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CAREER CONCERNS, INACTION AND MARKET INEFFICIENCY: EVIDENCE FROM UTILITY REGULATION*

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We study how incentive conflicts known as 'career concerns' can generate inefficiencies not only within firms but also in market outcomes. Career concerns may lead agents to avoid actions that, while value-increasing in expectation, could potentially be associated with a bad outcome. We apply this theory to natural gas procurement by regulated public utilities and show that career concerns may lead to a reduction in surplus-increasing market transactions during periods when the benefits of trade are likely to be greatest. We show that data from natural gas markets are consistent with this prediction and difficult to explain using alternative theories.

I. INTRODUCTION

One of the central problems that managers and regulators face arises when they must rely on agents, whose efforts and abilities are imperfectly observable, to choose actions that will advance the manager's or regulator's goals. The usual solution when efforts and abilities are unobservable is to reward agents on the basis of observable outcomes. As Holmstrom [1982/1999] discusses, an important question is how to design a mechanism based on outcomes that will motivate an agent to undertake the level of risk that is optimal from the principal's point of view. There is more than one

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possible impediment. One classic reason why an agent may undertake insufficient risk is that he or she is simply more risk averse over income than the principal is. If this is the case, then an incentive scheme that rewards an agent as a linear function of the principal's payoffs will result in less risk-taking than the principal would prefer.

Holmstrom describes a second reason for an agent to undertake insufficient risk that does not hinge on risk aversion over income: 'career concerns.' Career concerns arise when agents differ in their levels of ability and when long-term rewards (such as compensation, retention or promotion) depend not only on the outcomes of the agents' actions but also on what the principal infers from those outcomes about the agents' underlying levels of ability.

Examples in which rewards are based only on outcomes (and are therefore *not* influenced by career concerns) include sales commissions or any kind of piece-rate compensation. In these cases, agents are paid on the basis of output and the principal makes no attempt to assess how hard the agent worked or how skilled he or she is. In contrast, there are many examples in which career concerns arise because rewards depend on *ex post* inferences rather than on explicit functions of output alone. Consider, for example, the tenure review process for assistant professors. While more and better publications will help a professor receive tenure, there are generally no explicit contracts that specify how many papers of what quality will guarantee tenure. Instead, the tenure decision depends in large part on the senior faculty's inference about the candidate based on the candidate's output and observable actions.

A key insight of Holmstrom's is that if agents recognize that their rewards depend in part on the principal's *ex post* inference, then they may try to manipulate the principal's formation of that inference. Considering an agent delegated to make investment decisions, Holmstrom concludes that he will not prefer the investment opportunities that have the highest expected payoffs but instead those that 'leave him protected by exogenous reasons for failure' (Holmstrom [1982/1999], p. 179 in 1999 version). Said another way, the agent 'will take less risk, because of a concern for the negative talent evaluation that follows upon failure' (Holmstrom [1982/1999] p. 180 in 1999 version).

Career concerns have since been discussed in a variety of contexts in the economics literature. Scharfstein and Stein [1990] point to inference manipulation as a reason for managers to mimic the investment decisions of others ('follow the herd'). Brandenburger and Polak [1996] show that decision-makers whose rewards depend in part on what an outside observer ('the market') thinks of the decision will ignore their own contrary private information in order to choose what the market thinks is correct, a phenomenon they call 'covering your posteriors.' Prendergast and Stole [1996] show that agents may distort the degree to which they appear to learn from

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new information in order to distort the inferences drawn by their principals. Harbaugh [2006] shows that an agent will avoid gambles in which a loss has the potential to reveal poor judgment. Finally, Chevalier and Ellison [1999] show empirically that the portfolio choices of mutual fund managers and their promotion and retention outcomes are consistent with a career concerns model.

Business practitioners also recognize this phenomenon. During the 1980's, a period in which IBM dominated the emerging personal computer market, this behavior was embodied in a phrase that was known by every corporate purchasing agent: 'No one ever got fired for buying IBM.' Taking the risk of purchasing a different brand of PC was seen as having tangible downside for the purchasing agent if the alternative machine performed poorly and little upside if it resulted in overall cost savings.

In this paper, we aim to extend this aspect of the principal-agent literature by examining empirically the impact of career concerns not only *on the firm* but also *in the market* when many firms make decisions this way. Such impacts could arise in many situations, given the wide array of settings in which career concerns potentially apply. To date, studies examining the broader impacts of career concerns have focused on financial markets, showing that career concerns can exacerbate credit cycles (Rajan [1994]), preclude information revelation (Dasgupta and Prat [2008]), and amplify the impact of financial shocks on bond prices (Guerrieri and Kondor [2009]). In contrast, we examine markets for a physical good—natural gas—over which firms hold private valuations. We find that career concerns in this setting reduce firms' incentives to undertake transactions, distorting market prices and resulting in a loss of surplus-increasing trade.

We focus on the gas procurement decisions of regulated gas utilities (local distribution companies). Regulators, who are the principals in this context, want utilities, who are the agents, to minimize their costs so as to minimize ultimately the costs to ratepayers, but at the same time they want utilities to ensure service quality by avoiding service curtailments. We argue that career concerns in this setting are manifest at the firm level as *inaction* in forward wholesale markets: utilities will avoid transactions that could lead regulators to conclude that the utility was to blame for negative outcomes such as high procurement costs or service failures.[1] In our model, utilities may receive only a noisy signal of whether they should sell or purchase gas in forward markets. We argue that even if a utility believes that selling gas in the forward market is the better decision in expectation, it may instead make no forward transaction if there is a possibility that it will later need to re-purchase gas at a very high price on the spot market or be forced to curtail customers. The need for high-cost spot market

[1] In other contexts, career concerns can lead to inefficiently high levels of effort, rather than inaction.

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procurement may still arise should the utility not undertake a forward transaction; however, in this case the utility will be able to blame its inaction on exogenous market forces because local natural gas markets are occasionally illiquid. That is, the utility will be able to claim that it attempted to purchase gas on the forward market but was thwarted by illiquidity. The utility cannot make this argument if it actually sold gas during the forward market, since it will have revealed itself as having adjusted inventories in the (*ex post*) wrong direction. Thus, inaction is a means for the utility to protect itself from revealing a mistake in judgment.

When multiple utilities are affected by career concerns and display a resulting preference for inaction, the efficiency of wholesale markets may be adversely affected. In particular, in 'tight' markets in which demand is high and the threat of extremely high spot prices and even curtailments is salient, inaction will lead to a reduction in the volume of forward transactions and a forward price premium. In this way, career concerns that operate within a firm can spill over to have implications for market outcomes. In our context, the implication is that efforts on the part of agents to influence principals' inferences can distort markets by eliminating Pareto-improving trades. Moreover, this distortion occurs at the times when the potential gains from trade are likely to be greatest.

The data and our empirical analysis do not permit a direct test of career concerns. Rather, we use market-level data from more than 100 local gas markets between 1993 and 2008 to establish two empirical regularities: forward price premia increase and forward trading volumes fall in tight markets. These two regularities are consistent with our model of career concerns, and we argue that they are not well-explained by a standard model of forward markets. Thus, our tests of career concerns are indirect. Unfortunately, firm-level data on transactions are not available, so we cannot observe individual actions within a firm that could yield more compelling evidence of career concerns, nor can we investigate inter-firm differences in incentives or organization. Within the standard model of forward markets, we do consider two factors that could drive some of the market outcomes we observe, namely price risk aversion and 'security of supply' concerns (i.e., stockout risk). We conclude that, given the institutions of the natural gas market, these factors could create a forward price premium, but neither could explain the decline in forward market trading volumes that we find occur when the market is tight. Here again our inference is indirect. While we consider what we think are the most likely alternative explanations, there could be other alternative theories that are consistent with one or both of our empirical findings.

In what follows, we first present in section II a simple, general model that formalizes the idea that career concerns can lead to inaction and then relate the model to the context of natural gas procurement. Section III describes the relevant institutional details of the natural gas industry and the specific

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incentives for inaction in tight markets. Section IV discusses the impacts of inaction on market performance and derives market-level empirical implications. Section IV also describes several alternative mechanisms that might generate similar empirical predictions in these markets. Sections V and VI describe, respectively, our data and empirical approach. Section VII presents our empirical results and discusses the extent to which the estimated results support either career concerns or alternatives as explanations for what we observe. Section VIII concludes and discusses broader implications.

