ABSTRACT

Title of dissertation: PRICING STRUCTURES IN US COAL SUPPLY CONTRACTS

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The subject of my dissertation is the study of coal procurement by electric utilities in the US over 2 decades, from 1979 to 2000. Energy markets are typically characterized by severe contracting problems. Buyers and sellers therefore employ various instruments, such as contract length or complex pricing arrangements, to restrict these problems. Relationship specific investment, wherein buyers make investments specific to their suppliers, has been advanced as a prominent explanation for contractual length.

Investment decisions are however endogenous in length or pricing, making causal identification of the role of investment specificity difficult. In chapter 2, I attempt a resolution. I use the 1990 Clean Air Act Amendment as an exogenous shifter of the extent of relationship specific investment. A key feature of the Amendment's design helps me define a difference-in-difference

model arguably free of the endogeneity issues discussed above. I find that the plants forced into switching - Phase I plants located in the US Midwest - are more likely to choose fixed price contracts than those that were not. Further they also write contracts of shorter terms, with the reduction being approximately 30%.

Considerably little is known about the performance implications of contractual choices. These form the basis for Chapter 3. Here I find prices to be lower, by between 5% to 20% of the total transaction price, but the probability of renegotiation higher, under fixed price contracts than under escalator or cost-plus contracts. Contract choices appear consistent with a trade-off between establishing incentives ex-ante and lowering negotiation costs ex-post, with relationship specific investments in particular making such a trade-off compelling.

Chapter 4 considers the regulatory environment these utilities were subject to. Both incentive based regulation as well as the restructuring of electricity generation are smaller in comparison to relationship specific investment in terms of their effects on contractual decisions. Consequently, when evaluating the effect of these reforms, ignoring the contractual structure of fuel procurement - and therefore investment specificity - leads to large and significant biases in their impacts.

PRICING STRUCTURES IN US COAL SUPPLY CONTRACTS

by

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Chapter 1

Introduction

The subject of my dissertation is the study of coal procurement by electric utilities in the US over 2 decades, from 1979 to 2000. Energy markets are typically characterized by severe contracting problems: investments tend to be large, discrete and limited in flexibility of use. The fear of opportunistic behavior may result in under-investment or waste investment that has been sunk into a particular project. Recognizing this, buyers and sellers employ various instruments, such as contract length or complex pricing arrangements, to mitigate such fears. Relationship specific investment, wherein buyers make investments specific to their suppliers, has been advanced as a prominent explanation for contractual length.

Investment decisions are however endogenous in length or pricing, making causal identification of the role of investment specificity difficult. In chapter 2, I attempt a resolution. I use the 1990 Clean Air Act Amendment as an exogenous shifter of the extent of relationship specific investment. A key feature of the Amendment's design helps me define a difference-in-difference model arguably free of the endogeneity issues discussed above. I find that the plants forced into switching - Phase I plants located in the US Midwest - are more likely to choose fixed price contracts than those that were not. Further they also write contracts of shorter terms, with the reduction being approximately 30%.

Considerably little is known about the performance implications of contractual choices. These form the basis for Chapter 3. Here I find prices to be lower, by between 5% to 20% of the total transaction price, but the probability of renegotiation higher, under fixed price contracts than under escalator or cost-plus contracts. Contract choices appear consistent with a trade-off between establishing incentives ex-ante and lowering negotiation costs ex-post, with relationship specific investments in particular making such a trade-off compelling. Increased renegotiations under fixed price contracts does not appear to lead to increased transfers to suppliers, implying these price reductions are not entirely a matter of rent reallocation.

Chapter 4 considers the regulatory environment these utilities were subject to. Both incentive based regulation as well as the restructuring of electricity generation are smaller in comparison to relationship specific investment in terms of their effects on contractual decisions. Consequently, when evaluating the effect of these reforms, ignoring the contractual structure of fuel procurement - and therefore investment specificity - leads to large and significant biases in their impacts.

The role of relationship specific investments has been neglected in both the discussion and analysis of regulatory policy over electricity. Arguably, this is a result of their influence over outcomes acting indirectly through procurement choices, prominently the type of contract written between the buyer and seller. The broad conclusion I reach is that relationship specific investments do have a causal effect on contract choices, which in turn have substantial effects on prices. While regulatory intervention does alter these choices, their influence is far more limited than that of specific investment.

Chapter 2

Regulation and Contract Design: The Impact of Relationship Specific Investment

2.1 Introduction

Firms often specialize their investments to their suppliers or buyers. To take an example, consider power plants built next to a coal mine. Locating next to a coal mine assures the plant of a reliable source of coal, as well as reducing transportation costs, and may require modification of equipment to suit the type of coal available. Similarly, mining efforts may be directed to confirm to the technology employed by the plant. Such relationship specific investments play a central role in modern theories of organization and contracts, particularly in the literature on transaction costs pioneered by Oliver Williamson (Williamson 1975, 1979, 1985)[1].

The argument goes as follows: although valuable, relationship specific investments raise the possibility of opportunism once the contract is in place and proceeds to completion. To guard against such opportunism, contractual safeguards such as price adjustment clauses, longer terms, or take-or-pay provisions are necessary. Such safeguards, however, inevitably entail the sacrifice of high-powered incentives. As investments become more specific, the cost of ex-post opportunism overtakes the cost of poor incentives and a switch in contract choice takes place.

Empirical verification of this causal link is difficult, as specific investments are usually endogenous in the choice of contract. Consider regressing contract characteristics, such as duration, on a measure of specific investment. The estimate of the effect of specificity in such a regression is likely to be biased, for two reasons. Relationship-specific investment can only be observed when parties choose to enter into that transaction. Due to the simultaneity that arises, it is difficult to rule out a third factor (such as managerial ability, size or bargaining power) that could affect both decisions. Parties may also choose to make investments specific to each other, meaning that specificity is a choice variable and not, therefore, exogenous to the contracting parties.

For these reasons, the role of relationship specific investments in guiding contract choice remains controversial. Chiappori and Salanie (2003) criticize

[1] Recently, the complexity of a transaction and the amount of ex-post adaptation have also been shown to be important (Bajari and Tadelis 2001, Forbes and Lederman 2009). I concentrate mainly on relationship-specific investment in this paper. Shelankshi and Klein (1995), Macher and Richman (2008) provide overviews of the empirical literature on transaction cost economics

the methodology of many of the studies that attempt to correlate investment specificity and contract or organizational choice, on the grounds that they do not control for the endogeneity of the investment decision. In a comprehensive review, Lafontaine and Slade (2007) also note the endogeneity problem inherent in many of these tests. David and Han (2005) carry out a meta-analysis of the empirical literature on transaction cost based explanations of organizational and contractual decisions. Using the 5% level of significance as a cut-off criterion, they find that out of a total of 107 tests relating to relationship specific investments, 39 find statistically insignificant effects. Despite these problems, there is, as yet, little effort toward a solution.

To obtain plausible exogenous variation in investment decisions, I exploit a key environmental regulation - the Clean Air Act Amendment of 1990 - as an exogenous shock that forces investment to become less specific. Reduced specificity, in turn, encourages greater flexibility in switching between alternate suppliers, and the risk of ex-post opportunistic behavior falls. Such a switch in investment choice should result in shorter term, fixed price contracts.

An important feature of the Amendment, crucial to the specification of the econometric model, lies in its design. The Amendment was structured in two phases. In its first phase, the Amendment targeted only a subset of coal-fired plants (Phase I plants), for whom limits on emissions would start to bind in 1995. Phase II would include all remaining plants and emission limits would start to bind in 2000. In addition, the influence of the Amendment in terms of encouraging switching between coals also varies by the location of the plants. I use these two exogenous source of variation to define a difference-in-differences model, which identifies the impact of relationship specific investment.

Coal supply arrangements between power plants and coal mines are a very good candidate for studying the implications of relationship-specific investment, given the long lived, immobile nature of investments on both sides of the transaction. Unsurprisingly, therefore, there exists a prior literature examining these arrangements. In general, the predictions of the theory find confirmation[2].

Paul Joskow (1987) studies a sample of US coal contracts in force during 1979. He argues that western coal required more specific investment as it was more heterogenous, making it difficult to switch suppliers, thus leading to longer-term contracts. Confirming this hypothesis, Joskow finds contracts with western coal suppliers to be a decade longer in duration than contracts with Appalachian coal suppliers. Kerkvliet and Shogren (2001) employ a different data set, a sample of contracts signed between 1972 and 1984. They use the length of time between the announcement of a contract and the first delivery as a measure of relationship specificity, a longer lag allowing more time for the buyer to customize and test boilers. Contract duration, they find, rises as the time delay between announcement and delivery rises.

By concentrating on the period leading up to the mid 1980s, both these studies ignore the widespread regulatory changes that took place beginning in the early 1980s and continued until the late 1990s, such as the deregulation of the railroads, the Clean Air Act Amendment, and deregulation

[2] My summary of the literature is quite selective. I only detail those findings related to the central hypothesis I examine in this paper.

of electricity generation. To account for these changes, Kozhevnikova and Lange (2009) study a panel of coal contracts in force from 1980 to 2000. They interpret these changes, broadly speaking, as increasing the number of alternatives the buyer has, thus reducing contract duration. They find evidence of such reduction, by up to 6 years, with railroad deregulation in particular accounting for large changes.

None of these papers, however, concern themselves with the endogeneity of the investment decision[3]. An equal criticism may be made for most of the empirical literature seeking to link investment specificity to contract structure; it is not confined to the coal contract literature alone. The widespread nature of the problem is perhaps an indication of the difficulty in finding a solution.

In addition to identifying exogenous variation in investment decisions, I focus on the type of pricing arrangement. All three studies cited above, and much of the empirical literature, concerns itself with contract length. One problem in using length as the outcome is that it is difficult to understand whether a given change in length corresponds to a significant change in contractual relations. In contrast, changes in pricing arrangements are discrete and can thus be easily understood as indicating changes in behavior.

Access to detailed information on the identity of the power plant allows me to incorporate plant fixed effects. To the extent that there are factors

[3]For instance, Joskow (1987) uses an indicator variable to define the region the mine operates in. Although the intention is to capture variation in coal characteristics - which is not a choice variable - the decision to contract with a western (or Appalachian) coal supplier is a choice. Such a variable is not, therefore, exogenously determined. To take another example, Kozhevnikova and Lange (2009) account for the Clean Air Act Amendment by including an indicator variable for whether a contract was signed after 1990. The decision to sign a contract following the Amendment is again endogneously determined.

operating at the level of the power plant that are invariant over time, I am able to control for any resulting omitted variable bias. Given the nature of the electricity and coal mining industry, such factors may be important[4].

I use data from 1980 to 2000, which provides sufficient time before and after the announcement of the policy to analyze its impact on plant procurement decisions. These arrangements switch from base price with escalation clause contracts ("escalator contracts" from henceforth) to fixed price contracts (Figure 5)[5]. I also examine contract length in some detail. To assess the robustness of the results, I also study other contract pricing terms to see if they were affected similarly.

I find that plants affected by the Amendment are more likely to sign fixed price contracts with their suppliers, with the probability increasing by between 0.164 to 0.255 units. These results are robust to altered definitions of the dependent variable, changes in the sample used, the influence of other possible confounding factors, and the impact of regulatory change[6]. In addition, contract length for affected plants falls by nearly 2.5 years, a reduction by 0.37 standard deviations. Last, while both repeated interaction and relationship specific investment influence pricing structure and length, specific investments appear to have larger effects, in terms of coefficient magnitude. In the next section, I describe how the Amendment may affect contract structure. I then describe the empirical model, and present estimates

[4]Phase I plants are larger and older than Phase II plants. These factors may influence the decision to adopt fixed price contracts, but as they are time invariant their influence is accounted for by the fixed effect.

[5]Years 1988 and 1989 are excluded as, in these years, no fixed price contracts were recorded, and there is a high likelihood of a discrepancy in the data.

[6]I consider two policy changes: the deregulation of the railroads following the 1981 Staggers Act, and the possible impact of the deregulation of the electricity market.

of this model. I close with some limitations of the present study, and draw implications for environmental regulation.

2.2 Contracts, specific investment and the Clean Air Act Amendment of 1990

There is a basic trade-off inherent in the choice of pricing arrangement when a buyer and a supplier sign a contract for the delivery of a product which requires specialized investments. A major implication of specialized investment is that both the buyer and supplier face a far smaller number of alternate traders once such investment has been made. The consequent shrinkage of the market provides an incentive for opportunistic behavior, since neither party to the contract can easily find alternate trading partners[7].

Such opportunistic behavior, or rent-seeking, can take the form of the supplier reneging on previously agreed terms, or threatening to do so[8]. Secure in the knowledge that the buyer must continue relations because termination of the contract implies too large a loss, the supplier may demand a larger share than was previously agreed upon. Lengthy negotiations are likely to ensue, which drains resources.

Contracts being too unwiedly, vertical integration was viewed as the main

[7]Such a realization is not new. Oliver Williamson (1975) notes that relationship-specific investments will create a costly haggling situation, which may be alleviated through the use of long-term contracts. Also, Victor Goldberg and John Erickson (1987: p 388-390) describe how relationship-specific investments make the cost of renegotiation higher. In the extreme, specializaton implies a bilateral monoply.

[8]For instance, if new regulations regarding the operation of mines to minimize their environmental impact come into force, the supplier is likely to know more about the true cost this imposes. With specific investments, the supplier can take advantage of the increased cost the buyer would face in finding other suppliers and attempt to extract rent.

strategy to counter such opporturnism (Williamson 1985), as the supplier now has little to gain. However, incentives to engage in least-cost production tend to get muted under such an organizational design. Masten and Crocker (1991) argue that such a construct takes too limited a view of contracts[9]. Frequently contracting parties will provide for procedures to redetermine prices in an adaptive manner. Contracting parties may agree ex-ante to agree to renegotiate, schedule a series of price increases ex-ante, or specify a formula by which the prices are to be increased.

Agreeing to renegotiate may be a preferable option given its flexibility, but it may not resolve bargaining cheaply. If information asymmetry is serious, and the costs of determining the true state of the world from individual claims are prohibitively high, agreeing to reneogitate does not go very far as a solution. Scheduling price increases ex-ante also runs into problems, however, because it is hard to imagine that contracting parties will be able to correctly anticipate all future conditions and appropriately adjust payments. Specifying a formula by which to fix prices appears the most likely candidate.

The simplest way to fix prices is to pay for all costs the supplier bears. Such a scheme, however, does not provide sufficient incentive to the supplier to produce cheaply, and opens the door to the possibility of fraudulent claims, which are costly to verify.

Participants in the market I study use a simple but ingenious workaround, the escalator contract. Such contracts let prices vary as a function of components of costs, suitably indexed. For certain components relating to govern-

[9] In addition, vertical integration between plants and mines was frequently disallowed in the US.

ment regulation, tax changes, or "changes in contract/union work rules" the supplier is allowed to pass through costs. For other aspects of cost - labour, machinery, depreciation, profit - a forumla fixes the price to be paid.

Labour costs are separated into different categories, and wage rates are "indexed"[10] to changes that are either specified by collective bargaining agreements applicable to the area the mine is located in or to the average wage rate actually paid at the mine. In some of these contracts, Joskow (1985) finds all increases in labour costs were passed through. Costs for the raw materials and machinery ("materials and supplies") involved in the mining of coal are compensated for based on the relevant parts of the Wholesale Price Index.

For these components of cost, the escalator contract is attempting to account for costs of supply without relying on supplier claims; rather, costs are being proxied for. Importantly the proxies are chosen to reflect as closely as possible the actual costs the supplier incurs[11].

Fixed price contracts occupy the other end of the spectrum. They specify a price fixed in advance for the entirety of the contract. For this reason, they are cheaper to write, as there is less requirement to put in possibly complex provisions for the various sources of cost the supplier is exposed to[12]. Fixed price contracts are also known to carry high powered incentives

[10] Joskow (1985) uses the term "indexed" for cases in which the wage component had a fixed weight in the price formula, and adjusted only for changes in prevailing wage rates. Further, the determination of what constitutes the average rate is specified under manning tables.

[11] Setting prices as "locally" as possible in the presence of specialized investment has been observed before (Crocker and Masten, 1991).

[12] Of course, there may be a lengthy negotiation stage in fixing the price. Such negotiations are only going to be longer, and therefore more costly, with more complex pricing arrangements.

for performance (Williamson 1985, Corts and Singh 2004). For these reasons, the parties may prefer a fixed price contract.

In practice, fixed price contracts and escalator contracts are the two most commonly used contracts, with the sum of the two accounting for nearly 80% of all the contracts (See Table 26.). Cost-plus contracts only account for 3.5% of all the data, indicating that monitoring costs tend to exceed the gains from the simplicity of such price adjustment[13]. Price renegotiation contracts are used, but only for 7% of the total observations. I do not find any use of ex-ante price schedules, although there is some use of contracts that tie prices to market conditions, but these only account for 1.38% of the entire data. Such variation in pricing structures is entirely consistent with the argument advanced above.

Physical asset specificity and the Clean Air Act Amendment of 1990 For coal procurement in the US, one way relationship specific investments are made by utilities is in their choice of boiler technology[14]. Coal varies in its chemical properties depending on where it is mined. Boilers were built to match the type of coal contracted for. Such matching was more specialized in the case of coal that comes from the western part of the US, as this coal tended to be far more heterogenous in quality, and thus required specialized boilers to burn it.

[13]Under cost-plus contracts the utility has the power to "question the reasonableness of cost incurred, to audit the mining company and to approve mining plans, capital expenditures and budgets", that is the utility has the right to monitor the mining company. Such a response indicates that utilities understand the moral hazard issues that arise under a cost plus contract.

[14]Power plants are made up of a number of generating units. A generating unit consists of a generator that converts mechanical energy into electricity, and a boiler that burns fuel to turn this generator.

The Clean Air Act Amendment of 1990 set limits on the amount of sulphur emissions power plants were allowed. The goal of the amendment was to reduce the amount of sulphur di-oxide (SO_2) emissions in the US by 10 million tons from the level that existed in 1980. Power plants were phased into the program in two stages. In the first stage, beginning in 1995, emission caps on a subset of plants - Phase I plants - were set to bind. Caps on the emissions from the remaining power plants were to be imposed in the second stage, which begins in 2000[15]. The total number of Phase I plants was 110.

To bring their power plants into compliance, electric utilities could either switch to coal with a low sulfur content, install scrubbers in the smoke stacks which would remove SO_2 from the smoke emitted or buy emission permits. Most utilities found the cheapest option was to switch to low sulphur coal, found in the western part of the US. Switching to an alternate coal was not easy. Being different chemically, simply burning Western coal in boilers not built for it would degrade the performance of the boiler (Bryers and Harding (1994)). Boilers built to burn Appalachian coal would have to be altered to accomodate western coal.

Blending the two coals (Western and Appalachian) turned out to be the primary way plants chose to lower emissions[16], but this was almost entirely unanticipated. The implication, in terms of incomplete contract transaction cost theory, is quite crucial. The specialization previously necessary to burn western coal now falls. The increased ability to switch coal implies a larger

[15]The cap was a multiple of the average use of fuel for the period 1985-1987. For Phase I plants, the multiplier was set equal to 2.5 pounds of SO_2 per mmBTU; for Phase II, it was 1.2 pounds of SO_2 per mmBTU.

[16]Interior coal, the third type of coal was of lower importance, and declines steadily over the period of study.

potential pool of suppliers. A larger pool of suppliers makes engaging in opportunistic behavior less likely, without requiring contractual provisions and the associated deficiencies with such provisions. This enables contracting parties to switch to fixed price contracts, as expected bargaining costs reduce.

Coal sourcing decisions by power plants provides some evidence of whether a larger pool of suppliers was indeed employed . In figure 2 I use data from the EIA 786 form, and plot the percentage of contracts in every year from 1983 to 2000 that were recorded as burning both kinds of coal (Western and Appalachian).

We see that Phase I plants burn, increasingly, a greater proportion of both kinds of coal. Importantly, this occurs after 1990, the year the Amendment was announced. Phase II plants, by contrast, do not seem to change their mix of coal for much of the period. Towards the end, around 1998, however, we can see a slight uptick for these plants. This fact will be important when considering the empirical specification.

Primarily, coal transportation takes place over rail, the costs of which used to be extremely high[17]. Railroad deregulation brought about by the Staggers Act of 1980 played a major role in reducing these costs. Ellerman and Montero (1998) argue that only plants located in the midwest would be major switchers to low sulphur western coal. Plants on or near the east coast are too far away for the reduction in transportation cost to matter, and plants close to western coal mines would be sourcing from them anyway.

In Figure 3, we can see evidence for this. In this figure, I plot the trend

[17] For the sample derived post-cleaning from the Coal Transportation Rate Database, 70% of the observations record the transportation as taking place through rail for at least part of the way from the coal mine to the power plant.

in the sulfur content of procured coal by Phase status and location of the buyer, using information contained within the CTRDB. We see clearly that Phase I plants in the midwest reduce the sulfur content of their coal, and this reduction is a long term change, staying in place after the limits begin to bind. The sustained drop in sulfur content is what we would expect if the type of coal these plants burnt was being changed.

By contrast, Phase I plants on the east coast only record a temporary drop in their sulfur content - a result perhaps consistent with Schmalensee et al (1998)'s argument that plants directed coal mines to source lower sulfur (not necessarily low sulfur) coal. We also see that Phase II plants in both locations do not show much change in their sulfur content, except for midwest plants, which towards the end (around the year 1998) show a small reduction. This reduction is what we would expect given the slight uptick over the same period shown by Phase II plants in Figure 2.

A major regulatory change that takes place over the period under study is the deregulation of the electricity market. I will attempt to account for this in the empirical analysis as well[18].

2.3 Specifying the Difference-in-Differences model

In Appendix I, I list the sources of data, and the steps taken to clean it.

[18]Changes in the level of competition amongst mines may perhaps be an additional explanation. Undertaking relationship specific investment eliminates (in the extreme) the force of competition; still, it may be that changes in competition occur alongside the change in specificity of investment. Calculating the Herfindahl-Hirschliefer Index for coal mines over the period 1990 to 2000 results in a very stable score, at or below 0.01. Albeit crude, this result is suggestive of a high degree of competition throughout the period under study, that does not change over time.

Dependent variables I use four definitions of the probability of choosing a fixed price contract, which are explained in Table 26[19]. Here, the first column contains the name, the second column explains which contracts are included and how these are recorded, while the third shows the percentage break-up for the variable that includes the maximum types of contracts. These definitions are meant to capture increasing levels of variation in the type of contract, which also make up significant portions of the data[20]. The main dependent variable of interest is Z_2, because here we focus squarely on the tradeoff between contracts that contain provisions for renegotiation versus fixed price contracts; the other definitions (Z_1, Z_3 and Z_4) are to be understood as a robustness check.

Main explanatory variables PHASE1 is an indicator variable that turns equal to 1 if the plant associated with the recorded contract is a Phase I plant, and is zero otherwise[21]. Time before and after treatment commences is captured by POST90, which takes on a value of 1 if the year the contract is in force is 1991 or later, and a value of zero otherwise. Finally, MIDWEST takes on a value of 1 if the plant is located in the midwest and 0 if it is not[22].

Additional variables To account for changes in transportation I use mainly two variables. MODES refers to the total number of different modes of trans-

[19] All definitions are made to enable estimation of a linear probability model. The reason for using such a model is described below.

[20] By "significant", I mean more than 1% of the total.

[21] I include power plants as Phase I plants, if any of their units were subject to reduction requirements under Phase I of the Clean Air Act Amendment.

[22] MIDWEST plants include plants located in Arkansas, Illinois, Iowa, Indiana, Kansas, Louisiana, Michigan, Minnesota, Mississippi, Oklahoma, Texas, and Wisconsin.

port used to ship coal. I expect that as alternate modes of transportation increase, the likelihood of signing fixed price contracts reduces as the uncertainty or complexity of the transaction rises. It may also be, however, that a greater number of modes of transportation imply more options to obtain coal. More options implies a greater ability to switch between suppliers, so the probability of a fixed price contract may rise[23].

ACCIDENTS is a variable which attempts to capture directly the institutional changes the railroads went through[24]. If railroad performance improved, this should show up in a reduced number of accidents, which implies fewer disruptions to existing contractual arrangements, and lower use of escalator or cost-plus contracts. I expect, therefore, that as ACCIDENTS increases, the probability of a fixed price contract should fall. I scale the total number of accidents by the total miles of track within any state to account for variation in state size and railroad networks, for the state where the mine is located[25].

Indicator variables control for the region where the coal is coming from: WEST for western coal, INTERIOR for interior coal and EAST for Ap-

[23] Joskow (1987) reasons that more transportation options imply reduced scope for opportunism, as one can switch between suppliers more easily. Kozhevnikova and Lange (2009) define a dummy variable that equals one if a mode of transportation other than rail is used. I have considered such a variable, but find results do not change. These results are included in the appendix.

[24] Although the Staggers Act was the main regulatory change, other regulatory changes also took place, notably the accounting procedure for depreciation that railroad companies could follow. See Saunders (2003). I try to account for these changes, by collapsing railroad performance into one variable. I use accidents because they serve best as a proxy for ex-post adaptation arising through the complexity of a transaction (Bajari and Tadelis 2001, Forbes and Lederman 2009), which may be affected by increased switching to rail.

[25] If improvements in rail lead utilities to systematically choose suppliers, this variable may be endogenous. I explore an alternate definition of this variable, in terms of the state where the plant is located, and find a slight increase in the effect of relationship specific investment. This result is included in the appendix.

palachian coal[26]. These variables are meant to account for regional variation in coal. Such variation increases the likelihood of hold-up and therefore lowers the probability of choosing a fixed price contract. Taking EAST as the base category, the coefficients on WEST and INTERIOR should be negative. Railroad deregulation, however, makes transportation cheaper. To the extent that transportation costs are a source of intra-regional variation, I expect a weakening in the explanatory power of these variables. The increased ability to switch, following the imposition of the Clean Air Act Amendment, may further reduce the importance of regional variation, again implying weak effects.

MINE-MOUTH records whether the contract is with a mine-mouth plants. Being an extreme form of relationship specific investment, I expect MINE-MOUTH to be negatively correlated with the use of fixed price contracts.

Differences between ex-ante specified and ex-post delivered coal are also controlled for. Ex-ante specifications are usually specified in terms of a lower limit on BTUs, and an upper limit on Ash and Sulfur content. I take the logarithm of the absolute difference between the ex-ante specified and the delivered amount[27]. I consider three characteristics: the BTU, Ash and Sulfur content of the coal[28]. I interpret these "delivery variables" as reflecting the difficulty of specifying product characteristics that are nonetheless important. The larger these variables, it may be more difficult to fully anticipate

[26] In the definition of these variables, I follow Joskow (1987). I use the term INTERIOR while Joskow uses the term MIDWEST. In all specifications, EAST is the base case.

[27] In some cases, contract level characteristics were not available, so I substitute for them using similarly defined variables at the coal county level.

[28] Additional characteristics are Tons and Moisture content. Including these characteristics does not substantially alter the conclusions. These results are included in the appendix.

all relevant characteristics of the transaction, implying a lower likelihood of using fixed price contracts.

Phase II plants may also engage in fuel switching investment. To rule this out, for a majority of the specifications, I only include data until 1995. I examine the robustness of this cut-off below. Also, 1995 was the year limits were set to bind on Phase I plants, and most (if not all) fuel switching investment would have been carried out by this year, otherwise these plants would run the risk of not being compliant with the Amendment's requirement. Contract changes toward fixed price contracts should have been initiated by this year, if they are to be explained by the reduction in specialization of investment.

There is a risk, however, that the effect of declining specialization may be under-estimated. One may, in response to this concern, increase the year in which the data is cut off, but then there is a risk of contamination if the control group (Phase II plants) start to react to their limits. I choose, therefore, a safer research design which admits a possible under-estimation. The magnitude of such under-estimation does not appear to be large, as I will discuss below.

The US market for electricity underwent deregulation in the late 1990s[29]. A major motivation for restructuring electricity generation was the high prices faced by consumers (Borenstein 2002). It may, therefore, be reasonable to account for any state-wise variation in electricity market performance which could have led to deregulation efforts and be a factor that confounds

[29]The earliest state to begin restructuring efforts is Texas, which started in 1995 by the enactment of Senate Bill 373.

the estimated model. I define RESTRUCTURE as equal to 1 for plants located in states that enact legislation to deregulate, but only after (and including) the year in which the legislation was passed. Effectively, this means that in the main specifications, RESTRUCTURE equals one only for plants located in Texas, since only Texas deregulates by 1995, and that too, in 1995. For specifications that include years beyond 1995, described later, other states also are included.

I also include controls for the level of dedicated assets (DEDICATE)[30], and for repeated interaction (REPEAT). Dedicated assets are predicted to raise the probability of ex-post opportunism, and therefore should be negatively correlated with the use of a fixed price contract. Repeated interaction may have either a positive or negative effect (Corts and Singh 2004). Previous knowledge of the supplier could raise fears of opportunism and increase the likelihood of writing a fixed price contract as the buyer attempts to counter the opportunistic supplier. Past interaction may also, however, play a role in sharing information about the supplier's operations, and the need for adaptation as supply conditions change. This would increase the likelihood of writing escalator clauses, and imply a negative correlation with the choice of a fixed price contract.

I employ a linear probability specification, for two reasons. One, the interpretation of the interactions in non-linear models has been subject to some

[30] It might appear odd that DEDICATE takes on values greater than one. This is possible because the same plant could source through multiple suppliers within the same contract. Intuitively, such contracts should be rarely used, and indeed they are. The median value, for instance, equals 0.8; the 99th percentile equals 1; and importantly only 49 observations (0.3% of the total observations) have DEDICATE greater than 1. Following Joskow (1987), I use a quadratic specification; results (included in the appendix) are little altered if a linear specification is used instead.

controversy (Ai and Norton 2003, Puhani 2012). Using a linear model avoids these complications. Two, a linear probability model allows for multiple dimensions of fixed effects. Given the wide cross-plant variation, it is necessary to include both plant and year fixed effects[31]. Across all specifications, I cluster standard erros by plant. Clustering at the level at which the outcome variable varies is crucial for valid inference in a difference-in-differences specification (Bertrand et al (2004))[32].

Formally, I estimate:

$$Z_{cpy} = \alpha_1 * PHASE1_p * POST90_y + \alpha_2 * PHASE1_p * POST90_y * MIDWEST_p + \alpha_3 * MIDWEST_p * POST90_y + \beta * \mathbf{X_{cpy}} + \gamma_p + \delta_y + \epsilon_{cpy} \quad (2.1)$$

where c indexes contract, p plant and y year.

As explained above, Phase I plants may respond differently to the Amendment in their emission reduction strategies, due to their location (Ellerman and Montero 1998). Much of the take-up of western coal, and the investments toward blending, would be concentrated, therefore, for plants located in the midwest. For this reason, I expect α_2 and α_3 to be positive. Phase I plants on the east coast faced comparatively less incentive to blend due to high transportation costs (although lower, they are still substantial) and relied heavily on Appalachian coal. Consequently, they might choose to source more lower sulfur coal from within the Appalachian belt. The resulting lower

[31] A two way fixed effect model will account for unobserved heterogeneity over time and across plants. Such heterogeneity is likely to be important in the current setting, as I discuss below while conducting the pre-trend tests.

[32] Also, linear probability models are defined such that the error term is heteroskedastic. Specifying panel robust standard errors controls for heteroskedasticity as well as serial correlation within clusters (Cameron and Trivedi 2005).

number of suppliers could raise fears of opportunistic hold-up ex-post. I expect, therefore, α_1 to be negative.

The vector X includes all the control variables discussed above. I also include plant and year fixed effects, γ_p and δ_y, respectively[33].

Pre-trend tests Do Phase I and Phase II plants show similar trends before the announcement of the Amendment? Graphically, I show this in figure 4. This figure plots, for each year, the percentage of total existing contracts recorded as being fixed price contracts. We can see that Phase I plants use more fixed price contracts than Phase II. Importantly, the difference starts at the year 1990, which is exactly what one would expect if the hypothesis of fuel switching following the Clean Air Act Amendment is correct. I perform three formal tests to assess whether Phase I and Phase II plants shared similar trends before the announcement of the Amendment.

The results for all these tests are shown in Appendix II. We may conclude from these results that Phase I and Phase II plants share similar trends in using fixed price contracts before the commencement of treatment.

2.4 Estimates of the specified model

Table 3 presents estimates of the base specification. PHASE1*POST90 is statistically insignificant, although of the expected sign. The main interaction term of interest - PHASE1*POST90*MIDWEST - has the expected sign and it is statistically significant, confirming the hypotheis of

[33]These fixed effects absorb PHASE1, POST90, MIDWEST and the interaction of PHASE1 with MIDWEST.

easier switching following reduced specificity, as a result of the Amendment. POST90*MIDWEST has the expected sign but is statisticially insignificant. The pattern of these results is invariant to changes in the definition of the pricing outcome variable. In addition, the point estimates are all relatively similar across the definitions, lending further strength to the results. Broadly therefore, we see strong confirmation of the hypothesis that Phase I plants, located in the midwest, are more likely to use fixed price contracts.

Electricity restructuring appears to have a negative influence on the propensity to write fixed price contracts, although it must be kept in mind that by 1995 only Texas had announced plans for deregulation. As I discuss below, once years following 1995 (and the resulting inclusion of more states that enact restructuring legislation) are included, RESTRUCTURE has statistically insignificant effects. The influence of restructuring therefore appears to be non-robust. Railroad deregulation appears to have strong effects as well, as the coefficient on ACCIDENTS is statistically significant and of large magnitude.

Mine mouth plants show no statistically significant difference in the adoption of fixed price contracts. Dedicated assets are statistically significant, but I do not find evidence for a non-linear relationship. For WEST and INTERIOR, we can see that the effects are weak. But that is precisely what is expected to occur if the Amendment led to easier switching among suppliers, as such switching reduces the effect of inter-regional variation. Finally, out of the delivery variables, SULF has statistically significant effects; however, the magnitude of these effects appears quite low.

Although statistically significant, are these results meaningful in terms of magnitude? Comparing across the indicator variables, the triple interaction term certainly does seem to have a large effect, approximately raising the probability of choosing a fixed price contract by 0.17 to 0.18 probability units. I have conducted an analysis comparing the estimates from the model in this study to the estimates from the three other studies on coal contracts. Broadly, the estimates here compare quite favorably. In particular, the triple interaction term shows coefficients that are within the same order of magnitude as those suggested by these other studies[34].

2.4.1 Equation, Sample specification and Contract length

I examine the sensitivity of the results to various changes in the specification and the sample in Table 4[35]. I do not report all the coefficients. Columns (1) to (4) show results with Z_2 as the dependent variable[36]. In column (1), I report the results that obtain from raising the cut-off year by one, that is, data up to and including the year 1996 is included. Given the discussion in Section 2.3, the more years are included, the greater should be the estimate on the triple interaction term.

We see that this is indeed the case, the point estimate on the triple interaction term increases from 0.175 to 0.214. We also observe that the

[34] This analysis is included in the appendix.

[35] One may be concerned that the owners of these plants - the utility companies - may differ amongst each other in ways that could bias the estimated results. For instance, companies can have distinct cultures that might influence management style and therefore procurement strategy. I attempt to control for such unobserved heterogeneity by including utility specific fixed effects, under the assumption that such differences are time-invariant. Results are little affected, and are included in the appendix.

[36] I only report a selected set of coefficients in Table 4; other coefficient estimates are reported in the appendix. Very similar results obtain when Z_2, Z_3, Z_4 are the dependent variables. Results with these variables are reported in the appendix.

error for the latter estimate remains the same as for the former. In Column (2), I do not exclude any years - we see that the estimate rises, this time to 0.255. However, as mentioned above, the problem with including years close to, and including, 2000 is that Phase II plants appear to also respond which risks the empirical design, despite the stronger estimate. Importantly, although the estimate rises when not excluding any years, the estimate is still within the same order of magnitude as when data is limited to 1995. Therefore, while the main estimates may possibly underidentify the effect of declining specificity, it would appear to be a reasonable trade-off for a safer design.

Another interesting result that occurs when we include all years is with respect to the PHASE1*POST90 coefficient. This variable is expected to be negatively correlated with fixed price contract use. Although the sign is observed negative in the main specification, it is only when we include all years is this correlation statistically significant. The point estimate for this interaction is however far smaller than for the triple interaction term, indicating that the strength of this response is quite weak, which is perhaps why the coefficient is insignificant when some years are excluded.

