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SHOCK VALUE: BILL SMOOTHING AND ENERGY PRICE PASS-THROUGH*

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Energy prices are volatile, affect every consumer and industry in the economy, and are impacted by regulations including gas taxes and carbon pricing. Like the pass-through literature in general, the growing energy pass-through literature focuses on marginal prices. However, multi-part pricing is common in energy retail pricing. I examine the retail natural gas market, showing that while marginal prices exhibit full or nearly full pass-through, fixed fees exhibit *negative* pass-through. This is consistent with the stated desire by utilities and regulators to prevent 'bill shock.' I discuss implications for pass-through estimation and for proposed alternative pricing structures for regulated utilities.

I. INTRODUCTION

ENERGY PRICE PASS-THROUGH HAS RECEIVED MUCH RECENT ATTENTION (Marion and Muehlegger 2011; Borenstein and Kellogg 2014; Fabra and Reguant 2014; Ganapati *et al*. 2016; Stolper 2016; Knittel *et al*. [2017]; Lade and Bushnell [2019]; Muehlegger and Sweeney [2017]; Chu *et al*. [2017]). 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 twenty per cent, and more than ten per cent of months saw a year-on-year price change of at least forty per cent. Because gas input costs are observable, the natural gas distribution utility sector provides an ideal setting for understanding firm behavior.

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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 *et al.* [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 full or nearly full pass-through, fixed fees exhibit *negative* pass-through.

These results are consistent with the 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 *et al.*, 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).

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 data set on utility input costs, revenues, and volumes transacted, I recover the typical price structure of natural gas distributors in the U.S. In particular, I estimate the response of both volumetric charges and fixed fees to changes in input costs. Consistent with anecdotal and survey 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

[1] Retail prices are usually called 'rates' or 'tariffs.'
[2] Gas 'commodity charges' are automatically-updated charges designed to reflect gas input costs.

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 six per cent 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 three to eighteen per cent 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 2019), 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 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 *et al.* [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, and Levinson and Silva [2019], which examines how price structures might respond to concerns about income inequality. More

[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.

generally, a long literature has examined utility and regulator behavior (Joskow *et al*. [1996]; Guthrie [2006]; Leaver [2009]; Borenstein *et al*. [2012]; Abito [2016]; Lim and Yurukoglu [2018]). Non-academic papers providing recommendations for utilities and commissions for dealing with rate shock include Graves *et al*. [2007] and Kolbe *et al*. [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 *et al*. [1997]; Johnson [2002]; Davis and Hamilton [2004]; Tappata [2009]; Lewis [2011]). 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 *et al*. [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 *et al*. [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 *et al*. [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]; Nakamura and Steinsson [2008]; Boivin *et al*. [2009]; Kehoe and Midrigan [2015]; Gorodnichenko and Weber [2016]), 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 (Sibly [2002]; Rotemberg [2005]; Anderson and Simester [2010]; Rotemberg [2011]). 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.

In the consumer antagonism literature, firms are attempting to avoid the switching by consumers of products or suppliers. That is one potential explanation for the behavior I observe, since fuel switching away from natural gas is possible, and also since some states have retail choice programs. However, these options are limited (for instance, in most states retail choice programs are non-existent or have very limited participation), so for many consumers, no alternative is available. In that case, demand is not directly impacted by bill shock. 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 consistent with the idea of perceived 'fairness' in utility pricing, akin to that described by Zajac [1985]. The consumer antagonism channel is of interest in many settings beyond utility pricing. 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 II provides background on utility pricing. Section III provides a model of retail pricing with and without the desire to avoid bill shock. Section IV shows empirical results for the price structure as well as capital expenditures. Section V concludes with thoughts on welfare and policy implications.

II. BACKGROUND

II(i). *Natural Gas Utilities*

Natural gas providers in the U.S. 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 U.S. 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 per cent 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 eight to fourteen dollars in nominal terms, changes several times for the first utility and just once for the second. 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]).

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.

[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, the typical (both mean and median) utility changes its volumetric mark-ups every two years. For fixed fees, the median frequency of changes is every three years and the mean is every four years.