II. A MODEL OF CAREER CONCERNS AND INACTION

II(i). *The Model*

This section presents a simple principal-agent model that demonstrates how career concerns may lead to inaction. In the model, some agents will prefer to take no action rather than take an action that increases the principal's value in expectation but potentially reveals the agent to be of the type the principal finds less desirable.[2]

Consider a risk-neutral principal that would like in each period to maximize a scalar value $V_t = \beta_t\theta_t$, where θ_t is a choice variable $\theta_t \in \{-1,0,1\}$ and β_t is a random variable with mean zero that is continuously distributed on $\left[\underline{\gamma}, \overline{\gamma}\right]$, where $\underline{\gamma} < 0 < \overline{\gamma}$.

The principal cannot observe β_t directly before having to choose θ_t, but the principal employs a risk-neutral agent whose job it is to know β_t in each period and to choose θ_t in order to maximize V_t. Each period, the agent receives compensation equal to some share of V_t, including when V_t is negative. Since the probability is zero that $\beta_t = 0$, it will always be optimal from the principal's perspective to have a well-informed agent choose either $\theta_t = 1$ or $\theta_t = -1$. Some share of the time, α, however, the agent is forced by exogenous circumstances to choose $\theta_t = 0$, which might be thought of as taking no action since it guarantees $V_t = 0$. The principal cannot verify in any given instance whether the agent has been forced to choose $\theta_t = 0$ or has done so voluntarily.

There are two possible types of agents. Agents know their types, but an agent's type is unobservable to the principal. Type A agents always get a perfect signal of β_t and, given their incentives, choose the optimal θ_t. Type B agents get a perfect signal of β_t with probability ρ ($0 < \rho < 1$ and uncorrelated with β). With probability $1-\rho$ they get a noisy signal, $\hat{\beta}$. The noisy signal is unbiased, $E\left[\hat{\beta}\right] = \beta$, but has support over $\left[\underline{\gamma}, \overline{\gamma}\right]$ and can indicate

[2] The model's setup is in the spirit of Brandenburger and Polak [1996]; it differs in that it focuses on the agent's possible strategy of taking no action at all in order to avoid revealing information about his or her type.

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the incorrect sign of β. The agent knows whether the signal it has received is perfect or noisy. The principal knows that both type *A* and type *B* agents exist but does not know which type its current agent is.

After each period, the principal observes β_t, θ_t, and V_t. The principal receives V_t and pays (or charges) the agent a share of it. The principal then decides whether to retain or fire the agent. If the agent is fired, a new agent is drawn from a pool of agents of both types. The probability of drawing a type *A* agent is known to the principal and is strictly between zero and one. Following the retention or firing decision, a new period begins. We assume that the environment is changing frequently enough, the relationship between principal and agent is short enough, or α is large enough that the principal cannot reliably infer whether the rate at which the agent takes action $\theta = 0$ is inconsistent with α.

This model implies the following results.

Result 1: If a type *B* agent wished solely to maximize the expected V_t (no career concerns), then it would never voluntarily choose $\theta_t = 0$.[3]
Result 2: An agent that chooses θ_t of the wrong sign is fully revealed to be type *B*.[4]
Result 3: If hiring is costless, the principal should always fire an agent revealed to be type *B*.[5]
Result 4: Depending on the type *B* agent's outside employment opportunity and discount rate, in equilibrium it may respond to an imperfect signal by claiming, untruthfully, that it is forced to select $\theta_t = 0$ that period.

The first three results follow directly from the model. Result 4 arises because a type *B* agent knows that if it makes a mistake, it will be fired immediately. When the type *B* agent knows that its signal is perfect, there is no chance that it will be fired if it acts in accordance with the signal. However, when the agent knows that its signal is imperfect, acting in accordance with the signal will lead with a nonzero probability to a mistake. If that probability is large enough (either because $\hat{\beta}$ is very close to zero or the signal is very noisy), if the agent's outside employment opportunities are poor enough relative to the existing contract, and if its discount rate is low enough, then the type *B* agent will choose to forego the

[3] Proof: When the signal is perfect, choosing θ_t with the same sign as β_t results in $V_t > 0$ with certainty. Even when the signal is imperfect, choosing θ_t with the same sign as $\hat{\beta}_t$ results in $E[V_t] > 0$.

[4] Proof: Type *A* agents are always perfectly informed. They know which θ_t will maximize V_t, and it is in their interest to choose that θ_t.

[5] Proof: The expected value of a new draw is higher than that of a certain type *B* agent because the new draw can be no worse than type *B* and because there is no scope for improvement in the model.

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chance to earn the positive payment it would obtain if it chose θ_t correctly.[6] It will instead claim that it could not choose a non-zero θ_t due to exogenous factors. This inaction prevents the principal from having an opportunity to infer that the agent is of the low-quality type.[7]

II(ii). *Correspondence of the Model to Natural Gas Procurement*

Here, we summarize the correspondence between the model and the context of natural gas procurement before giving a more complete description of the institutional features of natural gas markets in section III.

The principals in the model correspond to state Public Utilities Commissions (PUC's). PUC's have two primary objectives: (1) to ensure reliable gas supply so that customers will not be interrupted, even during peak demand periods; and (2) to minimize customer rates while allowing the utility to achieve a reasonable rate of return. The agents are local distribution companies (LDC's). LDC's are public utilities that are responsible for purchasing natural gas on wholesale markets and distributing that gas through a local network of gas lines to ratepaying customers in a defined geographic area.

The value function in the model represents the value of the LDC adjusting its gas position for period t, i.e., making transactions to change the amount of natural gas the LDC has available to fulfill the demand arising from its customers in period t. The LDC's position includes both gas the LDC has in storage in its local distribution area and scheduled gas deliveries arranged under long-term contracts with gas suppliers and interstate pipeline companies, either of which can be increased or decreased through pre-period t transactions. The value function V_t incorporates both the principal's goal of service reliability and its desire for the LDC to minimize its costs of operation and thereby minimize customer rates. Operation costs include the costs of procuring gas, expenses associated with holding excess reserves of gas in inventory, and opportunity costs of not selling gas on wholesale markets.

[6] The proof of this possibility result is straightforward by showing that it can't be privately optimal for a type B agent never to lie. Consider the case in which $\hat{\beta} = +\varepsilon$, arbitrarily close to zero. The gain from choosing $\theta \neq 0$ is arbitrarily small and the probability of being revealed to be type B is substantial, nearly 50% if $\hat{\beta}$ is distributed symmetrically. Under the assumption that the environment is changing sufficiently frequently that the principal cannot reliably infer whether the rate at which the agent takes action $\theta = 0$ is inconsistent with α, lying by choosing $\theta = 0$ does not impose a risk of being fired.

[7] It is important to the results that the principal not be able to commit never to fire the agent. Since the principal in equilibrium does not learn about the agent's type, such a commitment would be optimal for the principal because it would eliminate the incentive of a type B agent to choose not to act (acting always yields positive value for the principal in expectation). Assuming that the principal cannot commit to retain the agent seems appropriate in our context of utility regulation and in most business settings.

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An explicit, non-stylized form of this value function would be more difficult to specify than that of a typical profit function because the pressures PUC's face are political pressures rather than profit pressures. A document called the 'Natural Gas Information Toolkit' published in 2008 by The National Association of Regulatory Utility Commissioners describes the pressure PUC's and LDC's anticipated arising when summer 2008 gas prices hit record levels: 'Social dismay could occur, especially in cold areas of the country where households consume large amounts of natural gas during the winter months. Gas utilities, in addition, could experience higher bad debt and other financial problems and, along with state commissions, would be the recipients of public wrath,' (NARUC [2008] p. iii). Speaking in more general terms, the *Toolkit* says, 'State commissions and gas utilities have taken the brunt of public outcries over high gas prices. State commissions desire to have natural gas remain affordable for all customers and priced ' "fairly and reasonably," ' (NARUC [2008] p. 2).