Kozhevnikova and Lange (2009) exclude spot contracts and in column (3) I do the same. I define spot contracts as contracts with length less than, or equal to, one year of duration. It is not entirely clear why such contracts should be excluded, since if a utility has more flexibility in sourcing coal, they are more likely to buy on the spot market. I expect, therefore, when removing these contracts, the predicted effect should fall, as an important margin of reponse by the buyer is eliminated. Indeed, we can see that this does happen, with the fall being large enough to render the point estimate statistically insignificant. The main conclusion we can take from this is that excluding spot contracts is perhaps not appropriate.

In column (4), I examine the possible influence of coal protection programs that some states enacted in the wake of the Amendment. To protect local coal interests, five states - Illinois, Indiana, Ohio, Kentucky and Pennsylvania - enacted legislation incentivising the use of coal from their mines (Ellerman and Montero 1998). I interact POST90 with an indicator variable for these five states (PROTECT). As only Phase I plants are likely to be affected by such legislation, I define PROTECT as being 1 for Phase I plants in these five states and zero otherwise. We can see the estimates for the interaction variables are little altered, while the POST90*PROTECT is not statistically significant.

I have argued earlier that contract length as an outcome variable is not straightforward to interpret, nevertheless in Column (5), I show results with contract length as the dependent variable. Because I only observe contracts with length at least as great as the difference between when they were signed and 1979, the sample is truncated. OLS estimates are likely to be biased as the sampling process induces a correlation between the independent variables and the error term. Therefore, I use maximum likelihood methods in order to account for the truncation. This means that I can no longer interpret plant and year indicator variables as fixed effects, since that interpretation is valid only for the linear regression case. I include these indicator variables as controls to account, as much as possible, for unobserved heterogeneity.

For maximum likelihood estimates and truncated data, it is not clear if the analysis in Bertrand et al (2004) necessarily applies. Nevertheless I attempt to control for correlation in the error terms, following the prescriptions of the Bertrand et al (2004) study as closely as possible. Clustering standard errors lead to an incidental parameters problem as the number of clusters is extremely large, and I was unfortunately unable to conduct a joint test of significance. I therefore use the other procedure recommended by Bertrand et al (2004) to obtain correct standard errors, which is to collapse the data into two periods (pre and post the policy announcement), and then estimate the main specification, replacing the year indicator variables with a single indicator variable that equals one for all years following 1990[37]. These estimates are shown in Column (5).

We see a negative coefficient on the triple interaction term that is statistically significant, and suggests a fall in contract duration by 2.43 years as a result of declining specificity. It is interesting to compare this coefficient with the regional coal supply indicator variables, which Joskow (1987) uses to capture relationship specific investment. The coefficient of WEST equals 4.3 and that of INTERIOR equals 3.09. The lower coefficient on the triple interaction term suggests these regional indicator variables could perhaps be overstating the effect of relationship specific investment. Also, the coefficients on WEST and INTERIOR are far smaller than what Joskow found, a result one expects if relationship specific investment declines in importance due to easier supplier switching.

[37]Note that the case I analyze here deals with a policy that came into place at one time for all plants, so there is no question of varying years in which the policy went into effect. Under this condition, Bertrand et al (2004) find that this aggregation based method performs quite well.

Also interesting to note is that repeated interaction appears to have weaker effects than relationship specific investment. This pattern was observed when pricing alternatives was the dependent variable, and is observed again with contract length; both Kerkvliet and Shogren (2001) and Kozhevnikova and Lange (2009) also find a similar result. In terms of length, repeated interaction raises length by 0.61 years, considerably smaller than the coefficients above, and this estimate was statistically significant at only the 10% level of significance. One point of difference between length and pricing as dependent variables is that there is strong evidence of a non-linear relationship between dedicated assets and length. The coefficients on DEDICATE and its square term are both statistically significant and indicate an inflection point at roughly the mean value for DEDICATE[38].

One may question the earlier results relating to pricing structure since they do not control for length. Including length as an explanatory variable however confuses, in my view, effect for cause. Length and pricing are both outcomes, and must be regarded as such. Accordingly, I have estimated a SUR model including both length and pricing as outcomes, and find very little difference in the results. These results are reported in the appendix[39].

[38]Coefficients for WEST, MIDWEST, REPEAT, DEDICATE and DEDICATE_SQUARE are not reported in Table 4 but are reported in the appendix.

[39]I have also estimated instrumental variables regressions, following Kozhevnikova and Lange (2009), but find very weak support for the instruments themselves; first stage F-statistics are very low in all specifications and the instruments are statistically insignificant in the first stage in most specifications. These results are reported in the appendix.

2.4.2 Was the change driven by new suppliers?

A key question regarding the interpretation of the results so far is whether the shift in the contracts was driven by newer suppliers alone. One may argue that if the shift in contracts was restricted to newer suppliers, it may simply be some characteristic of these suppliers that drives the change. I examine this issue in two ways: in the first, I restrict the data to select a particular set of incumbent suppliers; in the second, I use REPEAT as an outcome variable. Based on both sets of results, I find strong evidence that Phase I midwest plants renegotiated contracts with already existing suppliers.

These results are shown in Columns (1) and (2) of Panel A, Table 5.[40] In Column (1), I restrict the data to only include suppliers with whom plants had a contractual relationship over the years 1979 to 1984. Restricting attention to this pool of incumbent suppliers allows us to test whether contractual changes were driven by older incumbents or newer arrivals. We see that the point estimate for the triple interaction term is only marginally higher, and statistically significant. In Column (2), I use REPEAT as the outcome variable. If the coefficient for the triple interaction term turns out to be positive, this will support the finding that effects are mostly unchanged even if we focus on earlier incumbent suppliers alone. We see that indeed this is the result: Phase I midwest plants are more likely to contract with a previous supplier, with the probability of such an event increasing by 6% for these plants. Interestingly, the opposite appears to happen for the east coast Phase I plants, supporting the hypothesis that these plants were writing contracts

[40] As before, I only show results with regard to the two interaction terms. Other coefficients are not reported to save on space; but are available on request.

with newer Appalchian suppliers.

I look at the characteristics of coal deliveries in columns (3) to (6). BTU and SULF are the outcome variables in columns (3) and (4), respectively. For plants who rely more on fixed price contracts, that is Phase I midwest plants, I expect a negative correlation with these outcomes. For plants increasing their reliance on longer term escalator contracts, that is Phase I east coast plants, I expect a positive correlation. We see confirmation of this when SULF is the outcome, which is the outcome when the coefficients are statistically significant.

Columns (5) and (6) offer further proof of the way plants renegotiated in response to the Amendment. Here, I look at actual BTUs and Sulfur shipped. We see that Phase I midwest plants buy more cleaner, lower BTU content coal, which is what one would expect, since they increase the use of western coal. These effects are not statistically significant however: again, this is consistent with the basic hypothesis that such plants were mixing different types of coal. A statistically significant effect would, in fact, indicate that plants were dramatically altering their supply base and would be inconsistent with both the basic hypothesis as well as the results in Columns (1) and (2).

For east coast Phase I plants, however, we see the opposite happening. Such plants appear to have increased reliance on both higher BTU and lower Sulfur coal. This pattern is precisely what we would expect if such plants turned toward lower sulfur coal within the Appalachian region, as the transportation costs for western coal for them were too high. It also confirms the statement in Schmalensee et al (1998) that plants turned toward lower-sulfur (not necessarily low sulfur) coal. Last, these results are consistent with the finding in Lange (2010) who finds that there was an increase in the use of low sulfur bituminous coal following the announcement of the Amendment and before Phase I was to begin.[41] Note also that the result for these plants in Column (2) - that they were more likely to buy coal from newer suppliers - is consistent with this interpretation.

Finally, there is also the question of how the adoption of scrubbers impacts the results here, especially in light of Schmalensee et al (1998)'s statement that plants that adopted scrubbers tended to sign long term contracts with their coal suppliers. Such plants, therefore, might also be more prone to using escalator contracts. I have, using information from the EPA's website, included a control for whether or not a plant installed a scrubber. I find the results are little affected. It must be kept in mind that since I only have scrubber data for 1980, 1985, 1990 and then on a yearly basis from 1993 onward, when including controls for scrubbers I am forced to drop a major portion of the data. Despite this significant loss of information, the results stay the same. These results are reported in the appendix[42].

2.5 Concluding remarks

I have attempted to exploit a policy driven source of exogenous variation in investment characteristics, as a way to identify the relationship between specialized investment and contract structure. The results support the theoretical implication that in the face of lowered specialization, contracting

[41] Appalchian coal is bituminous whereas western coal is sub-bituminous.

[42] I have also estimated models with the upper limit of sulfur, distance shipped and an indicator variable that equals one if any of the coal was transported by rail. I find little change in the main results. These are available in the appendix.

parties will choose fixed price contracts.

There are however a few limitations to the present study. These limitations can be broadly divided into two cateogries: econometric issues, and empirical issues. Under the former, there are two issues: first, I have had to use a linear probability model in the present study, because a two-way fixed effect model is needed, and I use a difference-in-difference procedure. As the outcome variables are categorical, a non-linear model is more approrpriate, but I am unaware of any non-linear econometric model that admits more than one dimension of fixed effect. Studies of organizational or contract design are bound to encounter categorical variables as dependent variables, though, so the development of non-linear models that allow multiple dimensions of fixed effects is quite clearly required.

Second, there may also be other ways to solve the problem of simultaneous choice of transaction and contract type. For instance, careful consideration of why the parties decide to engage in the transaction could lead to gathering additional kinds of data, and the problem could be overcome. The data requirement for a study of this kind may however be fairly daunting. For instance, in the present case, we would need to know why plants chose to locate where they did, their engineering technology, the state of the transmission network and the nature of the market they were selling power to.

Empirical issues relate to the specific data available, and these are once again twofold. One, I have used information at the plant level. Ideally, one would like to analyze behavior at the level of each generating unit; however, contractual information is only available at the level of the plant. Two, on a more abstract level, it is highly relevant that there currently does not exist any definition of specific assets, complexity or uncertainty that can be transparently applied to data. Put another way, the empirical measurement of transaction characteristics lags behind the theoretical work. Therefore, it is difficult to rule out measurement error or omitted variable bias entirely.

There may be some lessons here for the structuring of environmental regulation and perhaps for regulation itself. We have seen here how environmental legislation deeply alters the nature of contractual relationships between coal mines and power plants. It is striking to note in this regard that the vast majority of analysis within economics tries to deal with the problem of harmful emissions (and negative externalities more generally) with an almost exclusive focus on the producer of the emissions, which is the buyer side. Recently, Harstad (2012) has written about targeting the supplier side. What the present study urges is a proper consideration of the contractual relationship between the buyer and the supplier. After all, the shift to fixed price contracts has important welfare implications. Aside from the emission reductions that took place, utilities benefit from such contracts and it forms an important source of gain resulting from the 1990 Clean Air Act Amendment that has been almost entirely ignored until date.

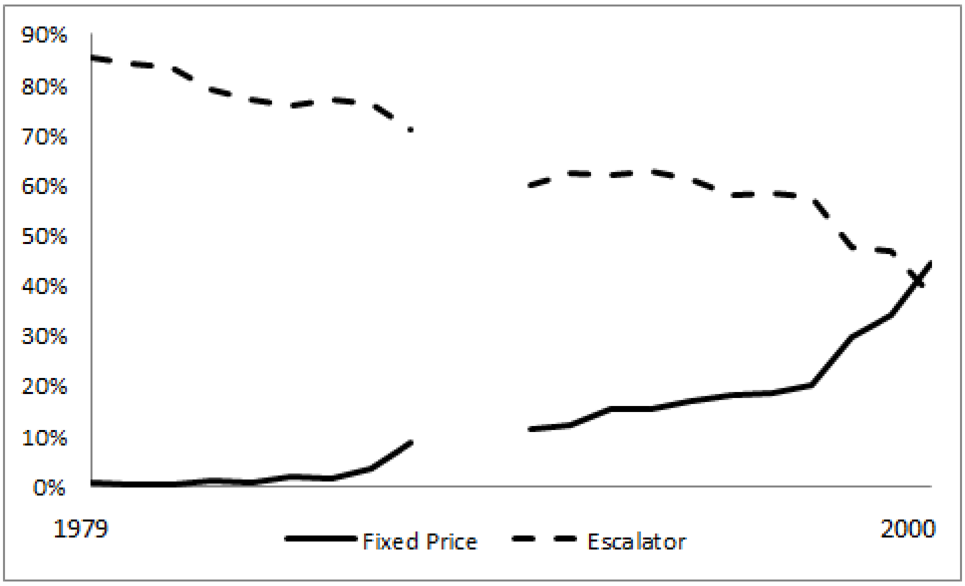

Figure 1: The rise of Fixed Price contracts: Fixed Price and Escalator contracts as a percentage of Total Contracts in existence in every year between 1979 and 2000 (Source: Coal Transportation Rate Database, Author's Calculation)

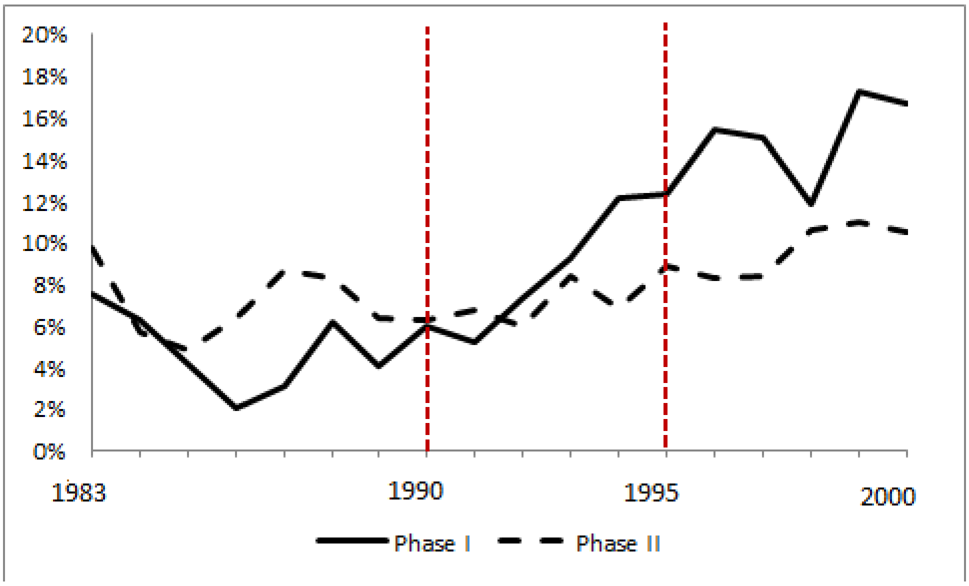

Figure 2: Suggestive evidence of Mixing: Phase I plants increasingly mix their coal (Source: EIA 786, Author's Calculation)

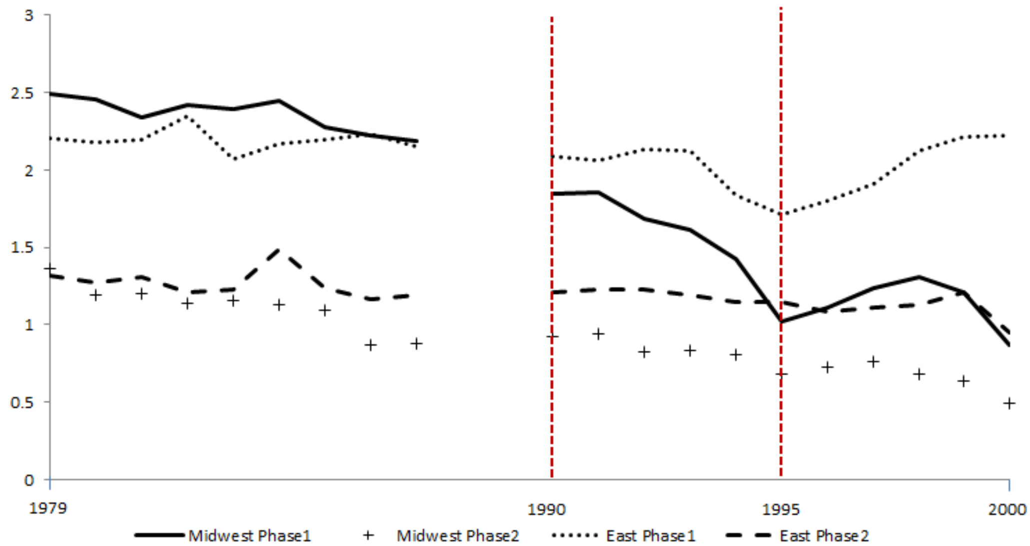

Figure 3: Average sulfur content (pounds/mmBTU) by Phase Status and Location (Source: Coal Transportation Rate Database, Author's Calculation)

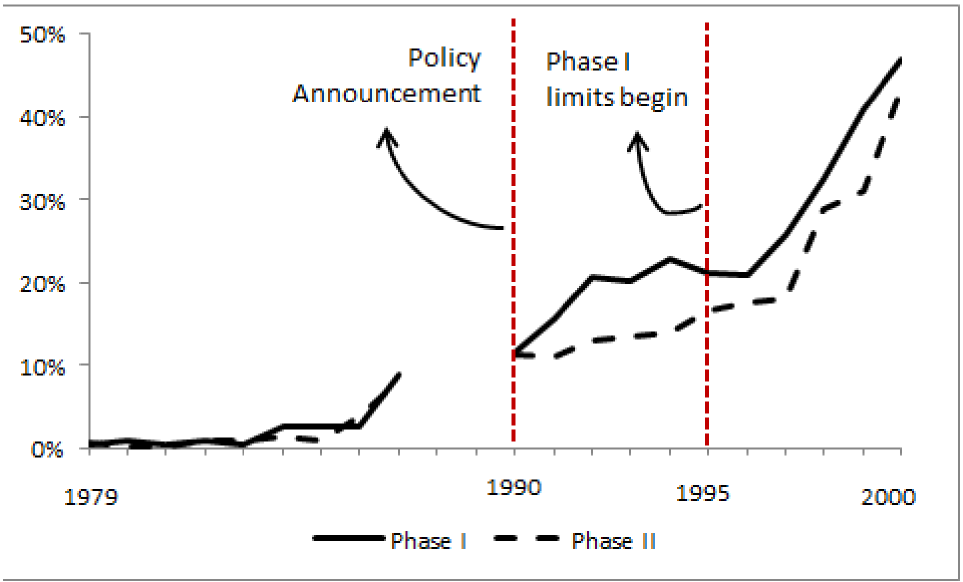

Figure 4: Motivation for the Difference-in-Difference Strategy: Phase I plants more likely to use Fixed Price contracts (Source: Coal Transportation Rate Database, Author's Calculation)

Table 1: Definitions of Dependent Variable

Dependent Variable	Contract type included	Values	Percentage
Z_1	Fixed price contracts	1	
[0.096]	Escalator clause contracts	0	
Z_2	Fixed price contracts	1	
[0.084]	Escalator clause contracts	0	
	Cost plus contracts	0	
	Price renegotiation	0	
Z_3	Fixed price contracts	1	
[0.083]	Price tied to market	0	
	Escalator clause contracts	0	
	Price renegotiation	0	
	Cost plus contracts	0	
Z_4	Fixed price contracts	1	12.00%
[0.079]	Price tied to market	0	1.38%
	Escalator + Price tied to market	0	2.82%
	Escalator clause contracts	0	66.80%
	Escalator + price renegotiation	0	1.29%
	Price renegotiation	0	6.83%
	Cost plus contracts	0	3.51%

Source: Coal Transportation Rate Database, Author's Calculation. Contracts that had a share lower than 1% in the data obtained post cleaning, or recorded as "Other" are not included. For each variable, below its name, the mean is given in square brackets.

Table 2: A Brief Summary of the Data

Name	Observations	Mean	Standard Deviation	Min	Max	Source	Description
PHASE1	15191	0.294	0.455	0	1	EPA	Indicator variable that equals 1 if contract is with a plant targeted under Phase I of Title IV of the Clean Air Act Amendment of 1990
MODES	14777	1.387	0.657	0	4	CTRDB	The total number of unique modes of transportation used to ship coal
ACCIDENTS	14240	0.007	0.030	9.34e-07	0.3808	FRA	Total accidents divided by total track miles for the state where the mine is located
MINE-MOUTH	14777	0.015	0.121	0	1	CTRDB	Indicator variable for whether plant is located at the mouth of a mine
LENGTH	14777	5.953	6.513	0	48	CTRDB	Length of the contract, calculated by subtracting year of signing from the year of expiry
WEST	14777	0.203	0.402	0	1	CTRDB	Indicator variable for whether coal supplier is located in the Western region
INTERIOR	14777	0.125	0.331	0	1	CTRDB	Indicator variable for whether coal supplier is located in the Interior region
EAST	14777	0.664	0.472	0	1	CTRDB	Indicator variable for whether coal supplier is located in the Appalachian region
MIDWEST	14777	0.420	0.493	0	1	CTRDB	Indicator variable for whether plant is located in the midwest

REPEAT	15375	0.817	0.386	0	1	CTRDB	Indicator variable for whether the plant and the supplier contracted with each other in the past
DEDICATE	13490	0.646	0.537	1.50e-05	42.083	CTRDB	Ratio of quantity within the specific plant-supplier contract to quantity for all contracts the supplier holds
BTU	14611	5.2856	1.4339	0	11.3679	CTRDB	The logarithm of the difference between the ex-ante specified BTU limit and the delivered amount
SULF	14324	-1.0702	1.1640	-17.3286	4.3087	CTRDB	The logarithm of the difference between the ex-ante specified sulfur limit and the delivered amount
ASH	14363	0.7801	1.1010	-6.1455	4.2427	CTRDB	The logarithm of the difference between the ex-ante specified ash limit and the delivered amount
QUANTITY	13489	10.1189	10.2601	2.55e-05	708.2199	CTRDB	Total quantity, in billion BTUs (derived by multiplying contracted for total tons by contracted for BTU content
YEAR	14777	1989	6.4680	1979	2000	CTRDB	The difference between the current year and the year the contract is set to expire
TOTALDISTANCE	14777	425.4985	541.8192	0	12040	CTRDB	The total distance the coal is shipped over, in miles
RESTRUCTURE	15375	0.0466	0.211	0	1	EIA	Indicator variable, equal to 1 in the years after, and including the year in which deregulation legislation was enacted, for plants located in US states AR, AZ, CA, CT, DE, DC, IL, ME, MD, MA, MI, MT, NV, NH, NJ, NM, NY, OH, OK, OR, PA, RI, TX and VA

Note: CTRDB refers to the Coal Transportation Rate Database, EPA refers to Environment Protection Agency, EIA refers to the Energy Information Administration and FRA refers to the Office of Safety Analysis, Federal Railroad Authority.

Table 3: Adoption of Fixed Price Contracts: Linear Probability Models

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0500	-0.0423	-0.0390	-0.0365
	(0.0494)	(0.0417)	(0.0411)	(0.0347)
PHASE1*POST90*MIDWEST	0.164**	0.175**	0.173**	0.167**
	(0.0811)	(0.0736)	(0.0732)	(0.0682)
POST90*MIDWEST	0.0119	0.0144	0.0162	0.0281
	(0.0454)	(0.0375)	(0.0368)	(0.0336)
RESTRUCTURE	-0.306**	-0.289**	-0.288**	-0.286**
	(0.121)	(0.117)	(0.118)	(0.117)
MODES	-0.00299	-0.00858	-0.00746	-0.00789
	(0.0110)	(0.0106)	(0.0104)	(0.0101)
ACCIDENTS	-0.409***	-0.409***	-0.406***	-0.416***
	(0.134)	(0.122)	(0.122)	(0.109)
MINE-MOUTH	-0.0259	-0.0397	-0.0401	-0.0623
	(0.0428)	(0.0366)	(0.0367)	(0.0469)
WEST	0.0171	0.0310	0.0305	0.0281
	(0.0440)	(0.0413)	(0.0413)	(0.0405)
INTERIOR	-0.0607	-0.0691	-0.069	-0.0655
	(0.0417)	(0.0352)	(0.0352)	(0.0345)
REPEAT	-0.0825***	-0.0774***	-0.0757***	-0.0789***
	(0.0133)	(0.0126)	(0.0123)	(0.0124)
DEDICATE	-0.0746**	-0.0755**	-0.0731**	-0.0882***
	(0.0346)	(0.0328)	(0.0321)	(0.0334)
DEDICATE_SQUARED	0.0211	0.0234	0.0218	0.0282
	(0.0227)	(0.0203)	(0.0198)	(0.0205)

Table 3 Continued

	Z_1	Z_2	Z_3	Z_4
BTU	0.00340	0.000525	0.000713	-0.000154
	(0.00391)	(0.00347)	(0.00342)	(0.00319)
SULF	-0.0119***	-0.00990**	-0.00996**	-0.0104**
	(0.00448)	(0.00428)	(0.00424)	(0.00418)
ASH	-0.00221	-0.00114	-0.00115	-0.000427
	(0.00323)	(0.00286)	(0.00276)	(0.00265)
Constant	0.257***	0.252***	0.243***	0.227***
	(0.0380)	(0.0361)	(0.0350)	(0.0352)
Plant Fixed Effects	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y
Observations	7,660	8,709	8,864	9,303
R-squared	0.126	0.109	0.108	0.103
Number of plantcode	292	296	299	299

All standard errors are clustered by plant. These errors are reported in parentheses, below the estimated coefficients. *** p<0.01, ** p<0.05. For a definition of the dependent variables, refer to Table 26.

Table 4: Sample selection, other explanations and contract duration

Dependent Variable	Z_2				Length[c]
Specification	(1) Drop years > 1996	(2) All years	(3) Exclude Spot Contracts[b]	(4) Coal protectionism	(5) Main specification; Maximum Likelihood
PHASE1*POST90	-0.0692	-0.0926**	-0.00509	-0.0237	1.428**
	(0.0404)	(0.0433)	(0.0220)	(0.0590)	(0.703)
PHASE1*POST90*MIDWEST	0.214***	0.255***	0.0818	0.174**	-2.435**
	(0.0736)	(0.0757)	(0.0494)	(0.0741)	(1.000)
MIDWEST*POST90	-0.00891	-0.0723	0.0433	0.0147	0.007
	(0.0372)	(0.0391)	(0.0225)	(0.0376)	(0.562)
POST90*PROTECT				-0.0318	
				(0.0642)	
Control Variables[a]	Y	Y	Y	Y	Y
Plant and Year Fixed Effects	Y	Y	Y	Y	
Plant and Year Indicator variables					Y
Observations	9,233	11,214	6,365	8,709	10,790
R-Squared	0.115	0.184	0.063	0.110	-
Log-Likelihood	-	-	-	-	-27,942.32
Number of Plants	300	305	285	296	326

Notes: Z_2 is the dependent variable for Columns (1) through (4); Contract length is the dependent variable for Column (5). Unless otherwise noted, standard errors clusterd by plant are reported in parentheses under the coefficients. ***$p < 0.01$, ** $p < 0.05$.

a: Control variables include MODES, ACCIDENTS, MINE MOUTH, WEST, INTERIOR, RESTRUCTURE, REPEAT, DEDICATE, DEDICATE_SQUARED, BTU, SULF, and ASH.

b: Spot contracts are defined as contracts with a length less than or equal to 1 year in duration.

c: Estimates for contract length are calculated using maximum likelihood to account for truncation. See text for details.

Table 5: The Structure of Renegotiation

	Incumbent Suppliers† (1)	REPEAT (2)	Coal Characteristics: BTU (3)	SULF (4)	BTUs Shipped (5)	Sulfur Shipped (6)
PHASE1×POST90 ×MIDWEST	0.143*	0.0631*	0.116	-0.379*	-124.4	-0.163
	(0.0663)	(0.0303)	(0.163)	(0.165)	(93.96)	(0.121)
PHASE1×POST90	-0.0307	-0.0555*	0.0416	0.246*	219.2**	-0.172**
	(0.0438)	(0.0235)	(0.0946)	(0.101)	(50.07)	(0.0637)
Controls††	Y	Y	Y	Y	Y	Y
Plant FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Observations	6,101	9,694	10,938	10,690	10,926	10,928
R-Squared	0.057	0.025	0.270	0.113	0.410	0.104
# Plants	275	306	316	313	316	316

Notes: All standard errors in parentheses, and are clustered by plant. ** p<0.01, * p<0.05.
†: The outcome variable in columns (1) to (3) is Z_4.
††: Control variables include MODES, ACCIDENTS, MINE MOUTH, WEST, INTERIOR, REPEAT, DEDICATE, DEDICATE SQUARED, BTU, SULF, ASH, RESTRUCTURE and a constant term. REPEAT is dropped in the specification for Column (2). DEDICATE and its squared term DEDICATE SQUARED is dropped in the specification for Columns (3) and (4). For the last four columns, BTU, SULF and ASH are dropped.

Chapter 3

The Comparative Performance of Long Term Contracts: Empirical evidence from long-term US coal transactions

3.1 Introduction

Beginning at least from Steven Cheung's analysis of share tenancy (Cheung 1968, 1969), economists have devoted an increasing amount of effort toward understanding the structure of various contractual arrangements such as contracts themselves or firm boundaries[1]. A contracting perspective has

[1]To be sure, concern with contract structure stretches back to at least John Stuart Mill (1848). I single out Cheung because this is the first paper from which concern over contracts within economics accelerated. Within this literature, I will concentrate on the incomplete contracting literature throughout this paper. See Macher and Richman (2008) for a recent survey of one strand of this literature.

also been fruitful toward assessing seemingly inefficient or unfair practices[2], particularly since the contractual nature of the problem is not obvious at the outset. Whether explicit or implicit, the aim throughout has typically been to understand the efficiency of the contract choices people make. Such knowledge may then be used to understand, or guide, the influence of policy.

It is equally important, however, to ask whether the choices made are in fact cheaper than their alternative, and if so, by how much. Answering this question not only tests the theories developed so far, but also goes further as we can evaluate the resources saved or lost by comparing the contract or organization chosen against its alternative. Far less is known about the existence or magnitude of such effects, and although recently there has been increasing attention paid to measuring such effects, by far the majority of the analysis centers over the impact of organizational decisions (Masten et al 1991, Sampson 2004, Forbes and Lederman 2012). The effect of contractual arrangements has seen very little systematic analysis, although Joskow (1988, 1990) is an early example.

The question I seek to answer is simply put: holding the boundary of the firm constant, do alternative contractual arrangements imply tangibly different performance outcomes? I study the effects of contractual choices made by US electric utilities in their coal procurement decisions. I focus particularly on the pricing structures within these contracts, and use the price paid to the coal mine as the main measure of performance.

[2] An example is Williamson's reduction of the problem of possibly unfair monopoly practices to the "make-or-buy" problem, and his emphasis that this really involves a trade-off between contracting and integration. See Crocker and Masten (1988) for a criticism of this approach.

A systematic comparison of the performance of alternate contract types could be potentially very important in influencing perspectives on efficient contractual structures in energy markets, as these markets are often governed by complex contractual arrangements, and such markets are only going to become more dominant in the future as energy becomes an increasingly important input in many economies. More generally, we may also understand the behavior of alternate contractual mechanisms as regulatory structures change. Also important is that since coal mining in the US was quite competitive, and coal transactions are relatively quite simple, any estimate of performance effects will be a lower bound on the economizing abilities of contracts.

I employ a dataset that contains 14,777 distinct contracts for coal procurement by US electric utilities, covering the period from 1979 to 2000. While in 1979, most contracts in existence (90%) contain escalator provisions based off of input costs or are explicit cost-plus contracts, by the year 2000 such contracts account only for 38% of the contracts in existence. The majority of the replacement is by fixed price contracts, which account for more than 50% of the total contracts in 2000. I find that where fixed price contracts are chosen, the average transaction price paid is between \$2 to \$4 per ton lower than the price that would result if base price with escalation clauses or cost plus contracts are used.

More generally, interpreting the shift from base price escalator contracts toward fixed price contracts as one indicating a shift from less to more complete contracts, I find that more complete contracts associate with lower prices, but also are subject to greater renegotiation. The pattern of the major contract choices - from escalator/cost-plus contracts toward fixed price contracts - thus appears consistent with a trade-off between these two characteristics. In addition, the predicted performance of the two contract types I examine is also consistent with my earlier demonstration of reduced asset specificity following from the 1990 Clean Air Act Amendment (Kacker 2013).

Contract type is endogenous in prices, and drawing a causal inference is therefore not straightforward. Accordingly, I use various techniques to account for any possible bias arising through selection: I employ two-way (plant and year) fixed effect models, a Heckman selection model, and an instrumental variables specification. All three point very clearly to the price reducing effects of fixed price contracts. Importantly, the magnitude of the reduction in price is quite similar across these models. I also demonstrate that despite fixed price contracts being more likely to be renegotiated, such renegotiation appears to lack any opportunistic element. In particular, for escalator contracts, I find renegotiations typically entail quantity, not price, changes. As such contracts are meant to support transaction specific investments, both parties place a high value on their existing relationship when such investments are present. Importantly, this supports an important but much ignored prediction of Williamson (1985, p.75 - 77), where he argues for precisely such a renegotiation pattern under a bilateral contractual governance structure.

For the particular industry that is the focus here, there exist various studies that examine coal procurement decisions by US electric utilities through the lens of transaction cost theory (Joskow 1985, 1987; Kerkvliet and Shogren 2001, Kozhevnikova and Lange 2009, Kacker 2013). Much less attention is given toward examining the performance effects of these contractual decisions. Joskow (1988, 1990) discusses the effects of long-term contracts in this industry on the flexibility of prices, and finds that prices tend to be rigid downward for older contracts during the early to middle 1980s. Such rigidity is consistent with the pattern of predicted prices I obtain from the Heckman model, which I discuss later. I now provide a brief background to coal transactions in the US, then go on to estimate performance effects of these contracts, and finally conclude.

3.2 Coal procurement in the US: a brief history

Long term contracts have been the dominant form of coal procurement within the US. These contracts vary primarily in their length and pricing structure. Contracts with durations of 30 years or more are not uncommon, while contracting over the spot market increased significantly over the 1990s. Simultaneously, pricing structures are also employed in order to govern such a long running relationship. Two of the most common price structures are base price (with escalator clauses) contracts and fixed price contracts. Apart from these two types, there also exist cost-plus contracts and price renegotiation contracts.

Base price contracts contain escalator clauses that attempt to account for various sources of changes in the average cost of supply (Joskow 1985). Cost-plus contracts essentially pass on all costs incurred by the supplier to the buyer. Price renegotiation contracts specify when the contracting parties will renegotiate their contracts. Finally, fixed price contracts fix a price for the entirety of the relationship[3].

The presence of significant relationship specific investments makes the writing of fixed price contracts inefficient. Fixed price contracts are unlikely to be able to deal with the many adaptations required when investments specific to the contractual relationship are present. Adaptations to changes in supplier costs, in particular, are needed. Cost-plus contracts can implement such adaptation, but these contracts are likely to suffer from heavy inefficiencies since suppliers can easily mislead their buyers about the true nature of costs by overstating these. In addition, if a supplier inefficiently mines coal, a cost plus contract contains no incentive to improve performance. It saddles the buyer with higher prices, which is costly both in itself and in that it also potentially exposes the buyer to regulatory overhaul[4], which is costly to the buyer.

Base price contracts with escalator clauses are likely to be chosen, since these contracts contain provisions that pay suppliers based on local average costs; such payment also saves the buyer from the costs incurred when sourcing from a particularly inefficient supplier. That being said, these contracts are unlikely to be able to anticipate all sources of cost or value changes, and by paying suppliers their costs do not convincingly provide good enough incentives to produce at low cost, so there is still some inefficiency involved

[3] Pre-comitting to an ex-ante specified price schedule can be understood as a form of a fixed price contract, although it is impossible to tell from the available information whether such schedules were drawn up or not.

[4] Utilities were subject to regulatory oversight regarding the prices they were paying their fuel prices.

(Joskow 1988, Kacker 2013). They are likely to be preferred to price renegotiation contracts, though, since they explicitly fix responses to exogenous events and so provide a cheaper solution than simply agreeing to renegotiate.

