	0.12***	0.12***		
	(0.02)	(0.03)	(0.02)	(0.02)		
$MC_{i,t-3}Q_{it}$	0.05*	0.07***	0.07***	0.07***		
	(0.03)	(0.02)	(0.02)	(0.02)		
Quantity	3.31***	3.04***	3.10***	3.06***		
	(0.44)	(0.26)	(0.74)	(0.26)		
Citygate price	-0.60**	-0.37*	-0.38**	-0.33**	-0.33**	-0.64***
	(0.26)	(0.18)	(0.16)	(0.16)	(0.13)	(0.20)
CDD						
HDD						
Citygate, lag 1		-0.13				
		(0.23)				
Citygate, lag 2		0.13				
		(0.16)				
Quantity, quadratic			-0.00			
			(0.06)			
Quantity, cubic			0.00			
			(0.00)			
Rising citygate indicator				-0.63*		
				(0.32)		
Observations	6,336	14,942	14,942	14,942	14,942	14,891
R^2	0.99	0.98	0.98	0.98	0.98	0.96

Notes: This table is identical to table 3 in the main text, with the following exceptions. Additional lags (4-12) on cost are included as controls, as in table 3, but are not shown here for space. All columns use fixed effects and a linear trend with the following exceptions. Column 13 is restricted to 2005 through 2015. Column 14 uses additional lags on the citygate variable. Column 15 controls for third-order polynomials for the quantity variables. Column 16 adds an asymmetric citygate effect (see text for details). Column 17 allows the markup and pass-through coefficients to vary by state and by five-year periods. Column 18 uses first-differences of all variables. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

Table A6: Estimating Commercial Rate Structures, Alternative Specifications

	(1)	(2)	(3)	(4)	(5)	(6)
Cost, $MC_{it}Q_{it}$, in $	0.50***	0.45***	0.46***	0.51***	0.45***	0.46***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
$MC_{i,t-1}Q_{it}$	0.21***	0.22***	0.22***	0.20***	0.22***	0.21***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
$MC_{i,t-2}Q_{it}$	0.10***	0.11***	0.11***	0.10***	0.11***	0.11***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
$MC_{i,t-3}Q_{it}$	0.06***	0.06***	0.05***	0.04**	0.05***	0.06***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Quantity	2.44***	2.73***	2.90***	3.13***	2.48***	2.83***
	(0.28)	(0.38)	(0.40)	(0.43)	(0.32)	(0.38)
Citygate price	-6.05***	-2.14	-3.96**	-8.88***	-1.97	-3.48**
	(1.98)	(1.40)	(1.57)	(2.02)	(1.38)	(1.42)
CDD						
HDD						
Citygate, lag 1						
Citygate, lag 2						
Quantity, quadratic						
Quantity, cubic						
Rising citygate indicator						
Observations	14,931	14,931	14,931	14,931	14,931	14,931
R^2	0.95	0.96	0.96	0.96	0.97	0.96

Notes: This table is identical to table 3 in the main text, with the following exceptions. Additional lags (4-12) on cost are included as controls, as in table 3, but are not shown here for space. All columns use fixed effects and a linear trend with the following exceptions. Column 1 has no seasonal controls. Column 2 uses a quadratic trend. Column 3 uses a cubic trend. Column 4 uses year effects. Column 5 uses state-specific linear trends. Column 6 controls for GDP growth and for PHMSA safety regulations. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