The value function at any point in time, V_t, dictates whether it is better (in expectation) for the LDC to purchase or to sell gas on the wholesale market. The job of the LDC is to know β_t, using projections of customer demand, and to act accordingly. The correct value of adjusting reserves is revealed when demand is realized, after the procurement decision has been made. The types of agents represent the possibility that some LDC's (or some individuals who are employed by LDC's) may be better than others at forecasting demand. The probability α that the agent is forced to choose $\theta = 0$ corresponds to the fact that local natural gas markets are occasionally illiquid, so that an LDC may not be able to trade without substantially moving the price or may not be able to find a counterparty at all.

The correspondence of the model's results to the natural gas procurement setting is that there may be instances in which the regulator's interest might be served best by the LDC's either buying or selling gas; however, the LDC would rather make no transaction than risk engaging in the wrong transaction. This preference for inaction occurs because the LDC, if it does nothing, can always claim *ex post* that it tried to do the right thing but was thwarted by the illiquidity of the market. Alternatively, taking an action would expose the LDC to the possibility that the action was incorrect, in which case the regulator would be able to infer clearly that a mistake was made.

III. NATURAL GAS PROCUREMENT AND INACTION IN 'TIGHT' MARKETS

This section presents the relevant details of natural gas markets and argues that LDCs' incentives for inaction will tend to be manifest only in 'tight' markets in which demand and prices are high. We also argue that the

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incentive for inaction will tend to be asymmetric, in that LDC's will be more wary of making sales of gas than of making purchases.

III(i). *Institutional Aspects of LDCs' Gas Procurement Decisions*

The delivery of natural gas to end-use consumers involves three stages: production from natural gas wells, interstate transmission, and local distribution. These three stages are handled by three different types of companies: natural gas producers, pipeline transportation companies, and LDC's, respectively. A fourth set of firms, gas marketers, act as intermediaries, aggregating volumes across producers (many of which are very small firms), matching buyers and sellers, and often taking market positions themselves.

Natural gas production in the United States is generally considered to be competitive — industry concentration amongst producers is extremely low — and wellhead prices have been fully de-controlled since 1993.[8]

The areas of the country in which natural gas is produced — a belt running northwest to southeast from the Rocky Mountains to the Gulf of Mexico[9]— is not where demand centers are. Demand is concentrated in the Northeast, Upper Midwest, and West Coast. Thus, a network of interstate transmission pipelines has been developed. The pipeline companies are distinct firms that do not own any natural gas themselves, but rather act as transporters of gas on behalf of producers, LDC's, and gas marketers. The maximum tariffs that interstate pipelines may charge are regulated by the Federal Energy Regulatory Commission (FERC) under a cost-of-service framework.

LDC's purchase gas on wholesale markets and deliver it to ratepaying customers.[10] Each LDC is regulated by its state's Public Utilities Commission (PUC), which controls retail prices through cost-of-service regulation in which the wholesale cost of gas supply is passed through to ratepayers. Retail prices generally adjust only with a lag, giving LDC's incentives to reduce their natural gas purchase costs if possible. An additional incentive is provided by the threat of a prudency review process should the PUC believe that the LDC is paying abnormally high prices for gas. An LDC can also expect to be reviewed if it does not procure sufficient gas supplies and must curtail customers. (Because retail rates are regulated and do not change on a day-to-day basis, there is little scope for end-use customer response to high wholesale prices.)

[8] Wellhead natural gas price deregulation began in 1978 with the Natural Gas Policy Act. Prices were fully de-controlled in 1993 under the Natural Gas Wellhead Decontrol Act.

[9] About 20% of the natural gas consumed in the U.S. is imported, about 90% of which comes from Canada.

[10] Some merchant electric generators and large industrial firms also purchase gas directly in wholesale markets.

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An LDC must make gas procurement decisions along two dimensions: (1) how far in advance to procure; and (2) whether to take ownership of wholesale gas at a location near its customers or at a location near gas producers. An LDC has three options for purchase timing: it can purchase gas through long-term contracts, through a monthly forward market called the 'bidweek' market, or in a day-ahead spot market. LDC's typically arrange to fulfill at least some of their natural gas needs by signing long-term contracts with natural gas marketers or relatively large producers that do their own marketing. These contracts often have time horizons measured in years and typically include (or are paired with) a purchase of transportation rights over the necessary pipelines to transport the natural gas from the production location to the LDC's distribution area.

The 'bidweek' market's name derives from the fact that it occurs during 'bidweek,' the last five trading days of each month. As it goes into bidweek, an LDC has a certain level of gas 'reserves' at its disposal to meet demand over the upcoming month. The level of reserves is determined by its long-term contracts and by storage carried over from the previous month. In the bidweek market the LDC can adjust its level of reserves by buying additional gas if it thinks its reserves are inadequate or by selling reserves for which the market price exceeds its private shadow value. Potential transaction partners include other LDC's, gas marketers, and large producers. Transactions in the bidweek market are for a specified volume of gas to be delivered to a local market for every day of the upcoming month. Bidweek markets operate at approximately 100 locations across the United States.

Finally, an LDC can make daily adjustments to its reserves through a day-ahead spot market. Spot markets, like bidweek markets, are local and provide LDC's with an opportunity to buy or sell gas in order to match their retail demand on a day-to-day basis.

In both the bidweek and spot markets, an LDC can carry out transactions near its service area or at some distance away. Should the LDC elect to take ownership near its customers, it must contract with a gas supplier for delivery to its local area; in this case, the supplier is responsible for arranging the necessary pipeline transportation. Alternatively, if the transfer of ownership occurs at a distant location, the LDC is responsible for contracting transportation. Transportation can be arranged either through a direct contract with the pipeline company or through a contract with an existing holder of transportation rights on the pipeline.

Market participants have indicated to us that the local bidweek and spot markets in areas served by LDC's are occasionally illiquid. These markets lack a centralized market-maker, and the consequent lack of information makes it difficult for LDC's to identify suitable trading partners and prices. Liquidity is also limited by a coordination problem because the transfer of the gas itself must be linked to a contract for the necessary pipeline transportation capacity. These search and coordination problems are

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particularly acute in the spot market, in which there is only one day to consummate a trade, although they are present at bidweek as well. Because of these barriers to trade, an LDC can occasionally find itself facing few suitable counterparties in its local market, leading to situations in which it can have market power exercised against it. Industry participants have also told us that instances may occur in which an LDC cannot complete a transaction at any price, particularly in the spot market.

III(ii). *Incentives for Inaction in 'Tight' Gas Markets*

We focus our analysis on the decisions of LDC's in the forward bidweek market. The task of an LDC in this market is to know whether to buy or sell gas given its initial reserve level, its projected customer demand over the upcoming month, and its projection of spot prices over the upcoming month. For example, if an LDC expects to need additional gas and believes that spot prices are likely to be higher than the price at which it can buy gas at bidweek, it should purchase bidweek gas.

LDC's are charged by regulators to be 'prudent' in acquiring gas supplies, which means (in very simple terms) that LDC's should acquire sufficient gas to serve customer demand and not pay too high a price for it. Regulators enforce this objective with the threat of prudency reviews and possible reprimands for LDC's who are determined *ex post* to have acted imprudently. The punishment value for LDC's of regulatory reviews is not easily specified, nor are punishments written into formal rules, but it is clear that the LDC's believe they are real and that their wish to avoid a review affects the decisions they make.

In particular, industry participants have expressed to us a belief that the expected regulatory penalty an LDC would face following a curtailment or a purchase of gas at an extremely high spot price varies with the inference the regulator would draw regarding why the incident happened. One utility executive told us with regard to this issue that '[avoiding] regret is the prime mover' in dealing with regulators. If an LDC is forced to purchase gas at extremely high spot prices or, even worse, curtail customers, it would prefer to be able to argue that it made a 'good faith effort' to avert the problem by buying gas at bidweek but was thwarted by an illiquid market. If the utility has in fact sold gas during bidweek, it will not be able to make this argument. Inaction during bidweek therefore protects LDC's from the risk of a particularly harsh regulatory review.[11]

Within the agency relationship between the regulator and the LDC, the threat of a regulatory review helps ensure that the LDC pursues the

[11] A 2001 report published by The National Regulatory Research Institute describes specific cases in which LDC's in various states were reprimanded or found to be imprudent for relying too heavily on spot markets and having to pay high prices for gas as a consequence (Costello and Cita [2001], pp. 59–62).