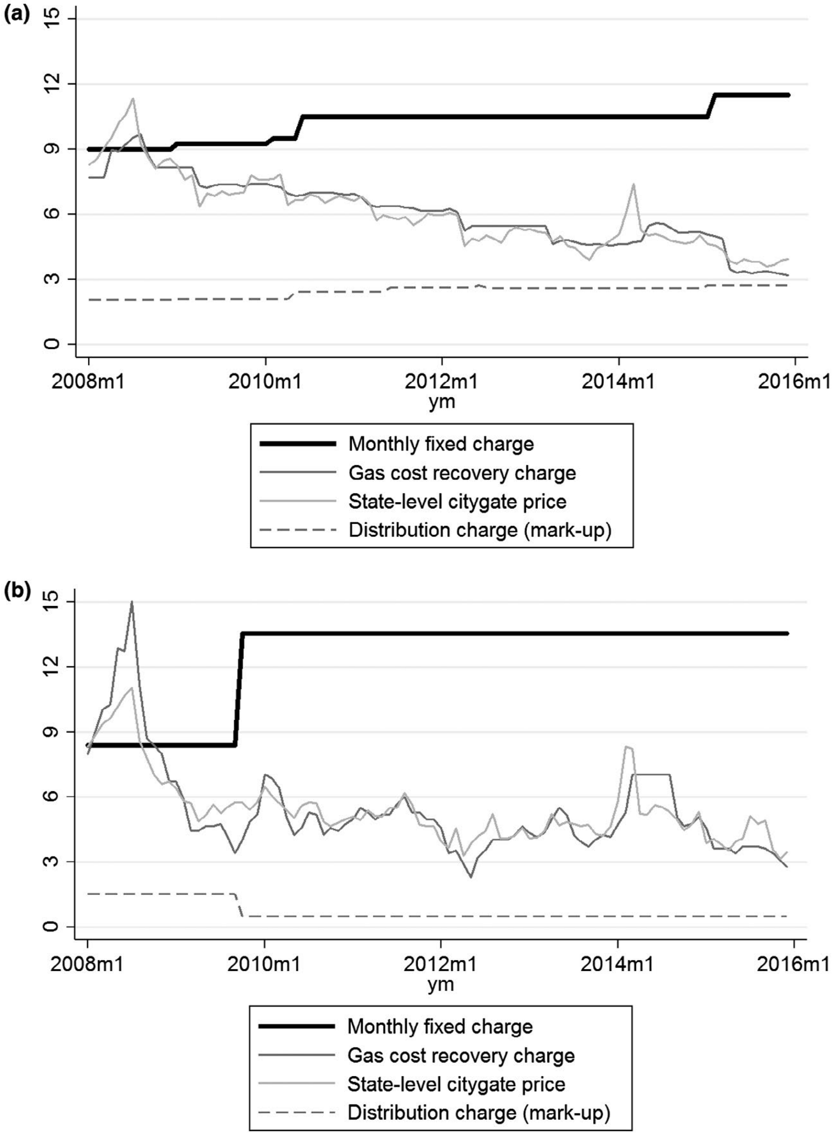

Figure 1
Bill Components for Two Example Utilities

Notes: 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 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.

II(ii). *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 *et al*. [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 docu-

[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*.

ments 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 *et al*. [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 *et al*. [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 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. America's natural gas utilities are using this opportunity to continue to improve our nation's 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 the '[l]ow 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

[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*.

[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?filingxml:id=1193125-15-106014&cik=1130310*.

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 Leaver [2009] or Abito [2016].[18]

II(iii). *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 (Graves and Levine [2010]; Costello [2016]). 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 (Graves and Levine [2010]; Borenstein *et al*. [2012]; Costello [2016]). The extent of hedging has varied over time, but recent reports indicate that the use of storage is nearly universal (perhaps accounting for a quarter or a third of winter volume) and the use of financial instruments is also widespread (typically at a term of around a year) (Energy Information Administration [2007]; Graves and Levine [2010]; American Gas Association [2016]; Costello [2016]). While long-term contracts are also used, they are frequently written with first-of-month pricing rather than fixed pricing (Graves and Levine [2010]; American Gas Association [2016]). Below, I consider

[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 *et al*. [1998]; Borenstein [2013].

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

[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. See the *Journal's* editorial web site for the Appendix.

how hedging would enter my model as well as how it could impact my empirical results.

III. 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 *et al.* [1996].[20] This could be because consumers 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 Zajac [1985] and Kahneman *et al.* [1986].[21] The regulator's problem then becomes:

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

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

[20] For extreme examples of political pressure, outside the U.S. context, see McRae and Meeks [2016].

[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.

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.

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,[22] 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 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 U.S. is under seven mcf per month (shown below, in Table II). 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.

Third, 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

[22] 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.

total does not rise.[23] 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.

It is worth thinking about two alternative versions of the model that could also lead to observed smoothing. First, consider the extensive margin, i.e., the consumer's decision to enter or exit the gas market, thus incurring or avoiding the fixed customer charge.[24] The above model assumes there is no extensive margin. In a setting where the firm has no discretion over the *level* of fixed costs, only over the *timing* of their recovery, and where consumers are forward-looking, the extensive margin is unlikely to be central for the analysis. 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. However, if the firm were able to adjust the total amount of fixed cost recovery, or if the consumer were myopic, then it would be possible to imagine a setting where bill smoothing is used to prevent consumers from exiting the market. Specifically, as the marginal price rises, the consumer surplus triangle (gross of fixed fees) falls. If it falls enough, then consumer surplus net of the fixed fee becomes negative, and the consumer chooses to exit the market.[25] Note this intuition is in line with the consumer antagonism literature cited above. The empirical analysis that follows explores the possibility of heterogeneity across states along this dimension.