Table A7: Estimating Commercial Rate Structures, Alternative Specifications

	(7)	(8)	(9)	(10)	(11)	(12)
Cost, $MC_{it}Q_{it}$, in \$	0.45***	0.46***	0.46***	0.40***	0.50***	0.46***
	(0.03)	(0.04)	(0.03)	(0.04)	(0.05)	(0.05)
$MC_{i,t-1}Q_{it}$	0.22***	0.24***	0.24***	0.22***	0.21***	0.19***
	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)
$MC_{i,t-2}Q_{it}$	0.11***	0.14***	0.14***	0.10***	0.13***	0.10***
	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)	(0.02)
$MC_{i,t-3}Q_{it}$	0.06***	0.06***	0.06***	0.06**	0.05**	0.05**
	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
Quantity	2.63***	2.70***	2.80***	3.11***	1.99***	2.21***
	(0.44)	(0.36)	(0.38)	(0.49)	(0.27)	(0.40)
Citygate price	-1.90	-1.01	-0.75	-1.95	-1.53	-4.75***
	(1.31)	(1.66)	(1.51)	(1.76)	(1.73)	(1.57)
CDD	-0.15					
	(0.66)					
HDD	0.68					
	(0.96)					
Citygate, lag 1						
Citygate, lag 2						
Quantity, quadratic						
Quantity, cubic						
Rising citygate indicator						
Observations	14,931	14,931	14,931	8,411	6,520	8,595
R^2	0.96	0.96	0.96	0.96	0.97	0.96

Notes: This table is identical to table 3 in the main text, with the following exceptions. Additional lags (4-12) on cost are included as controls, as in table 3, but are not shown here for space. All columns use fixed effects and a linear trend with the following exceptions. Column 7 controls for cooling degree days and heating degree days. Column 8 weights by customer count (time-invariant). Column 9 weights by volume sold (time-invariant). Column 10 restricts the sample to states with less than 50 percent of homes using natural gas for heating. Column 11 restricts to states with more than 50 percent of homes using natural gas for heating. Column 12 is restricted to 1990 through 2004. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

Table A8: Estimating Commercial Rate Structures, Alternative Specifications

	(13)	(14)	(15)	(16)	(17)	(18)
Cost, $MC_{it}Q_{it}$, in \$	0.51***	0.46***	0.45***	0.45***		
	(0.04)	(0.04)	(0.03)	(0.03)		
$MC_{i,t-1}Q_{it}$	0.23***	0.22***	0.22***	0.22***		
	(0.03)	(0.04)	(0.02)	(0.02)		
$MC_{i,t-2}Q_{it}$	0.10***	0.08*	0.11***	0.11***		
	(0.02)	(0.05)	(0.02)	(0.02)		
$MC_{i,t-3}Q_{it}$	0.05	0.06***	0.06***	0.06***		
	(0.03)	(0.02)	(0.02)	(0.02)		
Quantity	2.78***	2.74***	0.63	2.74***		
	(0.61)	(0.38)	(1.29)	(0.36)		
Citygate price	-5.81*	-2.84	-2.31*	-1.59	-1.86*	-3.52***
	(2.78)	(1.92)	(1.19)	(1.38)	(1.02)	(0.95)
CDD						
HDD						
Citygate, lag 1		-0.43				
		(1.33)				
Citygate, lag 2		1.62				
		(1.81)				
Quantity, quadratic			0.02			
			(0.02)			
Quantity, cubic			-0.00			
			(0.00)			
Rising citygate indicator				-4.20*		
				(2.18)		
Observations	6,336	14,931	14,931	14,931	14,931	14,879
R^2	0.98	0.96	0.96	0.96	0.97	0.93

Notes: This table is identical to table 3 in the main text, with the following exceptions. Additional lags (4-12) on cost are included as controls, as in table 3, but are not shown here for space. All columns use fixed effects and a linear trend with the following exceptions. Column 13 is restricted to 2005 through 2015. Column 14 uses additional lags on the citygate variable. Column 15 controls for third-order polynomials for the quantity variables. Column 16 adds an asymmetric citygate effect (see text for details). Column 17 allows the markup and pass-through coefficients to vary by state and by five-year periods. Column 18 uses first-differences of all variables. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