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regulator's prudency objectives. There are also political reasons for using the threat of a review. The regulator is ultimately accountable to the governor and legislature, and they in turn are accountable to their constituents. While high retail rates or curtailments will attract customer ire whenever they occur, the political fallout will be greater if the utility has taken some action that can be interpreted as having caused or contributed to the bad outcome. (Although the circumstances are quite different, the blackouts during the California electricity crisis and the subsequent recall of Governor Gray Davis suggest that a widespread belief that public utilities have been poorly overseen can have substantial political consequences.) An LDC can provide itself political 'cover' and some protection from 'Monday-morning quarterbacking' in a regulatory review of high-priced spot purchases or curtailments if it at least avoided selling gas in the preceding bidweek.[12]

In the simple model of section II, the principal's incentive to fire the agent following an incorrect decision stemmed from a rational inference about the agent's quality and the fact that the principal's value is maximized by hiring a new, potentially higher-skilled, agent. In the natural gas context, the regulator cannot 'fire' an LDC. While individual managers within an LDC could be fired, we have not found any instances of a PUC calling directly for the firing of an individual. Of course, career concerns could arise within the LDC itself, leading an individual manager responsible for gas procurement not to sell reserves, even at an expected positive value to the LDC, if there were a possibility that the LDC would subsequently need to buy the gas back on the spot market and face a prudency review.[13] In what follows, we will focus our discussion on the interaction between the regulator and the LDC. In this context, the relevant disciplinary actions we have in mind are not literal firings, but regulatory reviews, reprimands, and other such institutional—rather than individual—punishments.

An LDC's concern about regulatory reviews, political fallout, or inferences regarding its ability are likely to only be salient in what are referred to in the industry as 'tight' markets. A 'tight' bidweek market is one in which consumer demand for gas in the upcoming month is expected to be high relative to the total supply that is available to the LDC's in the region (including supplies available to be withdrawn from storage). More precisely, in a tight bidweek market, LDC's believe that there is some chance

[12] Although this paper models career concerns arising between LDC's and regulators, it could also be the case that LDC's faithfully implement the wishes of regulators but that there is something analogous to a career concern that arises between regulators and elected officials or between elected officials and the electorate.

[13] Such internal career concerns incentives could also be relevant for other market participants such as gas marketers, though in that case the incentive conflict would be between the personal career advancement of an employee and the (unregulated) profit motive of the gas marketer.

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that the customer demand that will be realized in the upcoming month will be sufficiently high that LDC's holding insufficient gas reserves will be forced to either pay very high spot prices or curtail customers if they cannot execute a spot purchase. Because of this curtailment risk, tight markets are naturally associated with high bidweek prices and high expected spot prices. For example, there were spells of particularly cold weather in the Northeast in February, 2003, January, 2004, and December, 2004–January, 2005; record low temperatures were set in Boston in the 2003 and 2004 events. During each of these spells, gas prices in the region increased substantially in both the bidweek and spot markets.[14] The bidweek price increases can be attributed to either forecasts of further cold weather or to the depletion of storage volumes during the cold snaps. These price increases were also partially transmitted to natural gas supply areas such as Louisiana via the interstate pipeline system. Other examples of tight markets include California in late 2000 following a period of intense demand for natural gas by electricity generators (and a supply disruption caused by an explosion on the El Paso pipeline system) and much of the eastern half of the U.S. in late 2005 following Hurricanes Katrina and Rita.

Tight markets are also likely to be associated with a high spot price variance. In a tight market, an LDC's supplies of gas may be insufficient to meet consumer demand. Thus, the LDC's marginal valuation of gas will be determined by how much gas it needs in order to serve the inelastic demand of its retail customers, rather than, for example, the value of storing gas for future months. As a result, the LDC's demand for gas in the market will become inelastic. Because the external supply of gas will also be inelastic due to pipeline capacity constraints, small shocks to customers' demand will translate into large spot price movements.

Career concerns are salient in tight bidweek markets because of this high spot price variance and the threat of curtailments. Even if bidweek prices are sufficiently high that an LDC believes that selling gas at bidweek is the value-maximizing decision in expectation, it faces the risk that a positive demand shock will require it to curtail customers or re-purchase the gas at a spot price that is much higher than the bidweek price at which it sold. Inaction in this situation will protect the LDC from a particularly severe regulatory review and an adverse reputational impact. In a market that is not tight, however, there is no threat of curtailment and the variance of spot

[14] At the Boston 'citygate' pricing point, for example, daily spot prices during February, 2003, January, 2004, and January, 2005 regularly exceeded \$10 per million British thermal units (mmBtu) and reached as high as \$47.50/mmBtu on January 15th, 2004 when a record low temperature of -4 degrees Fahrenheit was recorded. Bidweek prices for delivery in March, 2003, February, 2004, and February, 2005 were \$11.35, \$10.07, and \$9.36 per mmBtu, respectively. In contrast, the bidweek price did not exceed \$3.70/mmBtu throughout the winter of 2001–2002, for which there were only 5 days in which the high temperature was at or below the freezing point. (Historical weather data were obtained from WeatherSpark.com.)

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prices will be relatively low. There is therefore very little chance that the LDC will experience one of the adverse outcomes that the regulator wishes it to avoid.

Finally, the incentive for inaction in tight markets is likely to be asymmetric: an LDC will be more concerned about selling in a tight bidweek market than about buying. If an LDC sells gas, it exposes itself to the risk of a positive demand shock that could force it to either buy gas at an extremely high spot price or curtail customers, triggering a regulatory review. If the LDC instead buys gas at bidweek, it is exposed to the risk of a negative demand shock in which the spot price will fall below the bidweek price. In this scenario, however, the LDC will not be forced to reveal its (*ex post*) error by selling gas at spot. It can instead simply undertake no spot transaction and therefore avoid openly 'buying high and selling low.'[15] Furthermore, this downside risk scenario imposes no risk of a curtailment.[16] An LDC's willingness to buy gas in bidweek markets should not therefore be substantially affected by incentives for inaction, even in tight market situations.

IV. MARKET IMPLICATIONS OF CAREER CONCERNS IN TIGHT MARKETS

In order to consider the effect of inaction on market outcomes, we first describe how prices and volumes are determined in the bidweek and spot markets. At any point in time, LDC's will have different marginal values of the reserves they hold, which stem from differences in their initial reserve levels, expected local end-use demand, costs of storage, and future price projections. These differences drive trade in the bidweek and spot markets. In a market in which available supplies are ample relative to expected upcoming demand—that is, a market that is not tight—there is essentially zero near-term risk of curtailments or substantial price volatility. In this case, an arbitrage condition will bind between these markets, and the bidweek price should be approximately equal to the expected spot price, consistent with the weak-form efficient markets hypothesis.

In a tight market, however, LDC's that have career concerns will be less willing to sell gas during bidweek; they may prefer inaction. The impact of a threat of regulatory punishment is similar to a tax on forward sales of gas, increasing sellers' reservation values. Thus, career concerns cause

[15] Even if the regulator later observes from market survey data (such as that used in this paper) that the spot price was lower than the bidweek price paid by the LDC, the LDC can claim that the spot market was illiquid and that, had it purchased gas at spot instead, it would have been forced to pay a price similar to the bidweek price.

[16] A final reason for asymmetry arises because, if the regulatory punishment is convex in the absolute difference between the bidweek price and the spot price, the right-skewed distribution of spot prices implies that the expected punishment from positive demand shocks is greater than the expected punishment from negative demand shocks.

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transactions that would otherwise be Pareto-improving not to occur, creating a deadweight loss. The upward (or inward) shift in the bidweek gas supply curve increases the bidweek price and reduces the quantity of bidweek gas traded.[17] These two implications of career concerns and inaction form the basis of our empirical analysis. We will test whether it is the case that in tight markets, bidweek prices systematically exceed expected spot prices and whether the volumes of gas traded in tight bidweek markets are lower than volumes traded in bidweek markets that are not tight.[18]

Before we describe our empirical approach to estimating these effects, it is useful to consider whether factors other than career concerns could explain forward price premia and low transactions volumes in tight markets. There are several reasons apart from career concerns that forward price premia might arise. First, the illiquidity of spot markets suggests that an LDC would rather pay a premium at bidweek to 'lock in' gas supply over the upcoming month than rely on the spot market to respond to demand shocks and avoid curtailments. The industry refers to this preference as a concern for 'security of supply;' it is similar to stockout risk in other contexts. In equilibrium, security of supply concerns will lead to forward price premia in tight markets. Forward premia may also arise purely from price risk aversion if LDC's buying gas during bidweek are more risk-averse over money than are sellers.[19] Under price risk aversion, buying gas during a tight bidweek market provides insurance against spot prices that will have a high variance over the upcoming month.