Another extension of the model would lead to a slightly different explanation for observed bill smoothing. Suppose the utility hedges a portion of its volume – using storage, a long-term contract, or a financial instrument. Then if the marginal cost of gas rises, this change affects only a portion of volume purchased and sold. In this case, even though the utility would adjust its marginal price upward, the fixed fee could be adjusted

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

[24] For the natural gas market, exit from the market is possible for two reasons. The consumer may decide to switch fuels (for instance, by using electricity for cooking and space heating), or in some states, the consumer could decide to switch retailers. Fuel switching towards natural gas is expensive but has occurred in some parts of the country in recent years (Myers [2018]). Retail choice is available in many states, but in practice participation is very limited in all but a few states (Energy Information Administration [2011, 2017]). For analysis of retail choice in electricity markets, including a description of the consumer inertia that limits participation, see Puller and West [2013] and Hortacsu *et al.* [2017].

[25] The extensive margin could also matter in a setting with positive volumetric mark-ups, as detailed in Borenstein and Davis [2012].

downward with the firm still meeting its revenue constraint. To the extent that hedging was motivated by a desire to keep bill totals stable (as described in Section II(iii)), this would simply imply a different *mechanism* by which fixed fees are used to smooth bill shock. Below, I discuss the role of hedging in my empirical analysis.

Overall, this two-period model shows a context where the desire to avoid bill shock leads to bill smoothing. Under the assumptions made here (no uncertainty, homogenous customers, etc.), marginal prices are not distorted, and fixed fees are used to fully smooth all variable cost shocks. As a result, one would empirically observe negative pass-through to fixed fees.

It is possible that in a more complicated model, partial but not full smoothing would occur. For instance, if there were uncertainty, the form smoothing would take and the magnitude of the smoothing could depend on the regulator's expectation over the path of future cost shocks. Note also that in this simplified model there is no volumetric mark-up at the optimum, although in practice such mark-ups exist (Davis and Muehlegger [2010]). The presence of a mark-up could impact whether and how fixed fee smoothing is used by a regulator, and smoothing could be used for the mark-up as well as the fixed fee. To examine whether bill smoothing occurs in practice, and if so, how large it is and what form it takes, I next turn to empirical pass-through analysis.

IV. EMPIRICAL ANALYSIS

IV(i). *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 data set that aggregates this information across the more than 1,300 utility providers in the U.S.[26] However, I begin by leveraging three limited data sets: a survey by the American Gas Association, a survey by Memphis Light, Gas and Water (a municipal utility), and my own retail pricing search.

The American Gas Association has periodically conducted an unbalanced survey of fixed fees at around 150 to 200 utilities.[27] 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 England, Middle Atlantic, East North

[26] 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].

[27] 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_2015-03_customercharge2015.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_0.pdf*.

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).[28] 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.[29] The mean fixed fee in these data is $13 per customer per month.

Finally, I collect residential tariff data for the 40 largest utilities in the U.S., using a combination of searches of utility and commission websites, contacting utilities directly, and the Internet Archive (*archive.org*). The resulting data set 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.[30] Roughly matching the AGA survey data, the mean fixed fee in these data is $12 per customer per month. The mean volumetric mark-up is $4/mcf, and the mean gas commodity charge is $6/mcf.

Reassuringly, the mean fixed fee is roughly comparable across the three data sets. Additionally, while each data set has limitations, they are likely to be different across the sources, so no systematic error across the data sets 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 data collection does not yield a balanced panel nor a random sample, it does provide information at the monthly level for the largest utilities. It also allows for examination of volumetric prices (including a breakdown into gas costs and mark-ups), which are not in either the AGA or the MLGW data.

[28] 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.

[29] That is, I calculate the fixed fee as: the bill total at 1 mcf minus one quarter the difference between the five and one mcf bill totals.

[30] There are a few limitations to this data set, applying to both the fixed fees and the volumetric prices. First, the data set contains information on some, but not all, 'riders' – temporary surcharges (or occasionally credits) that do not require a full rate case. Second, the data set does not contain information on rates for anything other than the standard or default residential rate. For instance, low-income pricing is not in the data. Similarly, some utilities have different pricing plans across multiple service territories; in most cases, the data set has only captured the plan for one service area per state.

