Market Restructuring, Risk and Procurement Choices in Coal-Fired Electricity Generation

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Comments welcome.

Abstract

In this paper we analyze theoretically and empirically how upstream markets are affected by deregulation in downstream markets. A restructured market tend to be more uncertain than a regulated one, our theoretical analysis predicts that firms would respond to this increase in uncertainty by signing more rigid contracts with their suppliers. Using electricity market restructuring in the U.S. as our quasi-experiment, the empirical evidence strongly supports our theoretical predictions. We then investigate whether this change in procurement contracts has effected an increase in efficiency on the part of coal mines. We find that mines selling coal to plants on restructured markets are 12% more efficient than their counterparts working with regulated plants. Our findings have implications for the competitiveness of coal-fired generation in restructured electricity markets.

Keywords: Energy Policy, Electricity Market Deregulation, Procurement Contracts, Risk, Efficiency.

1 Introduction

Firms operating in regulated markets, especially those working under cost-of-service regulation, are often thought to be less efficient than firms operating under conditions of perfect competition. Competitive markets are in fact commonly seen by economists as conducive to higher technical efficiency. In most cases the argument relies on the notion that, under perfect competition, firms face stronger incentives for cost-minimization on the part of effort-averse managers than would instead be the case in a regulated context (Laffont and Tirole, 1993). Moving from this intellectual premise, many economists advocate freer, more competitive markets as the means to improve efficiency, reduce prices and increase welfare.

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In one of the rare occasions in which policy-makers have eagerly applied the prescriptions of economists, policy measures aimed at fostering competition have been commonplace in OECD countries since at least the late 1970s. Especially common have been attempts to deregulate previously regulated natural monopolies such as telecommunications, rail and air transportation, water provision, and energy generation and distribution. Obviously, economists interested in assessing the value of competition have not missed the opportunity to evaluate such policy changes (Ng and Seabright, 2001; Syverson, 2004; Davis and Kilian, 2011, for example). In particular, the restructuring of electricity markets has received special attention by economists due to a combination of political relevance and data availability (e.g. Newbery and Pollitt, 1997; Wolfram, 1999; Borenstein et al., 2002; Malik et al., 2011).

Most contributions assessing the impact of industry deregulation take a rather narrow view and discuss the consequences of the policy only for firms operating directly in the deregulated market (Borenstein et al., 2002; Bushnell and Wolfram, 2005; Fabrizio et al., 2007; Zhang, 2007; Davis and Kilian, 2011; Davis and Wolfram, 2012; Cicala, 2012; Chan et al., 2012). Such analyses, while informative, provide only a partial picture of the overall consequences of deregulation. Indeed, the aim of the policy is to increase welfare by eliminating all types of inefficiencies and transferring rents to the final consumers, and a fully-efficient outcome requires that efficiency gains be realized both by final producers and by their input suppliers. As a consequence, abstracting from possible effects impacting the supply chain upstream from the deregulated market is a relevant omission from a theoretical standpoint. This omission is likely to be significant from an empirical point of view as well in cases where the cost of specific inputs represents a significant share of the total costs of production, as fuel costs do in electricity generation. In this case, the level of costs for generators is bound to depend to a large extent on the efficiency of fuel producers. Thus, understanding whether deregulation provides the correct incentives for fuel producers to improve their efficiency is an important aspect to analyze.

In this paper, we discuss the consequences of regulation upwards along the supply chain. We first look at how deregulation efforts impact the fuel procurement contracting decisions between electricity generators and coal mines. Subsequently, we investigate the efficiency gains, if any, that follow from the changes in procurement contracts. In the first part of our work, we focus on two key dimensions of the contract, the rigidity of the price setting mechanism and its duration. On the one hand, contracts with more rigid price setting *de facto* make the coal mine the residual claimant to any efficiency gain, and hence provide higher-powered incentives for cost reductions. On the other hand, longer contracts tend to imply lower transaction costs per unit of time, which in itself means higher efficiency overall. Our theoretical model emphasizes the role of changes in the degree of uncertainty of the operating environment for energy generators, following the shift from cost-of-service regulation to market competition. The key testable implications we derive from the model are that we would expect to observe more rigid (such as fixed-price contracts), shorter contracts following the market restructuring. Given that about half of the states restructured their electricity market, a suitable control group for the plant's treated with restructuring is available. Using data on actual contracts signed by U.S. coal-fired generators with coal mines over the period 1979-2001, we are able to test these implications of the theory, and we find that the data substantially support our theoretical insights. In the second part of the paper, we use data on labour productivity in the mining industry to investigate the claim that more rigid prices in contracts are conducive to productivity gains. Moreover, we try to assess whether the changes in the contracting practices we identify can be linked to more frequent renegotiations, and to increases in transaction costs. Our analysis supports the first claim, while our results as refers to the second issue are more nuanced.

Our focus in this paper is on the increased exposure to risk experienced by electricity generators when cost-of-service regulation is removed, and they find themselves operating in a deregulated market. Rather than being insulated from fluctuations in (prudently incurred) costs via the cost-recovery mechanism provided by the cost-of-service regulation, the deregulated electricity generator faces two main type of uncertainty. The first is linked with the volatility of fuel prices, the second arises from the unpredictable nature of (wholesale) electricity prices. In principle, a variety of financial instruments – forward contracts, futures contracts, options, etc. – are available to generators to hedge those risks. In practice, however, given the limited possibility to efficiently store electricity, the severe constraints that exist on its transmission (both in physical terms and in terms of reliability), and the inelastic nature of (short-run) electricity demand, electricity prices on deregulated wholesale markets are substantially more volatile than any other commodity price (e.g. Liu et al., 2006; Yu et al., 2010), thus making effective hedging more difficult. Gross et al. (2010) also discusses the difficulty of hedging against long-run fuel price uncertainty, and the asymmetry between flexible high-marginal cost producers (price makers) and low-marginal cost producers (price takers) in their vulnerability to electricity price fluctuations. As a result, electricity generators need to adopt a tailored-made approach to risk management and risk assessment, and to accept the impossibility of perfectly hedging against the types of risk mentioned above. In what follows we study how the remaining risk coming from both the downstream wholesale electricity price volatility, and upstream fuel price uncertainty shapes the optimal contractual arrangements on the upstream market.

Our work is in the spirit of the seminal contribution by Cheung (1969), as we explicitly study the trade-off between transaction costs and risk distribution between contracting parties associated with different contractual arrangements, and it is also related to the vast literature on procurement contracts.[1] In his entry on '*Procurement*' in the New Palgrave Dictionary of Economics, Che (2008) emphasises that the theoretical literature on procurement contracts has focussed on situations characterized by significant information problems – such as the lack of observability/verifiability of costs and quality, and hidden action – that lead to procurement irregularities. The procurement of standardized goods and services in the absence of informational problems, however, has not received much attention in the literature so far in the general belief that standard competitive market mechanisms suffice for an efficient outcome (Che, 2008). While, coal is a standardized commodity, however, and the market for coal in itself does not suffer from substantial information problems since sellers can do very little to affect the quality of the coal they deliver and coal quality is verifiable, standard competitive market mechanisms does not seem well suited to deliver an efficient outcome. In fact, due to the highly inelastic nature of the (short-run) demand for coal, its bulky nature that prevents adequate storage, and the pervasive uncertainty on the output market, only a very small proportion of coal purchases occur on the sport market, while coal procurement is generally agreed via bilateral contracts that usually cover multiple deliveries and may last for decades (see Joskow, 1985, for example). Thus, the design of procurement contracts in this setting poses interesting theoretical and empirical questions, especially as to how the regulatory environment affects the nature of the optimal contract.

Among the many theoretical contributions on optimal procurement contracts and asymmetric information, our paper is closest to those that studies moral hazard in procurement. McAfee

[1] Che (2008) provides an excellent overview of the standard economic models of optimal procurement in markets with limited information. The literature review in Asker and Cantillon (2010) provides a more comprehensive list of publications in this literature.

and McMillan (1986) is a classic reference in this respect. There the optimal contract offered by the buyer to the risk averse seller implements a partial reimbursement rule that trades off incentives for cost reduction effort and the need to share risk. Similarly, Bajari and Tadelis (2001) focus on the trade-off between the cost reduction incentives and ex-post renegotiation inefficiencies. They conclude that a fixed-price contract is optimal for standard jobs, while cost-plus contracts are preferred when the job the buyer is contracting for is highly complex. Like these authors, we adopt a transaction cost approach to model the exposure to risk. In our framework the optimal contract balances the cost on contracting against the exposure to upstream uncertainty/risk (from the fuel price), by determining the optimal degree of price rigidity specified in the contract.

Due to data limitations, the empirical contract literature has lagged somewhat behind its theoretical counterpart.[2] Nevertheless, several authors have tried to explain the determinants of contract choice using different proxies for the characteristics of the principal, the agent and the task being contracted. Allen and Lueck (1992), Laffont and Matoussi (1995), and Ackerberg and Botticini (2002) focus on the determinants of agrarian contracts, Leffler and Rucker (1991) looks at timber harvesting, while Martin (1988), Lafontaine (1991), and Slade (1996) discuss contract choice in business franchising. Closer to our work, Corts and Singh (2004) study the impact of repeated interaction on the choice of fixed-price versus cost-plus contracts in the offshore drilling industry. In the present paper, we also study the interaction between the price rigidity decision and the length of interaction; in our framework, however, the two decisions are taken simultaneous and both characterize the optimal contract. Finally, there exists a literature that has looked specifically, at the determinants of contractual duration in coal procurement, using U.S. data. Joskow (1987), Kerkvliet and Shogren (2001) and Kozhevnikova and Lange (2009) all find evidence in support of the theory of transaction costs in contracts signed before 1979, between 1972 and 1984, and before 1999, respectively.