Both the pure security of supply story and the price risk aversion story are distinct from the career concerns and inaction story in that they do not involve asymmetric incentives for selling gas during bidweek relative to buying gas or doing nothing. Thus, the bidweek reservation price at which an LDC affected by security of supply concerns or price risk aversion will be willing to sell gas will be the same as the reservation price at which the LDC will be willing to buy. In the absence of a wedge between sellers' and buyers' reservation values, there is no obvious reason why a pure security of supply concern or price risk aversion should systematically lead to a reduction in transaction volumes in tight markets. (For a more complete discussion of these effects, see Borenstein, Busse, and Kellogg [2007].)

[17] An inward shift in the bidweek *demand* is not likely to result from career concerns, as explained above. If such a shift did occur, it would also reduce bidweek volume but would tend to lower bidweek prices relative to spot rather than raise them.

[18] For example, returning to the Northeast cold spells noted above, we find that bidweek prices substantially exceeded realized spot prices in each instance. During the December, 2004–January, 2005 cold spell, Platts actually recorded zero bidweek transactions at the Boston citygate for delivery in January. (While we do not believe that this zero is a data error, our empirical analysis excludes such zeros in order to be conservative.) We do not have volume data on the earlier cold spells since Platts did not record volume data during that period, as discussed in section V below.

[19] This explanation is undermined somewhat by the fact that the same firms are bidweek sellers in some months and buyers in other months.

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Moreover, there are several additional reasons to think that, in the absence of career concerns, bidweek market volumes should actually increase when spot markets are expected to be tight. The first reason is a scale effect: tight local gas markets are associated with cold weather and higher-than-normal volumes of gas deliveries to end consumers. This increase in delivery volume will tend to scale up the volumes that need to be traded in order to equate marginal valuations across firms. That is, if the volumes of initial reserves that are misallocated across firms (relative to their desired reserves for the upcoming month) increase with the total level of consumption in the market, then the forward quantity traded should increase in tight markets.

Second, trading volumes will increase in tight markets if market tightness is associated with increased heterogeneity of LDCs' demand levels. An increase in heterogeneity may arise through an increase in the variability of firms' demands, driven by uncertainty over demand shocks that potentially affect the LDC's in an area non-uniformly. Uncertainty about weather and customer demand that exists prior to the bidweek market, but is partially resolved by bidweek, will increase the level of misallocation that LDC's wish to correct through forward trading. Misallocation is likely to be greater in tight gas markets than in non-tight markets that are generally associated with relatively low local demand uncertainty.

Finally, the presence of transaction costs should also lead to higher trading volumes in tight markets. For a given quantity of misallocated reserves, the gains from reallocation are likely to be greater in a tight market. In a non-tight market, most LDC's operate in a fairly elastic region of their marginal valuation curve, implying that the gains from most potential trades will be small relative to the gains from trade in a tight market. Thus, if there are transaction costs of trading reserves, they will impede fewer trades in tight markets, leading to greater trading volumes.

While none of these three effects—scale, heterogeneity and transaction costs—decisively predicts how the quantity of gas traded in forward markets will behave in the absence of career concerns, each effect clearly tilts in the direction of greater forward transaction volumes in tight markets. The three effects taken together imply that it is unlikely that the security of supply or price risk aversion models alone would explain decreases in forward trading in tight markets. Thus, we may differentiate between inaction and these alternative models by empirically examining the relationship between bidweek trading volume and market tightness.

If career concerns do decrease trading volumes in tight markets, the welfare impact is likely to be particularly negative because tight markets are associated with inelastic demand and supply. Thus, the gains from trade are likely to be particularly large and preemption of those trades particularly costly.

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V. DATA

We obtained all natural gas market price and trading volume data from Platts' GASdat product. These data consist of location-specific observations in the day-ahead (spot) markets and the forward month (bidweek) markets, and are available from February, 1993, through March, 2008. Data are reported for more than 100 locations, each of which is a node on a pipeline where gas can be delivered to a local market or injected into the pipeline from a producing area. Platts obtains daily spot market prices and volumes via surveys of trades made at each location. The reported daily price at each location is the volume-weighted average price of reported trades. Bidweek data occur on a monthly basis, and Platts' bidweek prices represent the volume-weighted average price of all surveyed trades at each location during bidweek.[20] Bidweek takes place over the last five trading days of each month and consists of trades for gas to be delivered during the following month. Because our aim is to relate bidweek prices and volumes to spot prices, we average the daily spot data within each month so that they are compatible with the monthly bidweek data.[21]

The years and months covered by the spot price data vary by location. For example, data for Henry Hub in Louisiana span 1993 to 2008 while data at the Carthage Hub in northeast Texas are only available for 1997 to 2002. These variations in coverage occur because trading activity in some locations varies over time, and Platts does not record observations when there are an insufficient number of trades to allow it to determine the average price. There also exist missing observations within the coverage period of each location: 4.8 per cent of all possible spot price observations is missing. To avoid distortions when calculating average monthly spot prices, we eliminate from the data locations for which more than 1 per cent of observations is missing. These dropped locations are characterized by low transactions volumes and comprise one-fourth of the locations in the data.

Within the bidweek data, coverage similarly varies by location. Data for September, 2007, are missing for all but one location, and we drop this month from the data. Amongst the remaining bidweek location-months that overlap with spot market observations at non-dropped locations, bidweek prices are observed for 99.3 per cent of all possible location-months.

A merge of the bidweek and spot price data yields a dataset containing 9,496 location-months for which both spot and bidweek prices exist, spread

[20] Platts will sometimes use the median of reported prices if it finds that one high-volume transaction skews its bidweek sample. Unfortunately, there are no indicators in the data to determine which observations are computed in this way.

[21] We use an unweighted average of the daily spot prices rather than a volume-weighted average because the unweighted average better reflects the nature of bidweek transactions, which specify a fixed volume of gas to be delivered every day of the month.

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TABLE I
SPOT AND BIDWEEK DATA SUMMARY STATISTICS

	Number of observations	Number of locations	Median	Mean	Std Dev	Min	Max
Bidweek Price ($/mmBtu)	9496	98	3.09	4.01	2.47	0.84	19.76
Spot Price ($/mmBtu)	9496	98	3.01	4.01	2.41	0.87	23.96
Bidweek Volume (million cubic ft/day)	4410	74	338	538	582	1	4992
Spot volume (million cubic ft/day)	4324	69	352	557	690	0.807	8139

Notes: Price data cover February, 1993, through March, 2008. Volume data cover June, 1999, through March, 2008. Reported spot volumes are averages within each location-month. Volume data are reported in whole numbers; thus, the minimum bidweek volume is 1 without further significant figures. mmBtu denote millions of British thermal units.

over 98 locations.[22] Summary statistics for the spot and bidweek prices are shown in table I. Both data series are highly right-skewed, as indicated by the excess of the mean over the median prices and by the large observed maximum prices. The summary statistics of the spot and bidweek prices are very similar, and the difference in means of 0.2 cents per million British thermal units (mmBtu) is not statistically significant.[23] Thus, on average, there is no statistically discernible forward premium or discount in prices for natural gas.

Platts reports the volume of gas traded during bidweek at each market location from June, 1999 to March, 2008, with a gap in coverage from July, 2002 to June, 2004.[24] There exist 4,410 location-months, spread over 74 locations, for which bidweek volume, bidweek price, and spot price data exist.[25,26] Summary statistics for bidweek volumes are given in table I. In our empirical specifications, we will use the logarithm of volume to avoid

[22] The count of 9,496 location-months includes only those observations for which recursive regression spot price predictions can ultimately be generated, as discussed in section VI below. Without this restriction, there are 15,620 location-months.

[23] Statistical significance was tested via a paired t-test with standard errors two-way clustered on location and month-of-sample: the t-statistic is 0.05.