I also collect data on gas input costs to utilities. Specifically, I observe citygate prices in dollars per *thousand cubic feet* ($/mcf). The data are at the monthly state level, covering 1989 to 2015, and are from the Energy Information Administration (EIA) at the U.S. 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 *et al*. [2007]). I normalize all price variables to 2015 dollars, using the CPI-All Urban Less Energy. Note that since this citygate price variable is the average purchase price paid by the utility, it is inclusive of the hedging described in Section II(iii).[31] That is, any smoothing observed below is in addition to smoothing that occurs via hedging.

For each of the three data sets, I regress the monthly fixed fee on the citygate price, including fixed effects and a linear trend.[32] The level at which the fixed fee is applied varies across columns, since the cross-sectional unit varies. For Column 1, fixed fees are applied to Census divisions ($n = 9$). For Column 2, a utility in a city is the cross-sectional unit. For Column 3, the cross-sectional unit is a pricing plan at a utility. Most utilities are represented in the data set by a single pricing plan, but a few have, for instance, both a 'heating' and a 'non-heating' rate. In that case, each has its own fixed effect. Similarly, the frequency varies across data sets, based on data availability. For Column 1, the data are at the annual level, albeit with four to five year gaps. For Column 2, the data are annual, and for Column 3 they are monthly.

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 I. Column 1 shows a coefficient on citygate price of −0.47, statistically significant at the five per cent 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 data set, 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 per cent of 2015 levels) would translate to a four per cent 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

[31] Further analysis of this is discussed in the Appendix.

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

TABLE I
RESIDENTIAL BILL SMOOTHING

	(1) Fixed Fee	(2) Fixed Fee	(3) Fixed Fee	(4) Volumetric mark-up	(5) Volumetric gas cost
Citygate price, $/mcf	−0.47**	−0.31	−0.11**	−0.10**	0.96***
	(0.21)	(0.22)	(0.05)	(0.04)	(0.04)
Fixed effects	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes
Data set	AGA	MLGW	Top 40	Top 40	Top 40
Cross-sectional unit	Census division	Utility	Utility by rate	Utility by rate	Utility by rate
Frequency	Annual, with gaps	Annual	Monthly	Monthly	Monthly
Observations	27	337	5,410	4,549	3,219
Within R^2	0.63	0.08	0.17	0.04	0.75

Notes: Column 1 uses observations at the level of a Census division ($n = 9$), covering the years 2006, 2010, and 2015; the data source is AGA surveys. Column 2 uses an unbalanced panel of utility-level observations for 48 cities in the U.S. for the years 2007 and 2009-2016; the data source is a survey conducted annually by Memphis Light Gas and Water. Columns 3, 4, and 5 use an unbalanced panel of utility-level monthly observations for the approximately 40 largest utilities in the U.S. for the years 1994 to 2017; the data source is tariff sheets collected by the author. Most utilities are represented by just one rate; a few have, for instance, both a 'heating' and a 'non-heating' rate. Standard errors are two-way clustered by state and year in Columns 2 through 5. All prices are in 2015 dollars.
***Statistically significant at the 1% level. **5% level. *10% level.

in the bill total. However, with smoothing, \$0.47 (or seven per cent) 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 −0.31, albeit with noise. 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 point estimate of −0.11, also statistically significant at the five per cent level (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.

Finally, Columns 4 and 5 examine pass-through to volumetric prices, using the unbalanced panel from the 40 largest utilities. Given that these estimates cannot be compared across multiple data sets, in contrast to the results for fixed fees, they should be taken as suggestive. Column 4 examines pass-through to the volumetric mark-up, finding negative pass-through, i.e. smoothing. In contrast, gas cost recovery charges, which are separately delineated on the typical bill, exhibit full pass-through – a coefficient of one cannot be rejected at the five per cent level (Column 5). These results are intuitive: automatic pass-through clauses yield full pass-through, but smoothing may occur in volumetric mark-ups as well as in fixed charges. Because these results are limited to a non-random subset of utilities, I next turn to an empirical strategy that leverages a nationwide data set.

IV(ii). *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, for two of the data sets. 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[33] for four categories of 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

[33] Customer count data are annual.

TABLE II
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.

majority of volume delivered for the residential and commercial sectors (97 per cent for residential, 75 per cent for commercial) whereas only 20 per cent of industrial volumes delivered are represented in the reported industrial price.[34] Throughout my analysis, I focus on the residential and commercial sectors, for which data are more complete.[35]

Table II 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 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 motivated 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 II, 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.

[34] These data do not appear to be available for delivery to the electric power sector.
[35] I use data on the 48 contiguous states. A handful (approximately 0.1 per cent) of values are missing; these do not appear to be systematic.

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 average volumetric mark-up on natural gas purchases. I expand on their equation to estimate additional components of the price structure.

Re-writing Equation 7 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 10 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.[36] 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.