Our work below also touches upon the role of attitudes towards risk in contract choices. While a significant part of the literature seems to indicate that the empirical evidence supports a risk neutrality assumption for contracting parties (see, e.g. Allen and Lueck, 1995), Ackerberg and Botticini (2002) show that, once they account for the endogenous nature of the match between the seller and the buyer, the empirical evidence supports the hypothesis that different attitudes towards risk play a significant role in contract choices. This is likely to be especially the case in industries that are characterized by an obligation to produce, substantial transportation and storage costs for their bulky inputs, and the consequent inflexibility of operation in the short-run, such as electricity generation. It seems plausible, therefore, that producers operating in such an environment would be concerned not only with the expected returns of their decisions, but also with the associated risks. With this in mind, we adopt the classical Markowitz (1952, 1991) framework, and model the choice of contract similarly to a problem of portfolio selection. In our case the value of a contract can be expressed as a function of its expected returns (i.e. the profits associated with it), and its riskiness. Rather than resorting to traditional proxies for risk such as the variance, however, we build on current practice in the financial literature and use the concept of Conditional Value at Risk, $CVaR$, to capture the risk connected to a contract (Rockafellar and Uryasev, 2000; Yamai and Yoshiba, 2005).

The rest of the paper proceeds as follows, section 2 provides a concise overview of the market for coal in the U.S. in the period covered by our analysis and discusses the restructuring process started in the early 1990s. Section 3 contains our theoretical discussion and concludes with the testable implications that we take to the data. Section 4 presents the empirical

[2] For two recent surveys of this literature see Chiappori and Salanié (2002), and Corts and Singh (2004).

strategy that we use to take the theoretical prediction to the data, describes the data and discusses the results. In section 5 we discuss the economic implications of our theoretical and empirical analysis. Finally, section 6 concludes.

2 An overview of the coal-fired generation industry in the U.S. 1979-2001

The time period covered by our analysis corresponds to the peak of coal usage in the U.S. electricity market, as the oil embargoes of the 1970s created the conditions for an expansion in coal-fired electricity generation capacity. Coal supplied around 50% of the U.S. electricity through the 1980s, 1990s, and the early 2000s (U.S. EIA, 2010). Since coal plants tend to have higher start-up and shut-down costs, relative to oil and gas plants, coal capacity was generally built to supply the base-load of the electricity system, meaning that it was expected to run at all hours of the day, whereas oil and gas would only run for shorter periods. Hence, the main operational concern for operators of coal-fired boilers was to ensure an adequate and consistent supply of coal to meet base-load electricity demand. This led plants to utilize complex long-term forward contracts for procurement. Different types of contract were developed, which differed according to their varying degree of price rigidity. At one end of the spectrum one finds 'fixed-price' contracts, which would specify a single delivery price for the entire duration of the contract; at the other end of the spectrum, instead, the so-called 'evergreen' contracts stipulated that the price would be renegotiated at predetermined intervals, usually once a year. Other contracts had intermediate degrees of price rigidity, such as contracts that would specify a base price and a formula to compute increases or decreases from this base price, depending on economic and market conditions ('base-price plus escalation' contracts). Table 1 summarizes the most common types of contracts. These contracts proved to be surprisingly resilient to changes in input market regulation such as railroad market restructuring, and the emergence of a large spot market in the Western coal producing states (Joskow, 1985, 1990).

The desire for quantity/quality certainty, and the associated use of long-term forward contracts, was re-enforced by the structure of economic regulation in the electricity sector. Plants were regulated under a cost-of-service regulation, where the price of electricity was guaranteed by the state, depending on the plant's cost of generation. Crucially, once the state public utility commissions (PUCs) would approve a coal contract, they would then allow the plant to be compensated for the prices paid under that contract. The regulator put large weight on ensuring supply would meet demand rather than focusing on the cost of electricity. Furthermore, most plants were part of an integrated utility that also managed the transmission and distribution grids, so that plants had a great deal of certainty with respect to the price and quantity of the electricity they would sell. Moreover, it was difficult for new entrants to gain access given that incumbents managed the grid. This state of affairs considerably reduced the generators' incentives to minimize their generation costs, and left the mines with little pressure to improve their efficiency.

In 1992, the federal Energy Policy Act mandated that non-discriminatory access to the transmission grid be guaranteed, in an effort to encourage new generators to enter the market. Many states were also interested in encouraging lower cost generators to enter the generation market, and thus held hearings on how to reform their regulation of the electricity market. These hearings addressed possible ways to bring competition to the generation of electricity through potential legislation that separated transmission and distribution services from the generation and retail services of the electricity market. States that went through with electricity market restructuring set up a market where plants generally had to bid for the right to put electricity onto the transmission system and thus sell their output. Table 2 gives a list of the years when hearings were held and restructuring legislation passed, by state. Compared to the economic regulation that had existed before the mid-1990s, restructured electricity markets introduced risk in the output market for electricity generators. Whereas, as mentioned above, electricity generators in regulated markets were only marginally concerned by the uncertainty, in restructured markets little guarantee existed as to either price and quantity. In the next section we present a theoretical model to analyze how this change in uncertainty might have affected the choice of contract in the negotiation between electricity generators and coal mines.

Before turning to our theoretical discussion, it is worth pointing out here that, as emerges from Table 2, only about half of the States passed legislation to deregulate their electricity markets. This peculiarity of the US system provides us with the quasi-experimental set-up necessary to test whether the restructuring of the electricity market has lead to a change in the nature and the duration of the procurement contracts signed between generators and coal mines. By being able to use generators and mines in non-restructured states as our control group, we are indeed able to isolate the effect of restructuring on the choice of procurement contracts in restructured states.

3 A model of fuel procurement in electricity generation

We model the interaction between a coal-fired electricity generator and a coal mine.[3] The electricity producer needs to source coal to operate its boilers and produce steam to generate electricity for sale on the downstream market. The mine, on the other hand, extracts coal from the ground and sells the mined coal on the market. This interaction may result in the parties writing a (procurement) contract for the purchase of a specified quantity of coal from the mine to the generator. In what follows, we assume that the quantity of coal is given in each period and can be normalized to one.[4]

3.1 The value of a contract

For our purposes here, the key elements of the contract are its duration, d, and the price paid for each unit of coal, p^c. As regards the latter, the contract needs to specify how the price is determined over the whole duration of the contract. As discussed for example by Joskow (1988), different price adjustment provisions may be included in procurement contracts. The price can be fixed for the whole duration of the contract, which leads to the aptly named fix-price contract, for example. It can, however, be allowed to change over time, for example to compensate – partially or totally – the mine for unexpected changes in the level of its costs, or to reflect changes in economic conditions. Different types of contracts – base-price plus escalation, cost-plus, and evergreen, among others – differ according to the extent to

[3] In what follows we use the terms 'producer', 'generator', 'buyer' or simply 'plant' interchangeably. Instead, we refer to the coal producer as the 'mine', or simply the 'seller'.

[4] Most coal-fired generators serve base-loads given their low marginal cost of generation, and their high cost of ramping production up or down. Hence, such generators tend to produce continuously and their main concern in terms of procurement is the availability of a sufficient quantity of coal. In this market segment, then, the quantity of coal to be delivered each period is very closely related to the productive capacity of the electricity generator, and as such can be considered constant in the medium run.

which they allow for the costs actually incurred by the mine to be recovered. To capture the varying degree of price rigidity, we can write the delivery price of coal as consisting of a component that allows the seller to recoup its operating costs, $(1-r)\chi$, and a fixed part that allows for an appropriate rate of return on its assets, $\delta(r)$:

$$p^c = \delta(r) + (1-r)\chi. \tag{1}$$

In the expression above χ represents the production costs incurred by the mine. The mine's main activity is to extract coal from the ground, this process typically entails drilling and blasting the coal seam, removing the coal, crushing and separating the coal from other by-products, stockpiling and shipping, etc. The cost of this complex process varies across locations, seams and over time, and we assume that the mine knows the probability distribution of the cost of extraction, but it faces uncertainty, *ex-ante*, about the actual realization of the level of costs in each period. In particular, we assume that χ follows a normal distribution with mean $\mathbb{E}(\chi)$ and variance σ^2_χ.

For our purposes here coal is treated as a homogenous commodity. As a consequence, we would expect the level of the price to be the same, *ex-ante*, across contracts. In order for this to be the case, we adjust the level of the fixed component such that the expected price remains the same, irrespective of the level of r. It follows that δ is a decreasing function of r, with $\delta \in [\underline{\delta}, \overline{\delta}]$. In cost-plus contracts a full cost recovery is allowed, implying that $r = 0$. Hence, in the case of a cost-plus contract, we get $\mathbb{E}(p^c) = \underline{\delta} + \mathbb{E}(\chi)$. At the other end of the spectrum, a fixed-price contract is characterized by $r = 1$, implying that $p^c = \overline{\delta}$.

In line with the theoretical underpinnings of the transaction cost approach to contracting (Coase, 1937; Cheung, 1969; Williamson, 1975), we assume that for both seller and buyer negotiating an agreement, writing the relative contract, and managing the ensuing relationship with the counterpart entails potentially large costs, including the opportunity cost of devoting resources to contracting and administering the contract, rather than to alternative, more productive activities. We also assume, as discussed at length below, that different types of contracts entail different transaction costs, depending on the contract rigidity, and its duration, and that more complex relationships – for example those that require higher level of relation-specific assets – are generally more costly to shape and maintain. Crucially, we assume that these costs cannot be practically attributed to specific accounting posts and that, as a consequence, they cannot be included in the costs that can be recovered under a cost-plus contract by the seller, and under cost-of-service regulation by the buyer. In other words, transaction costs always contribute negatively to profits, irrespective of the regulatory environment and the pricing mechanism.