Broadly speaking, the transition from escalator (and cost-plus) contracts to fixed price contracts can be understood as a reduction in the incompleteness in the contractual relationships between the utilities and coal mines. Although escalator contracts contain a more complex pricing structure than fixed price contracts, by including open-ended clauses whose function is to escalate prices as costs of supply change, these are more incomplete than the simpler fixed price contract. Of course, the trade-off between these two contracts revolves, at least partly, around the presence of relationship specific investment. I expect that the use of fixed price contracts would lead to lower prices, as these contracts offer better incentives to suppliers to cut costs.

The coal market has undergone significant changes, particularly from the 1970s onward. Exogenous shocks to the price of oil, following from the OPEC's decision to restrict supply twice in the 1970s, particularly hit many pre-existing contracts, and led to substantial revision of existing (and future) prices. In addition, environmental regulation enacted around the same time also raised the value of low sulfur coal. Joskow (1988) studies contracts in existence over the years 1979 to 1981, provides a nice overview of the adjustments made within these contracts, and reached a major conclusion that although the contracts showed some rigidity in adjusting upward, the adjustment was quite rapid.

A major expectation around the end 1970s era built around increased demand and higher prices for coal did not materialize in the early 1980s.

Supply expanded considerably, especially in the Western part of the US, which should have led to a significant amount of renegotiation and downward revision of prices. Notice that the contracts, which earlier needed to adjust for higher prices, now need to adjust for lower prices. In a follow up study, Joskow (1990) studies contracts in force during the period between 1981 and 1985, and discovered that in revising prices downward, these contracts exhibit a great deal of rigidity.

The time period of the present study extends from the same period, but goes on to cover time until the year 2000. There are at least two major regulatory changes that affected the structure of these contracts: the first is the Staggers Act of 1980, which deregulated railroads and consequently reduced transportation costs by a large amount. The second is the 1990 Clean Air Act Amendment, which instituted a permit trading market for $S0_2$ emissions for the first time in history. I have documented elsewhere that this Amendment shifted the nature of investment made by power plants, which in turn influenced the structure of the contracts they wrote with their suppliers (Kacker 2013a). Consequently, contracts became shorter and, by 2000, fixed price arrangements overtake base price contracts as the dominant form of price structuring.

An important result from Joskow's work that bears importantly on the present study concerns the contractual response in the early 1980s. This was a time when coal markets softened considerably, and led to widespread renegotiation of existing contracts. At the same time, transaction specific investments were still very important at this stage, which required the use of escalator contracts, since such contracts provide protection against opportunistic behavior, albeit imperfectly. Arguably, other contract structures would perform worse, and it is not surprising that their use is limited. Therefore, the renegotiations that took place appear to be mostly in re-specifying base prices (for existing contracts) or negotiating for lowered prices (for new contracts), rather than any fundamental change in contract structures. I would expect, therefore, some turbulence in the behavior of prices under escalator contracts over this time period, as they adjust to a slack demand side.

Beginning 1990, the Clean Air Act Amendment took hold and led to substantial technological change, as power plants attempted to lower emissions in response to the regulation's demand. The primary response was to alter boilers in a manner that would allow them to burn more (lower sulfur) Western coal, which implied a reduction in specialization as the boilers become more flexible in their coal burning ability. At the same time, the cost of transporting such coal also fell dramatically, which only increased the incentives to engage in boiler alteration, since shipping coal from the west is no longer as expensive as it used to be[5]. So although it is the demand side that appears to have been affected by an exogenous shock, the fact that simultaneously fixed price contracts of shorter duration can be chosen (which, ceteris paribus, should provide for lower prices as they incentivise performance), probably implied a lowering of the prices paid. I now turn to the behavior of these prices, differentiated by contract type.

[5]Such alteration appears to have been undertaken systematically by plants located in the midwest, and particularly by those set of plants set to be impacted under Phase I of the 1990 Amendment.

3.3 Contract structure and prices

A striking feature of the coal procurement contracts in the sample is the shift over to fixed price contracts. Figure 5 shows this trend, and in Table 6 shows the relevant figures: we can see that the use of fixed price contracts in 1980 barely registers, being less than 1% of the total contracts in force, starts to rise by 1990 (accounting for 15% of the total) and by 2000 is the majority choice of contract (accounting for more than 50% of the total).

Such a shift in contract structure appears to be related to an overall reduction in price. Table 7 shows the average transaction prices paid at the mine and at the plant respectively, broken down by whether procurement was carried out under an escalator/cost plus contract or a fixed price contract. I include escalator and cost plus contracts together in one group, given that many of the escalation clauses built in were essentially attempting to adjust for supplier's costs of mining.

For some contracts, transaction prices at the mine was missing. In order to see if there are important differences between contracts for which prices are missing compared to those where they are not, I also report mean prices paid at the plant where mine prices are not missing. We can see that the price difference for prices paid at the plant falls by a little over \$3. More generally, I consider prices paid at the plant (delivered prices) as an alternate dependent variable to prices paid at the mine. Conceptually, it is difficult to see what separates these two prices. Although delivered prices include transportation costs, and for this reason may be considered less desirable, transportation costs are also likely to be implicitly incorporated into prices paid at the mine. For instance, it is highly likely that two mines, otherwise exactly similar, but only varying in terms of their distance from a plant, would offer different prices: the mine further away will accept a lower price to attract a buyer. In fact, such motivation in explicit in Joskow's analyses, wherein he argues that western coal producers would accept lower prices, and finds strong evidence for this.

Although in the abstract, therefore, delivered prices appear equal to mine prices, as a matter of practice they might be different. Mine price information is often not reported. Data on delivered prices, on the other hand, are much more widely available[6], and therefore there is likely to be less error involved in the collection of this information from the utilities. While I will use both sets of prices to draw inferences, I would stress the results associated with delivered prices more, as inferences made based on these prices are likely to be on stronger ground. In any case, I will use distance shipped as an explanatory variable, which ought to account for transportation costs, further diminishing the need to rely on mine price information. I expect delivered prices to be more influenced by transportation related effects than mine prices.

We can see there are fairly large differences, ranging from 6$ to 9$, amounting to between 15% to 30% of the total transaction price, depending on which price the denominator includes. The high t-statistics indicate that these differences are highly statistically significant as well. Figure **??** plots

[6]The availability is wide in two ways. One, within the Coal Transportation Rate Database, more observations exist for delivered prices. Two, there are other sources of data that track delivered prices. For instance, Joskow (1988) reports that government documents relating to the breakdown between spot and contract prices are available for delivered prices but not for mine prices. The widespread availability of delivered price information therefore makes it less likely that utilities would misreport such information, whether intentionally or unintentionally.

these means along with confidence intervals of 2 standard deviations; the red lines are drawn to indicate mine prices, while blue indicate prices paid at the plant. A key point to note from the figure is that fixed price contracts appear to have a relatively lower variance.

To be sure, these are only sample averages, without any controls for confounding factors (such as coal quality, labor costs, total reserves or differences in mining techniques), unobserved variables that could influence prices (differences among plants, such as their size, or differences across years, such as the development of stricter environmental regulation) and without any consideration of the error contained within the estimates. In the next section, I estimate more tightly controlled econometric models to calculate the effect of contract type on prices paid.

3.4 Price performance of contracts

Table 34 lists descriptive statistics and explanations for the variables I use. The main dataset I use is the Coal Transportation Rate Database. This information is taken from the FERC form 580 which surveys fuel and energy purchases by utilities. The survey is held once every two years, and all investor-owned utilities that own at least one generating station of 50 MW or more are required to respond. These utilities sell power at wholesale rates to other utilities.

In addition to this, I take data from several other sources. Information on railroad statistics comes from the Federal Railroad Authority. I use the Environment Protection Agency's website to delineate power plants in the

Coal Transportation Rate Database by phase status[7].

The triple of contract code, plant code and year identifies each observation in the data used. In the original data, there were a number of duplicate observations identified by the contract identification code and plant code; these were deleted. After this, and other cleaning, there are 4,675 contract - plant observations, observed over a period of 22 years. The total number of observations, post cleaning, equals 14,777. This is not equal to the product of the contract-plant by year as a change in pricing arrangement implies a change in contract code.

I use two different prices - prices paid at the mine (Mine Price), and prices paid at the power plant (Delivered Price), both free-on-board. We can see, as argued earlier, that there are many missing observations for prices paid at the mine. The use of prices paid the plant allows estimation from a much larger sample, and for reasons argued above, are likely to be more reliable. FIXED is an indicator variable that equals 1 if a given contract is fixed price and zero if it is an escalator/cost-plus contract[8]. I interpret this indicator variable as indicating a change in contract structure from more to

[7] To check for the accuracy, therefore, I compare this number to that given in Title IV of the Clean Air Act Amendment. This Title contains the provisions for enactment of the SO_2 trading scheme, details the emission reductions and clarifies the rules under which plants can obtain permits. A total of 110 power plants are included as Phase 1 plants, under Title IV. For the data in the Coal Transportation Rate Database, I obtain a total of 110 Phase 1 plants after merging with the information given by the Environment Protection Agency. We can be assured that information on the phase-wise distinction of plants is accurate.

[8] Escalator contracts typically specify an initial price, which is then set to escalate over the length of the contract. I do not have specific information that would help distinguish between negotiated base prices and consequent transaction prices. I do, however, have information on when the contract is signed, so by focusing on this sub-sample, it is possible to obtain information on base prices.

less incomplete[9], and expect prices to fall as the shift takes place.

Prices are likely to be influenced by various factors: the quantity contracted for, the region the coal is mined from, labor cost (particularly, around the area the mine is located in), the availability of shipping alternatives, the distance shipped, the overall status of the coal market, the characteristics of the coal itself, and general inflation trends[10]. The duration of the contract itself might also affect prices, if there is significant "front-loading" of costs into the ex-ante and transaction prices. Joskow (1988) argued that such behavior is unlikely to take place under escalator contracts. In the data I analyse however, there exists a mixture of escalator and fixed price contracts (as well as other types). Arguably, fixed price contracts would attempt to front-load costs, and so it is likely that contract length would affect prices for the given dataset. I defer a discussion of the role of contract duration until later, when I discuss the instrumental variable estimates.

I measure quantity (QUANTITY) by multiplying the contracted for lower bound on total tons by the contracted for lower bound on BTU content. I have information on the state and county the coal is mined in. I use this to define two indicator variables: WEST, and INTERIOR, to account for region wise variation in coal supply. Coal from the western part of the US is likely to be cheaper for at least two reasons: one, since it has to be shipped over larger distances, western coal producers are likely to lower their price (ceteris paribus) to attract buyers. Two, the nature of western coal mining

[9]In this definition, I treat escalator and cost plus contracts equally, since both attempt to adjust for supply costs. Later, when considering instrumental variable estimates, I will consider an alternate definition.

[10]These could affect the cost of machinery and other non-labor supplies.

allows for greater economies of scale. I expect Interior coal to show a similar pattern, but since the differences are less pronounced[11], the magnitudes are likely to be lower.

In 1990, the Clean Air Act Amendment was announced, which imposed limits on SO_2 emissions for a subset of plants (Phase 1 plants) beginning in 1995. It is likely that this led to a premium, or an increase in the premium[12] on low-sulfur coal. This might imply a rise in the price of western coal, which is low in sulfur content. Also, over the 1990s, a very active spot market develops for Western coal. To the extent that contracting over the spot market and writing shorter-term fixed price contracts are approximately substitutes[13] for each other, we might expect a lowered price for Western coal.

Labor costs are measured by COST. COST is taken from the Bureau of Labor Statistics employment cost index for the mining, construction and manufacturing sector. This cost index varies over time and over the cross-section[14], allowing for meaningful (if imperfect) identification of the role of labor costs. Labor costs are expected to lead to increased prices.

Transportation costs fall over this time period, as a result of the deregulation of the railroads following the Staggers Act. As a proxy for these costs, I use TOTALDISTANCE, the distance coal is shipped. As distance rises, transportation costs rise, so this leads to an expected positive correlation. MODES measures, to some degree, the alternate routes by which coal sup-

[11] Compared to the base case of Appalachian coal.

[12] Environmental regulations restricting the use of high-sulfur coal were in place at least from the 1970s onward, at both federal and state levels.

[13] I have argued elsewhere that they can be considered substitutes (Kacker 2013).

[14] The cost index is disaggregates the US into 4 regions, the northeast, south, midwest and west. Details of these regions, as well as the coal sourcing (WEST, INTERIOR) and plant location region (MIDWEST) that I will discuss later, are given in the Appendix.

ply can take place; we may expect that where the number of such routes is smaller, the prices are likely to be higher. ACCIDENTS measures insitutional reform in the railroads; as deregulation takes place, rail transportation becomes much more reliable, and thus enables utilities to capture gains from the falling cost of transportation. I expect, therefore, that ACCIDENTS should have a negative coefficient, as a decrease in reliability implies a lower price if the supplier wants to attract the buyer[15].

Coal markets underwent a deep and significant change over the twenty years under study here. Western coal production rises spectacularly, eventually producing more than Appalachian coal mines, while interior coal mines enter stagnation and decline. Also, bearing in mind the discussion earlier, the early to mid 1980s was a period in which supply expanded at a pace that was not expected. I include a measure of the amount of reserves known to be available in any given year to account for these far reaching changes. I expect that as reserves grow, prices fall. Further the change in known reserves is likely to vary across regions. To account for any such cross-regional variation, I interact RESERVES with indicator variables for the region where the coal is mined.

Finally, I include variables that measure the quality of the coal along four dimensions: the BTU, sulfur, moisture and ash content of coal shipped (BTU SHIPPED, SULFUR SHIPPED, ASH SHIPPED and MOISTURE SHIPPED). Higher BTU, lower sulfur coal is likely to be priced higher, so I expect BTU content to be positively related to price, and sulfur content to

[15]Such switching was undertaken as a result of the Clean Air Act Amendment (Kacker 2013).

be negatively related. Ash is detrimental to boiler performance, so higher ash content is likely to be penalized, implying a negative coefficient. I expect moisture content to show similar behavior. It is likely that some of the variation captured by WEST and INTERIOR is going to be picked up by these variables; therefore, in the fully specified model one may interpret the coefficents on WEST and INTERIOR as reflecting transportation, production and perhaps spot market differences.

Table 9 shows the results from the consideration of two way fixed effects models with clustered standard errors, with mine price as the dependent variable. From Columns (1) to (6), I show results when clustering standard errors (column (2)), when adding in plant and year fixed effects (columns (3) and (4)), and then controlling for quantity (column (5)) as well as coal sourcing region (column (6)). These fixed effects control for various sources of unobserved heterogeniety that are likely to be important[16].

The effect of transitioning from escalator/cost plus contracts to fixed price contracts is captured by FIXED. The estimated effect ranges, approximately, from \$6 to \$3. Since these prices are per ton, the implied effect for the average shipment is, in fact, quite large[17]. We can see the importance of clustering, in that the standard error nearly doubles. We can also see that adding in fixed effects reduces the estimated effect of contract structure on prices by nearly 50% - this is testament to the need for including such controls. While adding

[16]For instance, plants targeted to reduce emissions under Phase I of the 1990 Clean Air Act Amendment were larger than others. Plant size can plausibly systematically affect sourcing behavior, but is also invariant across time, implying that plant fixed effects will difference out size as an explanatory factor. Year fixed effects will account for inflation effects, to the extent that they affect all plants equally within any year.

[17]The average shipment in the data I have equals nearly 500,000 tons. A \$3 saving corresponds therefore to a \$1.5 million saving for each shipment, on average.

quantity doesn't change the results much, controlling for coal sourcing region raises the estimate by roughly 50 cents. The individual indicator variables for coal sourcing region - WEST and INTERIOR - indicate very large cross-regional differences in mine prices, in the expected direction. Note also that, as expected, INTERIOR has a lower coefficient than WEST.

I consider additional explanatory variables in Table 10. Columns (1) through (5) show results considering mine prices (in $/ton) as the outcome variable, while column (6) shows results considering the probability that a contract is modified[18]. I use contract modification as a proxy for renegotiation.

WEST and INTERIOR show strikingly different results, when additional controls are included. In particular, the coefficient for INTERIOR becomes statistically indistinguishable from zero when reserves are included. In parallel, the coefficient on WEST reduces remarkably, by approximately 50%. COST has the expected sign but is statistically insignificant. The existence of alternate modes of transportation does not appear to have important effects on prices, as MODES has coefficients that never become statistically significant. Railroad reliability, proxied by ACCIDENTS, appears to be very sensitive to model specification.

Changes in coal markets appear to have important effects. Increase in the supply of western coal shows the expected signs, is statistically significant and quite large in economic terms. The stagnancy and decline in interior coal appears to have led to lower prices for this type of coal. Interestingly, this

[18] The CTRDB includes information on whether a contract has been modified, and in which year such modification was carried out.

decline appears to have had slightly larger effects on mine prices than the rise in western coal, suggesting that mine prices are more sensitive to declining than booming coal markets.

Amongst the coal quality attributes, the number of BTUs alone appears to lead to be strongly positively correlated with mine prices, with the increase being between approximately $3.5 to $4 per ton for every unit increase in BTUs (which is in thousands). Surprisingly, sulfur shipped does not appear to strongly influence mine prices. Ash and moisture shipped also do not show a statistically significant effect on mine prices.

Comparing across Columns (1) to (5), we see that the effect of shifting over to fixed price contracts leads to a reduction in mine prices by a little more than $4 per ton. This is a very substantial effect, and while we should be cautious in drawing inferences from this result, the fact that the estimated coefficients change little across specifications indicates the presence of a significant shift. One might wonder given the large differences in prices, why fixed price contracts were not always used. As argued above, however, such contracts will typically fare poorly in the presence of relationship specific investment, leading to frequent and costly renegotiation as utilities and coal mine operators will need to frequently revise prices. To test this theory, I report in Column (6), results for the same model as in column (4), but with an indicator variable recording whether a contract underwent renegotiation (MOD) as the dependent variable. The aim of this is to discover whether shifting over to fixed price contracts results in greater renegotiation, as anticipated by transaction cost incomplete contract theory. We see a positive coefficient on FIXED, that is statistically significant, confirming that fixed price contracts are likely to lead to increased renegotiation.

One reason why the results with mine prices as the dependent variable are suspect is that these prices are reported for only a limited sample of the data. Delivered price information is available far more widely, and as argued above, it is difficult to distinguish between these two prices on a purely conceptual basis. In Table 11, I report the results considering the specifications in Columns (4) and (5) in Table 10, but with delivered prices as the dependent variable. We can see that the effect of FIXED is very similar, implying a $4 reduction in prices. The quantity contracted for has a strong positive effect on prices, in contrast with the results obtained for mine prices. Coal region sourcing appears to have statistically insignificant effects, while ACCIDENTS has a positive effect, in contrast once again with the results for mine prices. The positive effect of ACCIDENTS can be understood as reflecting the importance of transportation changes, given that delivered prices include transportation costs. We can see that distance shipped has the expected sign, but is statistically insignificant.

Reserves show similar results for delivered prices as with mine prices, with the response being greater for reserves of interior coal. Amongst the coal quality variables, BTUs has the expected positive coefficient which is also statistically significant. Sulfur shipped now shows a negative and statistically significant impact on prices, as expected. It is worth emphasizing both these effects are quite large, with a unit rise in BTUs shipped increasing delivered prices by nearly $5, while a unit rise in sulfur content reduces the same by approximately $1. To assess robustness, I also report results with the log of delivered prices in Columns (3) and (4). We can see that the results are quite similar[19].

Even with arguably better price information, we can see that the broad results with regard to the impact of fixed prices on actual transaction prices do not change much. There is some difference in the results when using the two types of price information, with the difference indicating that transportation changes are picked up by delivered prices. For this reason as well, arguably inferences made using delivered prices stand on more solid ground.

Of course, fixed price, escalator, cost-plus (or other) contracts are not exogenously assigned but are rather endogenously determined. Consequently, the OLS estimates might be biased as they do not control for the selection of the contract (Greene, 2003, pp 780). One way to deal with such a selection issue is to use the Heckman model.

3.4.1 Adjusting for selection effects: Estimates from the Heckman model

The Heckman model analyzes the effect of any "treatment" (here, this is the contract type) by breaking the process into two stages. In the first stage (the selection equation), the probability of choosing any particular contract is estimated. The second stage (the performance equation) then analyzes the impact of the choice, using the results of the first stage to adjust for contract selection. There exist two ways to estimate this model; either by maximum likelihood or by a two-step procedure (see Greene (2003), Chapter 22 for

[19] For these results, I use logged values of QUANTITY, COST, MODES, ACCIDENTS, RESERVES (and the interactions of RESERVES), BTU, SULFUR, ASH and MOISTURE shipped.

further details). I use the two-step procedure as the maximum likelihood method failed to converge[20].

Identification of the Heckman model requires at least some variables that explain selection but do not enter into the performance equation. I employ transaction characteristics to predict contract choice[21]. The characteristics I use are measurement difficulty, mine-mouth status of a plant, the presence of dedicated assets (DEDICATE) and the frequency of interaction between the buyer and seller (REPEAT). I also include WEST and INTERIOR, these variables enter into both equations therefore. Finally, I also exploit some of the exogenous changes induced by the 1990 Clean Air Act Amendment as well as the deregulation of the railroads following the Staggers Act of 1980.

As proxies for measurement difficulty, I use BTU_County, SULF_County, ASH_County, TONS_County and MOISTURE_County. I calculate these by first taking the absolute difference between the contracted for, and delivered characteristics of the coal for each observation. I then take the log of this value, and using the individual contract observations, calculate an average log value for each coal county[22]. As the difference between what is contracted for and what is delivered increases, the incentive to engage in costly search to examine the reasons for this difference also rises. I assume this cost to be large enough to cause a net social loss, were a full search to be undertaken. Buyers and sellers would instead prefer to write a contract that

[20]The two-step procedure first estimates, via probit, the Mills ratio. The second step estimates a regression of the dependent variable of interest on explanatory factors and the Mills ratio. The inclusion of the Mills ratio controls for selection, thus eliminating the bias in the OLS results, and allows a test for the presence of selection.

[21]I use FIXED as the dependent variable in the contract selection equation.

[22]It would be preferable to conduct such an exercise for each individual mine, but the information on mines is not very reliable.

could provide adequate support to the supplier to supply the contracted for amount. Such a contract would cover supplier costs, and would increase the probability of using escalator or cost-plus contracts. These are expected to positively influence the choice of escalator/cost plus contracts.The large cost associated with search also implies that such variables cannot enter into the price equation.

Mine-mouth plants are likely to integrated with their mines, and this implies a negative correlation for the coefficient of MINE-MOUTH (Tadelis 2002)[23]. As we move more westward, I expect a greater tendency to choose fixed price contracts since the supply of western coal rose remarkably over this time period and a very active spot market develops; additionally, as a result of the Clean Air Act Amendment, plants also learned how to burn western coal in combination with Appalachian coal thus reducing the relationship-specific character of their investments.

Dedicated assets are likely to raise the probability of escalator/cost-plus contracts, as the undertaking of such specialized investment requires contractual safeguards to account for any costly ex-post bargaining. Repeated interaction may either encourage greater sharing of knowledge regarding the costs of supply, thus raising the incentive to engage in escalator/cost-plus contracts or encourage fears of hold-up, reducing such an incentive. Given that both of these attributes imply a localization of the transaction, they are unlikely to affect prices, as it would be difficult to decide on the adequate compensation [24].

[23] I have also considered specifications in which the length and the mine-mouth status of the plant are included in the price equation, the results are little changed.

[24] See Joskow (1988) for the difficulties associated with defining a norm for market prices,

One may argue that repeated interaction could affect prices. If a buyer becomes knowledgable about the suppliers' production process, this could be used to fix prices. However, such knowledge would be captured in the specification of the pricing structure, which is captured in FIXED. I also include COST and a time trend variable (TIME) as a measure of inflation in the price equation, which controls for any other costs the supplier faces. Independent of FIXED, these two variables ought to capture the buyers' knowledge of the suppliers' production.

I have, in related work, argued that the Phase wise distinction imposed by the 1990 Clean Air Act Amendment led (in part) to the adoption of fixed price contracts (Kacker 2013), since it encouraged boiler alterations that increased the ability of plants to switch between coal suppliers. Particularly, plants placed under Phase I of the Amendment located in the midwest were most likely to respond. I therefore include indicator variables for phase status (PHASE1), location (MIDWEST) and their interaction. I expect the interaction term to be negatively correlated with the use of escalator/cost plus contracts.

Since these changes were carried out to reduce SO_2 emissions, I also interact these three variables with the SULF_County variable. I expect that measurement difficulty for sulfur would be lower for Phase I plants in the midwest, since their increased ability to handle alternate coals would mean that differences between specified and delivered coal matter less. This implies a negative correlation with escalator/cost plus contract use. I include MODES and ACCIDENTS as well, as additional proxies for railroad dereg-

in the face of specialized investment.

ulation. I expect an increase in both to lead to an increase in the choice of escalator or cost-plus contracts.

Table 12 shows the results with (1-FIXED) as the dependent variable. In column (1) I show the results that obtain when mine prices are the outcome variable in the second stage, and in column (2) I show results with delivered prices. BTU_County shows the expected positive coefficient, and is statistically significant. Moisture has the sign opposite to expectation, and is also statistically significant. Out of the rest of the coal characteristic measurement variables, sulfur has the expected sign, but is significant only when considering phase 1 plants in the midwest, and this too only with delivered prices as the second stage outcome variable.

In line with expectation, Phase 1 plants in the midwest are less likely to choose escalator/cost plus contracts, and this result is robust across the different prices. The transportation related variables MODES and ACCIDENTS do not appear to be strongly correlated with escalator/cost plus contracts. The region of coal sourcing appears important only when considering mine prices, as does whether a given plant is a mine-mouth plant or not. Dedicated assets and repeated interaction strongly influence the selection of contract, and this result is irrespective of which prices I consider.

In Table 13, I show the results of the second stage, performance equation. Columns (1) and (2) show results for mine prices, considering the selection of fixed price contracts and then the selection of escalator/cost plus contracts. Columns (3) and (4) shows the same for delivered prices. I have also included PHASE1 and MIDWEST (as well as their interaction), to allow for Busse and Keohane (2008) finding that plants near western coal and plants that were more heavily targeted by environmental regulation faced price discrimination by railroads. For their findings to carry through, both PHASE1 and MIDWEST, together with their interaction should show a positive coefficient with delivered prices (and, given the discussion above, these should carry over to mine prices as well)[25].

We can see, similar to the fixed effect results, quantity of coal procured is positively related to the prices, but for most of the specifications, this is not statistically significant. PHASE1 and MIDWEST have positive coefficients for mine prices and negative coefficients for delivered prices. These coefficients are also statistically signifcant. The interaction of the two is negatively correlated, and statistically significant for most of the specifications. These results offer mixed confirmation of the Busse-Keohane findings, and it is particularly interesting that the opposite effect shows when considering delivered prices.

In keeping with the OLS results, the coefficients on INTERIOR is not statistically significant, while WEST is, with the expected sign. The coefficients for WEST also show an interesting pattern conditional on selection: when fixed price contracts are selected, the relationship appears stronger, with the fall in prices being larger than when escalator/cost plus are selected. This indicates that escalator/cost plus contracts do not discriminate between coal from different regions, as much as fixed price contracts do.

The distance shipped appears to be strongly positively correlated, especially with delivered prices, in keeping with expectation. Across all specifi-

[25] Note that I cannot include these variables in the fixed effect models, since the plant level fixed effects will absorb them.

cations, we can see that both BTUs and sulfur shipped exert the expected effect, and the magnitude of the effect is also large. Delivered prices tend to adjust more than mine prices for these coal characteristics. We can also see that the implied effect is quite different for the different contract types, with the penalty for sulfur falling, and the payment for BTUs rising, as contracts move from fixed price to escalator/cost plus. These results are strikingly different from the OLS estimates.

Reserves show the expected sign, and the signs are similar to what was found with the OLS results. A major point of difference is that interior coal does not appear to exert a stronger influence, in fact, the pattern is reversed. Also, reserves only appear to matter for escalator/cost plus contracts. Labor costs are positively related to prices, but interestingly,, these appear to matter only for escalator/cost plus contracts. Given that one of the motivations behind these contracts was to control for supplier costs, this result indicates that such contracts' price adjustment clauses were meaningful. Inflation effects, summarized by the time trend TIME, tend to matter for both prices, with the coefficient being insignificant only for mine prices when fixed price contracts are chosen. Finally, we can see the importance of selection, indicated by LAMBDA, the coefficient of the Mills ratio. We can see that this coefficient is statistically significant for nearly all specifications, except for fixed price contracts when considering delivered prices.

In sum, accounting for selection leads to important effects. The behavior of the coefficients changes systematically, depending on which contract is selected. Importantly, labor costs tend to matter for escalator/cost plus contracts but not for fixed price contracts. Transportation costs appear far more important for delivered prices than for mine prices. Payment for coal characteristics also changes systematically across contract types. The selection effect also appears highly statistically significant, confirming the need to control for contract choice.

3.4.2 Counterfactual predictions for Prices

I use the models from Table 13 to estimate prices both at the mine and for coal delivered at the plant. Using prices estimated under distinct contract types will allow us to make meaningful comparisons across contracts. Table 14 contains these estimates. I report estimated mine and delivered prices under escalator/cost plus and fixed price contracts. These estimates are given for the full sample, and for only escalator or cost plus contracts and fixed price contracts.

According to the estimates, using fixed price contracts results in prices lowering by a little more than $3.5 per ton for mine prices, and by approximately $3.2 per ton for delivered prices. These increase slightly when looking only at escalator/cost plus contracts, and decrease slightly when looking only at fixed price contracts[26]. It is important to stress that when analyzing the escalator/cost plus contract sub-sample, the predicted price under fixed price contracts delivers us the counterfactual estimate.

We can see that, according to these estimates, if escalator or cost-plus contracts were organized as fixed price contracts, the utility would save approximately $4 per ton of coal shipped. On the other hand, fixed price

[26] We can also see that these prices are statistically significantly different from each other.

contracts organized as escalator or cost plus contracts would result in an increase in prices by roughly a little less than \$3 per ton. This asymmetry suggests that the loss (in terms of higher prices) associated with incomplete contracts is greater than for complete contracts, were they to be organized in an opposite manner.

These results are intriguing: why, if the price differences are so vast, were fixed price contracts not used sooner? As explained earlier in light of the OLS results, such contracts are poor at adaptation, and if the renegotiation required due to changing supply or demand conditions appears large, the costs of renegotiation may outstrip the benefits of lower prices. Before I discuss renegotiation, it may be instructive to analyze these predicted prices as they move across the 20 year period.

Figure 6 shows the prices predicted under the two contract types for the two types of prices, with 95% level confidence intervals. We can see that at the beginning (in 1979), predicted prices under both contract types are quite similar: in fact, delivered prices under fixed price contracts are large than under escalator/cost plus contracts. Fixed price contracts also vary far more than escalator/cost plus contracts, but by the final year under study the variance under both contract structures is roughly similar.

As mentioned earlier, the early 1980s was a time in which coal markets softened considerably, and Joskow (1990) argues that by around 1983 many modifications were put in place. We can see some evidence for this: prices under the two contract types start to diverge in a significant manner starting around 1980. This divergence reduces slightly by 1985, indicating the period between 1983 and 1985 was one of consolidation, but generally continues over time, with fixed price contracts always delivering cheaper prices.

I use the model estimated in Table 13 and Table 12 to predict the probability of modification. The results are shown in Figure 7. We can see that fixed price contracts start with a very high probability of modification, while the same probability associated with escalator/cost plus contracts is roughly half as much. We can also see that these probabilities both decline monotonically over time: this is consistent with the abandonment of relationship specific investment motivated by the 1990 Clean Air Act Amendment (together with the deregulation of the railroads)[27].

These results back up the claim made earlier by the linear probability model of renegotiation: although cheaper, fixed price contracts are relatively worse at adaptation. Therefore, when relationship specific investments were deep and vast, the cost of renegotiation arguably overtook the benefit of lower prices. However, when these investments declined in importance, the switch to fixed price contracts took place, as the need to renegotiate falls. This is most clearly seen by the fact that from 1979 to 1989, the probabilty of modification under fixed price contracts declines very little, but over the following ten year period, the probability falls by nearly 50%. The timing of this fall is exactly in line with the enactment of 1990 Clean Air Act Amendment.

Nevertheless, we may ask, did the market participants attempt to adjust their contracts in any significant manner to account for the widening differences in prices between the two contract types? If Joskow (1990) is correct, the escalator/cost plus contracts show great downward rigidity. One way therefore utilities could have adjusted to the diverging prices, in the face of

[27]Coefficients of this regression are given in the appendix.

downward rigidity, would be to negotiate substantially lower prices for new contracts, rather than renegotiate existing contracts. To analyze if this indeed took place, I select only newly signed contracts[28]. Figure 8 shows the results from running the models in Table 13 and Table 12 for these contracts.

We can see that, indeed, over the early 1980s newly negotiated escalator/cost plus contracts had far lower mine prices than their fixed price counterparts. However, we can also see that over time, this difference thins out, reflecting the lower need to write escalator/cost plus contracts. Delivered prices for the two contract types do not show much change from the earlier results.

The results that arise from controlling for selection suggest that while fixed price contracts generally deliver lower prices than escalator/cost plus contracts, this is not enough to call upon them. The importance of relationship specific investment makes the cost of renegotiation under fixed price contracts too high. Indeed, although prices diverge considerably across the two contract types, as long as escalator or cost-plus contracts are required (due to relationship specific investment), the evidence indicates that participants prefer to stick with the same contract type, but attempt to adjust for the changed prices by signing lowered prices for newly written contracts. Overall, this evidence is consistent with the theoretical tradeoff between renegotiation costs and efficient performance emphasized by Williamson (1985), Masten and Crocker (1991) and Bajari and Tadelis (2001).

[28]That is, the year of signing equals the year the contract is recorded as being in force.

3.4.3 Do suppliers gain from increased renegotiation?

Fixed price contracts, as we have seen, appear to reduce prices. Yet at the same time, they also lead to an increased probability of renegotiation. For instance, increased renegotiation could result from suppliers' demanding a change in contract terms, and such change could come at the expense of the buyer. It is unclear, therefore, what the overall weflare implications of the changed contract structure are. Understanding the drivers of renegotiation, and whether they vary by contract type, will help clarify the consequences of the contract change.

Breaking down contracts that were renegotiated, it is typically the case that a majority of contracts are renegotiated only once. There are, however, a substantial number renegotiated two or three times, but it is rare to see a larger number of renegotiations. Panel A of Table 15 shows the number of times a given contract-plant pair is renegotiated, by contract type. Of all fixed price contracts that are renegotiated, only about 3% are renegotiated more than twice. Similarly, for escalator contracts, only about 6% are renegotiated more than three times.

Although this may suggest that fixed price contracts are less likely to be renegotiated more frequently, it would be important to formally test this proposition, because such a result appears to be inconsistent with the previous result that fixed price contracts are more likely to be renegotiated. To do so, I define an indicator variable - MULTIPLE - that turns equal to one if the contract is recorded as being renegotiated more than once, and zero otherwise. Using this as the outcome variable, Panel B of Table 15 reports the associated regression results. Since the outcome is a binary variable, either a linear probability model, probit or logit model is appropriate.

Although a linear probability model has the problem that it can predict outcomes outside of the (0,1) bound, it is also the only model that can handle multiple levels of unobserved heterogeneity through the use of multiple levels of fixed effects. Given that the focus is on how fixed price contracts affect the tendency to engage in multiple renegotiations, and not on predicting their probability, it is arguably the more appropriate model. In addition, given the panel nature of the data, a linear probability model allows for clustered standard errors, improving inference.

Under a fixed price contract, the probability of undergoing multiple renegotiations turns out to be higher than under an escalator contract. As we can see by comparing columns (1) and (2) in Panel B of Table 15, controlling for length results in a slight increase of the probability of multiple renegotiations. In neither case, however, is the effect strong enough to be statistically significant. Of course, these results cannot be interpreted as causal, but nevertheless even as correlations they do not suggest fixed price contracts undergo a lower number of negotiations.

Renegotiations may involve changes in price or quantities or qualities of the coal shipped, all of these or some of these. Interpreting these changes involves some subtlety. Williamson (1985, p75 - 77) argues that when a condition of bilateral dependency prevails, and contracting parties renegotiate contract terms, they will seek out changes of a particular character. In particular, they will forego price changes for quantity changes.