Note that one might also be interested in whether the volumetric component of the bill responds to citygate prices. This answer is simply given by the estimated volumetric pass-through, γ. Unfortunately, while in practice the volumetric component of a typical bill is composed of gas cost recovery charges and volumetric mark-ups, γ combines the behavior of these two components. That is, smoothing via volumetric mark-ups is not separately identified in this specification from incomplete pass-through of gas cost charges. If one is willing to assume one-to-one pass-through of gas cost charges (because of the automatic pass-through clauses described above), then the coefficient γ can be tested against one, as a test of smoothing.

To summarize, the final specification is as follows:

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

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. The average volumetric mark-up is estimated by β, as in DM. Pass-through to the volumetric price is estimated in the γ coefficients.

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 identifying assumption for Equation 12 is that any unobservables (i.e., components of ε_{it}) are uncorrelated with MC_{it} and Q_{it}. If utility pricing were always determined strictly by two-part pricing with a fixed fee and a

[36] 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.

volumetric fee, and if there were no heterogeneity across time or across states, this would be very straightforward: unlike in many regression contexts, we would know the exact components of the left-hand side variable and would simply be decomposing the variable into its distinct parts.

The potential concerns for bias, then, would arise if Equation 12 failed to capture features of utility pricing. For instance, in the case of increasing block or decreasing block pricing, it is possible that the error term could be correlated with Q_{it}. In the survey data for the 40 largest utilities, the majority of the utilities have flat volumetric fees, although increasing and decreasing block prices are both observed.[37] I address this concern below, by incorporating higher order terms of the quantity variable. Below I also examine the possibility of heterogeneity across states and across times.

It has also been assumed for this equation that there are no unobservables correlated with MC_{it}. This would be violated if, for instance, the price of labor or other firm inputs were correlated with citgyate prices. To alleviate this concern, I have made the standard assumption that time series controls are adequate for absorbing such variation.

Finally, a remaining 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.

The results for Equation 6, separated by end-user type, are given in Table III. 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 per cent, with additional pass-through (of 46 per cent for residential, 43 per cent 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).[38]

[37] Of the 40 large utilities, 24 have a constant volumetric price, four have a non-constant price but with a cutoff well above the mean quantity consumed, seven have increasing block pricing (almost all in New York), three have decreasing block pricing (all in California), one has a non-standard rate structure, and one could not be located.

[38] Note the estimated volumetric pass-through of one contrasts with the survey results in Table I, which found smoothing of the volumetric mark-up. This may be because the Table I results are for a non-random subset of utilities. For instance, in practice the survey data over-sample New York (25 per cent of the survey observations, versus eight per cent of residential sales according to the EIA data). When dropping New York, the coefficient from Column 4, Table I is estimated to be only −0.04, and zero volumetric smoothing cannot be rejected.

Table III
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
Within R^2	0.85	0.83

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 multiplied 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 per cent 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 six per cent) 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 four per cent, although it is not statistically significant.

The magnitude of this smoothing effect is consistent with the survey evidence presented in Section IV(i), suggesting that empirically estimating the price structure is an appropriate strategy where pricing data are limited. Recall that the survey data used in Table I are not comprehensive, but they can be used with very few identifying assumptions. In contrast, the EIA dataset used in Table III encompasses a balanced panel of all utilities across all service territories and including all tariff components. However, the EIA data require more identifying assumptions since tariffs are estimated rather than observed. The section that follows explores the robustness of the Table III results in greater detail. In the meantime, it is reassuring that Tables I and III yield similar estimates for the bill smoothing coefficient.[39]

It is worth briefly noting the distributional implications of this smoothing. Suppose citygate prices were to rise \$1/mcf, and suppose demand were perfectly inelastic. Then all customers on the standard residential pricing plan would see the volumetric component of their bill total increase, by \$1 times their monthly usage in mcf. Acting against this effect would be a \$0.38 decrease in their fixed fee. As such, there is no distributional impact in terms of the *level* of the smoothing. However, in proportional terms, the smoothing would be larger for low-usage customers – and larger for the typical low-income consumer, as usage and income are (weakly) correlated (Borenstein and Davis [2012]). Using the mean usage across income quintiles reported in Borenstein and Davis [2012], I calculate that the coefficient of \$0.38 would translate into a 7.5 per cent smoothing effect for the lowest income quintile,

[39] 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 IV
RESIDENTIAL BILL SMOOTHING, ALTERNATIVE SPECIFICATIONS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Citygate price	−0.37**	−0.62***	−0.38**	−0.33**	−0.47*	−0.38**	−0.33**
	(0.16)	(0.18)	(0.16)	(0.16)	(0.24)	(0.16)	(0.16)
Rising citygate indicator							−0.63*
							(0.32)
State by month effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Linear trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quadratic trend	Yes	Yes	No	No	No	No	No
Cubic trend	No	Yes	No	No	No	No	No
Weather controls	No	No	Yes	No	No	No	No
Sub-sample: <50% heating	No	No	No	Yes	No	No	No
Sub-sample: >50% heating	No	No	No	No	Yes	No	No
Cubic quantity control	No	No	No	No	No	Yes	No
Observations	14,942	14,942	14,942	8,411	6,531	14,942	14,942
Within R^2	0.85	0.85	0.85	0.84	0.86	0.85	0.85