Given (1), we can parameterize the price setting mechanism by r, and define a 'contract' as a pair, $\gamma = \{r, d\}$, specifying the degree of price rigidity in the contract, and its duration. From the set of all possible contracts, Γ, the parties select the contract γ that maximizes the benefits they derive from the contractual relationship. Similarly to the familiar Markowitz (1952) set-up, we assume that both types of firm value contracts according to their perceived trade-off between risk and expected return. In line with recent practice in the financial contracting literature, however, rather than measuring risk using the variance of the portfolio returns, we adopt the concept of *conditional-value-at-risk* ($CVaR_\alpha$) associated with each contract as our proxy for risk (e.g. Yamai and Yoshiba, 2005).[5] As a consequence, both types of firm choose the contract that provides the best combination of expected profits and the

[5] For any given confidence level α, the *value-at-risk*, or VaR_α, of a portfolio is given by the smallest number v such that the probability that the loss in portfolio value exceeds v is not greater than $(1-\alpha)$. The $CVaR$ of a portfolio is, instead, defined as the expected loss in portfolio value during a specified period, conditional

size of the potential adverse consequences associated with the contract. The per-period value of contract $\gamma = \{r, d\}$ to firm type $i = \{g, m\}$, can thus be written in general terms as follows:

$$V^i(\gamma) = \mathbb{E}(\pi^i) - \theta^i \, CVaR_\alpha(-\pi^i), \text{ for } i = \{g, m\}, \tag{2}$$

where g and m are the generator's and the mine's identifiers, respectively, and θ^i is the relative weight attached to risk by type i in its objective function.

3.2 The mine

We start by specializing (2) for the case of the coal mine. Having extracted and processed the coal at a cost equal to χ, the mine can then deliver it to the generator in exchange for the agreed price, p^c, see equation (1).

As discussed above, we capture the transaction costs associated with contracting by including the term, k^m, to the cost of the mine. It is quite natural to think that such costs may change with the pricing mechanism and the duration of contract being stipulated. For example, a more rigid contract may be more costly to negotiate, as there are simply more contingencies to contemplate; on the other hand, a contract that specifies the price more rigidly – such as a fixed-price contract – reduces the level of effort exerted by the mine in accounting for, documenting and reporting its operating costs. As such, it entails lower administrative costs for the seller. In what follows, we assume that the latter effect is particularly important from the point of view of the mine, and thus assume that k^m is decreasing with r, i.e. we let $\partial k^m/\partial r < 0$. As refers to the duration stipulated in the contract, instead, one would normally believe that a longer contract would allow for the fixed stipulation costs to be spread over a longer time period, and hence reduce the per-period administrative costs. One needs to consider, however, that the longer the contract duration specified in the contract, the higher the probability that the seller might find it advantageous to breach the existing contract. This tendency might be driven by the desire to pursue more lucrative alternative opportunities elsewhere – a situation discussed, for example, by Joskow (1988) – or might arise because of negative developments in productive conditions. As discussed in section 2 above, coal procurement contracts specify in great detail the characteristics of the coal to be delivered, for example its heat, ash, moisture and sulfur contents. If the productive conditions of the mine change – because of an unexpected deterioration in the quality of the coal they extract, for example – the mine might find it very costly to keep operating within the framework of its current contractual obligations, and might prefer to breach the contract. Either way, breaching the contract adds more transaction costs and potentially large litigation costs to the total. With all this in mind, we conclude that k^m is likely to be increasing with contractual duration, d, i.e. $\partial k^m/\partial d > 0$. Since the likelihood of breach of contract is particularly high for contracts with more rigid price setting mechanisms, we further assume that $\partial^2 k^m/(\partial r \partial d) > 0$.[6] Finally, the type of transaction costs discussed above may be affected by other factors, among which relation-specific investments feature prominently as discussed by Joskow (1987). To reflect this possibility, we write the transaction cost component as $k^m(r, d\,; \mathbf{A})$, where $\mathbf{A}$ is a vector of cost-shifters. The need to incur relation-specific investments tends to increase the cost of entering the contractual relationship; at the same time, the presence of relation-specific assets

on the event that the loss is greater than or equal to VaR. Thus, $CVaR$ informs a portfolio holder about the size of the expected loss, conditional on the occurrence of an unfavorable event, rather than simply indicating the probability of an unfavorable event (Rockafellar and Uryasev, 2000). Liu et al. (2006); Yu et al. (2010) are two examples of papers using $CVaR$ in an energy-related context.

[6]We also assume that transaction costs are strictly convex in both arguments, so that $\partial^2 k^m/\partial x^2 > 0$, for $x \in \{r, d\}$.

is likely to reduce the attractiveness of alternative opportunities. Both arguments imply that a longer contractual duration becomes more desirable as the sunk costs may be spread over more periods, and the likelihood of breaching the contract is reduced. This reasoning leads us to conclude that the marginal costs of a longer contractual duration decrease with $\mathbf{A}$, i.e. $\partial^2 k^m/(\partial d\, \partial A_i) < 0$ for each component A_i of $\mathbf{A}$.[7]

Overall, we can write the mine's profits as

$$\pi^m = p^c - \chi - k^m(r, d\,; \mathbf{A}). \tag{3}$$

Substituting (1) into the expression above, and given our assumption above that mining costs are distributed according to $N(\mathbb{E}(\chi), \sigma_\chi^2)$, we can express the per-period value to the mine of entering into contract γ with the generator as follows:

$$V^m(\gamma) = (1+\theta^m)\Big[\overline{\delta} - \mathbb{E}(\chi) - k^m(r, d\,; \mathbf{A})\Big] - \theta^m b(\alpha) r \sigma_\chi, \tag{4}$$

where we made use of the fact that, as shown by Rockafellar and Uryasev (2000), for normally distributed portfolios the conditional value at risk can be written as

$$CVaR_\alpha(-\pi) = -\mathbb{E}(\pi) + b(\alpha)\,\sqrt{\mathrm{Var}(\pi)}, \tag{5}$$

where

$$b(\alpha) = (\sqrt{2\pi}\exp(\mathrm{erf}^{-1}(2\alpha-1))^2(1-\alpha))^{-1},$$

and $\mathrm{erf}(z) = (2/\sqrt{\pi})\int_o^z e^{-s^2}\mathrm{d}s$ is the Gauss error function.

3.3 The electricity generator

To derive the expression that represents the value of the contract from the point of view of the electricity producer, we first need to consider the determinants of the generator's profits. Obviously, the generator derives revenues from the sale of electricity, which may occur either on a regulated or a liberalized market. When the generator operates within a regulated market, the price of electricity (p^e) is set by the regulator to cover the firm's operating costs (c) and allow for a fair rate of return on its assets. In this case, we can write $p^e = \mu + c$, where c represents the generator's operating costs, and μ is the unitary mark-up over costs recognized by the regulator.[8] When the generator sells electricity on a liberalized market, it instead faces a competitive environment, and takes the price of electricity as exogenously given. Since the price of electricity is *ex-ante* unknown, this introduces uncertainty in the generator's objective function. For the sake of simplicity, we assume that p^e is normally distributed with mean $\mathbb{E}(p^e)$, and standard deviation σ_e.

To generate electricity, the producer naturally incurs costs. In this simplified set-up, we focus purely on fuel costs and abstract from all remaining operating costs, so that c equals p^c, the price of one unit of coal.

As in the case of the coal mine, in addition to these operating costs, we include the transaction costs associated with bargaining, contracting, and managing the relationship with the

[7] Since we have no priors about the impact of changes in relation-specific investments on the degree of rigidity of the pricing mechanism, nor could we think of a mechanism through which a change in A would *directly* affect the cost of r, in what follows we assume $\partial^2 k^m/(\partial r \partial A) = 0$.

[8] Note that to simplify the notation, we have chosen our measurement units such that one unit of electricity is produced with one unit of coal.

counterpart, k^g, in the profit expression. In what follows, we assume that k^g is increasing with the degree of price rigidity as writing a more rigid contract is more costly, as discussed above for the case of the mine, while the generator doesn't need to incur the administrative costs that the mine faces to record, document and report its extraction costs for the purpose of having them refunded by the generator. Hence, we let $\partial k^g/\partial r > 0$. Furthermore, we assume that from the point of view of the generator the cost of contracting declines with the duration of the contract – trivially, the costs are incurred less frequently so the per-period cost decreases. Indeed, the generator does not face the costs that arise from the expected breach of contract, as discussed above for the mine, i.e. $\partial k^g/\partial d < 0$. This is because the generator has lower incentives to breach the contract than the mine, and it most likely would be on the receiving end of any compensation in case of breach of contract by the mine. As discussed in the previous section, however, we want to allow for the possibility that the transaction costs discussed here might depend on a set of cost shifters, $\mathbf{A}$. In this case, an increase in $\mathbf{A}$ – for example an increase in transaction-specific assets – further reduces the marginal cost of a the contractual duration. Thus, $k^g(r, d\,; \mathbf{A})$, and $\partial^2 k^g/(\partial d\, \partial A_i) < 0$, for each $A_i \in \mathbf{A}$.[9]

We can then write the expression for profits for the generator as a function of the regulatory context, as follows,

$$\pi^g = \lambda p^e + (1-\lambda)(\mu + p^c) - p^c - k^g(r, d\,; \mathbf{A}), \text{ for } \lambda = \{0, 1\}, \tag{6}$$

which implies that the per-period value for the generator of signing up to contract $\gamma r, d$ is:

$$V^g(\gamma) = (1+\theta^g)\Big\{\lambda\big[\mathbb{E}(p^e) - \overline{\delta} - \mu\big] + \mu - k^g(r, d\,; \mathbf{A})\Big\} - \theta^g b(\alpha)\lambda\sqrt{\sigma_e^2 + (1-r)^2\sigma_\chi^2}. \tag{7}$$

3.4 The optimal choice of contract

We assume that there is a large number of potential sellers (mines) on the market relative to the number of buyers (generators), so that we let the buyer make a take it or leave it offer to the seller, offering a contract that guarantees the mine a value of zero. With this assumption in mind, the problem of the generator reduces to the problem of selecting from the menu of all contracts, Γ, the one that maximizes its objective function, (7), while guaranteeing the participation of the mine. Formally, the generator chooses the contract $\gamma^* = \{r^*, d^*\}$ that solves

$$\gamma^* \equiv \arg\max_{\gamma\in\Gamma} = \{V^g(\gamma) | V^m(\gamma) \geq 0\}. \tag{8}$$

We are now in a position to derive our first result, which refers to the impact of deregulation in the downstream market on the characteristics of the optimal contract:

Proposition 1. *The degree of price rigidity specified by the optimal contract, r^*, is monotonically non-decreasing in the degree of market liberalization, λ, while the optimal duration of the contract, d^*, is monotonically non-increasing in the same.*

Proof. See Appendix A □

According to this result, as the downstream market gets deregulated the generator finds it more profitable to offer contracts characterized by an increasing degree of price rigidity

[9]Notice that also in this case we assume that changes in $\mathbf{A}$ do not affect the marginal transaction cost of a more rigid contract, i.e. $\partial^2 k^g/(\partial d\, \partial A_i) = 0$.

and/or a shorter duration to its coal provider. The intuition behind this results is in fact rather straightforward. In a regulated market, the cost-of-service regulation faced by the generator *de facto* insulates it from any adverse realization of the mining cost variable, χ. Hence, in this context the generator only needs to pick the right combination of price rigidity and duration to minimize its transaction costs while at the same time ensuring the continued participation of the mine in the exchange. As the degree of market gets liberalized (i.e. as λ increases), however, the generator is left facing the prospect of potential losses via the uncertainty associated with the now variable market price for its output, and the oscillation in the cost of its input – see the last term in equation (7). As the downstream market is perfectly competitive by assumption, the only option left to the generator to reduce its exposure is to limit the uncertainty associated with the price of coal. To achieve this, the generator offers the mine a contract with a higher degree of price rigidity which limits the negative consequences in terms of profits of a bad realization of χ. In doing so, however, it is the turn of the mine to become more exposed to the same bad outcome. To satisfy the mine's participation constraint, the buyer needs to offer a shorter contractual duration, which reduces the cost of contracting for the mine, and makes the new contract more palatable.