[24] This gap occurs due to a changeover in publications by Platts, prompted by its merger with FT Energy in 2001. While prices are reported for these dates, volumes are not. In addition, there are a further 147 observations outside of these dates during which prices are reported but not volumes.

[25] The 4,410 observations do not include 46 location-months for which we observe a bidweek volume of zero. We drop these observations because our empirical specification uses the logarithm of bidweek volume, and a tobit specification is impractical and subject to the incidental parameters problem given the large number of fixed effects used (Neyman and Scott [1948], Greene [2004]). We have examined an alternative specification in which we code the observations with zero volume as having a volume of one million cubic feet, the lowest volume observed in the data. This approach yields estimated bidweek volume effects that are slightly stronger in magnitude than those discussed below.

[26] We have also estimated our price regressions using the 4,410 observations we use for the volume regressions rather than the 9,496 observation results reported in the paper. We obtain comparable results with the smaller subset.

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scaling problems associated with the fact that some locations generally see much larger volumes than others: average volumes at each location range from 4 million cubic feet per day to approximately 1,300 million cubic feet per day.

VI. EMPIRICAL FRAMEWORK AND OPERATIONALIZATION OF MARKET 'TIGHTNESS'

Our theory of career concerns and inaction yields two implications for natural gas markets: (1) bidweek prices will exceed expected spot prices in tight markets; and (2) bidweek volumes will be lower in tight markets than in markets that are not tight. A natural measure of tightness is the expected spot price of natural gas. Tight bidweek markets are defined as cases in which LDCs' expected spot demand for gas is high relative to available supply, a condition that naturally leads to an increase in the expected spot price. We therefore aim to test our hypotheses by estimating the parameters of the following equations:

$$BidWeek_{it} - Spot_{it} = \beta_0 + \beta_1 \, E[Spot_{it}] + \mu_i + f(t) + \varepsilon_{it}. \tag{1}$$

$$\ln(Volume_{it}) = \gamma_0 + \gamma_1 \, E[Spot_{it}] + \nu_i + g(t) + \eta_{it}. \tag{2}$$

Here, $BidWeek_{it}$ is the price during bidweek of month t–1 for gas to be delivered at location i in month t, $Volume_{it}$ is the trading volume during the bidweek of month t–1 at location i, and $Spot_{it}$ is the average daily spot price for gas at location i over month t. $E[Spot_{it}]$ is the expectation at the beginning of bidweek in month t–1 of $Spot_{it}$. The μ_i and ν_i are location fixed effects, and $f(t)$ and $g(t)$ are 8th-order Chebychev polynomials in time that control for the secular upward trend in natural gas prices over the sample period.[27] If forward price premia arise in tight markets, then β_1 will be positive. If forward volumes are lower in tight markets, then γ_1 will be negative.

In order to estimate equations [1] and [2] directly, we would have to observe $E[Spot_{it}]$. Because we do not observe market participants' expectations of spot prices for a particular month, we must take an indirect approach. We begin by noting that market participants are experienced, professional traders and should therefore have spot price expectations that are unbiased predictors of the actual spot price. Thus, any new information that becomes available after expectations are formed will be orthogonal to the information that is incorporated into the expected spot price:

$$Spot_{it} = E[Spot_{it}] + \xi_{it}, \quad \xi_{it} \perp E[Spot_{it}] \tag{3}$$

[27] We have also estimated all equations using 6th and 10th order polynomials; doing so does not substantially change the reported results.

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Using equation [3], we can estimate equations [1] and [2] by substituting $Spot_{it}$ for $E[Spot_{it}]$ and accounting for the endogeneity introduced by ξ_{it}:

$$BidWeek_{it} - Spot_{it} = \beta_0 + \beta_1\, Spot_{it} + \mu_i + f(t) + (\varepsilon_{it} - \beta_1 \xi_{it}). \tag{4}$$

$$\ln(Volume_{it}) = \gamma_0 + \gamma_1\, Spot_{it} + \nu_i + g(t) + (\eta_{it} - \gamma_1 \xi_{it}). \tag{5}$$

Using $Spot_{it}$ as a right-hand-side regressor introduces classical measurement error in both [4] and [5] and simultaneity bias in [4]. In order to use $Spot_{it}$ as a regressor, we need an instrument that is correlated with the realized spot price but uncorrelated with the errors $(\varepsilon_{it} - \beta_1 \xi_{it})$ and $(\eta_{it} - \gamma_1 \xi_{it})$.

As an instrument, we construct a forecast of the spot market price that is based on information available to us and determined prior to the bidweek market in period t–1.[28] To illustrate our approach, suppose we wish to forecast the spot price at the Chicago Citygate in November, 2001, using information available to traders at the start of bidweek in October (October bidweek is when forward contracts are set for delivery in November). We cannot, of course, use the bidweek price itself to create the forecast, as our aim is to test for a premium in the bidweek price during tight market periods. Instead, we construct the forecast using two additional pieces of information: (1) the New York Mercantile Exchange (NYMEX) futures price of gas at Henry Hub, Louisiana, for delivery in November 2001, priced at the start of bidweek;[29] and (2) the spot price differential from Henry Hub to Chicago, also priced at the start of bidweek. The former yields a measure of the expected price of gas at Henry Hub in November, which will be correlated with November prices nationwide, while the latter measures the price differential to Chicago near the end of October, which will be correlated with the price differential in November. Because of the deep liquidity of both the NYMEX futures market and the Henry Hub spot market, and because the majority of NYMEX market participants have no intention of taking physical delivery of gas, NYMEX futures prices are not subject to security of supply or career concerns that might drive a forward price premium in tight markets. Thus, we may use the NYMEX futures market to generate unbiased forecasts of Henry Hub spot prices.

More generally, for all locations and months in our data, we forecast the expected spot price for location i in month t using equation [6] below, in which $Future_{HH.t}$ is the NYMEX futures price for delivery at Henry Hub in

[28] As an alternative to our instrumental variables approach, we could replace $E[Spot_{it}]$ in equation [1] directly with our forecast of spot price. However, doing so would cause the estimated standard errors to be biased downwards (Murphy and Topel [1985]).

[29] A NYMEX futures contract specifies a price for delivery of gas for a calendar month at the Henry Hub pipeline interconnect and storage facility in Louisiana.

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month t, taken at the start of bidweek in month t–1; $Spot_{i,t-1}$ is the spot price at location i at the start of bidweek in month t–1; and d_i is a location fixed effect.

$$(6) \qquad SpotForecast_{it} = a_0 + a_1 Future_{HH,t} + a_2 \left[Spot_{i,t-1} - Spot_{HenryHub,t-1}\right] + d_i$$

To use equation [6] to predict expected spot prices, we must first estimate the equation's parameters—a_0, a_1, a_2, and the d_i's—by running the regression specified in equation 7 below. This equation includes an unobserved orthogonal disturbance v_{it} to account for information revealed between the start of bidweek in month t–1 and month t.

$$(7) \qquad Spot_{it} = \alpha_0 + \alpha_1 Future_{HH,t} + \alpha_2 \left[Spot_{i,t-1} - Spot_{HenryHub,t-1}\right] + \delta_i + v_{it}$$

In the process of estimating equation [7] and then generating forecasts using equation [6], we take care to avoid using any future information in our forecasts. That is, when we forecast the spot price for month t using equation [6], we use parameters that are estimated using only information revealed prior to month t–1. This means that we do not use our entire sample of spot price information to produce estimates of the α's and δ_i's from equation [7], and then apply these estimated parameters to generate a full time series of prices from equation [6].

Instead, we estimate equation [7] using recursive regressions. Rather than estimate a single set of $\hat{\alpha}$'s, we estimate a different coefficient vector $\hat{\alpha}_t = \left(\hat{\alpha}_{0t}, \hat{\alpha}_{1t}, \hat{\alpha}_{2t}, \hat{\delta}_t\right)$ for each month t using data only up to month $t-2$. These coefficients are then substituted for the corresponding a's and d's in equation [6] to generate expected spot prices for month t. While this approach ensures that our spot price prediction for any month t does not include any information revealed after t, it does come with the cost that there are few observations with which to estimate equation [7] in the early part of our sample. To avoid generating estimates based upon only a handful of points, we predict spot prices only for locations and months for which the coefficient vector in [7] was estimated using at least 24 observations.[30]

Results from the estimation of equation [7] are summarized in Table II. For illustration, the first column of this table reports results using the full sample of spot price data. The estimated coefficients on the NYMEX future price and the spot price differential are positive, as expected, and

[30] There is a tradeoff in setting the minimum number of observations required to estimate equation [7]: a high minimum number yields more precise predictions of spot prices but reduces the total number of predictions and therefore the number of observations in the main specifications, equations [4] and [5]. The primary results concerning forward price premia and trading quantities in local natural gas markets do not qualitatively change as we adjust the minimum number, even when we increase it to 48 months.