Notes: The 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 uses a quadratic trend. Column 2 uses a cubic trend. Column 3 controls for cooling degree days and heating degree days. Column 4 restricts the sample to states with less than 50 per cent of homes using natural gas for heating. Column 5 restricts to states with more than 50 per cent of homes using natural gas for heating. Column 6 controls for third-order polynomials for the quantity variables. Column 7 adds an asymmetric citygate effect (see text for details).
***Statistically significant at the 1% level. **5% level. *10% level.

a 6.9 per cent effect for the middle income quintile, and 5.7 per cent effect for the highest income quintile.

IV(iii). *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 observe directly 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 IV, which focuses on the residential sector. Full estimation results, along with commercial sector results and additional robustness checks, are given in Tables A3 through A8 in the Appendix.

First I estimate the specification using alternative controls: including a quadratic time trend, a cubic time trend, or weather controls (Columns 1 through 3). Specifications in the Appendix drop time-series controls; drop seasonal controls; include year effects; include state-specific linear trends;

or control for GDP growth and for safety regulations taking effect in 2010 that may have impacted utility expenditures (Hausman and Muehlenbachs [2019]). The negative impact of the citygate price is robust to these alternative specifications, and the magnitude is occasionally larger than in the main specification.

I next separate the sample according to the portion of homes in the state that use natural gas for their home heating.[40] 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 4 and 5). An additional specification in the Appendix drops the three states with active and well-subscribed retail choice programs; results without these states are similar to the main results.

I next verify that the results are not driven by various mechanical features of the main specification. First I 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 6; results for the smoothing coefficient remain similar. In the Appendix, I also include two lags of the citygate price. The coefficients on lagged citygate are not statistically significant, 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 next allow for an asymmetric smoothing effect by including a dummy for whether citygate prices have risen year-on-year. The estimated coefficient is negative, consistent with utilities, regulators, or customers being more concerned with rising bill totals than with falling bill totals. However, the confidence interval is large, so this result should be taken only as suggestive. Note the negative and statistically significant coefficient on citygate price remains, indicating that the bill smoothing effect is not solely present when citygate prices are rising (Column 7).

Additional robustness checks in the Appendix are as follows. I weight by either customer counts or volume sold (time-invariant). I also separate the sample into early (1989-2004) and late (2005-2015) periods. I next allow for heterogeneity in the pass-through and mark-up coefficients to vary by state and by five-year blocks. Finally, I estimate the specification in first differences

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

rather than levels. I estimate a negative smoothing effect for all of these alternative specifications.

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 I.

Overall, while I have considered a very wide range of potential empirical issues, I consistently 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. The magnitude of the effect varies somewhat across these alternative specifications, with the lowest point estimate −0.23 and the highest −1.18 (see Appendix). These estimates imply that three to 18 per cent 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 the alternative specifications from −0.75 to −8.88, implying smoothing of one to 17 per cent at the typical quantity purchased. These negative point estimates are consistent with bill smoothing, matching the theoretical model as well as the anecdotal evidence from the utility industry.

IV(iv). *Frequency of Fixed Fee Changes*

As described in the background section, volumetric gas cost recovery charges tend to update every month, whereas volumetric mark-ups and fixed charges are changed only every couple of years. This may explain, at least in part, why the previous sections found only partial smoothing of cost shocks via the fixed fee. In some months, zero smoothing can occur because utilities are not able to adjust mark-ups and fixed fees. At other times, such as during a rate case, fees may be able to change freely. There may also be intermediate cases: times when a temporary rider can be added, removed, or adjusted – but where the magnitude of the change is smaller than that allowed during a full rate case.

To understand the impact of this, I estimate the heterogeneity of the smoothing effect across three groups of utilities, sorting utilities by how frequently they experience rate changes. Specifically, for each sample month for which I observe fee data for the forty large utilities described in Section IV(i), I generate an indicator variable equal to one if the fixed fee changed in nominal terms from the previous month. I then calculate the mean of this variable for each utility/rate combination. The mean is only

0.05 and the median 0.02: as described above, in a typical utility, fixed fees only change every two to four years. I group the utility/rate units into three groups: those with a low frequency of rate changes (fewer than one per cent of sample months); medium frequency (one to two per cent of sample months); and greatest frequency (at least two per cent of sample months). Note that a comparable analysis cannot be conducted using the EIA data from Section IV(ii), since revenue data (as opposed to rate data themselves) do not allow me to observe how frequently fixed fees change.