The previous discussion underlines the fundamental tension that exists in our model from the point of view of the buyer, following the restructuring of the downstream market. In a restructured market, the electricity generator wishes to reduce its exposure to risk, but is not willing to incur excessive transaction costs, and at the same time she needs to satisfy the participation constraint for the mine. Thus, it accords with our intuition that the optimal choice of procurement contract may changes with the overall level of risk, and with the relative costliness of the two instruments, r and d, in terms of transaction costs, as is shown in the following result:

Proposition 2. *The sign of the derivative of the optimal choice of contract rigidity and duration with respect to changes in the values of key parameters are as follows:*

	Choice variable	
Parameter	r^*	d^*
A_i	$-$	$+$
σ_e^2	$-$	$+$
σ_χ^2	?	?

Proof. See Appendix B □

The first line of the table in Proposition 2 informs us that an increase in A_i, our short-hand for a change in any of the cost-shifters that affects the transaction costs, reduces r and increases d. Returning to our interpretation of A_i as the level of asset-specific investment entailed by the contractual relationship, it is straightforward to see that, since more relation-specific assets reduce the transaction costs associated with a longer contract, longer, less rigid contracts will naturally emerge from situations where sunk costs of this type are more pervasive, e.g. for mine-mouth plants-mine relationships (See the discussion in Joskow, 1987, for example). The mechanism at work here is also interesting as it will help us in our identification efforts in the empirical part of the paper. Given our assumptions in the theoretical modelling, the lengthening of the contractual duration is *directly* caused by the change in the relation-specific assets. The change in the pricing mechanism, instead, only emerges indirectly, by virtue of the strict convexity of the transaction cost functions.

Next we turn to the consequences of an increase in risk, proxy-ed by the volatility of the price of electricity, and by the variance of the extraction costs. As discussed above, having to operate in a more uncertain environment carries the risk of higher losses for the generator, as is clear from the fact that the $CVaR$ component of V^g increases with both σ_e^2 and σ_χ^2. The impact of changes in the former are relatively more straightforward to analyzed. As the volatility of the electricity price increases, the generator, in order to maximize the value of the contract, can only attempt to reduce its transaction costs. Recalling that k^g is increasing with r and decreasing with d, and strictly convex in both, it is reasonable to expect that the generator's proposal to the mine would now consist of a more flexible, longer contract. This type of contract, however, turns out to be more expensive for the mine in terms of contracting costs. Nevertheless, the mine would sign it as it still satisfies the participation constraint, due to the reduction in the mine's exposure to the risk of a bad draw of its extraction costs, χ, that follows from the move to a more flexible pricing mechanism.

Changes in the dispersion of the extraction costs, σ_χ^2, are more complicated. On the one hand, from the point of view of the generator a higher level of σ_χ^2 imply a tightening of the mine's participation constraint in equation (8), as the value of the contract for the mine unequivocally falls with σ_χ. The generator's optimal response to this change in risk would be to propose a new combination of r and d that ensures the mine's participation by reducing the mine's contracting costs. One would then expect that the buyer proposed a new contract characterized by a more rigid pricing mechanism, and a shorter duration of the contract, as both tend to reduce the cost of contracting from the mine's standpoint. One must not forget, however, that the increase in uncertainty also enters directly the $CVaR$ component of the generator's valuation of the contract. This second effect is similar to the change in σ_e^2 that has been shown in the previous paragraph to lead to longer, more flexible contracts. Not surprisingly, given that these changes have been shown above to lead to two opposite reactions, it is in general not possible to sign the direction of the change in r and d in this case, and the net direction of change is ultimately an empirical question. Similar to the case discussed above for changes in relation-specific assets, it is important to note here that changes in the level of risk exposure affect *directly* the optimal level of r, whereas the choice of contractual duration is only indirectly affected. We return to this property of the model when we discuss the strategy for empirical identification below.

3.5 Taking the theory to the data.

The theoretical discussion presented so far provides several insights into the contracting behaviour of generators and coal mines. From the theoretical results derived above, we can derive specific implications for what we would expect to observe in the data. The key results of our analysis are summarized in Proposition 1, which immediately leads us to formulate the main testable hypotheses that we are going to subject to empirical scrutiny in the next part of this paper. As refers to the degree of price rigidity, we can state the following:

Hypothesis 1. *The degree of rigidity of the price-setting mechanism specified in the contract should not be lower,* coeteris paribus*, for contracts signed by electricity generators operating (mostly) in restructured markets than for generators operating (mostly) in non-restructured ones.*

Its counterpart in terms of contract duration is:

Hypothesis 2. *The duration specified in the contract should not be longer,* coeteris paribus*,* *for contracts signed by utilities operating (mostly) in restructured markets than for utilities operating (mostly) in non-restructured ones.*

From proposition 2, where the results of our comparative statics exercises are formalized, we can obtain testable hypotheses that refer to the impact of changes in key parameters on the choice of pricing-mechanism rigidity and contractual duration. Firstly, we get that

Hypothesis 3. *The degree of rigidity of the price-setting mechanism specified in the contract should not be higher,* coeteris paribus*, for contracts that require a higher level of relation-specific investments, and for contracts signed during periods of higher electricity price volatility.*

Finally, we have, in terms of contractual duration, the following:

Hypothesis 4. *The duration specified in the contract should not be shorter,* coeteris paribus*, for contracts that require a higher level of relation-specific investments, and for contracts signed during periods of higher electricity price volatility.*

4 An empirical investigation of contract choices

In this section we take the hypotheses derived in Section 3.5 above and we confront them with the data. All the hypotheses discussed above are formulated in terms of the effects of changes in the regulatory environment on the optimal degree of rigidity and duration of procurement contracts. It follows that the empirical counterpart of the analysis will have to focus on explaining both contractual rigidity and duration. In particular, we are interested in assessing how the restructuring of electricity markets has affected the optimal choice of procurement contract.

In the most general terms, the estimation model for the rigidity of price-setting mechanism can be written as,

$$r_i = \alpha_0 + \alpha_1 d_i + \alpha_2 \Delta_i + \alpha_3 \mathbf{X_i} + \alpha_4 \mathbf{Z_{1,i}} + \varepsilon_{1,i}; \tag{9}$$

whereas for the contractual duration, we have,

$$d_i = \beta_0 + \beta_1 r_i + \beta_2 \Delta_i + \beta_3 \mathbf{X_i} + \beta_4 \mathbf{Z_{2,i}} + \varepsilon_{2,i}. \tag{10}$$

The first dependent variable, r, is an ordinal variable that ranks the rigidity of the contractual price setting mechanism in contract i between 1 (least rigid) and 4 (most rigid). Table 1 provides a more detailed description of the types of contracts that fall in each category. The second dependent variable is the duration of the contract, d, expressed in years. The remaining independent variables at the right-hand side of (9) and (10) are a difference-in-difference variable (Δ), a set of control variables ($\mathbf{X}$), and a set of instrumental variables ($\mathbf{Z}$), for each of the regressions. Finally, $\varepsilon_{1,i}$ and $\varepsilon_{2,i}$ are idiosyncratic error terms.

4.1 Identification

The estimation model described in equations (9) and (10) presents some issues that require further discussion. It is clear that the data available to estimate the equations only provide information on the equilibrium outcomes of the bargaining process taking place between plants and mines, and that the choice of pricing mechanism and contractual duration occur simultaneously. This leads to endogeneity concerns that might lead to the computation of biased estimates for the coefficients of the empirical model, if not addressed properly. In order to correct for these potential biases, an instrumental variable approach can be utilized, and instruments for both rigidity and duration need to be employed.

To find appropriate instruments in this context one needs to identify variables that only affect one of the choice variables directly, while not directly impacting on the remaining one. In our search we are guided by the theoretical framework developed in section 3, and in particular by the results we discussed in Proposition 2. In the process of proving the claims in Proposition 2, we show that the risk proxies (σ_e^2 and σ_χ^2) impact directly only on the choice of r, whereas the cost-shifters, $\mathbf{A}$, only directly affect the choice of d. Thus, we identify plausible instruments for each of the two equations.

