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Abstract: This paper examines how 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 directly 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.

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1. 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 regards 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 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 not 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." Harbaugh (2006) shows that an agent will avoid gambles in which a loss has the potential to reveal poor judgment. 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 1980s 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 *on 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 may 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 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. 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 spot price or be forced to curtail customers. The need for high-cost spot market 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 natural gas markets are frequently 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, as 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 judgement.

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. We show that these two predictions hold empirically in volume and price data from local natural gas markets and argue that they are jointly difficult to explain via other factors. 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.

In what follows, we first present in section 2 a simple, general model that formalizes the idea that career concerns can lead to inaction and then relates this concept to the context of natural gas procurement. Section 3 describes the relevant institutional details of the natural gas industry and the specific incentives for inaction in tight markets. Section 4 discusses the impacts of inaction on market performance and derives market-level empirical implications. Sections 5 and 6 describe, respectively, our data and empirical approach.

Section 7 presents our empirical results, and section 8 concludes and discusses broader implications.

2. A Model of Career Concerns and Inaction

2.1 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.

Consider a risk-neutral principal that would like to maximize a scalar value V_t that in each period t is a linear function of x_t, a scalar choice variable. The slope of V_t is unknown to the principal. At the beginning of each period, x_t takes on an initial value x_{t0}. The principal employs a risk-neutral agent whose job it is to know the slope of the V_t function at x_{t0} and move the choice variable to $x_{t0}+1$ or $x_{t0}-1$ depending on the sign of $V_t'(x_{t0})$. $V_t'(x_{t0})$ is continuously valued so that it equals 0 with zero measure.

The agent's only possible choices are to increase or decrease x_t by 1, or to leave it unchanged. The agent receives compensation equal to some share of the improvement in V_t relative to $V_t(x_{t0})$. Since the slope of $V(\cdot)$ is never zero, it will always be optimal from the principal's perspective to change x_t in the appropriate direction. Some share of the time, α, however, the agent is unable to change x_t for exogenous reasons. The principal knows neither α nor whether, in any given instance, the agent is able to change x_t.

There are two possible types of agents. Agents know their types, but an agent's type is unobservable to the principal when the agent is hired. Type A agents always get a perfect signal of $V_t'(x_{t0})$ and, given their incentives, move x_t in the value-improving direction if they can. Type B agents get a perfect signal of $V_t'(x_{t0})$ with probability β $(0 < \beta < 1)$, but with probability $1-\beta$ they get an imperfect but still informative signal. The imperfect signal still gets the sign of $V_t'(x_{t0})$ correct with probability ρ $(\rho > 0.5)$. The agent knows whether the signal it has received is perfect or imperfect. The principal knows that both types of agents exist but does not know the values of β or ρ.

After each period, $V_t'(x_{t0})$ is revealed to the principal, as is the outcome of the agent's action: whether x_t was increased, decreased, or left unchanged. The principal receives the value $V_t(x_t) - V_t(x_{t0})$ and pays the agent a share of this value. 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 unknown to the principal. Following the retention or firing decision, a new period $t+1$ begins with a new draw of $V'_{t+1}(x_{t+1,0})$.

This model implies the following results.

Result 1: To maximize the expected V_t, a type B agent should always move x_t when possible.

Result 2: An agent that moves x_t in the wrong direction is fully revealed to be type B.

Result 3: If hiring is costless, the principal should always fire an agent revealed to be type B.

Result 4: Depending on the type B agent's outside employment opportunity and discount rate, it may want to respond to an imperfect signal by claiming, untruthfully, that it is unable to change x_t 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 immediately fired. 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 probability $1-\rho$ to a mistake. If $1-\rho$ is large enough, 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 chance to earn the positive payment it would obtain if it adjusted x_t correctly. It will instead claim that it could not adjust x_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.[1]

2.2 Correspondence of the model to natural gas procurement

Here, we summarize the correspondence between the model and the context of natural

[1] 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.

gas procurement before giving a more complete description of the institutional features of natural gas markets in section 3.

The principals in the model correspond to state Public Utilities Commissions (PUCs). PUCs 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 (LDCs). LDCs 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 initial value of the choice variable, x_{t0}, corresponds to the amount of natural gas the LDC has available to it to use in fulfilling the demand arising from its ratepaying customers in period t. x_{t0} 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. The principal's value $V_t(x_t)$ incorporates both the principal's goal for service reliability and its goal 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.

The slope of the value function at the initial level of reserves, $V_t'(x_{t0})$, 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 this slope, using projections of customer demand, and to act accordingly. The correct slope is revealed when demand is realized, after the procurement decision has been made. The probability β that the agent is of type A represents the possibility that some LDCs (or some individuals who are employed by LDCs) may be better than others at forecasting demand. The probability α that the agent cannot change x_t corresponds to the fact that local natural gas markets are often 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 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 is incorrect, in which case the regulator would be able to clearly infer that a mistake was made.