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TABLE II
FULL SAMPLE AND RECURSIVE REGRESSION RESULTS FOR DETERMINANTS OF SPOT PRICE

	Full Sample Results	Mean Coef Over Valid RR Predictions (182 regressions)	Std Deviation of Coef Over Vaid RR Predictions (182 regressions)
Henry Hub (HH) future price	0.8796	0.8637	0.0671
	(0.0527)		
Location to HH spot price differential	0.3375	0.2905	0.1028
	(0.1043)		
N	13,848	—	—

Notes: Unit of observation is a location-month. 'Spot price' denotes the average of daily spot prices for the month. Regressors 'HH future price' and 'Location to HH spot price differential' are taken at the start of bidweek the month prior to that corresponding to the spot price dependent variable. Regressions include location fixed effects. Values in parentheses indicate standard errors two-way clustered on location and month-of-sample. Units for all prices are $/mmBtu (millions of British thermal units).

statistically significant. Standard errors for these estimates and all estimates discussed below are two-way clustered on location and month-of-sample to allow for arbitrary serial correlation of the residuals within each location and arbitrary cross-sectional correlation of monthly residuals across locations (Cameron, Gelbach and Miller [2011]).[31] This result indicates that the NYMEX futures price and the spot price differential carry useful information with which to predict current prices.

Table II also reports the results of recursive regressions of equation [7]. We ran 182 regressions to generate parameters for the forecast of spot prices from February, 1993, to March, 2008. The estimated coefficient on the NYMEX future price is positive in every regression, and the estimated coefficient on the price differential is positive for 180 of 182. We use these estimated parameters to forecast spot prices using equation [6] and then use these forecasts as instruments for the spot price in our main specifications, equations [4] and [5].

Before proceeding with estimating equations [4] and [5], we first verify empirically that our measure of market tightness is correlated with an important feature of tight markets: a high spot price variance. As discussed in Section III, in a tight gas market both demand and supply for gas should be relatively inelastic, implying that supply and demand shocks occurring between the bidweek and spot markets should drive large changes in the spot price relative to its expectation at bidweek. We operationalize this intuition by estimating equation [8] below, in which we instrument for $Spot_{it}$ using $SpotForecast_{it}$. If high expected spot markets are associated with tight markets, λ_1 should be positive. ρ_i and $h(t)$ denote location fixed effects and an 8th-order Chebychev polynomial in time.

[31] Throughout all our estimates, allowing for cross-sectional correlation substantially increases the estimated standard errors while allowing for serial correlation has only a mild impact.

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TABLE III
DETERMINANTS OF THE VARIANCE OF THE SPOT PRICE. DEPENDENT VARIABLE IS LOG((REALIZED SPOT PRICE—RECURSIVE REGRESSION PREDICTED SPOT PRICE)^2)

	(1)	(2)	(3)	(4)	(5)
Spot price (instrumented with recursive regression prediction)	0.8172 (0.1853)	0.7515 (0.1789)	0.7463 (0.1830)	0.7551 (0.1773)	0.7499 (0.1812)
Location fixed effects	Y	Y	Y	Y	Y
8th order polynomial in year-month	Y	Y	Y	Y	Y
Month-of-year fixed effects	N	Y	Y	Y	Y
Linear time trend * location fixed effects	N	N	Y	N	Y
Month-of-year * location fixed effects	N	N	N	Y	Y
Nnumber of observations	9496	9496	9496	9496	9496

Notes: Unit of observation is a location-month. 'Spot price' denotes the average of daily spot prices for the month. Values in parentheses indicate standard errors two-way clustered on location and month-of-sample. Units for all prices are $/mmBtu (millions of British thermal units).

$$\ln\left((Spot_{it} - SpotForecast_{it})^2\right) = \lambda_0 + \lambda_1\, Spot_{it} + \rho_i + h(t) + (\varepsilon_{it} - \lambda_1 \xi_{it}). \tag{8}$$

The estimate of equation [8] is given in column 1 of table III. The estimate of λ_1 is 0.817 and statistically significant at the 1 per cent level. The interpretation of this coefficient is that a one dollar increase in the expected spot price is associated with an increase in the variance of the realized spot price by a factor of 2.26. The within-location standard deviation of $\ln((Spot_{it} - SpotForecast_{it})^2)$ is equal to 2.62, so this estimated effect is economically significant.

Column 2 of Table III verifies that this result is not purely driven by seasonality by adding month-of-year fixed effects to the specification. The estimate of λ_1 changes little as a result. Column 3 allows for a linear location-specific time trend, column 4 allows for location-specific month-of-year effects, and column 5 allows for both a location-specific time trend and location-specific month-of-year effects. The interpretation of the estimate of λ_1 is essentially the same in each specification: the variance of the spot price is higher when the spot price is expected to be high. These last results verify that the increase in spot price variance in tight markets is not merely a seasonal phenomenon, nor is it driven by location-specific secular trends.[32]

VII. ESTIMATION RESULTS

VII(i). *Forward Price Premia*

The results of estimating equation [4] are reported in Table IV. The results presented in column 1 are those obtained through the estimation of [4] as

[32] Results of this regression and those discussed below are also essentially unchanged when location-specific 2nd or 4th-order polynomial time trends are allowed for.

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TABLE IV
DETERMINANTS OF FORWARD-SPOT PRICE DIFFERENTIAL. DEPENDENT VARIABLE IS THE DIFFERENCE BETWEEN THE BIDWEEK PRICE AND SPOT PRICE FOR EACH DELIVERY MONTH

	(1)	(2)	(3)	(4)	(5)
Spot price (instrumented with recursive regression prediction)	0.2720 (0.1332)	0.2603 (0.1142)	0.2648 (0.1163)	0.2545 (0.1109)	0.2591 (0.1130)
Location fixed effects	Y	Y	Y	Y	Y
8th order polynomial in year-month	Y	Y	Y	Y	Y
Month-of-year fixed effects	N	Y	Y	Y	Y
Linear time trend * location fixed effects	N	N	Y	N	Y
Month-of-year * location fixed effects	N	N	N	Y	Y
Number of observations	9496	9496	9496	9496	9496

Notes: Unit of observation is a location-month. 'Spot price' denotes the average of daily spot prices for the month. Values in parentheses indicate standard errors two-way clustered on location and month-of-sample. Units for all prices are $/mmBtu (millions of British thermal units).

written. Columns 2 through 5 follow the same progression as in Table III in adding additional controls for overall and location-specific seasonality and time trends. Across all five specifications, we estimate that the forward premium of bidweek prices over spot prices increases systematically with the expected spot price. The point estimates indicate that a $1.00 rise in the expected spot price is predicted to cause a $0.25 to $0.27 rise in the forward premium, depending on the specification.[33] The p-values for the results in columns 1 through 5 vary from 0.022 (columns 4 and 5) to 0.041 (column 1).

These results provide evidence of forward price premia in local natural gas markets at times and locations in which these markets are tight. This finding suggests that natural gas markets are not frictionless, liquid, riskless markets. At a minimum, when markets are tight, arbitrage between forward and spot markets fails to bring forward prices into equality with expected spot prices. In section IV, we discussed several factors that could lead to this forward premium: career concerns, security of supply, and price risk aversion. While a forward price premium is consistent with all three of these explanations, only career concerns are likely to lead to a reduced volume of transactions when markets are tight. Therefore we attempt next

[33] The existence of forward premia in tight markets does not contradict the finding that there is no forward premium on average (Table I) because tight markets are uncommon events. The distribution of predicted spot prices—after taking out the 8th order polynomial time trend and fixed effects—is highly right-skewed, and realizations in the far-right tail are required in order to yield expected forward premia. To have an expected forward-spot premium in the top 5% of the forward-spot differential distribution—an expected premium of at least $0.94—the results in Table III, column 1 suggest that the expected spot price would have to be at least $3.44. Such high expected prices occur only 3% of the time in the distribution of expected spot prices obtained from our recursive regressions. When these 3% of observations are dropped from the data, the average forward-spot price differential amongst the remaining observations is still statistically indistinct from zero (the average differential is -$0.053 with a standard error of $0.044).