Price changes, by definition, will hurt one of the two parties: an increase leaves the buyer worse off, while a decrease leaves the supplier worse off. Therefore, only those price changes which relate very transparently to exogenous conditions will be chosen. Typically, proving such a relation will be difficult for very idiosynctraic causes. Such causes are especially likely in a situation where parties have made specific investments. Contracting parties will therefore avoid price changes. Instead, Williamson argues for the use of quantity alterations. Decisions to increase or decrease quantities do not necessarily harm any party, and may work to the benefit of both.

If the renegotiations here trigger changes along these dimensions - that is, they involve quantity, not price, changes - then we may conclude the renegotiations taking place are not the result of opportunistic interventions but necessay responses to exogenous events. In such a case, it is difficult to imagine the renegotiations being detrimental to welfare. If we observe substantially large price changes following from renegotiations, however, it is possible that they are used for individual benefit at the cost of overall welfare.

In addition, since the type of contract changes, it is plausible that quantity alterations would be materially different under the different contract structures. I expect renegotiations under escalator contracts to have more powerful effects since it is under such contracts that the condition of bilateral dependency is strong. Under fixed price contracts, by contrast, neither parties have sufficiently large investments specific to each other. Consequently, faced with a renegotiation decision, the amount of change is likely to be lower. Such a result is more likely if renegotiations do not have opportunistic motives.

Beyond considering simply what effects should be seen, it is also possible to interpret their direction. As I have argued, utilities had signed on long term contracts expecting a rise in demand which did not materialize. I have also shown that over the time period when this lack of demand manifested itself, utilities were signing newer contracts that involved much lower prices than existing ones. If renegotiations were indeed not opportunistic but responses to exogenous events, I expect quantity reductions to occur more frequently, as a response to slack demand. Further, I expect such reductions to be carried out under escalator contracts, because it was when these contracts were the majority choice, for reasons argued above, that slack demand materialized.

In Table 16, I show results of regressions with prices (columns (1) and (2)) and quantities (columns (3) and (4)) as outcome variables. MODIFY, the indicator variable corresponding to whether a contract was renegotiated or not, equals 1 if the contract is renegotiated and 0 otherwise. Controlling for contract type, necessary given the earlier result that fixed price contracts are associated with significant price declines, we see that modification has no statistically significant effect on delivered prices[29]. Further, the interaction of MODIFY with FIXED also yields no statistically significant effect, although the coefficient rises by a factor of four. Although statistically insignificant, the effect of modification appears to be to reduce prices, which would only favor the buyer.

Quantities, however, are strongly affected by renegotiation. Using tons

[29] I use delivered prices because there are too few observations for mine prices when considering modified contracts.

of coal actually shipped, modification exerts a statistically significant effect reduction of around 67,500 tons. Examined with respect to the median, this corresponds to a 34% reduction in tons of coal shipped. For fixed price contracts, there does not appear to be a statistically significant effect, and the coefficient is less than one-tenth of that for escalator contracts. In terms of statistical significance, direction and quantitative impact, these results suggest very strongly that renegotiations under escalator contracts were not opportunistic, but instead were responses to exogenous events.

To further understand the characteristics of these renegotiations, I consider the probability of contracting with a repeat supplier, using REPEAT as the outcome variable in columns (5) and (6) in Table 16. As we can see, renegotiations under escalator contracts are significantly less likely to take place with a supplier with whom the utility has contracted previously, the probability falling by 7%. Under fixed price contracts, however, it is unclear whether renegotiations are more or less likely to involve a supplier the utility has previously dealt with. As before, fixed price contracts are less likely to be signed with a repeat supplier. Importantly, the reduction in statistical significance for renegotiations under fixed price contracts appears to come from an increase in the error.

Renegotiations will in most cases tend to put the contracting relationship under some strain. Being less likely to take place if parties have dealt with each other before indicates contracting parties value continuity in their relationship. Specifically, this mechanism comes into play when transaction specific investments are made, since theory predicts the use of escalator contracts here[30].

It is not surprising, therefore, that renegotiations that take place under escalator contracts do not appear to be opportunistic. Under these contracts, there is high value attached to continuing the relationship due to the specific investments made, and opportunistic actions (by buyer or supplier) would threaten the relationship, and indirectly the investments. For fixed price contracts, on the other hand, relationship continuity is less important, so it appears it is equally likely to renegotiate with a previous supplier as with a new one. Nevertheless, even here, as we have seen, renegotiations do not appear to follow opportunistic intent.

There also exists the possibility that suppliers and buyers were engaging in non-price/quantity adjustments. For instance, suppliers could send over more ash-laden coal, or coal that contains more sulfur. These could represent substantial gains to the supplier, if it corresponds to a reduction in supplier effort. Accordingly, in Table 17, I examine BTUs, Sulfur, Ash and Moisture shipped. As we can see, none of these characteristics are statistically significantly affected by renegotiation under either contract type. The coefficient estimates also suggest very small changes. There does not, therefore, seem to be evidence to suggest that non price or quantity characteristics were altered during renegotiations.

Overall, the pattern of results here are consistent with the notion that renegotiations were non-opportunistic under both escalator and fixed price

[30] It is also consistent with previous history working as a way to improve communication and/or knowledge about their side of the transaction. Even with this interpretation, though, such communication/knowledge would be with regard to what possible breakdowns could arise in the future. Such behavior is consistent with valuing relationship continuity.

contracts. Additionally, renegotiations under escalator contracts appear to be reactions to exogenous events and contracting parties value continuity in their relationship when operating under such contracts. Renegotiations under fixed price contracts involve far smaller changes. Despite the increased frequency of renegotiations under fixed price contracts, these renegotiations do not seem to trigger significant changes that would imply substantial welfare losses.

3.4.4 Accounting for length: Instrumental Variable estimates

At least two criticisms may be made of the analysis in the Heckman model above. One is that the duration, or length, of the contract is not controlled for. Although escalator or cost-plus contracts tend to be of longer duration than fixed price contracts, so that some of the effect of contract duration is probably picked up by FIXED, it may be preferable to explicitly control for length.

Second, the trade-off considered within the Heckman model was between cost-plus or escalator contracts and fixed price contracts. While these contracts account for the majority of all contracts in use, there is still a substantial number recorded as other contract types - price renegotiation, price tied to market, as well as mixtures between these and escalator contracts. These additional contracts make up roughly 18% of the total sample. Omitting these from the analysis may perhaps be restricting the sample so as to exaggerate the impact of fixed price contracts.

As a counter to these two criticisms, I estimate instrumental variable models of mine and delivered prices, with both price structure and length as endogenous variables[31]. I measure price structure using the variable CONTRACT, which takes on a value of 1 for a fixed price contract and zero for an escalator, cost-plus, price renegotiation or price tied to market contract.

I report instrumental variable (IV) estimates in Table 18. In the first two columns I show OLS estimates, with the same specification as in the previous OLS estimates [32]. In the second column I add in contractual length as an explanatory variable. In columns (3) to (5), I report IV estimates with plant fixed effects. Since I cluster standard errors by plant, I use GMM estimation, as this is more efficient than two stage least squares, when errors are not independent and identically distributed.

The instruments I use are DEDICATE and its square, to allow for non-linear effects on length (Joskow 1985). I also use another definition of dedicated assets, PLANT DEDICATE, calculated as the ratio of the total quantity within a contract to the total quantity across all contracts for any given plant in any given year. The repeated interaction term (REPEAT) and the sulfur measurement difficulty term are the final two instruments. Following Joskow (1985), I expect DEDICATE to show a U-shape curved for CONTRACT and an inverse U-shape for LENGTH. PLANT DEDICATE assets should increase the length of the contract, and therefore have a negative coefficient for CONTRACT. Repeated interaction could show either sign,

[31] I used the STATA command `xtivreg2` to estimate these instrumental variable models (Schaffer 2010).

[32] Note that since I include plant fixed effects, for both OLS and instrumental variable estimates, I cannot include the phase distinction and location variables I used in the Heckman model.

but the sign for LENGTH should be opposite to that of CONTRACT, for consistency. Sulfur measurement difficulty should be associated negatively with CONTRACT, and positively with LENGTH. I do not have any expectations with respect to quantity, this last should be properly understood as a robustness check.

The results indicate not only that fixed price contracts have important price reducing effects, but also that OLS models underestimate these effects. In addition, the inclusion of contract length leads to large changes in the estimated impact of fixed price contracts: indirect proof that the Heckman model is not perhaps appropriate. The instrumental variable models show that price reduces by about $7.5 due to the switch in contract. Controlling additionally for quantity leads to very small changes in the estimated effect for contract type, but the effect of length does increase.

We also see the coefficient of contractual length is positive and statistically significant. Longer term contracts are likely to be governed by less complete contracts, so the positive sign is consistent with the negative coefficient of CONTRACT[33]. Note also the trade-off between length and pricing structure: contracts would have to increase by a little more than 10 years in length to have an equivalent effect of switching toward fixed price contracts.[34]

Other variables show, in general, similar behavior as has been estimated under the previous models, except that distance shipped is no longer statistically significant even for the delivered prices. The coefficients on BTUs

[33]Interestingly, the coefficient on quantity contracted for turns negative in the IV estimates, when included as an additional exogenous variable. I do not report these results, but they are available on request.

[34]Joskow (1987) estimated that the impact of asset specificity raised contract length by the same number of years.

and sulfur shipped are quite similar to what was found earlier, with sulfur shipped having significant effects on delivered prices but not for mine prices. Reserves show a slightly different pattern, one that corresponds more to the OLS results, with interior reserves exerting a powerful reduction in both mine and delivered prices. Costs are not statistically significant in the instrumental variables specification.

As the number of instruments exceeds the number of endogenous variables, overidentification tests can be carried out.[35] In the present case, since the errors are clustered by plant, I report the Hansen J-statistic. Failure to reject the null hypothesis confirms that the set of instruments is not correlated with the error term in the second stage regressions. I also report the results of the underidentification test, once again adjusted for clustered errors, which rejects the null hypothesis, and indicates that the matrix formed by the reduced form coefficients on the excluded instruments is of full rank and the model is therefore identified.

Given the clustering of errors, it is not possible to check for weak instruments by comparing first stage F-statistics with the Stock and Yogo critical values; nevertheless, I report the relevant Kleibergen-Paap F-statistic. This F-statistic is calculated accounting for the clustering of error terms, and indicates the instruments are much stronger for delivered prices than for mine prices. In fact, the Kleibergen-Paap F-statistic for delivered prices is quite high, though of course, it is not possible to know whether these are high

[35] First stage results are reported in Table 19. The results indicate agreement with expected direction of nearly all the instruments, the only exception being SULF County, that shows a negative correlation with LENGTH.

enough[36]. I also report results of the Anderson-Rubin and Stock-Wright tests, both of which reject their null hypothesis, indicating the instruments are quite strong.

Using instrumental variables, I have thus been able to document that the earlier result of reduced prices from shifting to more complete contractual structures stands up to better measurement of the contracts used, as well as the effect of contractual length. These estimates imply that, on average, shifting to more complete contracts reduces prices by approximately $2 per ton.

To sum up all the results so far, I present estimates from the three models - the OLS, Heckman and IV - in Table 20. The estimates shown are for delivered prices, and are in dollars per ton. To gauge the impact of the change, I present crude calculations for the average shipment, and the total savings implied by the saving per shipment. The savings amount, roughly, to between 7% to 20% of the total delivered price. It is evident that the savings delivered by the change over to fixed price contracts and, more generally, in the direction of increased completeness made possible by the 1990 Clean Air Act Amendment and railroad reform, are quite large, between $20 billion to $54 billion. Considering that these results are for a market where the supply side is quite competitive, and the transaction is fairly simple[37], we may interpret these savings as lower bounds on the economizing potential of contracts (and governance structures) in general.

[36]Critical values for this statistic are not known at the moment.

[37]Compared to large construction projects or aircraft manufacturing.

3.4.5 What's in it for the mines?

A puzzle that remains is why mines would accept lower prices under the fixed price agreement. As pointed out above, they do not appear to engage in increased opportunistic behavior following the adoption of fixed price contracts. One possible answer is the systematically different performance, noted in Figure 8, of newly signed contracts. [38]

Recalling the discussion in Joskow (1988, 1990), when faced with a demand slowdown, these escalator contracts were found by Joskow to be significantly rigid downward in terms of prices. It appears that such downward rigidity problems worsened considerably over the 1990s. Combined with the reduction in the importance of specific investment noted in Kacker (2014), the inefficiency of escalator contracts in tracking actual prices could be one factor as to why even the mines would prefer to switch contracts.

Using the results from the Heckman model estimated previously, in Figure 9 I show the mean and 95% confidence intervals of predicted delivered prices for escalator contracts, distinguishing between new contracts only and the full sample. We see that in the period 1979 - 1987, there is some jockeying around of the two sets of prices, but they do not appear to be statistically significantly different, except in one year. In the period from 1990 onward, however, there is a marked discrepancy in these two series: new contracts consistently are signed for a lower average price than that existing for the full sample. The difference in statistically significant for five years, and the trend is clearly towards a lengthening difference. A similar pattern does not

[38]New contracts are defined as being those for which year equals year of signing. Obviously this restricts the sample to contracts signed no earlier than 1979.

hold for fixed price contracts (Figure 10): here newly signed and full sample contracts show similar patterns throughout.

Increasing differences between newly signed and full sample escalator contracts suggest escalator contracts were doing an increasingly poorer job of tracking prices. Otherwise, the two series should be alike: if escalator contracts were following relevant criteria for deciding prices well, newly signed contracts (which should account automatically for these criteria) should not indicate a divergent trend. But we see clearly that predicted prices for the full sample does not fall as fast as it does for the new contracts and indeed is flat from 1995 onward. As the full sample also includes newly signed contracts, this trend is probably an understatement.[39]

To further test for this pattern, I define an indicator variable NEW, which equals one if the contract has just been signed (that is, the year signed equals the year the contract is observed in). To aid interpretation of the behavior of escalator contracts, I defined INV FIXED which equals $(1 - FIXED)$, and INV CONTRACT which equals $(1 - CONTRACT)$. I consider the impact of these variables and their interaction in Table 21. If the pattern identified by the Heckman model estimates is correct, the interaction of NEW with INV CONTRACT or INV FIXED should be negative.

I use three sets of fixed effects - for year, plant and coal county - in Table 21 along with the control variables used in earlier regressions: these

[39] One may wonder why the tendency toward rigidity did not correct itself, but answering that will take us too far from the present focus of the paper. It is possible that the same reason highlighted by Joskow, that there was over-supply and these escalator contracts lacked any provision to adjust for less than anticipated demand, is at work here but at a larger scale. The 1990s were a time when Western coal expanded rapidly and could have eased up the supply situation considerably.

serve to isolate any unobserved variation along the three dimensions. Note that such controls are needed especially for estimating coefficients for escalator contracts, since as we saw earlier, such contracts have an important relational element to them. I wish to purge as far as possible the effect of common factors that could be affecting market participants, as this allows identification of transaction specific factors. That is, although there may be market wide factors affecting all participants, these effects must be different for different transactions.

In the first two columns of Table 21, I show earlier results for FIXED and CONTRACT. In columns (3) and (4), I replicate these for INV FIXED and INV CONTRACT. We see that only the sign changes, with everything else remaining the same, as should be the case. Columns (5) and (6) show that newer escalator contracts were indeed more likely to be signed with a lower price, with the effect being highly statistically significant.[40] This is very strong evidence that escalator contracts were doing a much worse job at tracking prices. I have also estimated the same regressions truncating the data at 1985, and find the results become statistically insignificant, with the coefficient on the interaction between NEW and INV CONTRACT falling to -0.20, a reduction of 88%. INV FIXED follows a similar pattern. These results supports the interpretation that escalator contracts became increasingly worse at tracking prices. [41]

Combined with the fact that escalator contracts were less likely to be

[40]Length may be an important countervailing factor, however these results are very robust to the inclusion of length. I do not report these to save on space, but they are available on request.

[41]I do not report these to save on space, but they are available on request.

chosen as a result of declining investment specificity, their poor tracking of prices arguably encouraged the adoption of fixed price contracts. The inefficiency caused by poor price tracking, which may have been tolerated under a regime on large investment specificity, is obviously no longer acceptable to the utilities, aside from the other reasons argued above as to why utilities might prefer fixed price contracts. Although mines do not lose by inefficient tracking, since they are being paid more, but the fact that newer contracts were being signed with significantly lower prices suggests strongly that utilities wanted to reduce prices while not risking the transactional relationship. Such a demand no doubt increases negotiation costs, and it is plausible that mines wished to avoid these added costs.

3.5 Conclusion

I have attempted to calculate the differential performance of contractual arrangements between US electric utilities and coal mines for a twenty year period from 1979 to 2000. The actual pattern of contract choices made reflect an intelligent trade-off between the costs of renegotiation that are handled better by the escalator contract and the benefits of high-power incentives, reflected in lower prices that are provided under a fixed price contract. The shift over to fixed price contracts appear to have followed a reduction in the relationship specificity of investment, and resulted in prices lowered by between 5% to 11%. And although such contracts are subject to renegotiation, I am unable to find strong evidence that such renegotiation can be interpreted as favoring either the buyer or supplier.

Escalator contracts are argued to be better at adapting to changes in cost of supply than demand side changes, unless the changes were sudden and unexpected, when they might fare poorly even with supply side changes (Joskow 1988, 1990). Therefore, when coal markets softened unexpectedly in the early 1980s in the US, prices in existing contracts were too high. Joskow found these contracts to be extremely rigid downward. As evidence complementary to such rigidity, I have found that during the same period, newly implemented escalator contracts had prices lower than both existing escalator contracts as well as the counterfactual estimated prices under fixed price contracts. Despite such rigidity, renegotiations under these contracts typically involve large and significant (both statistically and economically) significant changes in quantities but not prices, indicating that both parties place a high value on their relationship when specific investments are at stake and seek to avoid any stress that is more than necessary.

Although I have found that more complete contracts result in lower prices, due primarily to the high-powered incentives present in such contracts, it also true that more incomplete contracts show a degree of flexibility that makes them useful in situations where unanticipated events can cause major changes. Which contract to use depends on the particular nature of the transaction buyers and sellers find themselves in. A striking and robust result in this paper is that different contracts align with systematically different performance attributes. Performance implications provide a deeper test of the predictions of transaction cost incomplete contract theory, and the theory passes these tests in the present study.

Figures

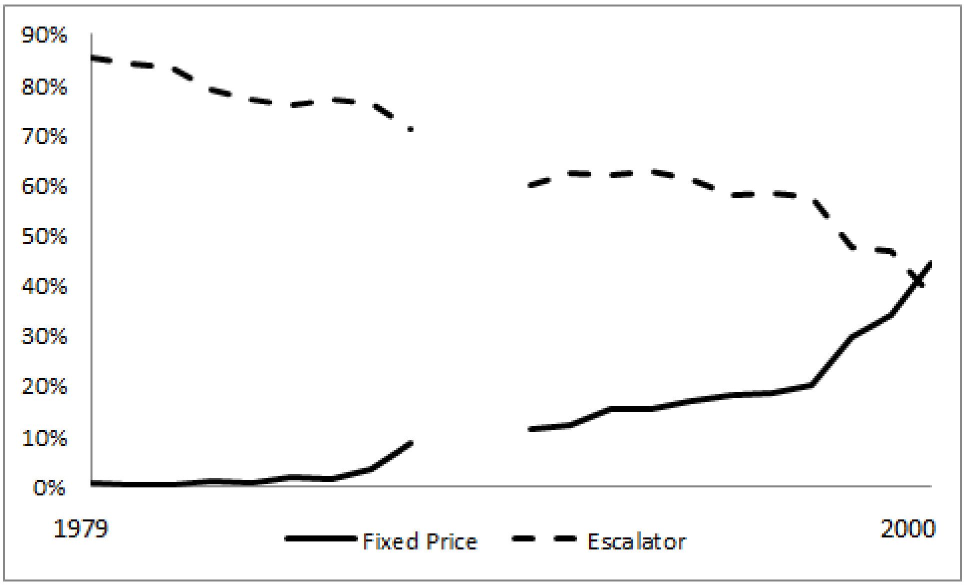

Figure 5: Rising use of fixed price contracts (Source: Coal Transportation Rate Database, Author's Calculation)

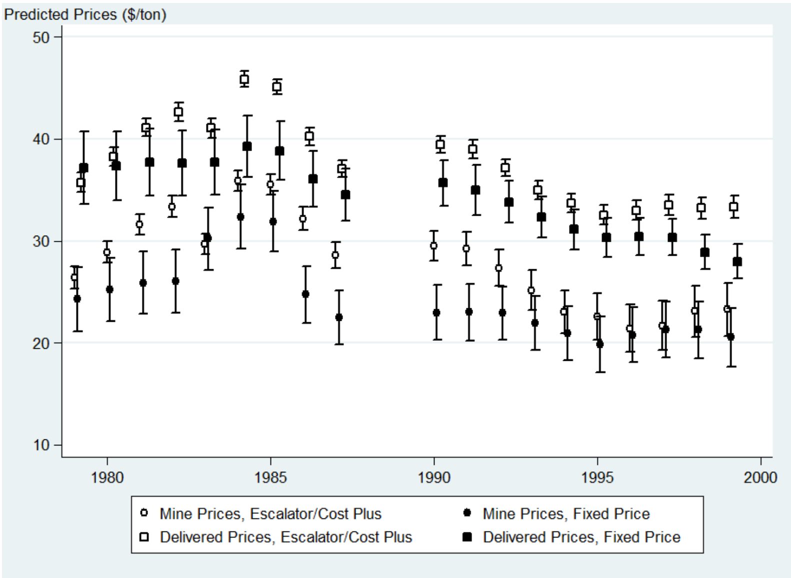

Figure 6: Predicted Prices ($/ton) from the Heckman Model

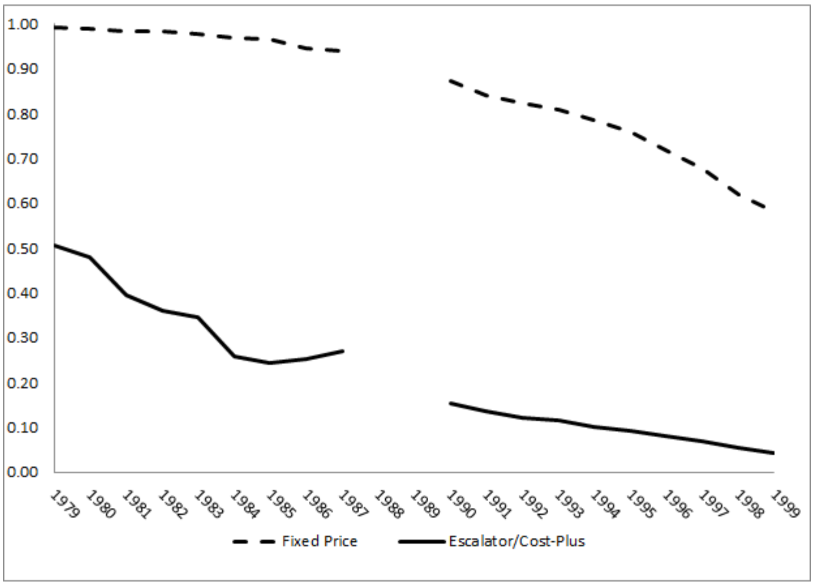

Figure 7: Predicted Renegotiation Probability from the Heckman Probit model

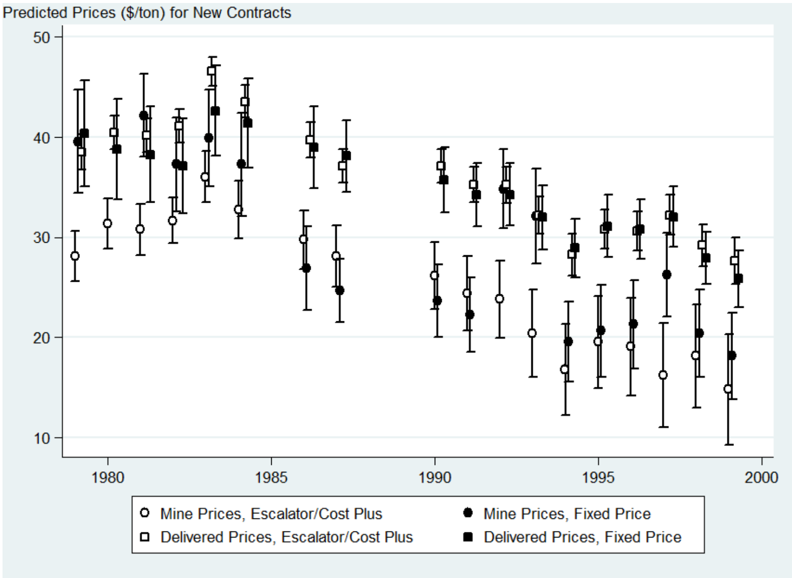

Figure 8: Predicted Prices ($/ton) for New Contracts

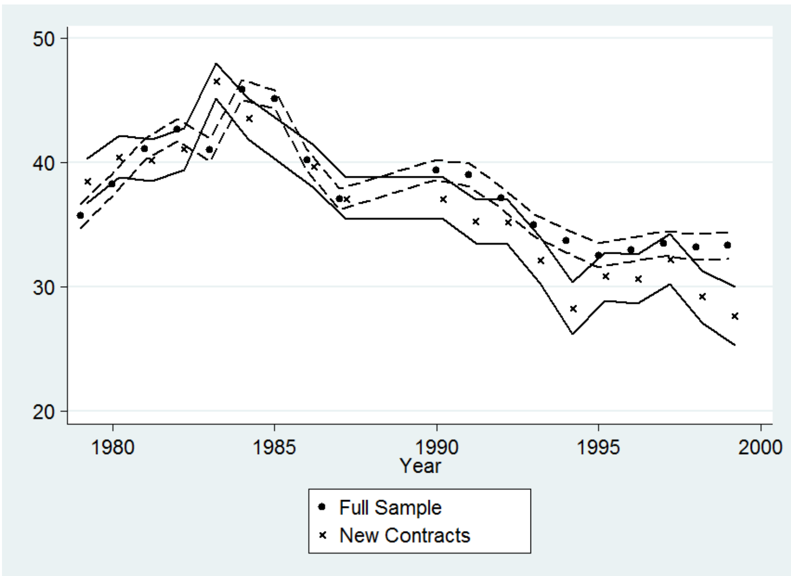

Figure 9: Comparing New Contracts to Full Sample: Escalator Contracts

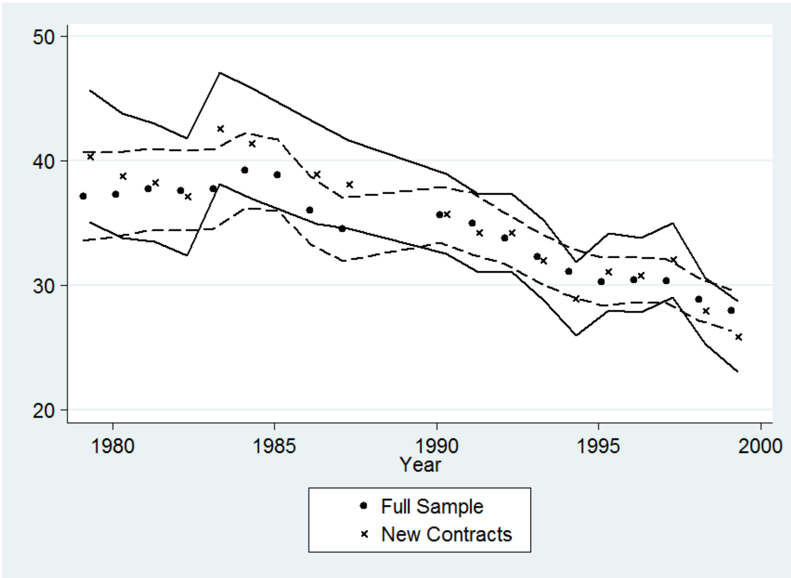

Figure 10: Comparing New Contracts to Full Sample: Fixed Price Contracts

Tables

Table 6: Use of Fixed Price Contracts over Years

Year	Fixed Price Contracts	Total Contracts	Percentage Fixed Price Contracts
1980	3	685	0.44%
1985	11	582	1.89%
1990	92	605	15.21%
1995	156	675	23.11%
2000	189	355	53.24%

Notes: Total contracts includes fixed price contracts, cost plus and escalator contracts.

Table 7: Price Variation by Contract Type

Panel A: Price variation by contract type

Contract Type	FOB Price Paid at Mine	FOB Price Paid at Plant	FOB Price Paid at Plant where Mine price not missing
Cost Plus/Escalator	29.65	37.73	39.36
Observations	4614	10312	4607
Fixed Price	23.38	28.77	33.18
Observations	302	1684	302
t-statistic for difference in means	13.971	30.153	

Panel B: Size of Differences

As a proportion of price under			
Cost Plus/Escalator contract	21.14%	23.75%	15.70%
Fixed Price contract	26.81%	31.14%	18.63%
Average of Cost Plus/Escalator and Fixed Price	23.64%	26.95%	17.04%

Note: "Cost plus/Escalator" contracts include both explicit cost-plus contracts and escalator contracts. Please refer to the text for an explanation for such a characterization. The test for difference in means was carried out under the assumption of unequal variances. All prices are in dollars per ton of coal.

Table 8: Summary Statistics

Variable	Observations	Mean	Standard Deviation	Min	Max	Source	Description
Mine Price	6066	29.17	9.65	2.83	194.18	CTRDB	Price Paid at the Coal Mine, Free on Board, $/ton
Delivered Price	14587	36.59	12.42	0.31	306.82	CTRDB	Price Paid at the Plant, Free on Board, $/ton
FIXED	12159	0.14	0.35	0	1	CTRDB	Dummy variable, equals 1 if contract if fixed-price, 0 if contract is cost-plus
PHASE1	14616	0.304	0.46	0	1	EPA	Dummy variable, equals 1 if the contract involves a plant that is targeted under Phase 1 of the Clean Air Act Amendment
MIDWEST	14777	0.420	0.493	0	1	CTRDB	Dummy variable, equals 1 if the contract involves a plant located in the midwest region
QUANTITY	13489	10.11	16.773	0.001	616	CTRDB	Total BTUs delivered by the contract, obtained by multiplying tons shipped with BTU content of coal shipped
DISTANCE	14260	4.65	5.435	0	120.40	CTRDB	Total distance involved in shipping coal, in hundreds of miles
COST	14271	100.56	23.60	56	141	BLS	Employment cost index from Table 7, Bulletin 2532, Bureau of Labor Statistics, September 2000
TIME	14785	10.378	6.47	0	21	CTRDB	Time trend, with 1979 as the starting year
BTU_COUNTY	14474	5.47	1.27	-0.405	11.368	CTRDB	Logs of absolute difference between ex-ante limits and delivered BTUs, averaged for coal counties by year
SULF_COUNTY	12823	-1.194	1.27	-17.328	1.923	CTRDB	Logs of absolute difference between ex-ante limits and delivered sulfur content, averaged for coal counties by year
ASH_COUNTY	12665	0.812	1.161	-6.397	3.192	CTRDB	Logs of absolute difference between ex-ante limits and delivered ash content, averaged for coal counties by year

Summary statistics, Table 34 continued

Variable	Observ ations	Mean	Standard Deviation	Min	Max	Source	Description
TONS_COUNTY	14447	12.34	1.39	0.405	17.328	CTRDB	Logs of absolute difference between ex-ante limits and delivered tons averaged for coal counties by year
MOIST_COUNTY	12388	0.80	1.29	-6.551	3.664	CTRDB	Logs of absolute difference between ex-ante limits and delivered moisture content, averaged for coal counties by year
MODES	14777	1.39	0.66	0	4	CTRDB	Number of distinct modes used for transporting coal
ACCIDENTS	14223	0.007	0.03	9.34E-07	0.381	FRA	Accidents per track mile, for state where mine is located
MINE MOUTH	14777	0.01	0.12	0	1	CTRDB	Dummy variable, equals 1 if plant is a mine-mouth plant, zero otherwise
WEST	14777	0.20	0.40	0	1	CTRDB	Dummy variable, equals 1 if coal is western coal, zero otherwise
INTERIOR	14777	0.13	0.33	0	1	CTRDB	Dummy variable, equals 1 if coal is from the interior, zero otherwise
EAST	14777	0.66	0.47	0	1	CTRDB	Dummy variable, equals 1 if coal is from the Appalachian region, zero otherwise
MIDWEST	14777	0.42	0.493	0	1	CTRDB	Dummy variable, equals 1 if plant is in the midwest, zero otherwise
REPEAT	14777	0.848	0.358	0	1	CTRDB	Indicator variable for whether the plant and the supplier contracted with each other in the past

Summary statistics, Table 34 continued

Variable	Observ ations	Mean	Standard Deviation	Min	Max	Source	Description
DEDICATE	13490	0.646	0.537	1.50e-05	42.083	CTRDB	Ratio of quantity within the specific plant-supplier contract to quantity for all contracts the supplier holds
PLANT DEDICATE	14083	0.690	0.850	0	13.4	CTRDB	Ratio of quantity within the specific plant-supplier contract to quantity for all contracts the plant holds
RESERVES	14372	2.067	1.862	0.001	7.22	EIA	Total reserves, in billion short tons, for each coal producing state, by year
BTUS SHIPPED	14753	11657.85	1657.176	373	96000	CTRDB	Total BTUs shipped, by contract
SULFUR SHIPPED	14754	1.377	1.222	0.09	87	CTRDB	Total Shipped Sulfur, per contract
ASH SHIPPED	14754	9.601	3.121	1.05	74.4	CTRDB	Shipped ash content, per contract
MOISTURE SHIPPED	12868	10.829	7.842	2.11	42.64	CTRDB	Shipped moisture, per contract
MOD	6128	0.265	0.441	0	1	CTRDB	Indicator variable that equals 1 if contract is modified in existing, or later, years and equals 0 otherwise.

Table 9: Performance Implications: Fixed Effects OLS estimates

Dependent Variable: Mine Prices ($/ton)						
	(1)	(2)	(3)	(4)	(5)	(6)
FIXED	-6.262***	-6.262***	-3.548***	-2.649***	-2.526***	-2.953***
	(0.580)	(0.993)	(0.571)	(0.680)	(0.712)	(0.657)
QUANTITY					-0.000471	0.00623
					(0.0110)	(0.00905)
WEST						-14.40***
						(2.075)
INTERIOR						-4.460***
						(1.583)
Constant	29.65***	29.65***	29.48***	24.63***	24.86***	27.75***
	(0.144)	(0.513)	(0.0350)	(0.328)	(0.316)	(0.618)
Plant FE	N	N	Y	Y	Y	Y
Year FE	N	N	N	Y	Y	Y
Coal County FE	N	N	N	N	N	N
Clustered standard error	N	Y	Y	Y	Y	Y
Observations	4,916	4,916	4,916	4,916	4,393	4,393
R-squared	0.023	0.023	0.013	0.180	0.183	0.275
Number of plantcode			298	298	285	285

Standard errors in parentheses. Where indicated, these errors are clustered by plant. *** p<0.01, ** p<0.05, * p<0.10.