Results are shown in Table V. Recall that the coefficient when all utility/rate combinations are pooled is −0.11 (Column 3 of Table I). The coefficient for the 'medium frequency' group is similar: −0.14, statistically significant at the five per cent level (Column 2 of Table V). In contrast, there is essentially no smoothing observed for the utility/rate units with nearly flat fixed fees, as expected (Column 1). And for the grouping of states with the most frequent changes (Column 3), the coefficient is more than twice as large (−0.24) as the pooled coefficient.

Two things are worth noting. First, it is essentially a mechanical result that the coefficient in Column 1 is nearly zero – for the utilities in that sample, fixed fees are not observed to change, so by definition smoothing is not observed. Along the same lines, it makes sense that the coefficient in Column 3 is larger – since fixed fees are observed to change more often, more smoothing is expected. At the same time, there may be other unobserved differences between the utilities across the three sub-groups.

Overall, these results point towards an explanation for the partial smoothing observed in all the previous results: the main results pool across rate case

TABLE V
HETEROGENEITY BY RATE CHANGE FREQUENCY

	(1) Least frequent	(2) Medium frequency	(3) Most frequent
Citygate price, \$/mcf	0.05	−0.14**	–0.24**
	(0.04)	(0.05)	(0.08)
Fixed effects	Yes	Yes	Yes
Linear trend	Yes	Yes	Yes
Observations	2,089	1,227	2,094
Within R^2	0.03	0.06	0.59

Notes: This table uses specifications identical to Column 3 of Table 1, but with heterogeneity by how often a utility's fixed fee is observed to change (in nominal terms) from one month to the next. The sample is divided into three groups. For the 'least frequent' sub-sample of utilities in Column 1 (13 units in ten states), fixed fees change in fewer than one per cent of the months. For the Column 2 sub-sample (eight units in eight states), fixed fees change in one to two per cent of the months. For the Column 3 'most frequent' sub-sample (24 units in 11 states), fixed fees change in at least two per cent of the months. Standard errors are two-way clustered by state and by year.
***Statistically significant at the 1% level. **5% level. *10% level.

periods when fixed fees are adjustable, and across periods when fixed fees are frozen.

IV(v). *Modeling Expectations over the Future Citygate Price*

One potential concern with the previous specifications is that the current citygate price may not accurately reflect the expecations of the regulator over the future citygate price. In a world where fixed fees are freely adjustable in all periods, this might not matter; the regulator could simply continue updating as new information about costs is revealed. However if the regulator is *committing* to a fixed fee that will hold even as new cost shocks occur, then using the current price could introduce measurement error. To examine this issue, I next model the regulator's expectations over the future path of the citygate price.

Unfortunately, an appropriate futures contract is not vailable. Futures contracts for natural gas tend to be both upstream of the price paid by utilities, and to be fairly short-term relative to the horizon over which fixed fees are frozen. For instance, the natural gas futures prices reported by the EIA are for Henry Hub prices, up to four months out. In contrast, I would ideally observe a futures contract at each state-level citygate, for a horizon of at least a year.

As such, I construct an expected future citygate price using forecasting regressions. Conceptually, this procedure takes two steps: the first constructs a rolling average citygate price, rather than a one-month spot price – since the fixed fee may be frozen for a certain period, the regulator will care more about the average future price over that period than about the price in just one month. Second, a forecast for that rolling average citygate price is generated using lagged citygate price – in particular, just the lagged prices available to the regulator at the time that the forecast is being created.

Specifically, in the first step I construct the rolling average citygate price over the previous twelve months. So for January, 1995, for instance, I average citygate prices from February, 1994, through January, 1995:

$$\overline{MC}_{it} = \sum_{j=0}^{11} \omega_{i,t-j} MC_{i,t-j}.$$

Here $\omega_{i,t-j}$ are state-specific calendar month quantity weights (e.g., the average quantity sold in Michigan in July).

I then regress the rolling average citygate price on the information available from the *previous* year:

$$\overline{MC}_{it} = \eta + \sum_{j=12}^{23} \lambda_j MC_{i,t-j} + \varepsilon_{it} \quad (7)$$

So for January, 1995, I regress the rolling average on prices from February, 1993, through January, 1994. Results from this regression are given in the Appendix.

Finally, I forecast the *following* year's rolling average price using the coefficients from Equation 14 and the most recent year's prices:

$$\widehat{MC}_{i,t+12} = \sum_{j=0}^{11} \hat{\lambda}_{j+12} MC_{i,t-j}$$

I.e., in January, 1995, I use the vector of twelve λ coefficients and the February, 1994, to January, 1995, price path, to get a forecast of the average rolling price for January, 1995, through December, 1995.