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TABLE V
DETERMINANTS OF LOG(BIDWEEK TRADING VOLUME)

	(1)	(2)	(3)	(4)	(5)
Spot price (instrumented with recursive regression prediction)	–0.0931 (0.0232)	–0.0956 (0.0213)	–0.0837 (0.0206)	–0.0961 (0.0217)	–0.0830 (0.0211)
Location fixed effects	Y	Y	Y	Y	Y
8th order polynomial in year-month	Y	Y	Y	Y	Y
Month-of-year fixed effects	N	Y	Y	Y	Y
Linear time trend * location fixed effects	N	N	Y	N	Y
Month-of-year * location fixed effects	N	N	N	Y	Y
Number of observations	4410	4410	4410	4410	4410

Notes: Unit of observation is a location-month. 'Spot price' denotes the average of daily spot prices for the month. Values in parentheses indicate standard errors two-way clustered on location and month-of-sample. Units for all prices are $/mmBtu (millions of British thermal units).

to distinguish amongst these theories, or at least assess which is dominant, by examining data on forward trading volumes in markets that are tight versus volumes in markets that are not tight.

VII(ii). *Forward Trading Volumes*

Column 1 of Table V reports the results of estimating equation [5] with the bidweek volume data. The estimated coefficient on the spot price demonstrates that forward trading volumes are significantly lower in tight markets. A $1.00 increase in the expected spot price is predicted to decrease the logarithm of forward trading volume by 0.093, equivalent to a decrease in volume of 8.9%. The effect is statistically significant at the 1% level and is robust to the addition of additional controls for overall and location-specific seasonality and time trends.

An alternative explanation for these forward volume results is that natural gas trading simply becomes more difficult when markets are tight. For example, it may be that it becomes difficult to physically consummate a trade when the gas delivery infrastructure is near its capacity. However, if such a transactions cost story explains the decrease in forward trading volumes when markets are tight, then we should also observe that spot trading volumes also decrease when markets are tight. The inaction model, on the other hand, does not imply decreases in spot trades. Thus, we can use data on spot trading volumes to distinguish these two explanations.[34]

Platts' spot market data provides observations of daily spot trading volumes, and we average these volumes within each location-month to generate monthly time series of spot market volumes at each location. For

[34] Another alternative hypothesis is that the correlation of shocks across utilities increases in tight markets, lowering transactions volumes. Under this hypothesis, volumes should decrease in both bidweek and spot markets, not just bidweek markets.

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Table VI
Determinants of log(Spot Trading Volume)

	(1)	(2)	(3)	(4)	(5)
Spot price	0.0106 (0.0085)	0.0128 (0.0091)	0.0126 (0.0089)	0.0121 (0.0099)	0.0119 (0.0098)
Location fixed effects	Y	Y	Y	Y	Y
8th order polynomial in year-month	Y	Y	Y	Y	Y
Month-of-year fixed effects	N	Y	Y	Y	Y
Linear time trend * location fixed effects	N	N	Y	N	Y
Month-of-year * location fixed effects	N	N	N	Y	Y
Number of observations	4324	4324	4324	4324	4324

Notes: Unit of observation is a location-month. 'Spot price' denotes the average of daily spot prices for the month. Monthly log(spot trading volume) is the average of the daily log(spot trading volume) for the month. Values in parentheses indicate standard errors two-way clustered on location and month-of-sample. Units for all prices are $/mmBtu (millions of British thermal units).

comparability to the bidweek volume results, we use only location-months for which bidweek volume data are also available. Spot volumes were not recorded at 5 of these locations; the spot volume dataset therefore consists of 4,324 observations spread over 69 locations.[35] Summary statistics for spot volumes are given in Table I; these volumes are of similar magnitudes to those in the bidweek market.

We examine the behavior of spot market volumes in tight markets by estimating equation [9] below. In estimating [9], we do not instrument for $Spot_{it}$ using $SpotForecast_{it}$ because we are interested the behavior of trading volumes during the spot market itself rather than the forward bidweek market. Thus, the actual spot price is the appropriate measure of market tightness rather than the *ex ante* expected spot price.

$$\ln(SpotVolume_{it}) = \theta_0 + \theta_1\, Spot_{it} + \phi_i + h(t) + \omega_{it} \tag{9}$$

Table VI presents the results of estimating [9], along with alternative specifications that control for overall and location-specific seasonality and time trends. In every specification, the point estimate of θ_1 is positive, small in magnitude, and statistically insignificant. The estimated confidence intervals rule out that a $1.00 increase in the spot price is associated with a decrease in spot volumes of more than 1%. These results suggest that the decreases in forward volumes observed in tight markets (table V) are unlikely to be explained by factors related to increased transactions costs, since such factors would presumably impact spot markets as well.[36]

[35] The bidweek volume results are essentially unchanged when estimated using this smaller, matched dataset.

[36] If [9] is estimated while instrumenting for $Spot_{it}$ using our forecast of $Spot_{it}$, the estimated effect is slightly negative, not statistically different from zero, but still statistically different from the estimated effects reported for bidweek volume.

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The implication of these results is that trade in forward markets is reduced when spot prices are expected to be high. This outcome suggests that there is a market inefficiency at work: forward markets shrink at the very time they are most needed. These reductions in forward quantities traded are consistent with the inaction model in which the regulator penalizes supply shortfalls caused by forward sales more than shortfalls caused by insufficient forward purchases. Absent the behavior caused by this regulatory asymmetry, a model of security of supply concerns alone would not predict the observed effects, nor would a model of price-risk aversion.

VIII. CONCLUSION AND BROADER RELEVANCE

We have presented a model of natural gas procurement by regulated utilities in which career concerns between the utilites and their regulators lead to an incentive for inaction in forward natural gas markets. In particular, in 'tight' market situations in which customer demand is expected to be high in the near-term, career concerns can lead a utility to be unwilling to sell gas in the forward market, even when the forward price exceeds the expected spot price over the upcoming month. This incentive for inaction derives from the possibility that a positive demand shock might force the utility to buy gas in the spot market at an extremely high price or even curtail its customers. When such an outcome can be linked to a sale of gas in the forward market, it will diminish the utility's reputation and may lead to a particularly harsh punishment by the regulator.

When several utilities in an area face career concerns and incentives for inaction, a forward price premium and a decrease in forward trade result. The incentive for inaction and commensurate reduction in trade is most salient in tight gas markets, as we verify empirically. Unfortunately, it is in such situations that trade is most valuable: demand is expected to be high and there may be a large increase in social surplus from transferring gas to those utilities that value it most.

As career concerns and problems of essential input procurement are hardly unique to the natural gas industry, we suspect that incentives for inaction may exist in other settings as well. Agents' responses to these incentives in aggregate can have significant market repercussions. For example, a procurement agent within a firm may carry excess inventories of inputs so (s)he can never be blamed for a disruption in the production process. In aggregate, this behavior would distort allocation of the inputs among input customers. Likewise, an agent might stick to historical sourcing when a new vendor would have higher expected value for the firm ('nobody ever got fired for buying IBM'). Again, in aggregate such behavior could make it difficult for a new input supplier to enter the market. Finally, human resource managers in an industry might prefer to select excessively conventional job candidates, thereby in aggregate discouraging

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people of less conventional talents or backgrounds from investing in the skills to enter the industry.

The imposition of particularly harsh penalties for observable actions that can be linked to negative outcomes may be efficient from the principal's point of view, suggesting that rational managers in an organization may be willing to apply them. However, we demonstrate that the impacts of these incentives extend beyond the principal-agent relationship in which they are applied and can cause significant market inefficiencies. In markets for necessary inputs, the career concerns generated by these principal-agent relationships can cause firms to be reluctant to engage in trades, even when differences in marginal valuations are significant.

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