Table 10: Performance Implications: Fixed Effect, OLS estimates

Dependent Variable	Mine Prices ($/ton)					*Probability (Modification)*
	(1)	(2)	(3)	(4)	(5)	(6)
FIXED	-3.196***	-3.305***	-3.153***	-4.233***	-4.520***	0.194***
	(0.670)	(0.687)	(0.621)	(0.572)	(0.602)	(0.0354)
QUANTITY	0.00541	0.00182	0.00535	0.0145*	0.0158**	-0.00322***
	(0.00915)	(0.0102)	(0.00942)	(0.00766)	(0.00621)	(0.001000)
WEST	-14.60***	-16.53***	-12.15***	-7.258***		0.00667
	(2.063)	(1.925)	(2.547)	(2.685)		(0.128)
INTERIOR	-4.771***	-4.358***	-2.020	2.165		-0.160*
	(1.561)	(1.602)	(1.857)	(1.696)		(0.0903)
COST	0.0595	0.140	0.108	0.0281	0.106	-0.0218*
	(0.132)	(0.147)	(0.138)	(0.145)	(0.181)	(0.0115)
MODES		0.187	0.0275	-0.418	-0.0847	0.00418
		(0.270)	(0.258)	(0.314)	(0.271)	(0.0208)
ACCIDENTS		-11.36*	-7.551	0.907	-22.13***	1.769***
		(5.929)	(5.304)	(12.12)	(6.824)	(0.386)
TOTALDISTANCE		0.313*	0.249	0.0790	0.0807	0.00177
		(0.188)	(0.181)	(0.151)	(0.158)	(0.00571)
RESERVES			0.871***	0.659***	0.810**	-0.0494***
			(0.257)	(0.201)	(0.365)	(0.0150)
WEST*RESERVES			-1.974***	-0.699	-4.301***	0.0405**
			(0.573)	(0.494)	(1.480)	(0.0175)
INTERIOR*RESERVES			-1.771**	-2.832***	-4.581***	0.180**
			(0.821)	(0.725)	(0.788)	(0.0843)

Table 10 continued

Dependent Variable	Mine Prices ($/ton)					*Probability (Modification)*
	(1)	(2)	(3)	(4)	(5)	(6)
BTU SHIPPED				4.068***	3.667***	-0.00913
				(0.472)	(0.480)	(0.0209)
SULFUR SHIPPED				-0.611*	0.308	0.0150
				(0.362)	(0.258)	(0.0205)
ASH SHIPPED				0.145	-0.000764	0.000589
				(0.127)	(0.115)	(0.00640)
MOISTURE SHIPPED				0.0688	0.457***	0.000546
				(0.105)	(0.133)	(0.00577)
Constant	24.33***	18.60**	19.01**	-24.75**	-22.71**	1.885**
	(7.848)	(8.675)	(8.284)	(10.52)	(9.956)	(0.795)
Plant FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Coal County FE	N	N	N	N	Y	N
Clustered standard error	Y	Y	Y	Y	Y	Y
Observations	4,369	3,962	3,693	3,041	3,041	3,349
R-squared	0.279	0.280	0.313	0.404	0.574	0.049
Number of plantcode	285	269	266	259	259	274

Standard errors in parentheses, clustered by plant. *** p<0.01, ** p<0.05, * p<0.10.

Table 11: Performance Implications: Delivered Prices, and Mine Prices in logs (OLS, Fixed Effect Estimates)

Dependent Variable	Delivered Prices ($/ton)		Log (Delivered Prices)	
	(1)	(2)	(3)[a]	(4)[a]
FIXED	-4.056***	-3.832***	-0.129***	-0.121***
	(0.416)	(0.409)	(0.0155)	(0.0167)
QUANTITY	0.0471***	0.0454***	0.00150***	0.00143***
	(0.0144)	(0.0140)	(0.000438)	(0.000430)
WEST	-1.156		-0.0697	
	(1.874)		(0.0456)	
INTERIOR	0.830		-0.0162	
	(1.195)		(0.0275)	
COST	0.204**	0.107	0.00152	-0.000872
	(0.0932)	(0.117)	(0.00230)	(0.00274)
MODES	0.299	0.347	0.00507	0.00911
	(0.242)	(0.227)	(0.00647)	(0.00594)
ACCIDENTS	14.01***	2.660	0.545***	0.252*
	(4.667)	(3.868)	(0.117)	(0.137)
TOTALDISTANCE	0.107	0.159	0.00288	0.00442*
	(0.121)	(0.100)	(0.00283)	(0.00252)
RESERVES	0.343*	0.381	0.00971	-0.00231
	(0.202)	(0.333)	(0.00591)	(0.00828)
WEST*RESERVES	-0.709***	-0.610	-0.101***	-0.0305
	(0.268)	(0.809)	(0.0277)	(0.0619)
INTERIOR*RESERVES	-2.427***	-2.823***	-0.0436***	-0.0631***
	(0.679)	(0.879)	(0.0119)	(0.0151)

Table 11 continued

Dependent Variable	Delivered Prices ($/ton)		Log (Delivered Prices)	
	(1)	(2)	(3)[a]	(4)[a]
BTU SHIPPED	4.939***	4.499***	0.130***	0.120***
	(0.451)	(0.410)	(0.0118)	(0.0114)
SULFUR SHIPPED	-1.267***	-0.964***	-0.0388***	-0.0333***
	(0.303)	(0.304)	(0.00806)	(0.00961)
ASH SHIPPED	0.107	-0.0226	0.00198	-0.000733
	(0.0959)	(0.0921)	(0.00239)	(0.00237)
MOISTURE SHIPPED	0.0247	0.330*	-0.00238	0.00414
	(0.127)	(0.191)	(0.00293)	(0.00388)
Constant	-38.46***	-31.89***	1.842***	1.992***
	(8.844)	(9.412)	(0.216)	(0.243)
Plant FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Coal County FE	N	Y	N	Y
Clustered standard error	Y	Y	Y	Y
Observations	8,510	8,510	8,510	8,510
R-squared	0.467	0.538	0.461	0.518
Number of plantcode	311	311	311	311

Standard errors in parentheses, clustered by plant. *** p<0.01, ** p<0.05, * p<0.10.

(a) Results in Columns (3) and (4) estimated using logged values of *QUANTITY, COST, MODES, ACCIDENTS, RESERVES, BTU SHIPPED, SULFUR SHIPPED, ASH SHIPPED, MOISTURE SHIPPED*.

Table 12: Heckman First Stage Estimates

	Probability (Escalator/Cost Plus)	
	(1)	(2)
BTU_County	0.132***	0.104***
	(0.0199)	(0.0330)
MOIST_County	-0.0583***	-0.139***
	(0.0208)	(0.0353)
ASH_County	0.0664***	0.00797
	(0.0239)	(0.0398)
SULF_County	0.0134	0.0192
	(0.0248)	(0.0410)
MIDWEST*SULF	-0.000605	0.0340
	(0.0376)	(0.0613)
PHASE1*SULF	-0.0118	0.201**
	(0.0528)	(0.0798)
PHASE1*MIDWEST*SULF	0.0507	-0.214**
	(0.0715)	(0.109)
PHASE1	0.0243	0.702***
	(0.0823)	(0.120)
MIDWEST	0.276***	0.225
	(0.0859)	(0.144)
PHASE1*MIDWEST	-0.383***	-0.826***
	(0.122)	(0.185)

Table 12 continued		
	(1)	(2)
MODES	0.112***	0.0885
	(0.0348)	(0.0573)
ACCIDENTS	2.172	2.035
	(1.436)	(2.191)
MINE-MOUTH	1.077**	0.186
	(0.469)	(0.607)
WEST	-0.267***	-0.0404
	(0.0684)	(0.120)
INTERIOR	-0.602***	-0.0662
	(0.0779)	(0.128)
DEDICATE	0.313***	0.249***
	(0.0520)	(0.0859)
REPEAT	0.898***	0.721***
	(0.0542)	(0.0879)
Constant	0.850***	0.991***
	(0.242)	(0.299)
Year Indicator variables	Y	Y
Observations	6,571	3,528

Estimates calculated using the Two-Step Heckman procedure. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.10. Column (1) shows estimates for the probability of choosing escalator or cost-plus contracts, when Mine Prices are the outcome variable in the second stage. Column (2) shows the same, considering Delivered Prices as the second stage outcome variable.

Table 13: Heckman Second Stage estimates

	Mine Prices		Delivered Prices	
	Fixed Price	Escalator/Cost Plus	Fixed Price	Escalator/Cost Plus
	(1)	(2)	(3)	(4)
QUANTITY	-0.0152	0.0144	0.0359	0.0806***
	(0.0384)	(0.00911)	(0.0261)	(0.00839)
PHASE1	1.880***	0.826*	-1.636***	-0.246
	(0.598)	(0.435)	(0.603)	(0.332)
MIDWEST	2.651***	1.184***	-1.684**	1.771***
	(0.737)	(0.457)	(0.685)	(0.305)
PHASE1*MIDWEST	-1.959**	-1.900***	0.909	-1.753***
	(0.848)	(0.644)	(0.793)	(0.500)
WEST	-7.944***	-2.688***	-5.692***	-1.016
	(1.831)	(0.835)	(1.269)	(0.638)
INTERIOR	0.218	-1.413	0.832	0.502
	(1.231)	(0.889)	(1.197)	(0.720)
TOTALDISTANCE	-0.171	-0.158***	0.764***	0.667***
	(0.104)	(0.0548)	(0.0616)	(0.0310)
BTUS SHIPPED	2.632***	3.912***	4.700***	5.428***
	(0.234)	(0.293)	(0.321)	(0.272)
SULFUR SHIPPED	-1.476***	-1.273***	-2.649***	-2.493***
	(0.315)	(0.195)	(0.287)	(0.163)
ASH SHIPPED	0.159	0.228***	-0.162*	-0.105*
	(0.114)	(0.0725)	(0.0886)	(0.0560)
MOISTURE SHIPPED	-0.200***	0.0391	0.162**	0.0537
	(0.0720)	(0.0708)	(0.0709)	(0.0598)

Table 13 continued

	Mine Prices		Delivered Prices	
	Fixed Price	Escalator/Cost Plus	Fixed Price	Escalator/Cost Plus
	(1)	(2)	(3)	(4)
RESERVES	0.202	0.629***	0.0412	0.317**
	(0.319)	(0.177)	(0.381)	(0.150)
WEST*RESERVES	-0.182	-1.461***	-0.737*	-1.186***
	(0.420)	(0.290)	(0.407)	(0.191)
INTERIOR*RESERVES	-0.216	-0.354	-0.0510	-0.644
	(1.054)	(0.504)	(1.300)	(0.505)
COST	0.143	1.068***	0.216*	1.227***
	(0.135)	(0.0639)	(0.123)	(0.0510)
TIME	-0.605	-3.915***	-1.365***	-4.906***
	(0.508)	(0.277)	(0.476)	(0.194)
Constant	-15.67	-83.86***	-26.87***	-99.40***
	(9.971)	(6.140)	(9.394)	(5.397)
Lambda (Mills Ratio)	1.059**	-3.751***	-0.166	-4.220***
	(0.503)	(0.774)	(0.552)	(0.705)
Observations	7,289	3,528	8,334	7,176

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 14: Counterfactual Predictions from the Heckman model

	Full Sample		Only Escalator/Cost Plus contracts		Only Fixed Price contracts	
	Escalator/Cost Plus contract	Fixed Price contract	Escalator/Cost Plus contract	Fixed Price contract	Escalator/Cost Plus contract	Fixed Price contract
Mine Prices	26.693	22.906	27.129	23.058	22.018	19.779
	[0.904]	[1.432]	[0.853]	[1.303]	[1.124]	[1.300]
Delivered Prices	36.608	33.369	37.226	33.881	31.166	28.543
	[0.467]	[1.224]	[0.461]	[1.481]	[0.522]	[0.918]
Price Differences						
Mine Prices	3.788		4.071		2.240	
t-statistic	112.961		101.165		24.521	
Delivered Prices	3.239		3.345		2.624	
t-statistic	115.183		90.842		39.720	

Standard errors of estimates are given in square brackets. Price differences are calculated by subtracting predicted prices under fixed price contract from those predicted by escalator/cost plus contracts. All prices are in $/ton.

Table 15: Multiple Renegotiations

Panel A: Frequency of Renegotiations, by Contract Type

	Escalator/Cost Plus		Fixed Price	
# times renegotiated	# Contracts	Percentage	# Contracts	Percentage
1	3,843	58.26	518	76.63
2	1,473	22.33	137	20.27
3	861	13.05	8	1.18
4	239	3.62	2	0.3
5	167	2.53	11	1.63
6	13	0.2		

Panel B: Linear Probability Models

	Probability of Multiple Renegotiation (1)	(2)
FIXED	0.0375	0.0457
	(0.0372)	(0.0376)
Length		0.00406
		(0.00214)
Controls[a]	Y	Y
Observations	8,547	8,547
R-squared	0.080	0.082
# Plants	313	313

Note: Standard errors, in parentheses, clustered by plant. ** p<0.05, *** p<0.01.
(a) Controls include: QUANTITY, COST, MODES, ACCIDENTS, DISTANCE, RESERVES (and the interaction of RESERVES with WEST and INTERIOR), BTU, Sulfur, Ash, Moisture content of coal shipped, Plant, Year and Coal County fixed effects.

Table 16: What does renegotiation entail? Examining Prices and Quantities

	Delivered Price ($/ton)		Tons Shipped (Millions)		Probability of Repeat Supplier	
	(1)	(2)	(3)	(4)	(5)	(6)
MODIFY	-0.418***	-0.286	-0.0630***	-0.0675***	-0.0831***	-0.0704***
	(0.156)	(0.197)	(0.0134)	(0.0175)	(0.00947)	(0.0116)
FIXED		-3.254***		-0.171***		-0.0593**
		(0.583)		(0.0528)		(0.0265)
MODIFY*FIXED		-0.993		0.00414		-0.0630
		(0.554)		(0.0403)		(0.0391)
Controls	Y[a]	Y[a]	Y[b]	Y[b]	Y[c]	Y[c]
Plant FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y
Coal County FE	Y	Y	Y	Y	Y	Y
Observations	6,407	5,097	6,917	5,487	7,501	5,979
R-squared	0.455	0.482	0.078	0.103	0.183	0.199
# Plants	290	279	305	294	293	284

Notes: Standard errors, in parentheses, are clustered by plant. ** p<0.05, *** p<0.01.
(a) Controls for columns (1) and (2) include: COST, MODES, ACCIDENTS, DISTANCE, Reserves (together with interactions of Reserves with WEST and INTERIOR), BTU, Sulfur, Ash, Moisture content of shipped coal and QUANTITY.
(b) Controls for columns (3) and (4) include: COST, MODES, ACCIDENTS, DISTANCE, Reserves (together with interactions of Reserves with WEST and INTERIOR), Sulfur, Ash, and Moisture content of shipped coal.
(c) Controls for columns (5) and (6) include: MODES, ACCIDENTS, DISTANCE, RESTRUCTURE, interactions of PHASE1, POST90 and MIDWEST, DEDICATE, and SULF

Table 17: What does renegotiation entail? Examining Coal Characteristics

	Sulfur Content		BTU Content (1000's)		Moisture Content		Ash Content	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MODIFY	-0.00951	-0.00655	-0.00126	-0.00474	-0.0356	-0.0675	0.107**	0.103
	(0.0144)	(0.0192)	(0.00971)	(0.00997)	(0.0481)	(0.0599)	(0.0456)	(0.0568)
FIXED		-0.0606		0.0244		-0.171		-0.0816
		(0.0609)		(0.0306)		(0.203)		(0.170)
MODIFY*FIXED		0.0269		0.0202		-0.0392		0.0854
		(0.0457)		(0.0389)		(0.178)		(0.123)
Controls[a]	Y	Y	Y	Y	Y	Y	Y	Y
Plant FE	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Coal County FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	7,139	5,685	6,934	5,505	6,429	5,119	7,139	5,685
R-squared	0.092	0.361	0.712	0.701	0.675	0.692	0.231	0.238
# Plants	294	283	305	294	290	279	294	283

Notes: Standard errors, in parentheses, are clustered by plant. ** p<0.05, *** p<0.01. All coal characteristics are for shipped coal. (a): Controls for columns (1) through (8) include: COST, MODES, ACCIDENTS, DISTANCE, Reserves (together with interactions of Reserves with WEST and INTERIOR), and QUANTITY.

Table 18: Price Effects, by Contract Type: Instrumental Variable Estimates (Price Paid at Plant)

	OLS		IV, GMM†		
	(1)	(2)	(3)	(4)	(5)
CONTRACT	-3.671***	-3.277***	-14.61***	-7.854***	-7.456***
	(0.405)	(0.384)	(1.856)	(2.365)	(2.345)
Length		0.147***		0.480***	0.712***
		(0.0297)		(0.117)	(0.200)
Quantity	0.0178**	0.0127*			-0.0698
	(0.00854)	(0.00691)			(0.0595)
Controls‡	Y	Y	Y	Y	Y
Observations	10,184	10,184	9,016	9,016	9,016
R-squared	0.437	0.444			
# Plants	316	316	299	299	299
Kleibergen-Paap Wald F statistic			21.63	20.11	27.35
Kleibergen-Paap Under ID			66.05	46.51	7.869
p value			0.00	1.93e-09	0.0488
Hansen J statistic			9.970	1.292	0.783
p value			0.0409	0.731	0.676

Standard errors, in parentheses, are clustered by plant; *** p<0.01, ** p<0.05, * p<0.10. The dependent variable in all regressions is the price paid at the plant. CONTRACT equals 1 if contract is recorded as fixed price, and 0 if recorded as cost-plus, escalator, price renegotiation, or price tied to market.

†: Instruments for all three columns (columns (3) to (5)) are DEDICATE, DEDICATE SQUARE, PLANT DEDICATE, REPEAT and SULF.

‡: Controls include COST, RESERVES, WEST, INTERIOR, Interactions of WEST and INTERIOR with RESERVES, DISTANCE, BTUs, Sulfur, Ash and Moisture Shipped, Plant and Year Fixed Effects for Columns (1) and (2). The same set of controls are used for Columns (3) to (5), but with year indicator variables instead of year fixed effects.

Table 19: Instrumental Variable Estimates: First Stage Regressions

	CONTRACT (1)	Length (2)	Quantity (3)
DEDICATE	-0.0627***	0.7398**	1.8840***
	(0.0195)	(0.2948)	(0.6499)
DEDICATE SQUARED	0.0123***	-0.5192***	-0.3908
	(0.0041)	(0.1181)	(0.3258)
PLANT DEDICATE	-0.0516***	1.8142***	6.4994***
	(0.009)	(0.1969)	(0.4114)
REPEAT	-0.1336***	0.9837***	1.4112***
	(0.0156)	(0.2029)	(0.2964)
SULF	-0.0131***	-0.1530**	-0.3996**
	(0.0049)	(0.0716)	(0.1573)

Standard errors, clustered by plant, in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Table 20: Marginal Price Reduction as a consequence of moving toward more Complete Contracts: Comparing estimates from different models ($/ton)

Method	Estimate	Standard Error	Measure used	Average shipment savings (Million $)	Total saving (Billion $)
Fixed Effects, OLS	4.056	0.572	FIXED	$2.013	$29.748
Fixed Effects, OLS	3.671	0.405	CONTRACT	$1.822	$26.924
Heckman (Two Step)	2.624	-	$\hat{P}_{FIXED}$ - $\hat{P}_{(1-FIXED)}$	$1.302	$19.245
Fixed Effect Instrumental Variables, GMM	7.456	2.345	CONTRACT	$3.700	$54.685

Average shipment savings are calculated by multiplying the estimate of price reduction with the average tons shipped. Total savings are calculated by multiplying the average savings with the total number of observations in the Coal Transportation Rate Database (which equals 14,777).

Table 21: Comparing New versus Existing Contracts

	Delivered Price ($/ton)					
	(1)	(2)	(3)	(4)	(5)	(6)
FIXED	-3.832***					
	(0.409)					
CONTRACT		-3.303***				
		(0.380)				
INV FIXED			3.832***			
			(0.409)			
INV CONTRACT				3.303***		
				(0.380)		
INV FIXED					3.926***	
					(0.414)	
NEW					-0.293	-0.211
					(0.305)	(0.321)

Table 21 Continued

	Delivered Price ($/ton)					
	(1)	(2)	(3)	(4)	(5)	(6)
INV FIXED*NEW					-1.679***	
					(0.377)	
INV CONTRACT						3.425***
						(0.379)
INV CONTRACT*NEW						-1.708***
						(0.381)
Controls†	Y	Y	Y	Y	Y	Y
Constant	-31.89***	-38.14***	-35.72***	-41.45***	-34.39***	-40.48***
	(9.412)	(9.328)	(9.442)	(9.301)	(9.457)	(9.323)
Observations	8,510	9,910	8,510	9,910	8,509	9,909
R-squared	0.538	0.504	0.538	0.504	0.542	0.508
# Plants	311	315	311	315	311	315

Note: Standard errors, clustered by plant, in parentheses. *** p <0.01, ** p<0.05, * p<0.10.
† Controls include: COST, MODES, ACCIDENTS, DISTANCE, Reserves (together with interactions of Reserves with WEST and INTERIOR), BTU, Sulfur, Ash, Moisture content of shipped coal, QUANTITY, Plant, Year and Coal County Fixed Effects.

Appendix

COST COST varies within any given year across four regions within the US: Northeast (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont); South (Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia); Midwest (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin); and West (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming).

MIDWEST MIDWEST includes all plants located in Arkansas, Illinois, Iowa, Indiana, Kansas, Louisiana, Michigan, Minnesota, Mississippi, Oklahoma, Texas, and Wisconsin.

Coal sourcing regions In the definition of these variables, I follow Joskow (1987), with the only change being that I use the term INTERIOR while Joskow uses the term MIDWEST. In all specifications, EAST is the base case.

Table 22: Heckman Probit Model estimates: Probability of Modification

Year	Fixed Price	Escalator/Cost-Plus
1979	0.993	0.505
1980	0.989	0.479
1981	0.984	0.395
1982	0.982	0.360
1983	0.978	0.347
1984	0.970	0.258
1985	0.965	0.245
1986	0.946	0.252
1987	0.939	0.270
1990	0.872	0.152
1991	0.841	0.136
1992	0.823	0.122
1993	0.810	0.115
1994	0.784	0.101
1995	0.760	0.093
1996	0.718	0.080
1997	0.676	0.070
1998	0.620	0.054
1999	0.582	0.042

Table 23: Heckman Probit model for Renegotiation Probability: First stage estimates

	Prob (Escalator/Cost Plus)
BTU County	0.0731***
	(0.0177)
MOIST County	0.00362
	(0.0175)
ASH County	0.0874***
	(0.0200)
SULF County	-0.119***
	(0.0208)
MIDWEST*SULF County	0.106***
	(0.0341)
PHASE1*SULF County	-0.0178
	(0.0421)
PHASE1*MIDWEST*SULF County	-0.000832
	(0.0641)
PHASE1	0.249***
	(0.0638)
MIDWEST	0.201***
	(0.0699)
PHASE1*MIDWEST	-0.544***
	(0.109)

Table 23 continued

	Prob (Escalator/Cost Plus)
MODES	0.0320
	(0.0298)
ACCIDENTS	3.520***
	(0.909)
MINE MOUTH	0.512*
	(0.272)
WEST	0.682***
	(0.0638)
INTERIOR	0.341***
	(0.0757)
DEDICATE	0.222***
	(0.0443)
REPEAT	0.555***
	(0.0607)
Constant	-1.901***
	(0.148)
Year dummies	Y
Observations	6,459

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.10.

Table 24: Heckman Probit model for Renegotiation: Second Stage estimates

Dependent Variable	*Probability (Modification)*	
	Fixed Price selected	Escalator/Cost-Plus selected
	(1)	(2)
QUANTITY	-0.00265	-0.00310
	(0.00326)	(0.00222)
BTUS SHIPPED	-0.0805	0.388***
	(0.0566)	(0.0981)
SULFUR SHIPPED	0.0639	0.0235
	(0.0437)	(0.0383)
ASH SHIPPED	0.00548	0.0788***
	(0.0146)	(0.0198)
MOISTURE SHIPPED	0.0252*	0.0538***
	(0.0134)	(0.0206)
WEST	0.156	0.951***
	(0.186)	(0.160)
INTERIOR	-0.115	0.151
	(0.175)	(0.188)
RESERVES	-0.00362	0.219***
	(0.0561)	(0.0525)
WEST*RESERVES	-0.0748	-0.179***
	(0.0552)	(0.0596)
INTERIOR*RESERVES	-0.0452	0.369*
	(0.175)	(0.191)

Table 24 continued

Dependent Variable	*Probability (Modification)*	
	Fixed Price selected	Escalator/Cost-Plus selected
	(1)	(2)
MODES	0.136***	-0.0244
	(0.0506)	(0.0445)
ACCIDENTS	33.75***	3.692***
	(10.96)	(0.916)
TOTALDISTANCE	0.00908	0.0219***
	(0.00933)	(0.00764)
COST	-0.0313*	-0.0302*
	(0.0190)	(0.0169)
TIME	0.00930	0.0419
	(0.0720)	(0.0623)
Constant	4.667***	-4.802***
	(1.562)	(1.844)
ATHRHO	-1.307***	1.294***
	(0.154)	(0.251)
Observations	6,039	6,459

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.10.

Chapter 4

Regulation, Restructuring and Procurement Strategy by US Electric Utilities

4.1 Introduction

In recent decades, the electricity industry in the US has witnessed some sweeping reforms (Joskow 2008). Beginning with incentive based regulation in the late 1970s and early 1980s, through the restructuring efforts beginning in the middle 1990s, there has been a consistent attempt to improve the performance, delivery and pricing of electricity. While much debate has taken place regarding the role of market power as a potential disadvantage of a deregulated electricity market, corresponding attempts to quantify the benefits (if any) of restructuring have been fewer.

Although restructuring of the electricity market has been implemented with a long run view in mind, to encourage more efficient use of existing capital and more investment in cheaper generating units, I attempt to quantify any short term gains that may result. I do so by asking what impacts restructuring may have had on the contractual relationships power plants have with their fuel suppliers. More precisely, I analyze the response of coal-fired power plants in terms of their coal procurement strategy to restructuring efforts. Fuel costs are a major component of short run marginal costs, and procurement strategies are usually chosen in a cost effective manner. While the lowering of such costs is not a major motivation for restructuring, it is nevertheless important to know if such effects exist, for if they do, they provide an additional incentive to consider restructuring.

Additionally, prior to restructuring, many states also enacted regulation aimed at improving generational efficiency. I focus on a subset of these programs that altered how utilities would be compensated for fuel costs incurred. Doing so enables a comparison between more direct, albeit piece-meal legislation and less direct but more broad based deregulation.

To answer these questions, I use a dataset on coal procurement decisions by investor owned utilities in the US from 1979 to 2000 . There exists wide variation in both the implementation and timing of these reforms, which are enacted exogenous to the power plants they target. I use this variation in exposure to different regulatory regimes to estimate their effect on coal procurement decisions. I find that while incentive based regulation encourages the use of fixed price contracts, restructuring promotes the use of escalator and cost-plus contracts. The effect of incentive based regulation appears quite robust, while that of restructuring is sensitive to model specification.

Both of these effects are smaller than the effect of specialized investment, often argued within the incomplete contracting transaction cost literature as being the primary explanatory factors behind contractual structure.

I also examine the impact in terms of actual prices paid by each individual plant. As fuel procurement is guided not just by regulatory policy but also specific investment, failure to control for the contract structures underlying procurement results in large and significant biases in the impact of these reforms. Existing analysis of reforms in this sector ignore procurement mechanisms, and their findings are in this sense questionable. Restructuring, I find, has statistically insignificant effects on coal prices. By way of contrast, regulatory reform, in the form of modified fuel cost programs, has large effects on coal prices, reducing fuel prices by a little more than $2.5 per ton of coal shipped.

Concering prior literature, it is hard to make a comparison since coal procurement in relation to restructuring has been little analyzed. Knittel (2002) finds that modified fuel cost programs encouraged greater efficiency; I find that such programs encouraged the writing of fixed price contracts[1]. Fabrizio et al (2007) analyze the impact of restructuring on input use, and while they find significant reductions in labor employed, the effects on fuel used are not significant. They do not, however, consider the impact of earlier regulatory efforts. Further, their analysis aggregates procurement decisions across all contract types, as they do not have information on contractual decisions. Since contracts vary widely both over time as well as within plant,

[1] In related work (Kacker 2013b), I find that such contracts do associate with a lower coal price. The cost savings the utility made may have had a role to play in the increased efficiency of the plants.

an important explanation for fuel use is left unaccounted for, leading to a possible omitted variable problem.

The present analysis may also have implications for recent thinking within incomplete contract theory to extend the theory's ambit beyond contracting across just bilateral trade, to consider contracting in its entirety (Williamson 2010, p 686). Since we have a situation where the buyer (the utilities) faced a deep structural change in the market where its product (the electricity generated) was sold, examining if any effects exist of this change on the procurement contract may tell us whether considering contracting in its entirety is a productive way to proceed. I discuss these considerations in the final section. For now, I describe the institutional structure of the electricity industry that led to first incentive based regulation, then restructuring, being adopted. I then explain the effects I expect to see, in terms of coal procurement decisions, and then present results of the estimated models.

4.2 The changing nature of the US electricity market

Electricity production within the US has been the subject of a great deal of structural change, especially over the last three decades. Traditionally run by cost of service regulation, over the last two decades, this industry has attempted a more decentralized, competitive method of organization. Within the US, the option of a switch to deregulated markets has been left up to individual states. The switch has had mixed results: some states have managed to succesfully deregulate (Texas), others started but stopped (California) and others chose never to start, preferring to run under cost of service regulation. Although the restructuring of the electricity sector that began in the mid-1990s towards a more deregulated market structure is doubtless one of the biggest such changes ever effected, there have been attempts to alter the incentive structure for generating utilities prior to this time period.

Electricity generation, transmission, distribution and retail was traditionally carried out by one vertically integrated firm within the US. Indeed, much the same structure continues to prevail in many countries of the world, both developed and developing. Electricity production, distribution and sale carry the property of natural monopolies: heavy costs (constructing power plants, laying down lines that carry electricity from the plants to the consumers) that can only be undertaken by one firm.

It would be wasteful to have, for example, two plants competing for the sale of electricity to one end-consumer. At any point in time, one of these plants would have to be turned off, resulting in heavy losses for that plant. This would in turn mean that, if full competition was allowed, no firm would enter since in expectation they could incur massive loss.

Keeping such an industrial structure in mind, early regulatory efforts were directed toward the problem of setting prices. It would not be prudent to leave the price setting to the individual firm supplying any particular set of consumers, for they would then set prices far above the marginal costs of supply as by definition any particular firm is a monopolist. The approach adopted in response to this was to have regulatory bodies set prices for the utility, based on the costs of supply that the utilities incurred.

Such cost-plus regulation, although sensible, has at least two problems. One, it is difficult to ascertain truthfully the costs incurred by any plant. Plant managers almost surely have better knowledge of the workings of the plant, compared to external regulators. The risk, therefore, that costs could be fudged in order to obtain better prices is both plausible and significant. Two, even if such opportunistic behavior is ruled out, paying for costs does not incentivise efficient production. Since costs are paid for, no individual supplier will seek to lower costs even if such opportunities existed. Therefore, supply continues under higher costs than is necessary, resulting in higher prices.

An additional related problem arises from the sheer nature of such price setting. As regulators attempt, with their limited information, to adjust prices they may discover utilities claiming costs such that the implied prices appear either too low or too high. Often, therefore, regulators held "rate hearings", investigating the claim of the particular utilities. Not only does this procedure involve a significant amount of cost, but prices during a rate hearing were typically frozen, so if utilities had a way to reduce costs during this interim stage they could so and would stand to reap the benefit of the artificial higher price.

Recognizing these difficulties, regulators have attempted to control for the poor incentives in both reporting costs, and keeping them to an efficient level[2]. Such incentive based regulation seeks either to reward good perfor-

[2]The inefficiency of cost-plus arrangements have long been recognized within economic theory. Joskow and Schmalensee (1986) describe very well the relationship of various theories within economics to alternate incentive structures adopted by various US States.

mance, or punish bad performance.

One particular type of such regulation relates to the compensation structure followed for costs of fuel. Fuel costs account for a significant proportion of the marginal cost of a power plant (Mansur 2007). An efficient system would adjust electricty prices in line with these costs, so that consumers face prices that properly reflect the costs of production and thus make optimal decisions. Typically the prices set by regulators incorporated the cost of procurement of fuel incurred by the utility. The problem, however, with such a cost plus contract is listed out above. Given that capital stock is fixed in the short run, lower cost procurement of fuel is certainly one way to seek more efficient production.

Some states replaced this procedure with one where lower supply costs are incentivised by effectively making the utility a residual claimant for any cost-savings achieved through lowered fuel costs. For instance, in the procedure followed by New York state, utilities were required to forecast fuel costs one year into the future. Differences between the forecast and actual fuel costs would be split between the utility (who would bear 20% of the difference) and the consumer (the remaining 80% would enter into altered electricity prices).

There were other forms of incentive based regulation that targeted various facets of electricity generation: programs aimed at improving the heat rate, or changes made to the calculation of the rate of return (which is how utilities were compensated for capital costs). All these programs were adopted to correct some of the deficiencies that exist in a system where a regulator attempts to set prices based on reported costs. Knittel (2002) analyzes the impact of such programs on plant efficiency. I however restrict attention within these programs to fuel cost modification programs, because they are most likely to be relevant in influencing pricing structures adopted in the contractual relationships utilities had with their coal suppliers. It is less clear how the alternate programs could influence these contracting decisions.

Although useful in the short run, the impact of such modified fuel cost programs is going to be only partial at best. There are other aspects to the generation, distribution and retail of electricity, with efficient investments in plant and machinery likely to bring the largest gains. Such investments can only occur over a medium to long run, however, and are perhaps best encouraged through widespread restructuring. A major benefit of such restructuring is that it forces utilities to consider the use of the resources at their disposal in totality, and it allows individual managers to make decisions, who are perhaps best placed to do so.

Significant technological changes in the generation of electricity also helped in rethinking the structure of the industry. While previously very large (and costly) coal fired plants were majorly employed to generate electricity, by the 1990s natural gas based generators that could be run on a much smaller scale began to become popular[3]. The small scale, and the fact that natural gas plants (unlike coal-fired plants) do not require as much time to start up or shut down, meant switching among such generators could be done at much lower cost. This increased ease of switching implies an easier price setting procedure under a deregulated regime.

Within a deregulated market, the price at which electricity is sold is

[3]Over the recent decade, the use of natural gas has exploded within the US.

decided through an auctioning process. Utilities submit a supply schedule specifying what they would be willing to sell at what price, the system operator aggregates these supply schedules, plots it against the demand schedule and the point at which the two schedules intersect decides the price. Utilities which submit supply schedules that go above this price will not be called upon to provide electricity.

Given such a price adjustment process, there is great incentive to be a low cost producer, since that guarantees supply. Utilities are made to face greater pressure to reduce costs, and this pressure is not applied from outside but is a property of the price setting process. Accordingly, under a deregulated process, utilities must internalize all costs - not just the ones the regulator decides must be reduced - and further there is no incentive in fudging costs, as no regulator reviews them.

These benefits come at an increased risk of suppliers distorting market performance by taking advantage of their market power. Electricity generation is somewhat peculiar, in that even a small market share can translate into fairly substantial price differences. As a reflection of this, much of the studies carried out on the impact of deregulation have looked at market power problems.

Both incentive regulation and deregulation carry important cost saving implications. As pointed out above, fuel costs tend to be a substantial proportion of total costs, at least in the short run. We may expect that coal procurement strategy varies with the incidence of these policy regimes. I will now briefly describe the expected effects, the data I use to analyze whether these effects actually exist, and how strong the effects are.

4.3 Expected effects of incentive regulation and deregulation

Here, I will sketch briefly the direction in which I expect fuel modification and deregulation programs to affect coal procurement strategy. Before doing so, I outline below the procurement strategies employed by utilities in sourcing coal.

In the early 1980s, most coal procurement took place through escalator contracts. These contracts specify a base price for the coal to be procured, and adjust the price as the costs of mining (broadly defined to include capital, labor and exogenous regulator induced costs, such as new environmental or safety standards) move up or down. Mining costs are accounted for through the use of an index that accounts for various categories of costs.

How price adjusts depends on the type of cost: for capital (machinery, supplies), a wholesale price index is used; for labor, wages are adjusted to reflect labor costs in the area the mine is located in (these wages are often decided through collective bargaining procedures); exogenous regulatory shocks (changes in taxation, changes in safety standard or in environmentally acceptable mining techniques) are treated in a fully cost plus way, that is, all costs incurred due to such regulation are passed through to the utility. In this manner, such contracts mimic cost-plus contracts without suffering from the associated incentive problems in reporting costs.

Nevertheless, by paying (at least approximately) for incurred costs, escalator contracts do not offer the supplier any gain from restricting costs to a lower level, with the implication that the price the utility pays may be greater than necessary[4]. Joskow (1988 1990) documents that such contracts tend to be rigid in their prices, and more rigid when adjusting costs downward than upward. Further, although they account well for changes to supplier's costs, they are worse at handling changing demand conditions.

The advantage such contracts hold, despite the problems sketched above, is that they are superior to any alternative pricing structure employed in terms of resolving bargaining conflicts. At least in terms of supplier conditions, these contracts are able to adjust quite flexibly in the face of changing circumstances. Such flexibility saves both parties from engaging in costly haggling, but as we see above, requires some sacrifice in terms of incentives and can be rigid when faced with rapidly changing demand side conditions.