Table A9: Summary Statistics, Utility by Year Panel

	Mean	Std. Dev.	N
Citygate price	7.58	2.38	2,666
Retail price			
Residential	13.30	3.79	2,629
Commercial	11.40	3.11	2,625
Industrial	9.76	3.54	2,371
Quantity			
Residential	6.49	1.84	2,666
Commercial	47.58	26.35	2,666
Industrial	5,778.13	11,683.51	2,666
Power Plant	111,957.71	320,432.13	2,666
Customers			
Residential	308,180.56	583,831.14	2,666
Commercial	24,624.75	34,062.64	2,666
Industrial	988.86	2,897.76	2,666
Power Plant	8.14	53.79	2,666
Expenditures			
Distribution O&M	6.90	3.21	2,578
Customer accounts, info, and sales	4.22	2.24	1,898
Administrative	10.50	7.26	2,577
Capital	10.30	10.44	2,440

Notes: A unit of observation is a utility in a year. For comparison with Table 2, the quantity and expenditure variables have been divided by 12 and thus are monthly amounts per customer. The sample covers 1998 through 2013. The subset of firms included is 229 large investor-owned utilities; see text for details. Prices are in $ per thousand cubic feet (mcf). Revenue is in $ per customer per month. Quantity is in mcf per customer per month. Expenditures are in $ per customer per month. Prices and revenue are listed in 2015 dollars.

Table A10: The Impact of Commodity Prices on Capital Expenditures, Alternative Specifications

	(1)	(2)	(3)	(4)	(5)
Citygate price	-0.19***	0.01	-0.41*	-0.12	-0.14*
	(0.06)	(0.10)	(0.22)	(0.08)	(0.07)
Quantity					
Residential		1.08*	1.01	1.12*	0.40
		(0.60)	(0.65)	(0.60)	(0.62)
Commercial		0.04	0.04	0.04	0.01
		(0.02)	(0.03)	(0.03)	(0.01)
Industrial		0.00	0.00	0.00	0.00*
		(0.00)	(0.00)	(0.00)	(0.00)
Power Plant		0.00	0.00	0.00	-0.00
		(0.00)	(0.00)	(0.00)	(0.00)
Heating degree days	-0.26	-0.70**	-0.78**	-0.77**	-0.34
	(0.17)	(0.33)	(0.33)	(0.33)	(0.29)
Utility effects	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	No	Yes	Yes
Year effects	No	No	Yes	No	No
Observations	2,434	2,434	2,434	2,434	2,434
R^2	0.63	0.63	0.64	0.63	0.59

Notes: Expenditures are per-customer and in 2015 dollars. Observations are weighted by the number of customers. Standard errors are clustered by state. Table is identical to Table 5 in the main text, with the following exceptions. Column 1 uses no controls other than utility effects and a linear trend. Column 2 uses a quadratic trend. Column 3 uses year effects. Column 4 uses the region-level average price as an instrument for the state-level price. Column 5 weights by customer count. *** Statistically significant at the 1% level; ** 5% level; * 10% level.

Table A11: Impacts of Citygate on Various Categories of Expenditures

	(1) Distribution	(2) Capital	(3) Customer Accounts, Info, and Sales	(4) Adminis-trative
Citygate price	-0.04	-0.13**	-0.00	0.02
	(0.03)	(0.06)	(0.02)	(0.03)
Quantity				
Residential	0.24	1.11*	0.19*	-0.30
	(0.27)	(0.59)	(0.10)	(0.21)
Commercial	0.01*	0.04	0.01***	0.02***
	(0.00)	(0.03)	(0.00)	(0.00)
Industrial	-0.00	0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Power Plant	-0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Heating degree days	-0.15	-0.76**	-0.11*	0.11
	(0.13)	(0.32)	(0.06)	(0.11)
Utility effects	Yes	Yes	Yes	Yes
Linear trend	Yes	Yes	Yes	Yes
Observations	2,574	2,434	1,891	2,573
R^2	0.82	0.63	0.78	0.85

Notes: Expenditures are per-customer and in 2015 dollars. Upper one percent expenditure outliers have been winsorized. Standard errors are clustered by state. *** Statistically significant at the 1% level; ** 5% level; * 10% level.