3. Natural Gas Procurement and Inaction in "Tight" Markets

This section presents the relevant details of natural gas markets and argues that LDCs' incentive for inaction will tend to be manifest only in "tight" markets in which demand and prices are high. We also argue that the incentive for inaction will tend to be asymmetric, in that LDCs will be more wary of making sales of gas than of making purchases.

3.1. 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 LDCs, 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.[2] 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[3] — 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, LDCs, 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.

LDCs purchase gas on wholesale markets and deliver it to ratepaying customers.[4] Each

[2] 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.

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

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

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 LDCs 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).

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. LDCs 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 it doesn't need and does not wish to store. Potential transaction partners include other LDCs, 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 LDCs 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 in its local area, and the supplier is responsible for arranging the necessary pipeline transportation. Alternatively, if the transfer of ownership occurs in 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 LDCs are frequently illiquid. These markets lack a centralized market-maker, and the consequent lack of information makes it difficult for LDCs 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 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 frequently 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.

3.2 Incentives for inaction in "tight" gas markets

We focus our analysis on the decisions of LDCs 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.

LDCs' incentives for inaction in the bidweek markets arise from a combination of market illiquidity and regulatory incentives that stem from the threat of prudency reviews. The punishment value for LDCs of regulatory reviews is not easily specified, nor are punishments written into formal rules, but it is clear that the LDCs believe they are real. 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 had in fact sold gas during bidweek, expecting at the time that spot prices would be relatively low, it would not be able to make this argument. Inaction during bidweek therefore protects LDCs from the risk of a particularly harsh regulatory review.

In the simple model of section 2, 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 incentive to punish an incorrect procurement decision may be more political in nature. The regulator is ultimately accountable to the governor and legislature, and they in turn are accountable to their constituents.[5] 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.[6]

An LDC's concern about 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 which consumer demand for gas in the upcoming month is expected to be high relative to the total supply that is available to the LDCs in the region (including supplies available to be withdrawn from storage). More precisely, in a tight bidweek market LDCs believe that there is some chance that the customer demand that will be realized in the upcoming month will be sufficiently high that LDCs holding insufficient gas reserves will be forced to either pay very high spot prices or curtail customers if they cannot execute

[5] 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 indeed have substantial political consequences.

[6] While we focus this paper's discussion on the principal-agent problem between regulators and LDCs, an incentive for inaction could also arise from principal-agent issues within the LDC itself. An individual manager responsible for gas procurement could have a strong career concerns incentive not to sell reserves, even at an expected positive profit to the LDC, if there is a possibility that the LDC will subsequently need to buy the gas back on the spot market. Such internal career concerns incentives could also be relevant for other market participants such as gas marketers.

a spot trade at all. Such a situation could be caused, for example, by a forecast that particularly cold weather may occur in the Northeast. Because of this curtailment risk, tight markets are naturally associated with high bidweek prices and high expected spot prices. They will also be associated with a high spot price variance. This high variance arises because the limited excess reserves of LDCs cause their realized spot demand for gas to closely reflect the realized inelastic demand of their customers rather than, for example, the value of storing gas for future months. Thus, LDCs' demand for gas in tight markets will be 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 repurchase 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 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 the 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."[7] Furthermore, this downside risk scenario imposes no risk of a curtailment.[8]

[7] 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.

[8] A final reason for asymmetry arises because, if the regulatory punishment is convex in the absolute dif-

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. Inaction should be manifest primarily in an unwillingness to sell gas in tight bidweek markets.

4. Market Implications of Career Concerns and Inaction 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, LDCs will have different marginal values of the reserves each holds that 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.

In a tight market, however, LDCs 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 transactions that would otherwise be Pareto-improving to not occur, thereby creating a deadweight loss. The upward shift in the bidweek gas supply curve increases the bidweek price and reduces the quantity of bidweek gas traded. 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.

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." In

ference 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.

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 LDCs buying gas during bidweek are more risk-averse over money than are sellers.[9] In this explanation, 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 reason why a pure security of supply concern or price risk aversion should lead to a reduction in transaction volumes in tight markets. In fact, there are several 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 LDCs 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 LDCs 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.

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

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 LDCs 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.

5. 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 an 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.[10] Bidweek takes place over the last five trading

[10] Platts will sometimes use the median of reported prices if it finds that one high-volume transaction skews

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.[11]

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 percent of all possible spot price observations are missing. To avoid distortions when calculating average monthly spot prices, we eliminate from the data locations for which more than 1 percent of observations are 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 percent 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 over 98 locations.[12] Summary statistics for the spot and bidweek prices are shown in table 1. 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

its bidweek sample. Unfortunately, there are no indicators in the data to determine which observations are computed in this way.

[11] 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.