Beginning in 1990, there was a distinct move toward fixed price contracts, that accelerates as the years go by. Such contracts simply fix a price in advance for the entirety of the contract. Assuming that the contract is negotiated under competitive conditions, an assumption that is easily met for the coal mining industry in the US over the time frame of this study, there is now a strong incentive for mining companies to seek out cheap methods of production, since the cheaper bid is (ceteris paribus) likely to win the contract.

The disadvantage with such a contract is that it contains no method for adjusting prices, as and when conditions change. One may expect, therefore, to renegotiate much more frequently with such contracts. The ultimate choice of contract therefore balances the importance of providing cost reducing in-

[4]It is not necessary that the mining company makes any profit from such behavior, indeed a deadweight loss may be incurred.

centives versus the possibility of long drawn bargaining hassles. As I have explained in related work (Kacker 2013a), one key factor around which this trade-off revolves is the requirement of specialized investment (Williamson 1985). Where such investment is necessary, the benefits to the escalator contract rise (and vice versa).

Most (between 80% to 90%) of the contracts in use in any given year involve one of these two contracts. In addition, "price renegotiation" contracts were also used. These contracts simply specify price to be renegotiated at pre-specified intervals. Remaining contract types - explicit cost-plus contracts, prices tied to market - make up the remainder, but none of these are widely used.

Modified fuel purchase programs raise the benefit to fixed price contracts, since they provide an additional advantage to the use of fixed price contracts: the utility gets to keep the savings through the lowered price. While these contracts would be subject to greater renegotiation, compared to a situation where no modified fuel purchase agreements exist, the overall calculus shifts in favor of fixed price contracts. Of course, this does not necessarily mean that fixed price contracts would eventually win out. I expect, therefore, modified fuel purchase programs to positively influence the use of fixed price contracts.

With electricity deregulation, the eventual outcome is unclear. For one, the intended aim of such restructuring is to provide medium to long term gains by encouraging investment primarily in fixed capital: improvements to existing plant and machinery, investments in new technologies that supply electricity cheaply. The impact over the short run, which, given that many of these programs were only adopted (if at all) by the late 1990s and I have procurement information until 2000, is all I can hope to capture, is going to deal primarily with fuel procurement. Such effects may not be very strong. Fabrizio et al (2007) for instance find that the impact of restructuring (over a similar time period as I have) affects labor and capital, but not fuel purchase.

In addition, the direction in which deregulation might affect coal procurement is also unclear, since the utility now is the residual claimant for all cost savings. If we compare to a regime where deregulation has not taken place, both the costs and benefits of the two contract types continue to matter. Therefore, unlike the modified fuel purchase programs, the direction in which deregulation affects coal procurement can be either positive or negative, depending on how an individual utility perceives the tradeoffs between the two contract types. What appears certain is that the effects are likely to be weak, given that deregulation is not geared to affect short run decisions.

Table 25 lists the states affected by the two types of programs, and the years in which the programs went into effect. Nearly all states held hearings before deciding whether to deregulate and restructure their electricity markets. Note that, in terms of the modified fuel cost pass through programs, I have taken my information from Joskow and Schmalensee (1986) rather than Knitell (2002). As Joskow and Schmalensee argue, their list represents programs that provided for a decoupling of prices and costs ex-ante and excludes those programs that would make ex-post changes. The former programs are likely to have influenced behavior, and for this reason I go along with the Joskow-Schmalensee definition.

4.4 Estimated effects on coal procurement strategy

I use various definitions of the outcome variable. These definitions are listed and described in Table 26. Out of these, four - Z_1, Z_2, Z_3, and Z_4 - are binary, zero-one variables. For all these variables, "1" corresponds to fixed price contracts, while "0" corresponds to only escalator contracts (Z_1); escalator, cost-plus and renegotiation contracts (Z_2); escalator, cost-plus, renegotiation and price tied to market contracts (Z_3); and finally all of these including any hybrid combinations (Z_4). The last - FPLUS - includes escalator, cost-plus and fixed price contracts, but differs in that it orders these in terms of how incomplete they are. Cost-plus are most incomplete since they allow for all costs to pass through, fixed price are the most complete since they do not allow any costs to pass through and escalator contracts are in between these two.

I have also listed the contributions each of these contract types make toward the full dataset, under the column titled "Percentage". We can see that escalator, cost-plus and fixed price contracts account for nearly 83% of the total contracts, and with price renegotiation contracts, this figure rises to nearly 91%. As we would expect, moving from Z_1 to Z_4, we see increased number of observations (as more contract variation is accounted for) and a fall in the mean value (as the denominator rises, but the numerator - that is, the total number of fixed price contracts - stays the same).

Table 27 lists the variables I use. ACT is an indicator variable that turns on for those plants located in states that passed legislation enabling the restructuring of the electricity sector, but only for the year in which the act was passed, and the years following the passing. Nearly all states considered restructuring, but at different times, and I include HEARING as equal to one in all years (and including the year in which) the hearings began. Therefore, ACT captures a change in rule, relative to when the changes began to be considered.

Note that simply passing the act does not automatically imply the commencement of restructuring; as a matter of fact, in many states restructuring typically commenced a few years after the act was passed. Many utilities, once aware that the state they operated in had begun a movement toward restructuring considered actively plans to reduce costs and increase efficiency. The coding structure I follow is an attempt to capture such behavior. Fabrizio et al (2007) consider a similar definition. There may also exist, prior to the announcement of a restructuring act, some impact simply due to the fact that hearings regarding the movement toward restructuring begin to be held. This forms another reason to include a separate coefficient for hearings.

FUEL is an indicator variable that turns equal to one for those plants located in states that Joskow and Schmalensee (1986) identify as enabling modification of fuel cost payment rules, but only in those years following and the year the plan was introduced. As we can see from Table 25, there exists wide variation in the timing and location of both the incentive regulation scheme and the restructuring effort. Since these programs were imposed upon plants, the variation is plausibly exogenous. Such variation across both the time dimension and the cross-section forms the basis for the identification of the effect of these programs. I am comparing, therefore, plants under the influence of these programs to those that are not. The latter includes the same plant in the past. I include both plant and year fixed effects, so that the comparison being made is free from any cross-plant variation that is time invariant (plants differ in terms of their size and technology, neither of which is likely to change across time) or any common year-wise shocks (such as the overall health of the economy, fuel price fluctuations or mining supply shocks that would affect all plants equally).

In addition to the fixed effects, I also include various contractual controls. These variables are necessary for they account for the influence of the deregulation of the railroads as well as various elements of investment decisions that incomplete contract theories argue are powerful determinants of contract structure. Coal being majorly shipped by rail, the procurement of it is likely affected by the deregulation of rail. Since the outcome I consider consists of various types of procurement contracts, the predictions of incomplete contracting need to be accounted for as well.

MINE MOUTH equals one for any contract associated with a plant that is built next to a mine. Such site-specific investments are argued to raise the gain from escalator or cost-plus contracts, since due to their geographic specialization, a significant amount of ex-post haggling is expected. WEST, INTERIOR and APPALACHIAN are indicator variables for whether the coal is syourced from the western, interior or Appalachian coal mines. Such inter-regional variation is argued to be important, because coal varies in its formation across regions; as we move west, the variation of coal characteristics rises, implying greater physical specialization, and thus the use of escalator or cost-plus contracts.

DEDICATE is calculated as the ratio of quantity within the specific plant-mine contract to quantity for all contracts the mine holds, in any given year. This is intended to capture the notion of dedicated assets, that is argued to increase the probability of ex-post negotiation, and thus the probability of escalator or cost-plus contracts. REPEAT is an indicator variable that captures whether the partcular plant-mine pair recorded in the contract had a previous relationship.

To account for the influence of the Clean Air Act Amendment of 1990, which I have argued elsewhere (Kacker 2013a), led to a reduction in the specialization of investment and thus a rise in fixed price contracts, I define two indicator variables: PHASE1, which equals one if the plant recorded in the contract was a Phase I plant, as per the Amendment's announcement; and MIDWEST, which equals one if the plant happens to be located in the midwestern US. Phase I plants, being immediately affected by the Amendment, are expected to respond by a greater amount than Phase II plants. In particular, those plants located in the midwest are expected to respond the greatest, since these plants would be most likely to mix and blend their coal (a mixture of high-sulfur Appalachian and low-sulfur western coal), leading to a reduction in the specialization required for the boilers to burn such coal, and a concomittant increase in the likelihood of fixed price contracts. By comparison, Phase I plants on the east coast are unlikely to experience such a reduction, since they face lesser incentives to mix their coal, but would nevertheless need to burn western coal. For these plants, I expect a lower likelihood of fixed price contract use.

Finally, I include two transportation related variables to proxy for the influence of the Staggers Act induced railroad deregulation: MODES, which counts the total number of unique modes of transportation required to ship the coal (whether rail, barge or truck); and ACCIDENTS, which calculates the ratio of total accidents to total track in the state the mine is located in. As deregulation proceeds, the cost of transportation by rail reduces, and so I expect the number of modes to fall, inducing a negative correlation between MODES and fixed price contract use. ACCIDENTS intends to proxy for the reduced uncertainty that resulted as deregulation took hold in the railroads, as the overall investment in track improved the reliability of transport via rail. I therefore expect a negative correlation between ACCIDENTS and the probability of writing fixed price contracts.

For many of the results, I consider a linear probability model, since only these models are capable of handling multiple dimensions of fixed effects. The major disadvantage, of course, to these models is that the error term is by definition heteroskedastic, and predicted probabilities often can be greater than one or less than zero. I am not interested in predicted effects, only in the explanatory power of the incentive regulation and deregulation efforts, so the latter objection although important is perhaps not entirely relevant. As for the former objection, I cluster the errors by plant, which corrects for the heteroskedasticity as well as any inter-temporal correlation within plant.

4.4.1 Effects on Contract Choices

Table 28 reports the effects of clustering and fixed effects when estimating the impact of both fuel modification and restructuring. I consider Z_2 as the outcome variable, as this variable includes a major portion of the data. In the first column, I only include ACT as the explanatory variable, and we observe a positive coefficient. The need to control for the fact that many states considered seriously the need to restructure, is outlined in column 2, whereby the inclusion of HEARING leads to a negative coefficient on ACT. In the third column, I add in the control for whether any plant was located in a state which modified (by the Joskow-Schmalensee argument) the cost of fuel procurement. We observe that the associated coefficient, although positive (as expected), is not statistically significant. However, we have not considered either the impact of clustering or fixed effects.

Columns (4) to (6), in sequence, show results of the model in column (3) when standard errors are clustered (column 4), year fixed effects are added (column 5) and plant fixed effects are added (column 6). We can see that clustering leads to huge increases in the error, although in terms of statistical significance, the results are not changed. The inclusion of the two fixed effects turns out to be extremely important: the impact of fuel modification turns to be statistically significant and positive as per expected, restructuring hearings appear to have little statistical significance in explaining procurement decisions, while the announcement of a shift toward restructuring is both statistically significant and negative, indicating that utilities are less likely to sign fixed price contracts if any of their plants need to participate in a deregulated market.

So far, however, I have not controlled for the influence of various contracting variables, as well as the regulatory proceedings with regard to the Clean Air Act Amendment and railroad deregulation. Table 29 shows the results that obtain when doing so, and also considers the possible variation as we alter the outcome variable (from Z_1 to Z_4). Columns (1) to (3) show the results when considering, as the outcome variable, Z_1, Z_3 and Z_4. In column 4, I consider Z_2 and in column 5, I add in coal county fixed effects to account for further unobserved variation, this time on the supply side. Finally in column 6, I report the results of an ordered probit model using FPLUS as the outcome variable.

We can see that the impact of restructuring has a negative effect on writing fixed price contracts, although this result is sensitive to definitions and requires (for Z_2 as the outcome variable) the inclusion of coal county fixed effects. Restructuring hearings appear to have little effect. Incentive based regulation, in the form of modified fuel cost programs, appears to have very strong and robust positive effects on the writing of fixed price contracts.

Moving on to the contracting variables, we see that dedicated assets and repeated interaction have a negative impact on writing fixed price contracts. The former result is a direct prediction of incomplete contract, transaction cost theory. I include a quadratic specification of this variable, following Joskow (1987) and find evidence of a u-shaped relationship between the probability of writing fixed price contracts and the amount of dedicated assets: indicating that, after a point, the magnitude of dedicated assets rises so high as to make any gains from opportunistic behavior (and the resulting haggling) unviable.

I consider an interaction between PHASE1 and POST90, an indicator variable that takes on the value of one if the year the contract is alive in is greater than, or equal to, 1990. I also consider another level of interaction with MIDWEST. As per expectation the triple interaction variable is positive, indicating that Phase I plants in the midwest did respond to the reduced specialization induced by the Clean Air Act Amendment and sign more fixed price contracts. Also, Phase I plants on the east coast, less likely to have experienced such reduction and likely to have experienced the opposite, given their lack of experience with western coal, appear to face an increased hold-up situation and prefer to write escalator or cost-plus contracts.

MODES appears to have little effect, but ACCIDENTS has a large and statistically signifcant effect in the expected direction. Finally, the region of coal sourcing also matters quite heavily, but only in terms of coal coming from the interior. The insignificant coefficient on WEST is most likely due to the controlling effect of the PHASE 1, MIDWEST variables. Note that in column 5, since coal county fixed effects are included, coal sourcing region and ACCIDENTS need to be dropped from the estimated equation.

The ordered probit model shows very similar results in terms of the impact of fuel modification and restructuring. Many of the contracting variables are also statistically significant, in the expected direction as well. These results show that the results are not sensitive to linear specifications of what is a categorical outcome variable, however such robustness claims must be qualified by the fact that I cannot control for multiple fixed effects (although I have included a full set of year indicator variables).

The results shown in column 6 are only regression coefficients, and unlike a linear model, cannot be interpreted as marginal effects. I therefore show the marginal effects implied by this model in Table 30 for the three distinct outcomes considered. We observe that the signs are as per expectation, although in terms of magnitudes, there are differences from the linear model. In particular, the impact of fuel modification appears roughly equal to that of restructuring efforts whereas in the linear model fuel modification appears roughly twice as powerful. Of course, this result must be qualified by the fact that the ordered probit has no fixed effects and only year indicator variables.

A striking result, consistent across all specifcations, is that the role of specific investment (proxied by the interaction between PHASE 1, POST90 and MIDWEST) is much more stronger in economic terms than either the fuel modification programs or electricity restructuring efforts. This indicates that, when considering the interaction between a buyer and seller, bilateral investments play a significantly greater role than contracting impacts that occur as a result of the changing market conditions the buyer experiences.

4.4.2 Price implications, by Regulatory Regimes

Although I have found that fuel modification programs tend to have stronger effects than restructuring on fuel procurement strategies, it is still relevant to ask whether fuel prices were significantly affected by either (or both) of these. Holding contract type fixed, in other words, would we expect to see systematic changes in coal prices, comparing plants across different regulatory regimes? Policy makers and regulators are likely to worry more about actual fuel prices than the contractual mechanisms that secure them, so understanding what (if any) effects regulations or restructuring have on fuel prices will be important. To repeat, Fabrizio et al (2007), do not have information on various contracts used (within or across plants) and perhaps their analysis may be affected by leaving out this information, due to the omitted variable problem.

It is plausible that both types of regulatory efforts - fuel modification and restructuring - would have some effect on prices. Consider the case of fuel modification programs. These programs transfer a proportion of cost savings over to the utility, with the rest being shared between the consumer and the utility. In parallel, any cost overruns would also be borne by the utility and the consumer in similar proportion.

If the utility believes that coal prices are going to increase, it needs to make an estimate of how much an increase would take place. A reduction in the rate of increase would be counted as a saving, but could still show up as a price increase. If the same utility operates a plant in a regime where no savings are forthcoming from reducing the rate of increase, we might expect little effort to do so. Consequently, prices will be higher for the utility operating in non-fuel adjustment regime compared to the same utility operating in a fuel adjustment regime[5]. I expect, therefore, that fuel adjustment programs negatively influence coal prices.

The impact of restructuring is harder to tell. One, as mentioned earlier, restructuring is not aimed at making short run decisions more efficient. Two, it is difficult to tell whether increased or reduced prices correspond to greater efficiency, since all relevant costs need to be internalized. If, as found earlier, restructuring leads to more escalator contracts being used, or rather does not imply the use of fixed price contracts, we might expect a rise in prices since such contracts tend to result in higher prices (than fixed price contracts).

[5] A similar reasoning holds for when prices are expected to fall.

In what follows, I use delivered prices as the dependent variable of interest. Delivered prices include both transportation costs and prices paid to the coal mine, so there is a risk in conflating transportation related changes with the impact I seek to isolate. Nevertheless, I use delivered prices because information on these prices is more widespread in the data, and therefore more reliable. In addition, I have information on shipping distance (TOTAL DISTANCE), modes of transportation (MODES) and railroad reliability (ACCIDENTS), all of which should control well for transportation related changes.

In addition to transportation, I control for the total quantity of coal sourced (QUANTITY)[6]. There exists significant cross-regional variation in the type of coal that can be procured. Broadly, as we move from the eastern Appalachian mines to the western mines, the coal lowers in BTU content and sulfur content. In addition, the type of mining varies, with western mines using more capital intensive techniques that rely on surface mining far more than eastern mines, which is typically found at a significant depth. Coal found in between, interior coal, varies between these two extremes. Accordingly, I use WEST, an indicator variable that equals one if a plant contracts with a western mine, and INTERIOR, a similar variable if the plant contracts with an interior mine[7].

I use, as a proxy for coal mines' labor costs, COSTS. COSTS is a wage index (for those working in the mining sector) taken from the Bureau of La-

[6]The contract dataset records ex-ante specified upper and lower limits on various coal characteristics. I obtain $QUANTITY$ by multiplying the ex-ante specified lower limit BTU content with the ex-ante specified lower limit tons to be shipped.

[7]See Kacker (2013a) for which states these indicator variables include.

bor Statistics[8]. Coal markets over the time period under study went through significant change, with western coal rising to dominance while interior coal declined and Appalachian coal stagnated. A major reason for this was the large expansion in known reserves of western coal. Accordingly, I use RESERVES, a measure of known reserves (in billion short tons). To account for the cross-regional shift toward increasing Western reserves, I interact RESERVES with WEST and INTERIOR. To measure the quality characteristics of coal, I also control for the BTU, sulfur, ash and moisture content of the coal finally shipped.

Coal contracts in the US may be subject to significant downward rigidity (Joskow 1990). Therefore, as an alternative to FUEL, I define an indicator variable FUEL NEW, which turns equal to one for all contracts that are both associated with plants located in a state which enacted fuel adjustment programs and "come into existence" either during, or after, the year the program starts[9]. The reason for choosing such a definition is to rule to rigidity as far as it possible. A benefit of using this definition is that it biases any finding toward zero.

A possible problem with FUEL NEW is that there may be situations where utilities are aware of prices falling due to exogenous reasons (a massive expansion of the supply base, for instance), and lobby for the passing of fuel adjustment programs, hoping to capture for themselves part of the price

[8]COSTS varies cross-sectionally at any given point in time. Different values are calculated for 4 different regions that together constitute the US. The contract dataset records the state the mine is located in. I use this information to match the appropriate value for COSTS. Of course, COSTS varies over time as well, allowing me to exploit both regional and temporal variation in mining labor costs as an explanatory factor for prices.

[9]Previously existing contracts have a value of zero according to this definition, whether they were renegotiated or not.

reduction. In such a case, although prices fall, and utilities get a share of this price reduction, it would be incorrect to interpret the falling price as indicating the efficacy of incentive-based regulation. The inclusion of RESERVES and COSTS should safeguard, at least partially, against this possibility. Further, prices fall because of transportation related changes, and as mentioned above, I include controls for such changes.

I also control for the contractual characteristics of pricing and length. PRICE ORDER is a variable that orders the various contracts in terms of their completeness. LENGTH measures the duration of the contract. Being endogenous, I use an instrumental variable procedure to estimate the effect of these variables. We will see that accounting for these variables causes dramatic changes in the estimated effects of both fuel adjustment regulation and restructuring, implying the omission of these variables leads to serious biases[10]. The Appendix lists summary statistics for these variables.

Table 31 shows the results of, considering delivered prices as the dependent variable[11]. Column (1) shows the results that occur when a two-way (plant and year) fixed effect model is estimated. The impact of fuel adjustment programs appears to have a positive effect on prices. Regulatory hearings also appear to increase prices, while actual legislation has no sta-

[10] I use a proxy for repeated interaction, REPEAT, and two measures of dedicated assets (DEDICATE and PLANT DEDICATE) as instruments. REPEAT is an indicator variable that equals one if a plant and a coal contractor have previously engaged in a contractual relationship. DEDICATE calculates, for any given year, the ratio of the total quantity within a given contract to the total quantity for all contracts held by the contractor. PLANT DEDICATE calculates, for any given year, the ratio of the total quantity within a given contract to the total quantity for all contracts held by the plant. For details on these variables, see Kacker (2013b).

[11] Full results including coefficients for other control variables are not reported in this table but are given in the appendix.

tistically significant effect, suggesting that any changes in prices related to restructuring took place much before any actual legislation was passed. In Column (2), I show results when FUEL NEW is used instead of FUEL. We see, in contrast to the earlier result, a negative effect of fuel adjustment programs.

Both these specifications do not control for either the price structure of the contract used, or the contracts' duration. In Column (3), I control for price structure using PRICE ORDER, and use the instrumental variable estimation to account for the possible endogeneity of this variable[12]. We see the effect of fuel adjustment programs continues to be negative, statistically significant, and rises (in absolute terms) by nearly $1 per ton of coal shipped, which is a very large increase in magnitude. In Column (4), I control additionally for contract duration, and in column (5) I include ACT NEW and HEARING NEW, defined analogously to FUEL NEW. There are some increases in the size of the coefficient on FUEL NEW, with the sign staying negative and the coefficient remaining statistically significant. Finally, in Column (6), I estimate the same model as in Column (4), but replace FUEL NEW with FUEL.

We see that the effect of FUEL is to increase prices, although the error is large enough to render the coefficient is statistically insignificant. We cannot, therefore, reject a zero or negative effect. The positive impact of FUEL indicates, however, that if utilities were lobbying to implement regulations in

[12] I use a fixed effect instrumental variable model, with errors clustered at the plant to account for the within-plant serial dependence amongst error terms, which is quite likely in the present setting. Given the clustering, I use a GMM technique to estimate the model, as this results in more efficient estimates than maximum likelihood, in the presence of non-i.i.d errors. I use the STATA command `xtivreg2` to carry out this estimation.

a way to benefit themselves, then they were also running the risk of raising prices for existing contracts. Note that FUEL aggregates together existing and new contracts, so the effect on existing contracts is likely to be higher. Such a pattern of price behavior casts some doubt on the hypothesis that these adjustment programs were put in place as a result of lobbying activity on the part of the utilities.

Restructuring appears to have had statistically insignificant effects across all specifications that include contractual characteristics. A striking result from these regressions is how important it is to control for these variables: the estimated effect of the fuel adjustment programs switches in signs, and that of restructuring turns insignificant. Not controlling for variations amongst contracts used to procure fuel appears to lead to significantly biased estimates. Further, the impact of the method of procurement, summarized by the pricing structure variable PRICE ORDER and contract duration variable LENGTH, has at least effects equal in magnitude to that of regulatory reform. In light of these results, we may wish to know how labor or capital is procured by utilities, in order to understand whether the effects of restructuring are affected once the mechanism of procurement is controlled for.

I show first stage results in Table 32, for instruments used in Columns (4), (5) and (6) of Table 31. We can see the instruments are individually highly significant, especially PLANT DEDICATE and REPEAT. First stage F-statistics, calculated to account for the clustered error matrix, indicate the instruments are quite strong[13]. I also report results of under- and over-

[13] These F-Statistics, the Kleibergen Wald statistics, do not currently have a list of

identification tests. These indicate the instruments used are both relevant and valid: the null hypothesis of the underidentification test is rejected indicating relevance and that of the overidentification test cannot be rejected indicating validity.

4.5 What we may conclude

In this paper, I have attempted to examine to what extent the impact of electricity restructuring and prior efforts at incentive regulation within the US may have had on coal procurement strategies by utilities. Broadly speaking, while I find that incentive based regulation does affect the type of contract utilities would write with their coal suppliers, the effect of restructuring is more modest. Neither of these two, however, appear as important in determining the form of contract undertaken as relationship specific investment.

Particularly worthy of attention is that restructuring does not seem to have substantial effects on prices, while more targeted regulation does. A striking result I obtain is that failure to control for the method of procurement of fuel is likely to result in very large and significant biases for the analysis of regulatory or restructuring reform. In addition to this, the effect of procurement method is as large as the impact of regulatory reform. As the choice of procurement is deeply affected by specific investments, and not just the regulatory structure in place, this finding questions analysis of electricity reform that ignores how input procurement takes place.

critical values to compare to, unlike the more conventional Stock-Yogo F-Statistics. Consequently, it is difficult to know for sure how strong the instruments are. Nevertheless, the F-statistic calculated for all specifications are close to 10, indicating the instruments are likely to be strong.

Some necessary qualifications exist, however. For one, the data I have only concerns coal-fired power plants. I do not have contractual information for natural gas based power plants, and certainly over the 1990s, such plants grew in importance. Given that natural gas plants operate with a technology that is very different from coal fired plants, and indeed this technological difference was an important motivation toward encouraging the movement toward restructuring, the exclusion of such plants may have important effects on the results obtained. Until further information could be available, however, it will be difficult to know for sure.

A further limitation of the study is that there is comparatively less information available after restructuring went into effect. A dataset with more years of observations following the implementation (or, as in the case of California, subsequent withdrawal) of restructuring might help clarify whether the effects I find continue, decline or strengthen over time.

What does seem to be certain is that the consideration of contracting in its entirety has merit. In this regard, the influence of electricity restructuring on the contractual relationships utilities have not only with their retail buyers, but also their fuel suppliers must be studied in greater detail. The analysis so far has mostly concerned itself with the behavior of the generating arm of the electricity industry or the nature of the relationship between the generators and the retail buyers. As I hope I have shown, there are important effects of such bilateral relationships upstream. More precisely, the change in the nature of such relationships appears to have effects on upstream relationships the generator has with its input supplier. A full analysis may need to consider this system of contracting relationships in its entirety.

Table 25: States Affected by Restructuring and Incentive Regulation

Program	States Affected
Modified fuel cost pass through	California(1983), Michigan (1979),New York (1983), New Jersey (1977), North Carolina (1983), Oregon (1980), Pennsylvania* (1990)
Hearings about restructuring	All states except North Dakota; From 1995 (New Hampshire, Texas) to 2000 (Nebraska)
Restructuring legislation passed	Texas (1995)
	California, New Hampshire, Pennsylvania, Rhode Island (1996)
	Illinois, Maine, Massachusetts, Montana, Nevada, Oklahoma (1997)
	Connecticut, Michigan, New York (1998)
	Arizona, Arkansas, Delaware, Maryland, New Jersey, New Mexico, Ohio, Oregon, Virginia (1999)
	District of Columbia (2000)

Source: Joskow and Schmalensee (1986), EIA (http://www.eia.gov/cneaf/electricity/page/restructuring/restructure_elect.html).
*: The program for Pennsylvania was recorded as pending in Joskow and Schmalensee (1986). I have recorded the program for this state as having passed in 1990. Given that I do not use data for 1988 and 1989, even if the program passed in 1987, much of the variation is still going to be picked up by the definition I have followed.

Table 26: Definitions of Dependent Variable

Dependent Variable	Contract type included	Values	Percentage
Z_1	Fixed price contracts	1	
[0.096]	Escalator clause contracts	0	
(11639)			
Z_2	Fixed price contracts	1	
[0.084]	Escalator clause contracts	0	
(13168)	Cost plus contracts	0	
	Price renegotiation	0	
Z_3	Fixed price contracts	1	
[0.083]	Price tied to market	0	
(13372)	Escalator clause contracts	0	
	Price renegotiation	0	
	Cost plus contracts	0	
Z_4	Fixed price contracts	1	12.00%
[0.079]	Price tied to market	0	1.38%
(13979)	Escalator + Price tied to market	0	2.82%
	Escalator clause contracts	0	66.80%
	Escalator + price renegotiation	0	1.29%
	Price renegotiation	0	6.83%
	Cost plus contracts	0	3.51%
$FPLUS$	Fixed price contracts	2	
[1.102]	Escalator clause contracts	1	
(12159)	Cost plus contracts	0	

Source: Coal Transportation Rate Database, Author's Calculation. Contracts that had a share lower than 1% in the data obtained post cleaning, or recorded as "Other" are not included. For each variable, below its name, the mean is given within square brackets, while parentheses show the total number of observations included by the definition.

Table 27: Summary Statistics for data used in regressions

Variable	Observations	Mean	Standard Deviation	Minimum	Maximum	Source
ACT	14777	0.0486	-	0	1	EIA(1)
HEARING	15034	0.1485	-	0	1	EIA
FUEL	15034	0.2016	-	0	1	Knittel (2002), Joskow and Schmalensee (1986)
MINE MOUTH	14777	0.0150	-	0	1	CTRDB
WEST	14777	0.2036	-	0	1	CTRDB
INTERIOR	14777	0.1254	-	0	1	CTRDB
APPALACHIAN	14777	0.6639	-	0	1	CTRDB
DEDICATE	13490	0.6466	0.5378	1.59E-05	42.0833	CTRDB
REPEAT	14777	0.8490	-	0	1	CTRDB
PHASE 1	14616	0.3042	-	0	1	EPA(2)
MIDWEST	14777	0.4201	-	0	1	CTRDB
MODES	14777	1.3876	0.6578	0	4	CTRDB
ACCIDENTS	14223	0.0072	0.0308	9.34E-07	0.3808	FRA(3)

(1) EIA: http://www.eia.gov/cneaf/electricity/page/restructuring/restructure_elect.html
(2) EPA: http://ampd.epa.gov/ampd
(3) FRA: http://safetydata.fra.dot.gov/OfficeofSafety/Default.aspx

Table 28: Impact of Restructuring and Incentive Regulation: Fixed Effects and Clustering
Dependent variable: Z_2

	(1)	(2)	(3)	(4)	(5)	(6)
ACT	0.160***	-0.117***	-0.118***	-0.118**	-0.126**	-0.111***
	(0.0134)	(0.0156)	(0.0157)	(0.0547)	(0.0522)	(0.0407)
HEARING		0.308***	0.309***	0.309***	0.0562	-0.0205
		(0.00967)	(0.00971)	(0.0308)	(0.0440)	(0.0356)
FUEL			0.00342	0.00342	-0.0111	0.131**
			(0.00727)	(0.0309)	(0.0296)	(0.0546)
Constant	0.126***	0.0947***	0.0941***	0.0941***	0.00826	-0.0119
	(0.00303)	(0.00308)	(0.00339)	(0.00967)	(0.00608)	(0.0155)
Year FE	N	N	N	N	Y	Y
Plant FE	N	N	N	N	N	Y
Clustering standard errors	N	N	N	Y	Y	Y
Observations	13,168	13,168	13,168	13,168	13,168	13,168
R-squared	0.011	0.082	0.082	0.082	0.146	0.159
Number of plants errors clustered over						339

Standard errors in parentheses. Where indicated, these errors are clustered by plant. ** $p < 0.05$, *** $p < 0.01$.

Table 29: The Impact of Restructuring and Incentive Regulation: Controlling for contracting variables

Dependent Variable	Z_1	Z_3	Z_4	Z_2	Z_2	FPLUS
Model	OLS	OLS	OLS	OLS	OLS	Ordered Probit
	(1)	(2)	(3)	(4)	(5)	(6)
ACT	-0.0603	-0.0787	-0.0850**	-0.0781	-0.0854**	-0.326***
	(0.0416)	(0.0401)	(0.0395)	(0.0408)	(0.0375)	(0.0710)
HEARING	-0.0359	-0.0345	-0.0381	-0.0332	-0.0462	0.0189
	(0.0370)	(0.0334)	(0.0324)	(0.0342)	(0.0356)	(0.0937)
FUEL	0.225***	0.153***	0.122**	0.166***	0.156***	0.223***
	(0.0663)	(0.0535)	(0.0494)	(0.0546)	(0.0491)	(0.0392)
MINE-MOUTH	-0.0403	-0.0330	-0.0487	-0.0398	-0.0789	-0.928***
	(0.0539)	(0.0371)	(0.0447)	(0.0400)	(0.0401)	(0.135)
DEDICATE	-0.0492***	-0.0456***	-0.0532***	-0.0458***	-0.0462***	-0.376***
	(0.0146)	(0.0138)	(0.0137)	(0.0140)	(0.0139)	(0.0678)
DEDICATE_SQUARED	0.00159***	0.00152***	0.00170***	0.00153***	0.00150***	0.0428
	(0.000348)	(0.000329)	(0.000326)	(0.000332)	(0.000328)	(0.0441)
REPEAT	-0.127***	-0.119***	-0.126***	-0.120***	-0.115***	-0.651***
	(0.0127)	(0.0121)	(0.0125)	(0.0122)	(0.0124)	(0.0399)
PHASE1*POST90	-0.116***	-0.0832**	-0.0744**	-0.0876**	-0.0691	-0.167**
	(0.0416)	(0.0378)	(0.0320)	(0.0383)	(0.0372)	(0.0752)
PHASE1*POST90*MIDWEST	0.260***	0.243***	0.230***	0.247***	0.181***	0.760***
	(0.0784)	(0.0719)	(0.0679)	(0.0727)	(0.0660)	(0.0838)
MIDWEST*POST90	-0.0376	-0.0464	-0.0242	-0.0467	-0.0195	-0.121
	(0.0392)	(0.0340)	(0.0308)	(0.0349)	(0.0343)	(0.0647)

Table 29 continued

Dependent Variable	Z_1	Z_3	Z_4	Z_2	Z_2	FPLUS
Model	OLS	OLS	OLS	OLS	OLS	Ordered Probit
	(1)	(2)	(3)	(4)	(5)	(6)
MODES	-0.0135	-0.0116	-0.0130	-0.0143	-0.0109	0.0103
	(0.0102)	(0.00995)	(0.00970)	(0.0103)	(0.00998)	(0.0240)
ACCIDENTS	-0.524***	-0.494***	-0.517***	-0.513***		-0.182
	(0.146)	(0.134)	(0.121)	(0.135)		(0.670)
WEST	-0.0192	-0.00584	-0.0105	-0.00218		0.296***
	(0.0333)	(0.0314)	(0.0312)	(0.0311)		(0.0470)
INTERIOR	-0.0857**	-0.0823**	-0.0773**	-0.0861***		0.492***
	(0.0360)	(0.0327)	(0.0322)	(0.0326)		(0.0527)
PHASE1						-0.0749
						(0.0464)
MIDWEST						-0.174***
						(0.0494)
Constant	0.137***	0.143***	0.162***	0.146***	-0.524***	
	(0.0265)	(0.0242)	(0.0233)	(0.0246)	(0.0920)	
Cut 1						-2.108***
						(0.0863)
Cut 2						1.237***
						(0.0853)
Year FE	Y	Y	Y	Y	Y	-
Plant FE	Y	Y	Y	Y	Y	-
Coal County FE	N	N	N	N	Y	-
Year Indicator variables	-	-	-	-	-	Y
Observations	10,181	11,694	12,248	11,510	11,942	10,595
R-squared	0.210	0.181	0.171	0.186	0.269	-
Pseudo R-Squared	-	-	-	-	-	0.18
Log Likelihood						-5055.557
Number of plants clustered over	304	309	309	307	308	-

Standard errors in parentheses clustered by plant. ** p< 0.05, *** p< 0.01.