Due to the difficulty to identify convincing proxies for the variability of electricity prices, we use as instruments for rigidity only variables that proxy for the plants exposure to input cost risk. Since coal is a product with a number of attributes, it is these attributes which determine the value of coal to a plant. As a consequence, from the point of view of a plant, input cost risk can be measured by how likely it is that lower quality coal is delivered in accordance to the contract. As discussed in section 3, mines are endowed with coal of specific attributes, and generally can do very little to alter the attributes of their coal.[10] When plants write a contract with a mine for monthly delivery of coal, they specify the limits of attributes that are acceptable for deliveries. Kerkvliet and Shogren (1992) point out that plants often use long term contracts to procure coal with attributes that match the design parameters of their boiler, so that the attributes specified in the contract are a function of the technical characteristics of the boiler, and as such can be deemed exogenous to the procurement choice. Generally, in the contracts the maximum (minimum) levels of attributes such as ash, sulfur, and moisture (Btu) that are allowed are specified. Ash, sulfur, and moisture are undesirable attributes, therefore specifying lower maximum levels of these attributes in a contract imply the requirement to source higher quality coal. Btus, instead, are a positive attribute; therefore a higher minimum level specified imply a higher quality coal. To measure the level of input cost risk for a plant, we compute Z-scores for each attribute. These scores represent the probability of being delivered coal with an attribute level that is allowed by the contract. Z-score are calculated for BTU, sulfur, moisture, and ash content using data from the Federal Energy Regulatory Commission Form 423 on coal supplied from 1972-2001. The mean and standard deviation of each attribute is determined for each Bureau of Mines coal producing district and the allowable level specified in the contract is used to calculate the Z-score according to: $\frac{\text{allowable level}-\text{mean}}{\text{standard deviation}}$. As the Z-score increases, there is a larger probability that lower quality coal (still acceptable according to the contract specifications) is in the coal district. This larger probability allows for more plant input cost risk and should be correlated with the rigidity of the contract, but not with the duration.

As empirical counterparts for the shifters of the transaction cost functions in the theoretical model, we focus on variables that might proxy for the likelihood of breach of contract, in particular we consider variables that proxy for the availability of alternative contracting partners (Joskow, 1987). As discussed in Section 3, factors which increase the availablity of alternative options should be correlated with a shorter duration. For example, a plant with a high level of dedicated assets would find it more expensive to use coal from an alternative source. As a consequence, we expect higher levels of dedicated assets to be correlated with a longer contractual duration. The instruments we use in this case are: a mine-mouth plant dummy; proxies for the level of dedicated assets that both the plant and the mine have in the relationship at the time of the first delivery; the ratio of coal sold in the spot market to

[10] Most attributes are inherent to the coal and can not be cleaned or washed to remove them

the total quantity of coal traded for the coal region the mine is located in, during the year the contract was signed; a dummy that indicates whether the plant can receive deliveries through multiple modes of transportation; the minimum quantity of coal to be transacted each month; and a dummy for the contract being signed after deregulation of the railroad industry. The level of dedicated assets proxy variables are the ratio of an individual contract quantity to the sum of the plant's (mine's) contract quantity. The higher the ratio, the more the plant/mine depend on that specific contract.[11] The post-rail deregulation dummy has a value of one for all contracts signed after 1983, and zero otherwise.

4.2 Data

The data we use to test this hypotheses are derived from the Coal Transportation Rate Database (CTRB), which is taken from the Federal Energy Regulatory Commission (FERC) Form 580 "Interrogatory on Fuel and Energy Purchase Practices". The data are a survey of investor-owned, interstate electric generator plants with steam-electric generating stations with more than 50 Megawatts (MW) of installed capacity. The data-set contains information on coal transactions for the years 1979-2001, including the price-setting mechanism, the cost of delivered coal, its quality, and the county of origin of coal purchases, as well as the lower and upper bounds for a number of coal quality attributes.

The data identifies contracts and any renegotiation of the contract. Only observations from contracts which have not been renegotiated are utilized to estimate the models in equations (9) and (10). The data-set lists the contract as having one of seven types of price adjustment mechanisms: Base price plus escalation; Price renegotiation; Price tied to market; Cost-Plus with a fixed fee provision; Cost-Plus with an incentive fee provision; Fixed price; Other. Table lists these types from the most rigid to the least rigid and lists, for each contract type, the definition provided by the FERC to plants in the survey's documentation. Contract types were numbered from 1 to 4 in increasing order of their rigidity, and the "Other" category was dropped.[12] Duration is calculated subtracting the year the contract was signed from the expiration year indicated in the data-set.

In what follows, we will use the variation over time and across U.S. states in the restructuring of the electricity market to identify the causal effect of changing regulation on procurement choices. Hence, for both regressions, the difference-in-difference indicator of interest, i.e. Δ in equations (9) and (10), is a dummy variable that assumes the value of 1 for contracts signed by electricity generators operating in restructured states after legislation was passed to restructure the electricity market, and 0 otherwise. Additionally, a restructured state dummy is created which takes the value of one if a state ever restructures its electricity market and is zero otherwise. Control variables utilized are contract characteristics or changes to regulatory policy. Other policy variables are a post-ARP dummy which takes the value of one for all contracts signed in 1991 or after and is zero otherwise. An interaction dummy was created to determine whether the plant and mine had written a contract previously. It takes the value of one if the plant and mine had previously written a contract together. Next, a dummy is created for the presence of a scrubber (a piece of capital that removes SO_2 from the waste stream). Dummy variables are created for the coal-producing region, as defined by the Energy

[11] Unfortunately, the data does not contain a mine identification code, thus a county of coal origin code is used as a substitute.

[12] Alternative forms of this ordinal ranking for rigidity were specified, and robustness checks were conducted using these alternative dependent variable for r. The result were found to be qualitatively very similar. The full results of these tests are available from the authors upon request.

Information Administration (EIA). The three regions are Appalachian, Interior, and Western.

Summary statistics for the data can be found in Table 3. The variables are shown by treatment and control group and by timing of restructuring. In both groups, the rigidity and duration fall after the treatment goes into effect. Most of the other variables follow similar pattern across the two groups when the treatment goes into effect. Two noticeable differences are that the minimum quantity to transact in a contract is higher in control plants and that treatment plants sign contracts with Appalachian region mines more than control plants.

4.3 Results

Table 4 presents the results of the estimation of equations (9) and (10), which test the relationship between electricity market restructuring, the contractual duration and the rigidity of the contract. In all regressions, we correct for potential state-level serial correlation by clustering at the state level. Figure 1 shows how the rigidity of contracts for plants in restructured states evolves relative to the rigidity of contracts for plants in states that do not restructure. Contract rigidity in restructured states is not statistically different than the rigidity in non-restructured states before states began passing restructuring legislation. This implies that the two groups were behaving similarly before restructuring took place.

The first column of Table 4 presents the results of an ordered probit model, where the potential endogeneity of duration is not controlled for. In this case, electricity market restructuring led to more rigid contracts being signed, the coefficient of the variable Post Restructuring is positive and statistically significant at the 10% level. The second column presents a GMM estimation where, following our identification strategy, we instrument for the duration of a contract using the available empirical proxies for transaction cost shifters.[13] The J-test for overidentifying restrictions indicates that the instruments are exogenous. The set of instruments also passes the test for weak instruments with Cragg and Donald's 1993 F-statistics equal to 105.343, which is higher than Stock and Yogo's 2005 critical value for 5% maximal IV bias, which is equal to 19.86. As in column 1, the coefficient on the variable capturing the electricity market restructuring implies that more rigid contracts are signed after restructuring. Notably, the estimate of the coefficient for this variable is now significant at the 1% level.

Comparing the coefficient on duration between column 2 and column 1, we note that not controlling for the simultaneous determination of rigidity and duration leads to a negative bias in the estimated effect of duration. This sign of the bias complies with our theory, which reveals that at the optimum the level of rigidity and contract duration are substitutes.

Columns 3 and 4 show the 3SLS estimation results where we use the same instruments for duration as those used in the GMM estimation of column 2, and, in addition, we employ empirical counterparts for the exposure to risk as instruments for the rigidity regression. The instruments for rigidity are used in the duration regression when controlling for covariance in the errors across equations. Electricity market restructuring leads to more rigid contracts being signed, while it does not affect the duration of contracts. The effect of duration on rigidity is slightly more negative than in the GMM specification, but still less than the ordered probit, and is again significant at 1%.

The signs and significance of the included control variables are largely consistent with our theoretical predictions. First consider the additional variables that capture variations in the

[13] These estimations have been carried out using the `ivreg2` package in STATA 13.

regulatory environment. Post SO_2 Regulation indicates an increase in the level of uncertainty in the contractual relation by increasing the potential cost for the plant of receiving sub-standard coal quality. Similarly, the indicator variable for Mandatory Phase I Plant reflects that plants with older boilers are more sensitive to the more stringent environmental regulation, thus suffer more from variations in the quality of delivered coal. Since both of these variables are associated with increases in uncertainty, it is expected that they are associated with signing more rigid contracts. Indeed in all our estimations these variables' coefficients are statistically significantly positive.

Related to the mechanism described above one can derive predictions about how the level of Z-scores of ash, sulfur, moisture, and BTU affects the choice of rigidity. Recall that an increase in the Z-scores or ash, sulfur and moisture and a decrease in the Z-score of BTU is associated with a higher likelihood that the plant receives a lower quality of coal which affects its production efficiency. Higher levels of these variable, therefore, are associated with greater input cost uncertainty. According to our theory this higher level of input cost uncertainty should lead to higher rigidity. This intuition is confirmed by the estimated coefficient of Z-Ash, Z-Sulfur, and Z-BTU which all have the expected signs. For completeness, we also perform a test of the joint hypothesis that all variables in this group are significant. We find these variables to be jointly significant at 1% in all three regression models.

Notice that all variable discussed until now capture the degree of uncertainty under which the plant operates.

The indicator variable Previous Interaction has an estimated positive effect on the level of rigidity. This effect, however, becomes not significant once we control for the possible endogeneity of duration. The mechanism underlying this result is that a previous interaction reduces the transaction cost of negotiating and writing the contract. As a result, writing a more rigid contract becomes cheaper for plant-mine pairs that have already signed a previous contract. This effect may, however, be insignificant as there are other factors that have a greater impact on the optimal level of rigidity and duration.