This forecast future average price can then be used in the smoothing regressions to estimate the magnitude of fixed fee smoothing, in lieu of the current observed price. I run the same regressions using survey data as in Table I and using EIA data as in Table III. For space considerations, I show only the coefficient on the citygate price. Results are given in Table VI.

If the spot price is not an accurate measure of the regulator's belief about the future price, then using it introduces measurement error, potentially attenuating estimates. That is, we would expect to see larger coefficients on the forecast price. Four of the five columns show a coefficient that is larger than the coefficient on the spot price from the previous specifications. Column 2, for instance, shows a (noisy) coefficient of −0.50, compared to −0.31 in Column 2 of Table I. Similarly, Column 3 shows a coefficient of −0.20, compared to −0.11 in Column 3 of Table I. Column 4 also shows a larger coefficient: −0.47, compared to a coefficient on the citygate price of −0.38 in Column 1 of Table III. At the typical quantity consumed, this corresponds

Table VI
Using Forecasted Price

	(1) AGA	(2) MLGW	(3) Top 40	(4) EIA, Resid.	(5) EIA, Comm.
Forecasted citygate price, \$/mcf	−0.28	−0.50	−0.20**	−0.47**	−1.92
	(0.20)	(0.38)	(0.08)	(0.21)	(1.69)
Fixed effects	Yes	Yes	Yes	Yes	Yes
State by month effects	No	No	No	Yes	Yes
Linear trend	Yes	Yes	Yes	Yes	Yes
Observations	27	293	4,985	14,942	14,931
Within R^2	0.57	0.08	0.19	0.85	0.83

Notes: This Table uses specifications identical to those in Tables 1 and 3, but the following year's average citygate price has been forecasted using the last twelve lags of the monthly citygate price. Columns 1 through 3 match Table 1, and use AGA survey data, MLGW survey data, and tariff data for 40 large utilities, respectively. Columns 4 and 5 match Table 3, and use EIA revenue, quantity, and cost data for the residential and commercial natural gas sectors. See text for details.
***Statistically significant at the 1% level. **5% level. *10% level.

to smoothing seven per cent of a cost shock. However for Column 1, the coefficient is somewhat lower than the comparable estimate from Table I, and for Column 5 the coefficient is essentially identical to the comparable estimate from Table III. None of the coefficients are statistically different from their current-price counterparts. Overall, it appears that somewhat larger estimates of the smoothing effect are obtained in regressions that allow the regulator to have more sophisticated beliefs about the future citygate price than a simple random walk. However, the difference in the coefficients is not economically significant.

IV(vi). *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 II 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 data set on expenditures for large investor-owned utilities. For this subset (n = 207) of investor-owned utilities, I observe data on capital expenditures[41] at an annual level for 1998-2013 in addition to quantity sold and average price by sector.[42] While only available for some utilities, these tend to be the largest firms; as such, this panel accounts for around 80 per cent of the residential and commercial volume distributed in the U.S. over this time frame. These

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

[42] 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.

TABLE VII
THE IMPACT OF GAS INPUT PRICES ON CAPITAL EXPENDITURES

	Capital
Citygate	−0.13**
	(0.06)
Utility effects	Yes
Linear trend	Yes
Observations	2,434
Within R^2	0.04

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.

data are reported to state-level public utility commissions, and they have been assembled across state-level records by SNL, a provider of industry data. Summary statistics are provided in the Appendix. I winsorize the right tail (the upper one per cent) 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 (HDD's),[43] 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 VII 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 III. 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 VII, capital spending falls by $0.13 per customer (statistically significant at the five per cent 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 II. The fracking supply boom lowered natural gas prices by $3.45/mcf from 2007 to 2013 (Hausman and Kellogg [2015]); the coefficient in Table VII implies that utilities in this sample increased capital expenditures by five per cent as a result. Robustness checks are shown in the Appendix; the result is somewhat sensitive to the time series controls used.

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

V. 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 used 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 per cent 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, quantity consumed remains at the socially optimal level. Note that in contrast, hedging as a strategy to reduce bill volatility can impact 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 per cent 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.[44]

Future research could examine the political and strategic processes by which rates are set, with a focus on this smoothing behavior. Future work could also relate this smoothing behavior to distributional questions in rate-setting. For instance, it would be interesting to examine how the process plays out in Democratic versus Republican states, in states with high

[44] If the overall level of expenditures is distorted, welfare implications could also arise because of demand elasticity along the extensive margin, as in Borenstein and Davis [2012].

proportions of households below the poverty line, or in states with high proportions of elderly households.[45]

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 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 is likely to 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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[45] Related questions are investigated in the context of electric utilities in Levinson and Silva [2019].

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