Table 30: Marginal Effects from the Ordered Probit model

	Probability of choosing		
	Fixed Price (1)	Escalator (2)	Cost Plus (3)
ACT	-0.0535***	0.0223***	0.0312***
	(0.0101)	(0.00225)	(0.00836)
HEARING	0.00355	-0.00213	-0.00142
	(0.0177)	(0.0108)	(0.00697)
FUEL	0.0440***	-0.0286***	-0.0154***
	(0.00812)	(0.00574)	(0.00249)
MINE-MOUTH	-0.113***	-0.0170	0.130***
	(0.00912)	(0.0198)	(0.0285)
WEST	0.0599***	-0.0406***	-0.0193***
	(0.0102)	(0.00770)	(0.00266)
INTERIOR	0.106***	-0.0772***	-0.0289***
	(0.0128)	(0.0106)	(0.00257)
DEDICATE	-0.0610***	0.0370***	0.0239***
	(0.00704)	(0.00465)	(0.00292)
REPEAT	-0.147***	0.111***	0.0354***
	(0.0103)	(0.00907)	(0.00199)
PHASE1*POST90	-0.0296**	0.0154***	0.0142**
	(0.0126)	(0.00560)	(0.00708)
PHASE1*POST90*MIDWEST	0.183***	-0.149***	-0.0340***
	(0.0241)	(0.0223)	(0.00232)
MIDWEST*POST90	-0.022	0.0121**	0.00989
	(0.0115)	(0.00581)	(0.00570)
MODES	0.00192	-0.00114	-0.000785
	(0.00449)	(0.00266)	(0.00183)
ACCIDENTS	-0.0340	0.0201	0.0139
	(0.125)	(0.0741)	(0.0511)
PHASE1	-0.0138	0.00797	0.00584
	(0.00844)	(0.00475)	(0.00370)
MIDWEST	-0.0323***	0.0185***	0.0137***
	(0.00903)	(0.00502)	(0.00407)
Observations	10,595	10,595	10,595

Standard errors for marginal effects calculated using the delta method, using the model in Column 6 of Table 29. ** p<0.05, *** p<0.01.

Table 31: Regulation, Restructuring and Contracts: Effects on Prices

Dependent Variable	Delivered Prices ($/ton)					
Estimation Method	OLS	OLS	IV GMM	IV GMM	IV GMM	IV GMM
	(1)	(2)	(3)	(4)	(5)	(6)
ACT	-1.022	-0.792	-2.387**	-1.292		-1.594*
	(0.762)	(0.774)	(1.120)	(0.823)		(0.835)
HEARING	1.783***	1.729***	2.001**	1.065		1.190
	(0.666)	(0.662)	(0.901)	(0.771)		(0.771)
ACT NEW					0.595	
					(1.397)	
HEARING NEW					1.212	
					(1.001)	
FUEL	2.257***					0.0974
	(0.550)					(0.912)
FUEL NEW		-1.471**	-2.390**	-2.485***	-2.638***	
		(0.642)	(1.114)	(0.615)	(0.604)	
PRICE ORDER			-4.319***	-2.073***	-2.186**	-1.983***
			(0.678)	(0.762)	(0.851)	(0.740)
LENGTH				0.550***	0.545***	0.576***
				(0.132)	(0.137)	(0.131)
Constant	-28.09***	-37.15***				
	(8.366)	(7.997)				
Control Variables	Y	Y	Y	Y	Y	Y
Observations	10,442	10,442	9,899	9,899	9,899	9,899
R-squared	0.417	0.417	0.185	0.343	0.337	0.338
# Plants	318	318	304	304	304	304

Standard errors, clustered by plant, in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Control variables include *QUANTITY*, *WEST*, *INTERIOR*, *COST*, *MODES*, *ACCIDENTS*, *TOTAL DISTANCE*, *RESERVES*, interactions of *RESERVES* with *WEST*, *INTERIOR*, *BTUS Shipped*, *SULFUR Shipped*, *ASH Shipped* and *MOISTURE Shipped*. In addition, OLS regressions include Plant and Year fixed effects. IV regressions include Plant fixed effects and year indicator variables.

Table 32: Regulation, Restructuring and Contracts: Effects on Prices (First Stage Results)

	New Contracts (Fuel)		New Contracts (Fuel, Restructuring)		All Contracts	
	PRICE ORDER	LENGTH	PRICE ORDER	LENGTH	PRICE ORDER	LENGTH
	(1)	(2)	(3)	(4)	(5)	(6)
REPEAT	-0.436***	1.11***	-0.410***	1.163***	-0.442***	1.037***
	(0.062)	(0.188)	(0.062)	(0.187)	(0.062)	(0.191)
DEDICATE	-0.170***	0.028	-0.151***	0.051	-0.171***	0.011
	(0.054)	(0.214)	(0.054)	(0.215)	(0.053)	(0.212)
DEDICATE	0.005***	-0.004	0.004***	-0.005	0.005***	-0.004
_SQUARED	(0.001)	(0.004)	(0.001)	(0.005)	(0.001)	(0.004)
PLANT	-0.112***	1.616***	-0.112***	1.620***	-0.112***	1.576***
DEDICATE	(0.039)	(0.191)	(0.039)	(0.191)	(0.039)	(0.186)
Observations	9,899		9,899		9,899	
Weak Identification						
Kleibergen Wald F-Statistic	9.389		9.281		9.952	
Underidentification test						
Kleibergen-Paap LM statistic	25.941		22.575		27.92	
p-value	< 0.001		< 0.001		< 0.001	
Overidentification test						
Hansen J-Statistic	0.914		1.063		0.948	
p-value	0.633		0.587		0.622	

Standard errors, clustered by plant, in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Appendix

Table 33: Restructuring, Regulation and Coal Prices: Full Results

Dependent Variable	Delivered Prices ($/ton)					
Estimation Method	OLS	OLS	IV, GMM	IV, GMM	IV, GMM	IV, GMM
	(1)	(2)	(3)	(4)	(5)	(6)
ACT	-1.022	-0.792	-2.387**	-1.292		-1.594*
	(0.762)	(0.774)	(1.120)	(0.823)		(0.835)
HEARING	1.783***	1.729***	2.001**	1.065		1.190
	(0.666)	(0.662)	(0.901)	(0.771)		(0.771)
ACT NEW					0.595	
					(1.397)	
HEARING NEW					1.212	
					(1.001)	
FUEL	2.257***					0.0974
	(0.550)					(0.912)
FUEL NEW		-1.471**	-2.390**	-2.485***	-2.638***	
		(0.642)	(1.114)	(0.615)	(0.604)	
PRICE ORDER			-4.319***	-2.073***	-2.186**	-1.983***
			(0.678)	(0.762)	(0.851)	(0.740)
LENGTH				0.550***	0.545***	0.576***
				(0.132)	(0.137)	(0.131)
QUANTITY	0.0214**	0.0212**	-0.00923*	-0.0130**	-0.0132**	-0.0128**
	(0.00931)	(0.00920)	(0.00504)	(0.00551)	(0.00557)	(0.00545)
WEST	-0.339	-0.353	-1.456	-3.446*	-3.306*	-3.523*
	(1.827)	(1.841)	(2.185)	(1.959)	(1.953)	(1.962)
INTERIOR	1.237	0.978	0.973	0.257	0.197	0.304
	(1.049)	(1.050)	(1.308)	(1.105)	(1.113)	(1.124)
COST	0.0683	0.236**	0.491***	0.252*	0.257**	0.160
	(0.0945)	(0.0919)	(0.137)	(0.129)	(0.131)	(0.107)
MODES	0.284	0.250	0.326	0.251	0.242	0.240
	(0.239)	(0.242)	(0.258)	(0.218)	(0.217)	(0.221)

Table 33 Continued

Estimation Method	OLS	OLS	IV, GMM	IV, GMM	IV, GMM	IV, GMM
	(1)	(2)	(3)	(4)	(5)	(6)
ACCIDENTS	13.73***	14.89***	5.291	5.349	5.128	4.320
	(4.586)	(4.608)	(5.228)	(4.847)	(4.881)	(4.879)
TOTAL DISTANCE	0.0816	0.0959	0.139	0.186*	0.181*	0.164
	(0.109)	(0.109)	(0.112)	(0.100)	(0.101)	(0.100)
RESERVES	0.294	0.292	0.449**	-0.127	-0.103	-0.148
	(0.199)	(0.206)	(0.222)	(0.248)	(0.258)	(0.246)
WEST*RESERVES	-0.762***	-0.789***	-0.825**	-0.0693	-0.0962	-0.0479
	(0.257)	(0.263)	(0.322)	(0.316)	(0.327)	(0.309)
INTERIOR*RESERVES	-1.885***	-1.696**	-2.767***	-2.033***	-2.005***	-2.173***
	(0.656)	(0.659)	(0.823)	(0.747)	(0.757)	(0.760)
BTUS SHIPPED	4.667***	4.622***	4.736***	4.795***	4.804***	4.764***
	(0.419)	(0.421)	(0.441)	(0.427)	(0.428)	(0.428)
SULFUR SHIPPED	-1.277***	-1.211***	-1.398***	-1.180***	-1.205***	-1.229***
	(0.286)	(0.281)	(0.310)	(0.291)	(0.295)	(0.297)
ASH SHIPPED	0.157	0.135	0.145	0.124	0.131	0.124
	(0.104)	(0.104)	(0.103)	(0.102)	(0.102)	(0.103)
MOISTURE SHIPPED	0.0546	0.0449	0.0768	0.0473	0.0460	0.0442
	(0.113)	(0.113)	(0.124)	(0.117)	(0.118)	(0.117)
Constant	-28.09***	-37.15***				
	(8.366)	(7.997)				
Plant FE	Y	Y	Y	Y	Y	Y
Year FE	Y	Y	-	-	-	-
Year Indicator	-	-	Y	Y	Y	Y
Observations	10,442	10,442	9,899	9,899	9,899	9,899
R-squared	0.417	0.417	0.185	0.343	0.337	0.338
# Plants	318	318	304	304	304	304

Standard errors, clustered by plant, in parentheses. *** p<0.01, ** p<0.05, * p<0.10.

Table 34: Summary Statistics

Variable	Observations	Mean	Standard Deviation	Min	Max	Source	Description
Delivered Price	14587	36.59	12.42	0.31	306.82	CTRDB	Price Paid at the Plant, Free on Board, $/ton
QUANTITY	13489	10.11	16.773	0.001	616	CTRDB	Total BTUs delivered by the contract, obtained by multiplying tons shipped with BTU content of coal shipped
DISTANCE	14260	4.65	5.435	0	120.40	CTRDB	Total distance involved in shipping coal, in hundreds of miles
COST	14271	100.56	23.60	56	141	BLS	Employment cost index from Table 7, Bulletin 2532, Bureau of Labor Statistics, September 2000
MODES	14777	1.39	0.66	0	4	CTRDB	Number of distinct modes used for transporting coal
ACCIDENTS	14223	0.007	0.03	9.34E-07	0.381	FRA	Accidents per track mile, for state where mine is located
WEST	14777	0.20	0.40	0	1	CTRDB	Dummy variable, equals 1 if coal is western coal, zero otherwise
INTERIOR	14777	0.13	0.33	0	1	CTRDB	Dummy variable, equals 1 if coal is from the interior, zero otherwise
EAST	14777	0.66	0.47	0	1	CTRDB	Dummy variable, equals 1 if coal is from the Appalachian region, zero otherwise
REPEAT	14777	0.848	0.358	0	1	CTRDB	Indicator variable for whether the plant and the supplier contracted with each other in the past

Summary statistics, Table 34 continued

Variable	Observ ations	Mean	Standard Deviation	Min	Max	Source	Description
DEDICATE	13490	0.646	0.537	1.50e-05	42.083	CTRDB	Ratio of quantity within the specific plant-supplier contract to quantity for all contracts the supplier holds
PLANT DEDICATE	14083	0.690	0.850	0	13.4	CTRDB	Ratio of quantity within the specific plant-supplier contract to quantity for all contracts the plant holds
RESERVES	14372	2.067	1.862	0.001	7.22	EIA	Total reserves, in billion short tons, for each coal producing state, by year
BTUS SHIPPED	14753	11657.85	1657.176	373	96000	CTRDB	Total BTUs shipped, by contract
SULFUR SHIPPED	14754	1.377	1.222	0.09	87	CTRDB	Total Shipped Sulfur, per contract
ASH SHIPPED	14754	9.601	3.121	1.05	74.4	CTRDB	Shipped ash content, per contract
MOISTURE SHIPPED	12868	10.829	7.842	2.11	42.64	CTRDB	Shipped moisture, per contract

Table 35: PRICE ORDER definition

0	Cost-Plus contract
1	Price Renegotiation
2	Escalator + Price Renegotiation
3	Escalator contract
4	Escalator + Price tied to market
5	Price tied to market
6	Fixed price contract

Appendix

Appendix I: Data description

The main dataset I use is the Coal Transportation Rate Database (CTRDB)[14]. In addition to this, I take data from several other sources. Information on railroad statistics comes from the Federal Railroad Authority[15]. Information on electricity restructuring is taken from wesbites maintained by Energy Information Administration[16].

I use the Environment Protection Agency's website[17] to delineate power plants in the Coal Transportation Rate Database by phase status[18]. Table 2 lists descriptive statistics and explanations for the variables I use.

[14]This data is available at http://www.eia.gov/cneaf/coal/ctrdb/database.html. FERC form 580, which surveys fuel and energy purchases by utilities, forms the basis for this dataset. The survey is held once every two years, and all investor-owned utilities that own at least one generating station of 50 MW or more are required to respond. These utilities sell power at wholesale rates to other utilities.

[15]I obtained this by running online queries at http://safetydata.fra.dot.gov/OfficeofSafety/Default.aspx.

[16]http://www.eia.gov/cneaf/electricity/page/restructuring/restructure_elect.html.

[17]I used the EPA's Air Markets Programs Data system, available at http://ampd.epa.gov/ampd to obtain the relevant information.

[18]Title IV of the Clean Air Act Amendment details the provisions for enactment of the SO_2 trading scheme. Under this Title, a total of 110 power plants are included as Phase 1 plants. Each power plant is assigned a unique identifying code. I use this code, called the plant code, to match the data in the Coal Transportation Rate Database with the information provided by the EPA's website. After matching, I obtain a total of 110 Phase 1 plants in the CTRDB.

Table 36: List of Appendices

Number	Title
I	Data Description
II	Pre-Trend Tests
III	Sample specification checks for all Pricing dependent variables (Z_1, Z_2, Z_3, Z_4)
IV	Altered definition of ACCIDENTS
V	Considering only Midwest and East Coast Plants
VI	Scrubber Adoption
VII	Including additional coal characteristics
VIII	Alternative measures of transportation changes
IX	Other explanatory variables
X	Excluding the state of Texas
XI	Instrumental Variables technique of Kozhevnikova-Lange (2009), replicated
XII	Results from a Seemingly Unrelated Regression, considering contract length and pricing as endogenous variables
XIII	Impact of Clustering, Fixed Effects and additional explanatory variables
XIV	Comparing estimates to related studies

I took a number of steps to ensure these data were accurate and reliable. The dataset includes a unique identifying code for each contract. This contract code, together with the plant code and year, identifies each observation in the data I eventually use for the analysis. In any given year, there were a number of duplicate observations, that is, in the same year two (or more) observations share the same entries; I exclude such duplicate entries. I dropped observations for which any or all of the following conditions held: the length of the contract was negative or greater than 100, the year signed or the year of expiry was equal to zero or the year of expiry was set before 1979, the year the dataset begins. Finally, I exclude years 1988 and 1989, since for these years contract pricing structure information was not reliably collected.

After these, there are 4,675 contract - plant observations, observed over a period of 20 years, with 14,777 total number of observations[19]. For a number of plants, multiple years of data were not available. In total, 343 plants had data for more than one year; this number therefore forms the upper bound for the total number of plants reported in the regression results. The total number of Phase I plants was 110, out of these data existed in more than one year for 89 plants.

Appendix II: Pre-Trend tests

For the first, I only include data till the commencement of treatment (1990), drop the first two terms on equation(2.1) and include separate year dummy variables for Phase I and Phase II plants. The equation I estimate is[20]:

[19]This is not equal to the product of the contract-plant by year as a change in pricing arrangement implies a change in contract code, and two years (1988, 1989) are omitted.

[20]Z_1, Z_2, Z_3 and Z_4 are the outcome variables I employ. The explanatory variables I

$$Z_{cpy} = \sum_{y=1979}^{1990} \beta_{1y} * PHASE1_{py} + \sum_{y=1979}^{1990} \beta_{2y} * (1 - PHASE1_{py}) + \Delta * X_{cpy} + \epsilon_{cpy} \quad (4.1)$$

I then jointly test whether the coefficients for the control and treatment year dummies are significantly different from each other:

$$H_0 : \beta_{1y} - \beta_{2y} = 0 \forall y = 1979...1990, y \neq 1988, 1989 \quad (4.2)$$

In the third test, I again only include data till 1990, drop the first two terms from equation(4.1) but this time include a time trend interacted with PHASE1 and MIDWEST. If the coefficient on the interactions of the time trend, PHASE1 and MIDWEST is statistically insignificant, then we may conclude that there is little difference between Phase I and Phase II plants before the Amendment was announced. The equation I estimate is[21]:

$$Z_{cpy} = \gamma_1 * TREND_y + \gamma_2 * PHASE1_p * TREND_y + \gamma_3 * PHASE1_p * MIDWEST_p * TREND_y + \gamma_4 * MIDWEST_p * TREND_y + \Delta * X_{cpy} + \lambda_p + \epsilon_{cpy} \quad (4.3)$$

where TREND equals 1978 subtracted from the year the contract is observed

use are MINE-MOUTH, WEST, INTERIOR, MODES, ACCIDENTS, BTU, SULF and ASH along with the year dummies for treatment and control groups.

[21] As before, Z_1, Z_2, Z_3 and Z_4 are the outcome variables I employ; the other explanatory variables I use are MINE-MOUTH, WEST, INTERIOR, MODES, ACCIDENTS, BTU, SULF and ASH. For this test, I also include plant fixed effects.

in (for 1990, the value of TREND equals 10 since 1988 and 1989 are excluded), and the test is

$$H_0 : \gamma_2 = 0, \gamma_3 = 0, \gamma_4 = 0 \tag{4.4}$$

Before turning to the formal analysis, it is perhaps instructive to observe differences among Phase I and Phase II plants in terms of their contracting behavior. Preceeding the Amendment both Phase I and Phase II plants share very similar propensities to write fixed price contracts, and after the announcement, Phase I shows a far higher propensity to do so. Further, while the cross-plant differences in this variable are not significant before 1990, these do become signficant after 1990.

In terms of the type of coal being sourced, I observe a very stark increase in the use of western coal for Phase I plants, by 10 percentage points, with a resulting decline in the average sulfur content. Phase I plants also tended to source a greater quantity of coal, on average, before the Amendment, indicating their larger size. Such cross-plant differences make the use of a two-way fixed effect model imperative[22].

Panel A of Table 37 reports the results of the first test (Equation 4.1). All standard errors employed for estimating equation 4.1 were clustered at the plant level. We observe that for all definitions, the null hypothesis of equal effect cannot be rejected at conventional levels of significance.

Panel B reports the result of a similar test, only this time I compare Phase 1 plants by location. That is, I compare Phase 1 plants located in the

[22] A more detailed description of these trends is available on request.

midwest to Phase 1 plants located on the east coast, and carry out the same test as above. We can see that once again, the null hypothesis of equal effect across these two groups cannot be rejected.

Panel C of Table 37 reports the results of the third test (Equation 4.3). Once again, all standard errors used to estimate equation 4.3 are clustered by plant. For all definitions, the null hypothesis cannot be rejected. On the basis of these tests, we may conclude both Phase I and Phase II plants show similar trends in terms of contract pricing structure before the Amendment was announced.

Table 37: Appendix II: Pre-Trend tests

	Z_1	Z_2	Z_3	Z_4
Panel A: Test #1				
F-Statistic	0.26	0.49	0.49	0.35
p-value	0.98	0.88	0.87	0.95
Panel B: Test #2				
F-Statistic	1.48	1.49	1.47	1.79
p-value	0.15	0.15	0.15	0.07
Observations	4930	5654	5764	5965
Number of Plants	295	302	305	305
Plant FE	Y	Y	Y	Y
Panel C: Test #3				
TREND	0.0209***	0.0174***	0.0167***	0.0158***
	(0.0057)	(0.0048)	(0.0047)	(0.0045)
PHASE1*TREND	-0.0020	-0.0027	-0.0021	-0.0035
	(0.0086)	(0.0067)	(0.0066)	(0.0057)
PHASE1*MIDWEST* TREND	0.0026	0.0033	0.0027	0.0038
	(0.0099)	(0.008)	(0.008)	(0.0073)
MIDWEST*TREND	-0.0135**	-0.0105	-0.0098	-0.0085
	(0.0063)	(0.0054)	(0.0053)	(0.0051)
R-Squared	0.076	0.060	0.058	0.055
Observations	4846	5568	5678	5879
Number of Plants	282	288	291	291
Plant FE	Y	Y	Y	Y

In all the regressions, standard errors are clustered by plant. For Panel C, standard errors for the estimated coefficients are in parentheses below the estimated coefficients. *** $p< 0.01$, ** $p<0.05$.

Appendix III: Sample specification checks, full results

In this section, I list out the full results of running the sample specification checks for all pricing outcome variables Z_1, Z_2, Z_3 and Z_4. As we can see, there is little difference amongst the various pricing outcome measures, in terms of these checks.

Table 38: Sample specification: Include years until 1996

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0834	-0.0692	-0.0649	-0.0573
	(0.0485)	(0.0404)	(0.0397)	(0.0329)
PHASE1*POST90*MIDWEST	0.208**	0.214***	0.211***	0.199***
	(0.0810)	(0.0736)	(0.0730)	(0.0681)
POST90*MIDWEST	-0.0153	-0.00891	-0.00655	0.0110
	(0.0448)	(0.0372)	(0.0363)	(0.0324)
RESTRUCTURE	0.00268	0.0115	0.0133	0.00738
	(0.0793)	(0.0787)	(0.0753)	(0.0683)
MODES	-0.0107	-0.0154	-0.0140	-0.0148
	(0.0106)	(0.0104)	(0.0101)	(0.00980)
ACCIDENTS	-0.403***	-0.399***	-0.392***	-0.407***
	(0.135)	(0.123)	(0.122)	(0.111)
MINE-MOUTH	-0.0176	-0.0289	-0.0264	-0.0487
	(0.0437)	(0.0376)	(0.0370)	(0.0477)
WEST	0.0122	0.0295	0.0281	0.0265
	(0.0411)	(0.0390)	(0.0390)	(0.0383)
INTERIOR	-0.0530	-0.0612	-0.0603	-0.0569
	(0.0416)	(0.0355)	(0.0356)	(0.0348)

Table 38 continued

	Z_1	Z_2	Z_3	Z_4
REPEAT	-0.0921***	-0.0882***	-0.0868***	-0.0908***
	(0.0133)	(0.0126)	(0.0124)	(0.0125)
DEDICATE	-0.0746**	-0.0734**	-0.0704**	-0.0885**
	(0.0375)	(0.0350)	(0.0342)	(0.0352)
DEDICATE_SQUARED	0.0264	0.0277	0.0255	0.0338
	(0.0257)	(0.0225)	(0.0219)	(0.0225)
BTU	0.00227	-0.000997	-0.000679	-0.00133
	(0.00372)	(0.00341)	(0.00336)	(0.00312)
SULF	-0.0114**	-0.00976**	-0.00969**	-0.00966**
	(0.00438)	(0.00415)	(0.00411)	(0.00407)
ASH	-0.00106	0.000106	0.000146	0.000517
	(0.00332)	(0.00290)	(0.00279)	(0.00265)
Constant	0.171***	0.186***	0.179***	0.196***
	(0.0325)	(0.0304)	(0.0300)	(0.0293)
Plant F.E	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	8,128	9,233	9,394	9,868
R-squared	0.134	0.115	0.113	0.106
Number of Plants	297	300	302	302

Standard errors are in parentheses. ** p< 0.05, *** p< 0.01..

Table 39: Sample specification: Including all years

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.125***	-0.0926**	-0.0879**	-0.0785**
	(0.0477)	(0.0433)	(0.0424)	(0.0354)
PHASE1*POST90*MIDWEST	0.268***	0.255***	0.251***	0.237***
	(0.0821)	(0.0757)	(0.0747)	(0.0698)
POST90*MIDWEST	-0.0760	-0.0723	-0.0701	-0.0423
	(0.0447)	(0.0391)	(0.0380)	(0.0337)
RESTRUCTURE	-0.0533	-0.0761	-0.0780	-0.0861**
	(0.0432)	(0.0430)	(0.0421)	(0.0413)
MODES	-0.0154	-0.0171	-0.0141	-0.0154
	(0.0102)	(0.0104)	(0.0101)	(0.00978)
ACCIDENTS	-0.514***	-0.519***	-0.503***	-0.525***
	(0.146)	(0.135)	(0.134)	(0.122)
MINE-MOUTH	-0.0367	-0.0375	-0.0286	-0.0450
	(0.0529)	(0.0415)	(0.0388)	(0.0481)
WEST	-0.0267	-0.0102	-0.0129	-0.0167
	(0.0335)	(0.0317)	(0.0318)	(0.0316)
INTERIOR	-0.0835**	-0.0777**	-0.0748**	-0.0691**
	(0.0368)	(0.0339)	(0.0338)	(0.0332)

Table 39 continued

	Z_1	Z_2	Z_3	Z_4
REPEAT	-0.123***	-0.116***	-0.116***	-0.123***
	(0.0131)	(0.0125)	(0.0123)	(0.0127)
DEDICATE	-0.0235	-0.0172	-0.0179	-0.0293
	(0.0215)	(0.0213)	(0.0212)	(0.0211)
DEDICATE_SQUARED	-0.0183**	-0.0199**	-0.0192**	-0.0164*
	(0.00784)	(0.00823)	(0.00833)	(0.00891)
BTU	0.000767	-0.00366	-0.00337	-0.00406
	(0.00380)	(0.00360)	(0.00358)	(0.00333)
SULF	-0.00903**	-0.0115**	-0.0111**	-0.0112***
	(0.00450)	(0.00449)	(0.00445)	(0.00427)
ASH	-0.00158	7.08e-05	0.000378	0.00194
	(0.00379)	(0.00335)	(0.00323)	(0.00314)
Constant	0.222***	0.670***	0.653***	0.661***
	(0.0358)	(0.0459)	(0.0451)	(0.0452)
Plant F.E	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	9,920	11,214	11,398	11,952
R-squared	0.203	0.184	0.179	0.171
Number of plantcode	302	305	307	307

Standard errors are in parentheses. ** p< 0.05, *** p< 0.01..

Table 40: Sample Specification: Excluding spot contracts

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.00293	-0.00509	-0.00471	-0.00280
	(0.0272)	(0.0220)	(0.0218)	(0.0175)
PHASE1*POST90*MIDWEST	0.0704	0.0818*	0.0815*	0.0776*
	(0.0532)	(0.0494)	(0.0493)	(0.0459)
POST90*MIDWEST	0.0453*	0.0433*	0.0437*	0.0440**
	(0.0261)	(0.0225)	(0.0224)	(0.0201)
RESTRUCTURE	-0.124*	-0.114*	-0.114*	-0.115*
	(0.0662)	(0.0635)	(0.0635)	(0.0616)
MODES	-0.00454	-0.00634	-0.00610	-0.00601
	(0.00826)	(0.00725)	(0.00698)	(0.00692)
ACCIDENTS	-0.109	-0.0925	-0.0931	-0.144*
	(0.0815)	(0.0729)	(0.0728)	(0.0748)
MINE-MOUTH	-0.0154	-0.0114	-0.0115	-0.0222
	(0.0345)	(0.0298)	(0.0297)	(0.0346)
WEST	0.0231	0.0315	0.0313	0.0300
	(0.0352)	(0.0351)	(0.0351)	(0.0339)
INTERIOR	-0.0912**	-0.0879***	-0.0878***	-0.0848***
	(0.0394)	(0.0314)	(0.0314)	(0.0305)

Table 40 continued

	Z_1	Z_2	Z_3	Z_4
REPEAT	-0.0275**	-0.0268***	-0.0264***	-0.0267***
	(0.0106)	(0.00955)	(0.00925)	(0.00886)
DEDICATE	-0.0225	-0.0321	-0.0316	-0.0366*
	(0.0253)	(0.0211)	(0.0210)	(0.0211)
DEDICATE_SQUARED	0.000538	0.00701	0.00657	0.00880
	(0.0165)	(0.0123)	(0.0122)	(0.0122)
BTU	6.65e-06	-0.00226	-0.00203	-0.00224
	(0.00283)	(0.00250)	(0.00244)	(0.00226)
SULF	-0.00457	-0.00321	-0.00330	-0.00370
	(0.00527)	(0.00480)	(0.00474)	(0.00504)
ASH	-0.000952	-0.00136	-0.00132	-0.000898
	(0.00245)	(0.00227)	(0.00218)	(0.00205)
Constant	0.0858***	0.0995***	0.0966***	0.0999***
	(0.0260)	(0.0240)	(0.0235)	(0.0227)
Plant F.E	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	5,489	6,365	6,495	6,871
R-squared	0.069	0.063	0.063	0.061
Number of plantcode	279	285	288	289

Standard errors are in parentheses. ** p< 0.05, *** p< 0.01..

Table 41: Sample Specification: Including control for local coal protectionism efforts

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0295	-0.0237	-0.0206	-0.0243
	(0.0661)	(0.0590)	(0.0585)	(0.0467)
PHASE1*POST90*MIDWEST	0.163**	0.174**	0.172**	0.167**
	(0.0814)	(0.0741)	(0.0736)	(0.0684)
POST90*MIDWEST	0.0122	0.0147	0.0164	0.0282
	(0.0454)	(0.0376)	(0.0368)	(0.0336)
RESTRUCTURE	-0.306**	-0.289**	-0.288**	-0.286**
	(0.121)	(0.118)	(0.118)	(0.117)
MODES	-0.00296	-0.00852	-0.00740	-0.00789
	(0.0110)	(0.0106)	(0.0104)	(0.0101)
ACCIDENTS	-0.402***	-0.402***	-0.399***	-0.410***
	(0.135)	(0.122)	(0.122)	(0.109)
MINE-MOUTH	-0.0232	-0.0383	-0.0387	-0.0612
	(0.0435)	(0.0370)	(0.0371)	(0.0472)
WEST	0.0157	0.0298	0.0293	0.0272
	(0.0436)	(0.0411)	(0.0411)	(0.0403)
INTERIOR	-0.0602	-0.0686*	-0.0685*	-0.0651*
	(0.0419)	(0.0355)	(0.0356)	(0.0347)

Table 41 continued

	Z_1	Z_2	Z_3	Z_4
REPEAT	-0.0820***	-0.0771***	-0.0755***	-0.0787***
	(0.0133)	(0.0126)	(0.0123)	(0.0124)
DEDICATE	-0.0739**	-0.0749**	-0.0725**	-0.0878***
	(0.0343)	(0.0324)	(0.0318)	(0.0332)
DEDICATE_SQUARED	0.0209	0.0232	0.0215	0.0281
	(0.0225)	(0.0201)	(0.0196)	(0.0204)
BTU	0.00339	0.000539	0.000727	-0.000131
	(0.00392)	(0.00347)	(0.00342)	(0.00319)
SULF	-0.0119***	-0.00997**	-0.0100**	-0.0105**
	(0.00447)	(0.00427)	(0.00424)	(0.00419)
ASH	-0.00232	-0.00123	-0.00123	-0.000484
	(0.00320)	(0.00284)	(0.00273)	(0.00263)
PROTECT*POST90	-0.0357	-0.0318	-0.0315	-0.0237
	(0.0704)	(0.0642)	(0.0640)	(0.0561)
Constant	0.257***	0.251***	0.243***	0.226***
	(0.0380)	(0.0361)	(0.0350)	(0.0351)
Plant FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	7,660	8,709	8,864	9,303
R-squared	0.126	0.110	0.108	0.103
Number of plantcode	292	296	299	299

Standard errors are in parentheses. ** p< 0.05, *** p< 0.01..

Table 42: Sample Specification: Including utility fixed effects

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0383	-0.0337	-0.0307	-0.0295
	(0.0500)	(0.0422)	(0.0417)	(0.0349)
PHASE1*POST90*MIDWEST	0.156	0.171**	0.170**	0.164**
	(0.0825)	(0.0748)	(0.0744)	(0.0696)
POST90*MIDWEST	0.0156	0.0169	0.0184	0.0303
	(0.0461)	(0.0381)	(0.0374)	(0.0341)
RESTRUCTURE	-0.311***	-0.294**	-0.292**	-0.291**
	(0.119)	(0.115)	(0.116)	(0.114)
MODES	-0.00265	-0.00831	-0.00717	-0.00767
	(0.0110)	(0.0107)	(0.0104)	(0.0101)
ACCIDENTS	-0.491***	-0.473***	-0.470***	-0.492***
	(0.160)	(0.145)	(0.145)	(0.147)
MINE-MOUTH	-0.0222	-0.0372	-0.0376	-0.0602
	(0.0432)	(0.0370)	(0.0371)	(0.0473)
WEST	0.0199	0.0332	0.0327	0.0304
	(0.0442)	(0.0414)	(0.0414)	(0.0407)
INTERIOR	-0.0594	-0.0679	-0.0679	-0.0645
	(0.0417)	(0.0352)	(0.0352)	(0.0345)

Table 42 continued

	Z_1	Z_2	Z_3	Z_4
REPEAT	-0.0812***	-0.0762***	-0.0747***	-0.0779***
	(0.0134)	(0.0126)	(0.0123)	(0.0124)
DEDICATE	-0.0849**	-0.0836**	-0.0812**	-0.0956***
	(0.0359)	(0.0334)	(0.0327)	(0.0340)
DEDICATE_SQUARED	0.0295	0.0298	0.0280	0.0340
	(0.0239)	(0.0208)	(0.0203)	(0.0210)
BTU	0.00283	-3.60e-05	0.000156	-0.000562
	(0.00385)	(0.00341)	(0.00336)	(0.00314)
SULF	-0.0118***	-0.00979**	-0.00985**	-0.0103**
	(0.00448)	(0.00428)	(0.00425)	(0.00419)
ASH	-0.00187	-0.000773	-0.000791	-4.27e-05
	(0.00323)	(0.00287)	(0.00276)	(0.00265)
Constant	0.278***	0.265***	0.251***	0.215***
	(0.0394)	(0.0374)	(0.0368)	(0.0355)
Plant FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Utility FE	Y	Y	Y	Y
Observations	7,660	8,709	8,864	9,303
R-squared	0.137	0.119	0.117	0.111
Number of plantcode	292	296	299	299

Standard errors are in parentheses. ** p< 0.05, *** p< 0.01..

Appendix IV: Alternate definitions of the ACCIDENTS variable

There is a possibility that, as utilities systematically choose suppliers partly due to transportation problems, using a supplier side definition of the risk of accidents (and the concomittant need to renegotiate, with the costs such renegotiation brings) as I have throughout the paper risks endogeneity. I therefore consider three alternate definitions: using a buyer side definition, that is, accidents per track mile in the state the plant is located in (BUYER ACCIDENTS); using an average of the accidents per track mile for the state the mine is located in and the state the plant is located in (ACCIDENTS (Averaged)); and the absolute difference between the accidents per track mile for the state the mine is located in and the accidents per track mile for the state the plant is located in (ACCIDENTS (Difference)).

Mainly the results don't change. The only substantial change is that, BUYER ACCIDENTS, there is an insignificant effect of accidents on structuring contracts. This is entirely understandable as by the time the coal has arrived in the state the plant is located in, any changes are likely to be dealt with far cheaper than if the disruption occured upstream where the supplier is located. Indeed, the third definition (ACCIDENTS (Difference)) is perhaps the most appropriate alternative, as it accounts for any existing ability of the plant and the mine to deal with disruptions. If rail transportation disruptions are frequent, the plant (and the mine) is likely to have developed ways to handle such cases. And, similarly, if disruptions are rare, plants and mines would be far more averse to any disruptions.