Last, we discuss the effect of the variable Underground Mine on the choice of contract type. As discussed above this variable proxies for the level and uncertainty of mining costs as underground coal is more costly to extract, and underground mines face higher probability of industrial accidents. Moreover, underground mines have traditionally a more unionized work-force, thus they are more exposed to macroeconomic shocks that affect the labor market. Thus, unlike the variables above, Underground Mine reflects mostly the degree of uncertainty under which the mine operates. The estimated coefficient for this variable is negative and significant in all regressions on contract type. To fully understand the mechanism at work here, we also need to discuss the effect of this variable on duration. Our results show that the sign of the coefficient for Underground Mine is positive and significant at 1% (see the fourth column of Table 4). This result indicates that contracts signed with underground mines are on average less rigid and longer. Going back to our theoretical framework, recall that to satisfy the mine's participation constraint a generator trades off the degree of cost sharing embedded in the contract with the contractual duration. For a mine characterized by a higher degree of production uncertainty, the relative cost of signing a longer contract is lower, thus the generator optimally offers a contract with longer duration and higher degree of cost sharing.

As a robustness check, we estimate our equations 9 and 10 by excluding contracts signed previous to 1989. The results of these estimations are presented in Table 5. The results are generally unchanged in terms of sign and significance. Again, there is a drop in the coefficient on duration when it is instrumented, as we would expect a negative bias due to the simultaneous causality between rigidity and duration.

5 Evidence of wider economic consequences

Our theoretical discussion and empirical evidence so far have illustrated that restructuring in the downstream market has real effects on the contractual behavior of parties upstream. In particular, the move to more rigidly priced contracts emerges prominently from both the theoretical and empirical analysis. In what follows we address some of the wider economic consequences that one would expect from a shift to more rigid contracts. As we will see, these consequences are far from unequivocal.

5.1 Productivity

The results given in Tables 4 and 5 match our theoretical predictions regarding the rigidity of the price adjustment mechanism. Our findings that plants in a restructured electricity market shifted to more rigid price adjustment mechanisms are interesting *per se*, as they highlight a novel channel through which market restructuring operates. An even more important economic question, however, is whether we can find evidence that the high-powered incentives associated with rigid price adjustment mechanisms have lead coal mines to improve their efficiency, and ultimately overall welfare. To test whether mines responded to the incentives provided by contracts written with plants in restructured states, a difference-in-difference model can be used. The model is,

$$p_{i,t} = \zeta_i + \gamma_1 \Sigma_{i,t} + \gamma_2 \mathbf{X_{i,t}} + \varepsilon_{i,t}; \tag{11}$$

where $p_{i,t}$ is state i's coal mine labor productivity in year t, ζ_i is a state fixed effect, $\Sigma_{i,t}$ is the difference-in-difference variable, $\mathbf{X_{i,t}}$ is a vector of control variables, and $\varepsilon_{i,t}$ is an idiosyncratic error term. State coal mine labor productivity is measured as the short tons of coal produced per employee per hour and is taken from the EIA's Coal Industry Annual. The difference-in-difference variable equals one if any of state i's mines sold coal under contract to a plant whose state had held hearings concerning restructuring the electricity market and is zero otherwise. Information on sales of contract coal is taken from FERC 423 dataset. As control variables we use state i's GDP, total mining employment, production of coal in year t, and year dummy variables. State GDP is taken from the Federal Reserve Bank of St.Louis, mining employment is taken from the EIA's Coal Industry Annual, and total production is taken from the FERC 423 dataset.

Figure 2 show the evolution of the change in labor productivity for mines which sold coal under contract to plants in restructured states relative to those that did not. Labor productivity estimates for the two groups are not statistically different from each other until 1996, when a number of states passed restructuring legislation. After this year, mines which sell coal under contract to plants in restructured states begin to increase their productivity relative to those mines which did not sell coal under contract to plants in restructured states. Table 6 shows the results of the estimation of equation (11). When mines in a state begin selling coal to plants in restructured states, there productivity increases by about 12%. This finding confirms our intuition that restructuring of the electricity market led to a reduction in the cost of coal. Both Cicala (2012) and Chan et al. (2012) find that plants which face electricity market restructuring pay a statistically lower price of coal. However, neither papers discuss the mechanism which would lead to this outcome.[14] Here the mechanism is identified as the shift to more rigid contract types after restructuring, which should introduce higher-powered incentives for cost savings. Interestingly, the magnitude of the coefficient of restructuring on coal mine productivity in Table 6 is consistent with the drop in coal prices found in Cicala (2012) and Chan et al. (2012). Cicala (2012) finds a 12% drop in coal prices while Chan et al. (2012) estimate the drop to be closer to 8%, both broadly in line with our results that suggest a 11.8% improvement in productivity.

5.2 Renegotiation

The change in contracting behavior associated with restructuring, however, may lead to other impacts which are less welcome. One way in which the change in contracting behavior could lead to lower welfare is through increased transaction costs, for example as a consequence of more frequent renegotiations. To gauge the significance of this mechanism we analyze the effect of contract rigidity on renegotiation. Here the equation is,

$$m_i = \theta_0 + \theta_1 r_i + \theta_2 d_i + \theta_3 \mathbf{X_i} + \varepsilon_i; \tag{12}$$

where m_i is the time to first renegotiation of the contract, r_i and d_i are the rigidity of the price adjustment mechanism and duration of contract i, X_i is a vector of control variables, and ε_i is an idiosyncratic error term.

Table 7 shows the results of the estimation of equation (12) using a poisson model. A more rigid price adjustment mechanism is associated with lower number of years until first renegotiation. This effect is not altered for contract signed after the state the plant is located in passed a law to restructure the electricity market.

This evidence is suggestive of the fact that restructuring might have harmful effect on welfare via an increase in the likelihood that contracts be renegotiated in any given period. In as far as frequent renegotiations imply an increase in the industry wide transaction costs, this result point at a negative contribution to welfare that can be indirectly attributed to the restructuring efforts of the regulator.

6 Conclusions

The last 30 years has seen policymakers move to deregulate previously regulated natural monopolies, and electricity markets have been no exception. The analysis presented in this paper expands on the previous literature by providing evidence of how upstream markets are effected by deregulation of downstream markets. During the 1990s, a number of states restructured their electricity market so that plants could no longer be assured of cost recovery or a dedicated buyer for their output. A restructured market increased the uncertainty which plants operated under, as they then competed to sell electricity and could not be guaranteed an output price. We present a theoretical discussion of the likely impact of these changes on the optimal choice of procurement contracts. Our analysis predicts that plants would respond to the increased uncertainty of a restructured electricity market by signing contracts for coal delivery with a more rigid price adjustment mechanism. In our model, the use of a more rigid price adjustment mechanism reduces the plant's exposure to uncertainty in upstream prices,

[14] Cicala (2012) shows that mines which sell to plants in restructured states are more productive but does not discuss what drives this outcome.

offsetting the downstream increase in uncertainty. Our empirical evidence strongly supports our theoretical predictions.

One effect of the change to a more rigid price adjustment mechanism is that it provides higher-powered incentives to the upstream supply chain, coal mines in this instance. Results here show that these increased incentives led to an improvement in coal mine productivity. The magnitude of this increased productivity coincides with the estimated reduction in coal prices recently discussed by Cicala (2012) and Chan et al. (2012). We argue that the evidence provided here can be interpreted as one possible mechanism behind the price reductions found in Cicala (2012) and Chan et al. (2012).

Finally, one might be concerned that the productivity improvements we identify could be offset by changes in the transaction cost associated with the more rigid contracts that are being signed. In this respect one issue would be the more frequent renegotiation of more rigid contract. To test for this, the time to first renegotiation is estimated. Our findings reveal that a more rigid price adjustment mechanism is indeed associated with a shorter time to first renegotiation, providing an empirical basis to our concerns. More empirical work, however, is needed to assess the net impact of deregulation on efficiency in the upstream market.

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A Proof of Proposition 1

The optimal contract choice is given by the solution to the following problem:

$$\begin{aligned} \max_{r,d} \quad & (1+\theta^g)\Big\{\lambda\big[\mathbb{E}(p^e) - \overline{\delta} - \mu\big] + \mu - k^g(r,d\,;\mathbf{A})\Big\} - \theta^g b(\alpha)\lambda\sqrt{\sigma_e^2 + (1-r)^2\sigma_\chi^2}, \\ s.t. \quad & (1+\theta^m)\Big[\overline{\delta} - \mathbb{E}(\chi) - k^m(r,d\,;\mathbf{A})\Big] - \theta^m b(\alpha) r\sigma_\chi \geq 0. \end{aligned} \tag{A.1}$$

The associated Lagrangian is

$$\begin{aligned} \mathcal{L} = (1+\theta^g)\Big\{\lambda\big[\mathbb{E}(p^e) - \overline{\delta} - \mu\big] + \mu - k^g(r,d\,;\mathbf{A})\Big\} - \theta^g b(\alpha)\lambda\sqrt{\sigma_e^2 + (1-r)^2\sigma_\chi^2} + \\ + \eta\{(1+\theta^m)\Big[\overline{\delta} - \mathbb{E}(\chi) - k^m(r,d\,;\mathbf{A})\Big] - \theta^m b(\alpha) r\sigma_\chi\}, \end{aligned}$$

and the necessary first-order conditions for a maximum are:

$$\frac{\partial \mathcal{L}}{\partial r} = -(1+\theta^g)\frac{\partial k^g}{\partial r} + \theta^g b(\alpha)\lambda\Big[\sigma_e^2 + (1-r)^2\sigma_\chi^2\Big]^{-1/2}(1-r)\sigma_\chi^2 - \eta(1+\theta^m)\frac{\partial k^m}{\partial r} - \eta\theta^m b(\alpha)\sigma_\chi = 0, \tag{A.2}$$

and

$$\frac{\partial \mathcal{L}}{\partial d} = -(1+\theta^g)\frac{\partial k^g}{\partial d} - \eta(1+\theta^m)\frac{\partial k^m}{\partial d} = 0. \tag{A.3}$$

Well know results in monotone comparative statics (see Milgrom and Shannon, 1994, theorem 5) assert that if $\mathcal{L}$ is supermodular in $(r, -d)$ and exhibits increasing returns in $(r, -d, \lambda)$, then the solutions to the maximization problem $r(\lambda)$, and $d(\lambda)$ are monotone non-decreasing and non-increasing, respectively.