[12] 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 6 below. Without this restriction, there are 15,620 location-months.

are very similar, and the difference in means of 0.2 cents is not statistically significant.[13] 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.[14] There exist 4,410 location-months, spread over 74 locations, for which bidweek volume, bidweek price, and spot price data exist.[15,16] Summary statistics for bidweek volumes are given in table 1. In our empirical specifications, we will use the logarithm of volume to avoid 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.

6. 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:

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[13] 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.

[14] 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.

[15] 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.

[16] 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.

$$BidWeek_{it} - Spot_{it} = \beta_0 + \beta_1 \; E[Spot_{it}] + \mu_i + f(t) + \epsilon_{it}. \quad [1]$$

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

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 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.[17] 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 in natural gas markets the same participants operate month after month, that the participants are professional traders and purchasing agents, and that the transactions are for sizeable monetary values. Under these circumstances, we expect that market participants' expectation of the spot price will be an unbiased predictor of the realized spot price. That is, market participants will incorporate all available information into their expectations so that any difference between their expectation and the realized spot price will be due to information that was not available at the time expectations were formed. This new information will therefore be orthogonal to the information that is incorporated into the expected spot price:

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

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}:

$$BidWeek_{it} - Spot_{it} = \beta_0 + \beta_1 \; Spot_{it} + \mu_i + f(t) + (\epsilon_{it} - \beta_1 \xi_{it}). \quad [4]$$

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

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

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 $(\epsilon_{it} - \beta_1 \xi_{it})$ 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 $t-1$.[18] 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 bias 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;[19] 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 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 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

[18] 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).

[19] 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.

d_i is a location fixed effect.

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

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—by running the regression specified in equation 7 below. This equation includes an unobserved orthogonal disturbance ν_{it} to account for information revealed between the start of bidweek in month $t-1$ and month t.

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

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 $\hat{\alpha}_t = (\hat{\alpha}_{0t}, \hat{\alpha}_{1t}, \hat{\alpha}_{2t}, \hat{\delta}_t)$ 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.[20]

[20] 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.

Results from the estimation of equation [7] are summarized in table 2. 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 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 2010).[21] This result indicates that the NYMEX futures price and the spot price differential carry useful information with which to predict current prices.

Table 2 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 3, 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.

$$\ln((Spot_{it} - SpotForecast_{it})^2) = \lambda_0 + \lambda_1 \; Spot_{it} + \rho_i + h(t) + (\epsilon_{it} - \beta_1 \xi_{it}). \qquad [8]$$

The estimate of equation [8] is given in column I of table 3. The estimate of λ_1 is 0.817 and statistically significant at the 1 percent level. The interpretation of this coefficient is that a one dollar increase in the expected spot price is associated with an increase in

[21] 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.

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 II of table 3 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 III allows for a linear location-specific time trend, column IV allows for location-specific month-of-year effects, and column V 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.[22]

7. Estimation Results

7.1. Forward price premia

The results of estimating equation [4] are reported in table 4. The results presented in column I are those obtained through the estimation of [4] as written. Columns II through V follow the same progression as in table 3 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. The p-values for the results in columns 1 through 5 vary from 0.022 (columns IV and V) to 0.041 (column I).

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 4, we discussed several factors that could lead to this forward premium: career concerns, security of supply, and price risk aversion.

[22] 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.

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. We therefore next attempt 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.

7.2. Forward trading volumes

Column I of table 5 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.

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 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 4324 observations spread over 69 locations.[23] Summary statistics for spot volumes are given in table 1; 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

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

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.

$$\ln(SpotVolume_{it}) = \theta_0 + \theta_1 \ Spot_{it} + \phi_i + h(t) + \omega_{it} \qquad [9]$$

Table 6 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 5) are unlikely to be explained by factors related to increased transactions costs, since such factors would presumably impact spot markets as well.[24]

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 this result, nor would a model of price-risk aversion.

8. 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

[24] 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.

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 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. However, such situations are the circumstances in which 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 input among input customers. Likewise, the 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 may 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 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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Table 1: 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

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.

Table 2: 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 Valid RR Predictions (182 regressions)
Henry Hub (HH) future price	0.8796 (0.0527)	0.8637	0.0671
Location to HH spot price differential	0.3375 (0.1043)	0.2905	0.1028
N	13848	-	-

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.

Table 3: Determinants of the variance of the spot price
Dependent variable is log((realized spot price - recursive regression predicted spot price)^2)

	I	II	III	IV	V
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
Number of observations	9496	9496	9496	9496	9496

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.

Table 4: Determinants of forward-spot price differential
Dependent variable is the difference between the bidweek price and spot price for each delivery month

	I	II	III	IV	V
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

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.

Table 5: Determinants of log(bidweek trading volume)

	I	II	III	IV	V
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

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.

Table 6: Determinants of log(spot trading volume)

	I	II	III	IV	V
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

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.