To show that our objective function, $\mathcal{L}$, is supermodular in $(r, -d)$ and exhibits increasing differences in $(r, -d, \lambda)$ it suffices to show that the cross derivatives with respect to these three variables are non-negative (Milgrom and Shannon, 1994, theorem 6). Differentiating (A.2) with respect to $-d$ yields

$$\frac{\partial^2 \mathcal{L}}{\partial r \partial(-d)} = (1+\theta^g)\frac{\partial^2 k^g}{\partial r \partial(d)} + \eta(1+\theta^m)\frac{\partial k^m}{\partial r \partial(d)} > 0, \tag{A.4}$$

where the last inequality follows from the properties of $k^g(r, d)$, and the negativity of η. Differentiation of (A.2) and (A.3) with respect to λ yields

$$\frac{\partial^2 \mathcal{L}}{\partial r \partial \lambda} = \theta^g b(\alpha)(1-r)\sigma_\chi^2\Big[\sigma_e^2 + (1-r)^2\sigma_\chi^2\Big]^{-1/2} > 0, \quad \text{and} \quad \frac{\partial^2 \mathcal{L}}{\partial(-d)\partial \lambda} = 0, \tag{A.5}$$

respectively, which concludes our proof. □

B Proof of Proposition 2

The previous proof establishes that $\mathcal{L}$ is supermodular in $(r, -d)$. Differentiating the first-order conditions (A.2) and (A.3) with respect to $-A_i$, and $-\sigma_e^2$ one gets

$$\frac{\partial^2 \mathcal{L}}{\partial r \partial(-\sigma_e)} = \theta^g b(\alpha)\lambda(1-r)\sigma_\chi^2\left[\sigma_e^2 + (1-r)^2\sigma_\chi^2\right]^{-3/2}\sigma_e > 0, \quad \text{and} \quad \frac{\partial^2 \mathcal{L}}{\partial(-d)\partial(-\sigma_e)} = 0;$$

$$\frac{\partial^2 \mathcal{L}}{\partial r \partial(-A_i)} = 0, \quad \text{and} \quad \frac{\partial^2 \mathcal{L}}{\partial(-d)\partial(-A_i)} = -(1+\theta^g)\frac{\partial^2 k^g}{\partial(-d)\partial(-A_i)} - \eta(1+\theta^m)\frac{\partial k^m}{\partial(-d)\partial(-A_i)} > 0;$$

that immediately establish that $\mathcal{L}$ exhibits increasing differences in $(r, -d, -\sigma_e^2, -A_i)$, implying that r^* is non-increasing in σ_e, and A_i, while d^* is non-decreasing in both.

Finally, differentiating (A.2) and (A.3) with respect to σ_χ yields

$$\frac{\partial^2 \mathcal{L}}{\partial r \partial \sigma_\chi} = \theta^g b(\alpha)\lambda(1-r)\sigma_\chi\left[\sigma_e^2 + (1-r)^2\sigma_\chi^2\right]^{-1/2}\left\{2 - (1-r)^2\sigma_\chi^2\left[\sigma_e^2 + (1-r)^2\sigma_\chi^2\right]^{-1}\right\} - \eta\theta^m b(\alpha),$$

and,

$$\frac{\partial^2 \mathcal{L}}{\partial(-d)\partial\sigma_\chi} = 0,$$

where it is apparent that it is not possible to sign in general the first cross derivative. This completes our proof. □

Table 1: Description of Pricing Mechanisms

Ordinal Designation	Description
1, Most Rigid	Fixed-Price Contract. Price is fixed over the life of the contract.
2	Base Price Plus Escalation. Different components of the price escalate (or de-escalate) as a function of changing economic conditions (indices).
3	Price Tied to Market. Price tied to the price of coal being sold in a particular market. Product and market area are defined in the contract. Contract may contain a "Most Favored Nations" clause, i.e., supplier will not sell to any generator at a price lower than yours is paying.
3	Cost-Plus Contract with a Fixed Fee Provision. Purchaser agrees to pay all producer's costs plus a management fee. Some contracts provide for payment of both a management fee and a profit. This contract has a Fixed Fee provision.
3	Cost-Plus Contract with an Incentive Fee. Provision Purchaser agrees to pay all producer's costs plus a management fee. Some contracts provide for payment of both a management fee and a profit. This contract has an Incentive Fee provision, i.e., a variable fee that is tied to various productivity and cost reduction incentives.
4, Least Rigid	Price Renegotiation. The price is renegotiated at predetermined intervals, usually one year. This type of contract, frequently known as an *Evergreen Contract*, may also contain provisions for price adjustments between renegotiations.

Source: Federal Energy Regulatory Commission

Figure 1: Time Trend of Contract Rigidity in Treatment Group

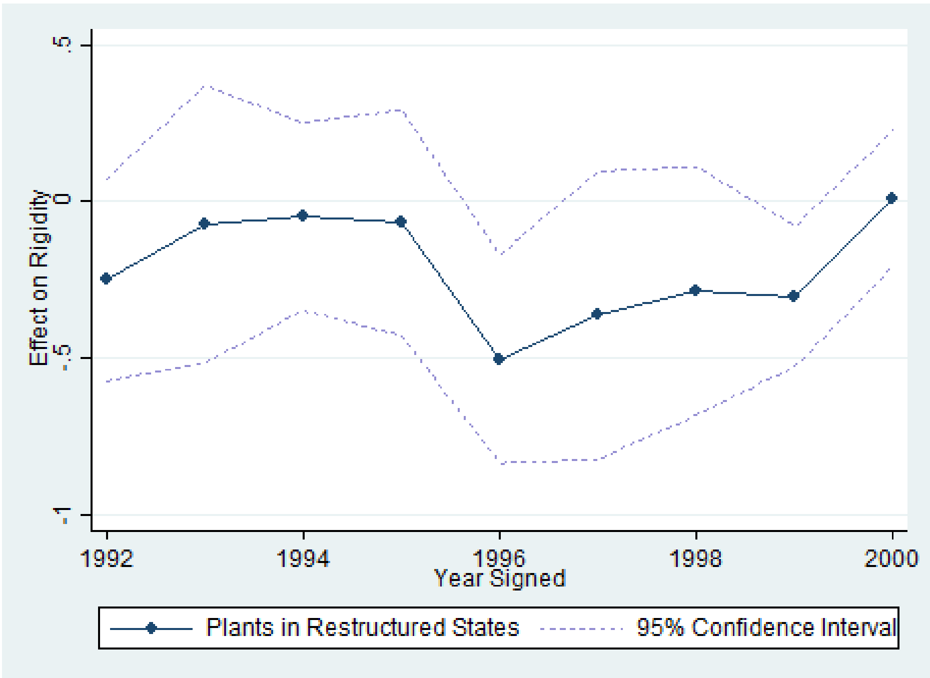

Figure 2: Time Trend of Coal Productiсvity in Treatment Group

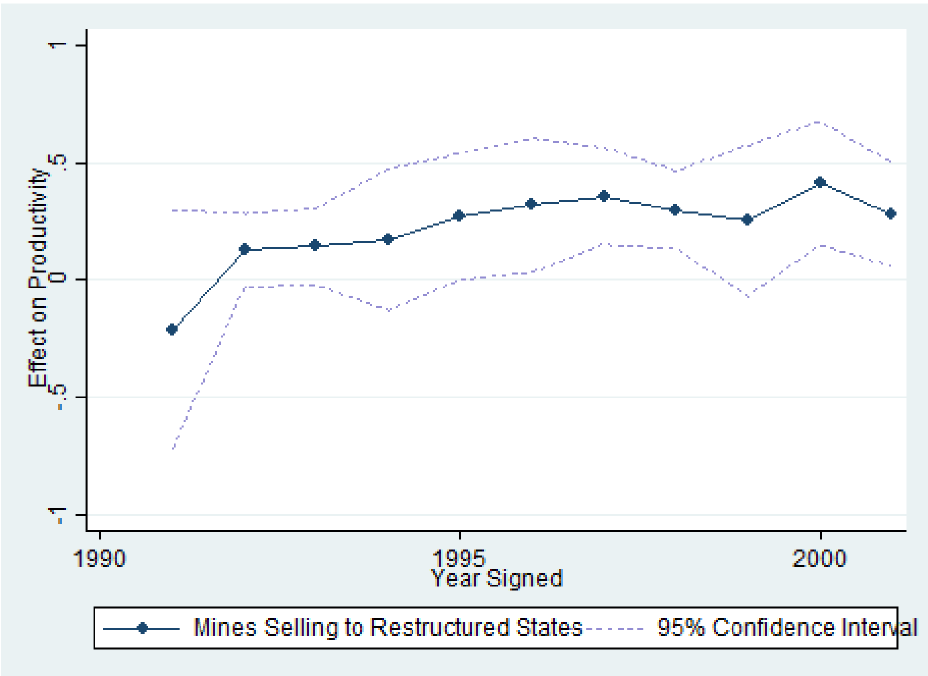

Table 2: Restructured States

State	Hearing Held	Law Passed
California	1994	1996
Connecticut	1994	1998
District of Columbia	1996	2000
Delaware	1995	1999
Illinois	1995	1997
Massachusetts	1994	1997
Maryland	1995	1999
Maine	1995	1997
Michigan	1994	2000
Montana	1996	1997
New Hampshire	1994	1996
New Jersey	1996	1999
New York	1993	1996
Ohio	1996	1999
Oregon	1995	1999
Pennsylvania	1994	1996
Rhode Island	1994	1996
Texas	1997	1999
Arkansas	1997	1999
Arizona	1995	1998
Indiana	1995	–
Kentucky	1996	1999
New Mexico	1995	1999
Nevada	1994	1996
Oklahoma	1995	1997
Virginia	1995	1999
West Virginia	1995	1999

Source: U.S. Energy Information Administration Status of Electricity Restructuring

Table 3: Summary Statistics

	All Data	Treated Before Treatment	Treated After Treatment	Control Before Treatment	Control After Treatment
Rigidity (Ordinal; Larger = More Rigid)	3.10	2.99	3.49	3.03	3.65
	(0.73)	(0.70)	(0.62)	(0.73)	(0.64)
Duration (Years)	6.25	5.52	2.43	8.49	2.96
	(8.09)	(7.59)	(3.26)	(9.21)	(4.07)
Contract Signed after Rail deregulation	0.61	0.66	0.77	0.53	0.67
	(0.49)	(0.48)	(0.42)	(0.50)	(0.47)
Contract Signed after ARP	0.28	0.23	0.77	0.16	0.67
	(0.45)	(0.42)	(0.42)	(0.37)	(0.47)
Contract Signed after Restructuring	0.03	0.00	1.00	0.00	0.00
	(0.18)	(0.00)	(0.00)	(0.00)	(0.00)
Plant in Restructured State	0.43	1.00	1.00	0.00	0.00
	(0.50)	(0.00)	(0.00)	(0.00)	(0.00)
Previous Interaction	0.51	0.52	0.72	0.49	0.53
	(0.50)	(0.50)	(0.45)	(0.50)	(0.50)
Z-Ash	-0.56	-0.55	-0.07	-0.57	-0.70
	(1.50)	(1.31)	(0.92)	(1.70)	(1.48)
Z-Sulfur	-0.25	-0.28	0.48	-0.28	-0.23
	(1.36)	(1.16)	(1.15)	(1.48)	(1.47)
Z-Moisture	0.13	0.20	0.71	0.01	0.11
	(1.18)	(1.14)	(0.59)	(1.26)	(1.13)
Z-Btu	0.10	0.25	0.17	-0.03	0.02
	(0.67)	(0.69)	(0.49)	(0.62)	(0.73)
Minimum Quantity	0.55	0.35	0.35	0.79	0.47
	(2.03)	(0.62)	(0.50)	(3.01)	(0.75)
Appalachia Mine	0.63	0.83	0.82	0.46	0.51
	(0.48)	(0.38)	(0.38)	(0.50)	(0.50)
Interior Mine	0.17	0.06	0.05	0.28	0.18
	(0.38)	(0.24)	(0.22)	(0.45)	(0.39)
Western Mine	0.20	0.11	0.13	0.26	0.31
	(0.40)	(0.31)	(0.33)	(0.44)	(0.46)
Scrubber	0.24	0.17	0.31	0.28	0.32
	(0.43)	(0.38)	(0.47)	(0.45)	(0.47)
Mine-mouth Plant	0.01	0.01	0.00	0.01	0.00
	(0.09)	(0.09)	(0.00)	(0.11)	(0.00)
Mine Dedicated Assets	0.15	0.14	0.14	0.17	0.12
	(0.26)	(0.24)	(0.24)	(0.28)	(0.25)
Plant Dedicated Assets	0.24	0.21	0.16	0.29	0.19
	(0.29)	(0.26	(0.23)	(0.32)	(0.26)
Mandatory Phase I Plant	0.18	0.13)	0.40	0.20	0.24
	(0.39	(0.34)	(0.49)	(0.40)	(0.43)
Spot Ratio	0.23	0.26	0.32	0.19	0.25
	(0.10)	(0.09)	(0.05)	(0.10)	(0.10)
Multiple Mode of Delivery	0.32	0.38	0.45	0.26	0.27
	(0.47)	(0.49)	(0.50)	(0.44)	(0.44)

Table 4: Rigidity Results - All Contracts

	Ordered Probit	IV[a]	3SLS	
	Rigidity	Rigidity	Rigidity	Duration
Duration	-0.0461***	-0.0198***	-0.0226***	
	(0.0065)	(0.0046)	(0.0040)	
Rigidity				3.790**
				(1.9030)
Post Restructuring	0.4237*	0.2862***	0.1751**	-0.4915
	(0.2424)	(0.0885)	(0.0894)	(1.0557)
Plant in Restructured State	-0.2989**	-0.1270**	-0.1218***	-0.7861*
	(0.1286)	(0.0650)	(0.0339)	(0.4072)
Previous Interaction	0.1101**	0.0334	0.0286	-0.1893
	(0.0559)	(0.0251)	(0.0322)	(0.3617)
Underground Mine	-0.5626***	-0.3268***	-0.3111***	3.7692***
	(0.1630)	(0.0888)	(0.0627)	(0.8754)
Post SO_2 Regulation	0.4911***	0.2075***	0.2283***	-2.999***
	(0.1278)	(0.0767)	(0.0402)	(0.7512)
Mandatory Phase I Plant	0.4714***	0.2488***	0.2133***	
	(0.1294)	(0.0635)	(0.0405)	
Z-Ash	0.0539**	0.0462***	0.0491***	
	(0.0262)	(0.0145)	(0.0170)	
Z-Sulfur	0.0750***	0.0165	0.0329**	
	(0.0261)	(0.0149)	(0.0146)	
Z-Moisture	-0.0374	-0.0182	-0.0003	
	(0.0427)	(0.0203)	(0.0179)	
Z-Btu	-0.1005	-0.0525	-0.0760***	
	(0.0900)	(0.0542)	(0.0266)	
Mine Dedicated Assets				0.6304
				(0.6280)
Plant Dedicated Assets				0.7454
				(0.6343)
Mine-mouth Plant				16.7337***
				(1.7094)
Spot Ratio				-4.8616**
				(2.7937)
Multiple Mode of Delivery				-0.4526
				(0.3762)
Minimum Quantity				3.8916***
				(0.2786)
Post Rail Deregulation				-5.0022***
				(0.6353)
Constant		3.3006***	3.2908***	-2.9722
		(0.0831)	(0.0545)	(6.1214)
Observations	2,015	1,914	1,914	1,914
R^2	0.1313[b]	0.1580	0.1588	0.1670
Hansen J-statistic		10.2341		
χ^2 p-value		(0.1151)		

Standard errors corrected for State-level serial correlation.
*, **, *** indicate 10%, 5% and 1% statistical significance, respectively.
a. Instruments for Duration: Mine Dedicated Assets, Plant Dedicated Assets, Mine-mouth Plant, Spot Ratio, Multiple Mode of Delivery, Minimum Quantity, and Post Rail Deregulation.
b. Pseudo-R^2 reported.
Time period is 1979-2001.

Table 5: Rigidity Results - Contracts signed after 1989

	Ordered Probit	IV[a]	3SLS	
	Rigidity	Rigidity	Rigidity	Duration
Duration	-0.0785***	-0.0262***	-0.0305***	
	(0.0106)	(0.0079)	(0.0083)	
Rigidity				1.371
				(0.960)
Post Restructuring	0.4213*	0.3483***	0.2742***	-1.606**
	(0.2307)	(0.1014)	(0.0992)	(0.7561)
Plant in Restructured State	-0.5400***	-0.2772***	-0.2883***	0.1777
	(0.1721)	(0.0931)	(0.0499)	(0.4414)
Previous Interaction	0.1576*	0.0802*	0.0534	-0.0530
	(0.0851)	(0.0443)	(0.0471)	(0.3413)
Underground Mine	-0.3873*	-0.2567**	-0.2392***	3.223***
	(0.2093)	(0.1074)	(0.0918)	(0.7112)
Post SO_2 Regulation	0.1547	0.2269***	0.1573***	-1.9781***
	(0.1089)	(0.0860)	(0.0521)	(0.4375)
Mandatory Phase I Plant	0.3017**	0.2444***	0.2027***	
	(0.1202)	(0.0651)	(0.0472)	
Z-Ash	0.0398	0.0396*	0.0194	
	(0.0501)	(0.0213)	(0.0273)	
Z-Sulfur	0.1079***	0.0455**	0.0431**	
	(0.0331)	(0.0221)	(0.0220)	
Z-Moisture	-0.2065*	-0.1230**	-0.0931	
	(0.1119)	(0.0505)	(0.0423)**	
Z-Btu	-0.3971***	-0.1909***	-0.2761***	
	(0.1480)	(0.0594)	(0.0472)	
Mine Dedicated Assets				0.8187
				(0.6197)
Plant Dedicated Assets				-0.7076
				(0.6340)
Mine-mouth Plant				26.1160***
				(3.5070)
Spot Ratio				-0.8711
				(2.3704)
Multiple Mode of Delivery				0.6025*
				(0.3478)
Minimum Quantity				2.5110***
				(0.2522)
Post Rail Deregulation				-15.1860***
				(1.4272)
Constant		3.3006***	3.498***	13.5454***
		(0.0831)	(0.0762)	(3.2271)
Observations	1,153	1,067	1,067	1,067
R^2	0.1403^b	0.1894	0.1978	0.1947
Hansen J-statistic		7.7320		
χ^2 p-value		(0.2584)		

Standard errors corrected for State-level serial correlation.
*, **, *** indicate 10%, 5% and 1% statistical significance, respectively.
a. Instruments for Duration: Mine Dedicated Assets, Plant Dedicated Assets, Mine-mouth Plant, Spot Ratio, Multiple Mode of Delivery, Minimum Quantity, and Post Rail Deregulation.
b. Pseudo-R^2 reported.
Time period is 1989-2001.

Table 6: Mine Productivity

	Fixed Effects
	Log of Labour Productivity
Log of Employment	-0.1183***
	(0.0484)
Log of State GDP	-0.1198
	(0.3367)
Log of Coal State Production	0.0143
	(0.0675)
Coal to Restructured State	0.1182***
	(0.0504)
Constant	3.4241
	(3.7409)
Observations	265
R-squared	0.304

Robust standard errors in parentheses.
*, **, *** indicate 10%, 5% and 1% statistical significance, respectively.
Year dummies included.

Table 7: Contract Renegotiations

	Poisson
	Time to Renegotiation
Rigidity	-0.0638***
	(0.0119)
Duration	0.0422***
	(0.0035)
Post Restructuring	0.0510
	(0.1423)
Rigidity*Restructuring	-0.0227
	(0.0461)
Duration*Restructuring	0.0113***
	(0.0041)
Mine-mouth Plant	-0.0381
	(0.0496)
Constant	1.1079***
	(0.2960)
Observations	5,775

Robust standard errors in parentheses.
*, **, *** indicate 10%, 5% and 1% statistical significance, respectively.