Table 43: Replacing ACCIDENTS with BUYER ACCIDENTS

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0481	-0.0489	-0.0455	-0.0410
	(0.0506)	(0.0436)	(0.0429)	(0.0362)
POST90*MIDWEST	0.0326	0.0304	0.0327	0.0461
	(0.0463)	(0.0401)	(0.0395)	(0.0358)
PHASE1*POST90*MIDWEST	0.155*	0.173**	0.171**	0.162**
	(0.0809)	(0.0741)	(0.0736)	(0.0684)
RESTRUCTURE	-0.315***	-0.305**	-0.303**	-0.300**
	(0.119)	(0.119)	(0.119)	(0.119)
MODES	-0.00137	-0.00136	-0.000335	-0.000649
	(0.0105)	(0.00936)	(0.00914)	(0.00893)
BUYER ACCIDENTS	-1.332	-1.029	-1.020	-1.180
	(0.908)	(0.916)	(0.914)	(0.716)
MINE-MOUTH	-0.0140	-0.0286	-0.0291	-0.0523
	(0.0378)	(0.0323)	(0.0324)	(0.0447)
WEST	-0.00431	0.00201	0.00103	1.36e-05
	(0.0380)	(0.0357)	(0.0356)	(0.0351)
INTERIOR	-0.0499	-0.0603*	-0.0598*	-0.0577*
	(0.0395)	(0.0338)	(0.0338)	(0.0332)

Table 43 continued

	Z_1	Z_2	Z_3	Z_4
REPEAT	-0.0828***	-0.0779***	-0.0762***	-0.0785***
	(0.0134)	(0.0127)	(0.0124)	(0.0124)
DEDICATE	-0.0684***	-0.0721***	-0.0714***	-0.0807***
	(0.0190)	(0.0177)	(0.0174)	(0.0180)
DEDICATE_SQUARED	0.0136***	0.0144***	0.0141***	0.0158***
	(0.00383)	(0.00387)	(0.00377)	(0.00410)
BTU	0.00292	0.000256	0.000421	-0.000450
	(0.00392)	(0.00348)	(0.00343)	(0.00319)
SULF	-0.0112**	-0.00940**	-0.00960**	-0.00967**
	(0.00473)	(0.00454)	(0.00455)	(0.00442)
ASH	-0.00242	-0.00155	-0.00148	-0.000717
	(0.00323)	(0.00281)	(0.00270)	(0.00259)
Constant	0.251***	0.243***	0.235***	0.222***
	(0.0384)	(0.0361)	(0.0349)	(0.0351)
Plant F.E	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	7,718	8,736	8,893	9,342
R-squared	0.136	0.122	0.121	0.115
Number of Plants	284	289	291	291

Standard errors are in parentheses. ** p< 0.05, *** p< 0.01..

Table 44: Replacing ACCIDENTS with ACCIDENTS (Average)

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0509	-0.0505	-0.0468	-0.0424
	(0.0509)	(0.0437)	(0.0430)	(0.0362)
POST90*MIDWEST	0.0106	0.00772	0.00969	0.0234
	(0.0463)	(0.0392)	(0.0384)	(0.0347)
PHASE1*POST90*MIDWEST	0.165**	0.183**	0.181**	0.173**
	(0.0819)	(0.0747)	(0.0742)	(0.0690)
RESTRUCTURE	-0.305**	-0.297**	-0.295**	-0.293**
	(0.122)	(0.119)	(0.120)	(0.118)
MODES	-0.00131	-0.000886	4.21e-05	-0.000692
	(0.0114)	(0.0101)	(0.00982)	(0.00957)
ACCIDENTS (Averaged)	-0.795***	-0.744***	-0.739***	-0.774***
	(0.286)	(0.266)	(0.266)	(0.234)
MINE-MOUTH	-0.0250	-0.0378	-0.0384	-0.0611
	(0.0420)	(0.0357)	(0.0358)	(0.0467)
WEST	0.0165	0.0248	0.0244	0.0225
	(0.0441)	(0.0412)	(0.0412)	(0.0405)
INTERIOR	-0.0607	-0.0698**	-0.0697**	-0.0663*
	(0.0417)	(0.0352)	(0.0352)	(0.0345)

Table 44 continued

	Z_1	Z_2	Z_3	Z_4
REPEAT	-0.0818***	-0.0768***	-0.0751***	-0.0782***
	(0.0138)	(0.0129)	(0.0126)	(0.0127)
DEDICATE	-0.0789**	-0.0911***	-0.0886***	-0.104***
	(0.0356)	(0.0330)	(0.0323)	(0.0338)
DEDICATE_SQUARED	0.0212	0.0296	0.0279	0.0346*
	(0.0229)	(0.0206)	(0.0200)	(0.0208)
BTU	0.00355	0.000688	0.000877	-2.84e-05
	(0.00405)	(0.00357)	(0.00351)	(0.00327)
SULF	-0.0117**	-0.00979**	-0.00986**	-0.0103**
	(0.00458)	(0.00438)	(0.00434)	(0.00428)
ASH	-0.00235	-0.00169	-0.00164	-0.000818
	(0.00334)	(0.00291)	(0.00280)	(0.00268)
Constant	0.256***	0.248***	0.239***	0.228***
	(0.0394)	(0.0371)	(0.0359)	(0.0364)
Plant F.E	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	7,387	8,392	8,545	8,984
R-squared	0.127	0.114	0.113	0.108
Number of Plants	284	288	290	290

Standard errors are in parentheses. ** p< 0.05, *** p< 0.01..

Table 45: Replacing ACCIDENTS with ACCIDENTS (Difference)

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0524	-0.0516	-0.0480	-0.0439
	(0.0508)	(0.0436)	(0.0429)	(0.0361)
POST90*MIDWEST	0.00932	0.00582	0.00786	0.0220
	(0.0465)	(0.0393)	(0.0385)	(0.0348)
PHASE1*POST90*MIDWEST	0.165**	0.184**	0.182**	0.174**
	(0.0820)	(0.0747)	(0.0742)	(0.0690)
RESTRUCTURE	-0.304**	-0.297**	-0.295**	-0.292**
	(0.123)	(0.120)	(0.120)	(0.119)
MODES	-0.00126	-0.000823	9.82e-05	-0.000604
	(0.0114)	(0.0101)	(0.00982)	(0.00955)
ACCIDENTS (Difference)	-0.355***	-0.370***	-0.367***	-0.356***
	(0.134)	(0.118)	(0.118)	(0.106)
MINE-MOUTH	-0.0257	-0.0381	-0.0386	-0.0605
	(0.0420)	(0.0357)	(0.0358)	(0.0460)
WEST	0.0156	0.0246	0.0243	0.0218
	(0.0441)	(0.0412)	(0.0412)	(0.0405)
INTERIOR	-0.0601	-0.0694**	-0.0693*	-0.0657*
	(0.0417)	(0.0352)	(0.0352)	(0.0345)

Table 45 continued

	Z_1	Z_2	Z_3	Z_4
REPEAT	-0.0816***	-0.0766***	-0.0748***	-0.0781***
	(0.0138)	(0.0129)	(0.0126)	(0.0127)
DEDICATE	-0.0789**	-0.0913***	-0.0888***	-0.104***
	(0.0356)	(0.0330)	(0.0323)	(0.0338)
DEDICATE_SQUARED	0.0213	0.0297	0.0280	0.0348*
	(0.0229)	(0.0206)	(0.0201)	(0.0209)
BTU	0.00337	0.000548	0.000742	-0.000184
	(0.00405)	(0.00358)	(0.00352)	(0.00328)
SULF	-0.0115**	-0.00972**	-0.00978**	-0.0101**
	(0.00459)	(0.00438)	(0.00434)	(0.00428)
ASH	-0.00226	-0.00157	-0.00152	-0.000710
	(0.00333)	(0.00290)	(0.00279)	(0.00267)
Constant	0.258***	0.249***	0.241***	0.229***
	(0.0392)	(0.0369)	(0.0357)	(0.0363)
Plant F.E	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	7,387	8,392	8,545	8,984
R-squared	0.126	0.114	0.113	0.107
Plants	284	288	290	290

Standard errors are in parentheses. ** p< 0.05, *** p< 0.01..

Appendix V: Only Midwest and East Coast plants

The discussion in the paper proceeds by grouping all non-midwest plants as east coast plants. While the presence of plants more west than the midwest is limited in the data (making about 5% of the total contract data), it is still relevant to check to see if the results are altered by including only east coast and midwest plants. The following table shows the main specification estimated from the sample with only midwest and east coast plants. The results, we can see, do not change appreciably.

Table 46: Only east coast and midwest plants

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0699	-0.0562	-0.0522	-0.0445
	(0.0570)	(0.0477)	(0.0468)	(0.0392)
POST90*MIDWEST	-0.00651	0.00146	0.00387	0.0209
	(0.0532)	(0.0438)	(0.0428)	(0.0380)
PHASE1*POST90*MIDWEST	0.182**	0.188**	0.186**	0.174**
	(0.0859)	(0.0771)	(0.0765)	(0.0706)
RESTRUCTURE	-0.302**	-0.284**	-0.282**	-0.281**
	(0.123)	(0.119)	(0.119)	(0.118)
MODES	-0.00159	-0.00830	-0.00730	-0.00680
	(0.0114)	(0.0111)	(0.0108)	(0.0105)
ACCIDENTS	-0.368***	-0.371***	-0.368***	-0.366***
	(0.134)	(0.121)	(0.121)	(0.108)
MINE-MOUTH	-0.0146	-0.0319	-0.0326	-0.0337
	(0.0488)	(0.0404)	(0.0405)	(0.0426)
WEST	0.0150	0.0299	0.0296	0.0266
	(0.0442)	(0.0415)	(0.0415)	(0.0408)
INTERIOR	-0.0609	-0.0689	-0.0688	-0.0654
	(0.0417)	(0.0353)	(0.0353)	(0.0346)

Table 46 continued

	Z_1	Z_2	Z_3	Z_4
REPEAT	-0.0853***	-0.0797***	-0.0781***	-0.0814***
	(0.0141)	(0.0133)	(0.0130)	(0.0131)
DEDICATE	-0.0631	-0.0636**	-0.0614	-0.0754**
	(0.0335)	(0.0319)	(0.0312)	(0.0328)
DEDICATE_SQUARED	0.0131	0.0160	0.0145	0.0207
	(0.0212)	(0.0192)	(0.0187)	(0.0195)
BTU	0.00469	0.00164	0.00179	0.000760
	(0.00410)	(0.00364)	(0.00358)	(0.00332)
SULF	-0.0115**	-0.00952**	-0.00961**	-0.0101**
	(0.00479)	(0.00457)	(0.00453)	(0.00445)
ASH	-0.00232	-0.00103	-0.00106	-0.000174
	(0.00339)	(0.00298)	(0.00287)	(0.00275)
Constant	0.272***	0.262***	0.253***	0.224***
	(0.0452)	(0.0415)	(0.0401)	(0.0383)
Plant F.E	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	7,060	8,055	8,194	8,623
R-squared	0.131	0.113	0.112	0.106
Number of Plants	259	262	265	265

Standard errors are in parentheses. ** p< 0.05, *** p< 0.01..

Appendix VI: Scrubber adoption

To deal with the emission limits set by the 1990 Clean Air Act Amendment, plants had two options. They could either choose to burn lower sulfur coal resulting immediately in lower emissions, or install scrubbers which would remove most of the harmful particulates from the emissions before these particulates could spread.

The main argument in the paper is that most plants, particularly those in the Midwest chose to burn more lower sulfur coal, particularly learning how to blend western and appalachian coals to produce lower emissions. And, since Phase I plants are expected to confirm to limits earlier, Phase I plants in the Midwest should be more likely to choose the blending strategy. Such a strategy implies a reduction in specialization and the resulting move toward fixed price contracts.

In this appendix I detail scrubber adoption by plants, in terms of their Phase status as well as geographic location. I also explicitly control for the adoption of scrubbers as a robustness check on the existing results. Information on scrubber use is taken from the EPA's website, using the same link as described in the paper to get information on Phase status of the plants.

For some plants I was unable to match the data in the contract dataset to the data on scrubber use. Specifically, the number of plants recorded as either installing or not installing scrubbers is lower than the total number of plants in existence. This is an important caveat to the results I obtain. Nevertheless, I have in total about 200 to 250 plants in any given year, with the average number of plants (in any given year) being 215. By comparison, in the contract dataset I have information on all Phase I plants (a total of 110) and many plants under Phase II (for a combined total of 343)[23]. Thus, although some data is lost when matching the two data sources, much still remains, and arguably much of the variation we are interested in still remains.

In addition, the EPA does not keep records online for many of the years before the passing of the Amendment (information is available for only 1980 and 1985) and for two years after the Amendment passed (that is 1991 and 1992). All data from these years had to be excluded.

In Table 47, I show the adoption of scrubbers in terms of Phase status. We can see that prior to the introduction of the Amendment, Phase I plants were far less likely than Phase II plants to have a scrubber installed, despite emitting more SO_2. For instance, in 1990, nearly 20% of the Phase II plants in the sample have scrubbers installed, compared to only 9% (approximately) of Phase I plants. From 1993 onwards, however, we see a rapid rise in the adoption of scrubbers by Phase I plants. Indeed, by the year 2000 Phase I plants have more scrubbers installed, in relation to the total number of such plants, than Phase II. In absolute terms though, there are always more Phase II plants with scrubbers.

Table 48 shows how adoption of scrubbers varied by the location of the plants. As argued in the main paper, Midwest plants are less likely to employ scrubbers since for them coal blending is a more attractive emission control strategy[24]. We can see this from the table, both in absolute and relative

[23] I require repeated observations - at least a plant has to enter in at least two different years - for any plant to remain within my final sample, which is why a number of plants drop out.

[24] Note I have segmented plants by “Midwest” and “East Coast”. This is not perfectly accurate, as some of the plants not in the midwest may be located in the western or

terms. 22 plants in the midwest are recorded as using scrubbers, while for the east coast, 37 plants are recorded as doing so[25]. In relative terms, by the year 2000, east coast plants are nearly twice as likely to have a scrubber installed.

It is in this sense that the Schmalensee et al (1998) description of "over-investment" can be undersood. East coast plants are likely to have badly under-estimated how cheap coal from the west would become, and installed more scrubbers (while continuing to burn Appalachian coal) than they required. Given that they under-estimated the cheapness of western coal, it is also similarly likely that they did not invest in coal blending technology. Thus when faced with burning cheaper western coal, their hold-up (or at least the potential for hold up) problem increases, resulting in the negative sign found earlier.

Examining the results of the main specification with a control for whether or not a plant installed scrubbers is therefore imperative. I include the variable SCRUBBER, which is an indicator variable for whether or not a plant installed a scrubber in that year, or installed one in previous years. The results are shown in the first four columns of Table 49, for the four definitions of the pricing variable. We see that the main result does not change, however the coefficient on the triple interaction term now increases across

mountain states. Many of the plants in "Non-Midwest", however, are likely to be on the east coast: roughly 95% of all observations in the contract dataset come from east coast and midwest plants. Eliminating "western" plants from the data does not alter the results in any significant manner, as reported in Appendix V.

[25] We would like the data to be consistent - if 22 plants by 1995 in the midwest, the same should show up in following years. However, the scrubber data I appears to have some amount of non-reporting occuring after 1995, which is why the number of midwest plants with installed scrubbers declines. For the regression specification, this is not going to be a problem, as I truncate the data at 1995.

all specifications (in comparison with the main specification). Interestingly, the coefficient for PHASE1*POST90, that is, the impact on east coast plants rises. Although the rise is not enough to make the point estimate statistically significant at the 5% level, it is in fact weakly significant (with a p-value equaling 0.063 for Z_2). SCRUBBER is itself not significant, however, implying that it is the coal blending effect (or the absence of it for east coast plants) that accounts for the main results. The other difference between these specifications and the main specification is the vanishing of statistical significance of the SULF variable.

To examine this further, I include additional interactions, delineating the impact of scrubber adoption by phase status and time of announcement. I report these results in the final column of Table 49. We can see that the coefficient for east coast Phase I plants is now statistically significant at the 5% level of significance, lending strength to the interpretation.

It is important to understand the robustness of these results. I am only using very limited data - only 2 years before the announcement of the Amendment and 3 years afterward - and get very similar results. Scrubbers by themselves appear to play little role in determining the contractual relationship power plants have with coal mines. Controlling for the presence of scrubbers increases the strength of the estimate of those plants that did not undertake coal blending, but realized the cheapness of western coal. Without investing in the appropriate technology to be able to blend western and appalachian coals, these plants anticipate greater hold-up when buying western coal, and entered into escalator contracts.

Midwest plants being closer to western coal, anticipated buying much more western coal, and anticipated the reduction in transport cost as well; therefore, they invested more in coal blending technology which allowed for more flexible switching between suppliers and thus the switch to fixed price contracts. East coast plants were caught unaware, did not make prior investments to blend coals and had to adjust their contracts appropriately to counter the increased hold-up potential.

Table 47: Scrubber Adoption by Phase Status

Year	# Phase II	# Phase I	# Phase II with Scrubbers	# Phase I with Scrubbers	% Phase I with Scrubbers	% Phase II with Scrubbers
1980	168	77	24	4	5.19%	14.29%
1985	179	77	26	6	7.79%	14.53%
1990	195	80	38	7	8.75%	19.49%
1993	183	75	40	6	8.00%	21.86%
1994	191	78	42	13	16.67%	21.99%
1995	185	77	43	16	20.78%	23.24%
1996	145	58	28	13	22.41%	19.31%
1997	145	57	28	12	21.05%	19.31%
1998	135	49	26	12	24.49%	19.26%
1999	133	50	27	12	24.00%	20.30%
2000	98	31	23	8	25.81%	23.47%

Data off a sample of the main CTRDB dataset for where I was able to obtain information on whether plants installed scrubbers or not. Total observations for this dataset equals 10646, and the number of missing observations (for the indicator variable describing the existence or not of a scrubber) equals 2406. Therefore, a total of 8240 observations were used to construct this table. This will differ from the total number of observations reported in the auxillary regression table in this section of the Appendix as the regressions only consider data until 1995.

Table 48: Adoption of Scrubbers, by Location

Year	# East Coast	# Midwest	# East Coast with Scrubbers	# Midwest with Scrubbers	% Midwest with Scrubbers	% East Coast with Scrubbers
1980	136	120	17	11	9.17%	12.50%
1985	144	114	19	13	11.40%	13.19%
1990	150	132	25	20	15.15%	16.67%
1993	135	130	26	20	15.38%	19.26%
1994	152	124	33	22	17.74%	21.71%
1995	146	122	37	22	18.03%	25.34%
1996	110	97	25	16	16.49%	22.73%
1997	111	95	25	15	15.79%	22.52%
1998	90	94	22	16	17.02%	24.44%
1999	90	93	23	16	17.20%	25.56%
2000	66	63	20	11	17.46%	30.30%

For the data used here, refer to Table 47.

Table 49: Main specification, controlling for the presence of scrubbers

	Z_1	Z_2	Z_3	Z_4	Z_2
PHASE1*POST90	-0.0736	-0.0693	-0.0687	-0.0545	-0.0937**
	(0.0458)	(0.0383)	(0.0378)	(0.0351)	(0.0441)
PHASE1*POST90* MIDWEST	0.169**	0.195***	0.196***	0.180**	0.190***
	(0.0808)	(0.0738)	(0.0734)	(0.0710)	(0.0696)
POST90*MIDWEST	0.0316	0.0289	0.0281	0.0427	0.0277
	(0.0440)	(0.0369)	(0.0361)	(0.0323)	(0.0369)
SCRUBBER	-0.0449	-0.0268	-0.0257	-0.0217	-0.126
	(0.102)	(0.0989)	(0.0989)	(0.0978)	(0.108)
PHASE1*POST90* SCRUBBER					0.164
					(0.0968)
SCRUBBER*POST90					-0.00817
					(0.0409)
RESTRUCTURE	-0.280**	-0.271**	-0.269**	-0.270**	-0.270**
	(0.121)	(0.120)	(0.120)	(0.120)	(0.119)
MODES	-0.0107	-0.0144	-0.0132	-0.0142	-0.0147
	(0.0145)	(0.0132)	(0.0130)	(0.0128)	(0.0132)
ACCIDENTS	-0.279	-0.280	-0.284	-0.308**	-0.300**
	(0.164)	(0.151)	(0.151)	(0.140)	(0.151)
MINE MOUTH	-0.0202	-0.0422	-0.0428	-0.0848	-0.0465
	(0.0647)	(0.0509)	(0.0510)	(0.0624)	(0.0489)
WEST	-0.000801	0.0107	0.0101	0.00783	0.0139
	(0.0415)	(0.0411)	(0.0410)	(0.0408)	(0.0409)
INTERIOR	-0.109**	-0.126***	-0.126***	-0.118***	-0.128***
	(0.0480)	(0.0400)	(0.0401)	(0.0396)	(0.0402)

Main specification, controlling for the presence of scrubbers (Table 49 continued)

REPEAT	-0.120***	-0.106***	-0.102***	-0.104***	-0.106***
	(0.0266)	(0.0249)	(0.0243)	(0.0240)	(0.0249)
DEDICATE	-0.120***	-0.117***	-0.111***	-0.132***	-0.120***
	(0.0447)	(0.0429)	(0.0414)	(0.0421)	(0.0425)
DEDICATE _SQUARED	0.0385	0.0323	0.0296	0.0386	0.0330
	(0.0273)	(0.0258)	(0.0250)	(0.0255)	(0.0256)
BTU	0.00162	-0.00267	-0.00234	-0.00346	-0.00228
	(0.00544)	(0.00498)	(0.00490)	(0.00447)	(0.00496)
SULF	-0.00575	-0.00521	-0.00545	-0.00622	-0.00498
	(0.00660)	(0.00595)	(0.00588)	(0.00540)	(0.00586)
ASH	-0.00832	-0.00971	-0.00958	-0.0101	-0.00882
	(0.00975)	(0.00829)	(0.00801)	(0.00714)	(0.00804)
Constant	0.261***	0.345***	0.333***	0.336***	0.358***
	(0.0480)	(0.0463)	(0.0451)	(0.0435)	(0.0469)
Observations	3,102	3,488	3,543	3,772	3,488
R-squared	0.115	0.104	0.102	0.098	0.107
Number of Plants	277	281	283	283	281

Standard errors are in parentheses. ** p< 0.05, *** p< 0.01. These regressions were carried out on the data as described in the notes to Table 47.

Appendix VII: Alternate specifications of coal characteristics

The next set of tables describes the results that obtain when altered specifications of coal characteristics are used, keeping everything else the same as in the main specification. In Table 50, instead of using a log transformation of the difference between the specified and delivered quality of coal, I include the difference in levels. In Table 51, I include characteristics of the coal actually shipped. In Table 52, I include characteristics of coal that were specified prior to delivery. In this last table, there is a possible endogeneity as specification is a choice variable. Therefore, in Table 53 I use state wise averages of coal characteristics specified prior to delivery.

All these various definitions do not change the basic results. The point estimate of the triple interaction variable varies slightly, but the changes are not substantial. One significant change is the ash related variables turn out to be significant, not the sulfur variables. One of the motivations for running a log specification was to reduce the presence of outliers, so perhaps this is one reason for the change in results.

Table 50: Main specification with Delivery Variables in Levels

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0422	-0.0345	-0.0310	-0.0341
	(0.0583)	(0.0491)	(0.0485)	(0.0396)
POST90*MIDWEST	-0.00297	0.00943	0.0115	0.0233
	(0.0434)	(0.0371)	(0.0364)	(0.0332)
PHASE1*POST90*MIDWEST	0.196**	0.197**	0.194**	0.191***
	(0.0882)	(0.0805)	(0.0801)	(0.0734)
RESTRUCTURE	-0.227***	-0.211**	-0.210**	-0.210**
	(0.0862)	(0.0829)	(0.0830)	(0.0819)
MODES	-0.00527	-0.0103	-0.00864	-0.00795
	(0.0125)	(0.0121)	(0.0117)	(0.0114)
ACCIDENTS	-0.357***	-0.349***	-0.345***	-0.369***
	(0.132)	(0.121)	(0.121)	(0.111)
MINE-MOUTH	0.00341	-0.0152	-0.0158	-0.0415
	(0.0527)	(0.0459)	(0.0461)	(0.0571)
WEST	0.0332	0.0442	0.0436	0.0374
	(0.0483)	(0.0457)	(0.0457)	(0.0448)
INTERIOR	-0.0776	-0.0837*	-0.0838*	-0.0781*
	(0.0505)	(0.0458)	(0.0458)	(0.0446)
REPEAT	-0.0873***	-0.0783***	-0.0763***	-0.0795***
	(0.0147)	(0.0137)	(0.0134)	(0.0135)
DEDICATE	-0.114**	-0.0972**	-0.0932**	-0.114**
	(0.0485)	(0.0449)	(0.0435)	(0.0454)
DEDICATE_SQUARED	0.0515	0.0412	0.0380	0.0479
	(0.0365)	(0.0322)	(0.0310)	(0.0320)

Table 50 Continued

BTU_DIFF	-2.71e-06	-4.34e-06	-4.27e-06	-4.60e-06
	(6.19e-06)	(5.28e-06)	(5.20e-06)	(4.39e-06)
SULF_DIFF	-0.00853	-0.00654	-0.00683	-0.00892
	(0.00892)	(0.00744)	(0.00727)	(0.00680)
ASH_DIFF	-0.00510***	-0.00408***	-0.00401***	-0.00330**
	(0.00168)	(0.00152)	(0.00151)	(0.00144)
Constant	0.332***	0.215***	0.210***	0.221***
	(0.0471)	(0.0270)	(0.0266)	(0.0264)
Year Fixed Effects	Y	Y	Y	Y
Plant Fixed Effects	Y	Y	Y	Y
Observations	6,470	7,304	7,448	7,853
R-squared	0.134	0.114	0.112	0.105
Number of plantcode	290	294	297	297

All standard errors are clustered by plant. These errors are reported in parentheses, below the estimated coefficients. *** p<0.01, ** p<0.05. For a definition of the dependent variables, refer to Table 26.

Table 51: Main specification replacing Delivery Variables with shipped coal characteristics

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0531	-0.0448	-0.0412	-0.0392
	(0.0476)	(0.0398)	(0.0391)	(0.0330)
POST90*MIDWEST	-0.00320	0.000913	0.00316	0.0151
	(0.0439)	(0.0366)	(0.0359)	(0.0327)
PHASE1*POST90*MIDWEST	0.165**	0.174**	0.172**	0.166**
	(0.0776)	(0.0704)	(0.0703)	(0.0656)
RESTRUCTURE	-0.291***	-0.277**	-0.276**	-0.275**
	(0.110)	(0.108)	(0.108)	(0.108)
MODES	-0.00214	-0.00766	-0.00633	-0.00676
	(0.0109)	(0.0105)	(0.0102)	(0.00995)
ACCIDENTS	-0.414***	-0.407***	-0.403***	-0.412***
	(0.134)	(0.121)	(0.121)	(0.108)
MINE-MOUTH	-0.0205	-0.0458	-0.0465	-0.0666
	(0.0485)	(0.0377)	(0.0371)	(0.0441)
WEST	-0.000389	0.0190	0.0191	0.0137
	(0.0475)	(0.0435)	(0.0425)	(0.0420)
INTERIOR	-0.0622	-0.0784**	-0.0787**	-0.0768**
	(0.0433)	(0.0361)	(0.0358)	(0.0353)
REPEAT	-0.0839***	-0.0777***	-0.0761***	-0.0792***
	(0.0135)	(0.0126)	(0.0123)	(0.0124)
DEDICATE	-0.0505***	-0.0494***	-0.0489***	-0.0563***
	(0.0147)	(0.0137)	(0.0135)	(0.0139)
DEDICATE_SQUARED	0.00156***	0.00160***	0.00159***	0.00176***
	(0.000350)	(0.000324)	(0.000320)	(0.000330)

Table 51 Continued

BTUs Shipped	-1.82e-06	-3.48e-06	-3.50e-06	-4.96e-06
	(9.79e-06)	(8.47e-06)	(8.41e-06)	(8.43e-06)
Shipped Sulfur	-0.00630	-0.000318	0.000110	-0.000192
	(0.00975)	(0.00846)	(0.00214)	(0.00217)
Shipped Ash Content	-0.00401	-0.00353	-0.00341	-0.00293
	(0.00296)	(0.00256)	(0.00254)	(0.00242)
Constant	0.249**	0.339***	0.247**	0.268**
	(0.119)	(0.118)	(0.105)	(0.106)
Year Fixed Effects	Y	Y	Y	Y
Plant Fixed Effects	Y	Y	Y	Y
Observations	7,861	8,945	9,100	9,539
R-squared	0.118	0.104	0.102	0.098
Number of plantcode	295	299	302	302

All standard errors are clustered by plant. These errors are reported in parentheses, below the estimated coefficients. *** p<0.01, ** p<0.05. For a definition of the dependent variables, refer to Table 26.

Table 52: Main specification replacing delivery variables with pre-specified limits on coal characteristics

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0403	-0.0368	-0.0337	-0.0308
	(0.0462)	(0.0388)	(0.0383)	(0.0323)
POST90*MIDWEST	0.0114	0.0104	0.0121	0.0242
	(0.0428)	(0.0354)	(0.0348)	(0.0315)
PHASE1*POST90*MIDWEST	0.153**	0.165**	0.164**	0.156**
	(0.0766)	(0.0698)	(0.0695)	(0.0648)
RESTRUCTURE	-0.293***	-0.279**	-0.277**	-0.276**
	(0.113)	(0.110)	(0.110)	(0.110)
MODES	-0.000964	-0.00719	-0.00614	-0.00666
	(0.0111)	(0.0106)	(0.0104)	(0.0101)
ACCIDENTS	-0.412***	-0.406***	-0.404***	-0.408***
	(0.135)	(0.122)	(0.122)	(0.107)
MINE-MOUTH	-0.0336	-0.0556	-0.0557	-0.0737*
	(0.0474)	(0.0369)	(0.0368)	(0.0433)
WEST	0.0464	0.0564	0.0549	0.0498
	(0.0517)	(0.0441)	(0.0441)	(0.0431)
INTERIOR	-0.0544	-0.0694*	-0.0697*	-0.0674*
	(0.0445)	(0.0363)	(0.0364)	(0.0358)
REPEAT	-0.0863***	-0.0794***	-0.0776***	-0.0807***
	(0.0133)	(0.0125)	(0.0122)	(0.0123)
DEDICATE	-0.0521***	-0.0504***	-0.0500***	-0.0575***
	(0.0146)	(0.0136)	(0.0134)	(0.0139)
DEDICATE_SQUARED	0.00159***	0.00162***	0.00161***	0.00179***
	(0.000347)	(0.000323)	(0.000318)	(0.000328)

Table 52 Continued

BTU lower limit	4.94e-06	4.15e-06	3.91e-06	3.06e-06
	(1.25e-05)	(9.23e-06)	(9.23e-06)	(9.04e-06)
Sulfur Upper Limit	-0.00261	0.000533	0.000369	-2.99e-05
	(0.00651)	(0.00541)	(0.00539)	(0.00525)
Ash Upper Limit	0.00379***	0.00233**	0.00222**	0.00223**
	(0.00113)	(0.000966)	(0.000947)	(0.000885)
Constant	0.0952	0.196	0.107	0.125
	(0.153)	(0.123)	(0.113)	(0.111)
Year Fixed Effects	Y	Y	Y	Y
Plant Fixed Effects	Y	Y	Y	Y
Observations	7,861	8,945	9,100	9,539
R-squared	0.123	0.106	0.104	0.099
Number of plantcode	295	299	302	302

All standard errors are clustered by plant. These errors are reported in parentheses, below the estimated coefficients. *** p<0.01, ** p<0.05. For a definition of the dependent variables, refer to Table 26.

Table 53: Main specification replacing delivery variables with state wise averages of pre-specified limits on characteristics

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0601	-0.0514	-0.0477	-0.0478
	(0.0477)	(0.0401)	(0.0396)	(0.0340)
POST90*MIDWEST	-0.00648	-0.000738	0.00149	0.0139
	(0.0426)	(0.0354)	(0.0348)	(0.0316)
PHASE1*POST90*MIDWEST	0.183**	0.188***	0.185***	0.179***
	(0.0777)	(0.0703)	(0.0700)	(0.0656)
RESTRUCTURE	-0.282***	-0.270***	-0.268***	-0.268***
	(0.0964)	(0.0955)	(0.0961)	(0.0971)
MODES	-0.00455	-0.00942	-0.00794	-0.00841
	(0.0107)	(0.0103)	(0.0101)	(0.00989)
ACCIDENTS	-0.415***	-0.404***	-0.399***	-0.410***
	(0.136)	(0.124)	(0.124)	(0.110)
MINE-MOUTH	-0.0182	-0.0383	-0.0389	-0.0598
	(0.0480)	(0.0368)	(0.0368)	(0.0456)
WEST	-0.0855*	-0.0547	-0.0531	-0.0466
	(0.0506)	(0.0469)	(0.0469)	(0.0461)
INTERIOR	-0.0860*	-0.103**	-0.102**	-0.0890**
	(0.0500)	(0.0408)	(0.0408)	(0.0399)
REPEAT	-0.0823***	-0.0766***	-0.0750***	-0.0785***
	(0.0133)	(0.0123)	(0.0121)	(0.0122)
DEDICATE	-0.0449***	-0.0450***	-0.0446***	-0.0529***
	(0.0142)	(0.0133)	(0.0131)	(0.0136)
DEDICATE_SQUARED	0.00142***	0.00148***	0.00147***	0.00167***
	(0.000339)	(0.000315)	(0.000311)	(0.000323)

Table 53 Continued

BTU lower limit	0.0107	0.0166	0.0160	0.00757
(State average)	(0.0159)	(0.0149)	(0.0149)	(0.0145)
Sulfur Upper Limit	-	-	-	-
(State Average)	-	-	-	-
Ash Upper Limit	-0.0345***	-0.0317***	-0.0309***	-0.0260***
(State Average)	(0.00768)	(0.00708)	(0.00704)	(0.00664)
Constant	0.519***	0.548***	0.461***	0.434***
	(0.0780)	(0.0820)	(0.0703)	(0.0685)
Year Fixed Effects	Y	Y	Y	Y
Plant Fixed Effects	Y	Y	Y	Y
Observations	7,861	8,945	9,100	9,539
R-squared	0.128	0.112	0.110	0.103
Number of plantcode	295	299	302	302

All standard errors are clustered by plant. These errors are reported in parentheses, below the estimated coefficients. *** p<0.01, ** p<0.05. For a definition of the dependent variables, refer to Table 26. Sulfur limits averaged over states dropped as this variable was highly collinear.

Appendix VIII: Alternate measures of transportation changes

For the main specification I use MODES and ACCIDENTS as the main explanatory variables capturing the changing rail industry. Instead of these, I present results including instead the definition Kozhevnikova and Lange (2009), which is an indicator variable that takes on the value of one if any (or all) of the shipment from mine to plant takes place by any mode other than rail (NON-RAIL). I also include interactions with the total distance shipped (DISTANCE) and phase status, since Busse and Keohane (2008) find evidence of price discrimination against Phase I plants by railroad companies, with plants closer to western coal being more susceptible.

I expect the presence of alternate modes of transportation would improve the chances of writing fixed price contracts, since the seller is less able to hold-up (if only one line of track connects the plant to the mine, the mine has greater power to behave opportunistically than if other forms of transportation (barges for instance are often used by plants located around the Great Lakes) are present as well). I expect a positive coefficient on NON-RAIL, therefore.

Following Busse and Keohane (2008), Phase I plants are more likely to face discriminatory pricing by railroads, so I include an interaction of NON-RAIL with PHASE1. The interaction is expected to be positive as having an alterate mode of transportation is likely, given Busse and Keohane's argument, to be more important for Phase I plants. I include a separate variable for the total distance shipped (DISTANCE) and an interaction of this variable with NON-RAIL, to account for the location based discrimination found by Busse and Keohane. If alternate sources of transportation exist, and if location matters in terms of possibly discriminatory activity by the railroads, then this interaction should be positive. I also interact WEST with DISTANCE as an alternative test, with the expectation that for western coal, the larger the distance, the lower the probability of price discrimination and the associated hold-up, implying a positive coefficient on the interaction variable.

I took a number of steps to ensure the data on distance shipped was as accurate as possible. A large proportion of observations (approximately 1600) had distance shipped recorded as 0 (zero) miles, and these observations were not from mine-mouth plants (mine-mouth plants have plants built next to mines, so it is possible to have zero distance shipped for such plants). For these observations, I calculated the median distance shipped for each coal county-plant county pair for every year, and used this average as a proxy for the distance shipped. The remaining observations were retained, as I could not find any obvious fault with them[26].

For some observations county wise information for every year was missing or equal to zero, and I replaced the original distance shipped data with state wise averages instead. Around 600 observations still had distance shipped recorded as zero despite coming from non-mine mouth plants, for these I used one year lagged median values by county and state. After this, 151

[26]Given that most transportation takes place through rail, and there are a limited number of rail lines connecting any two counties, using an average measure is likely to be close to the actual distance shipped. The correlation coefficient between the original distance shipped and the distance shiped calculated as above equals 0.96, with a standard error of 0.002. Albeit crude, such a high correlation, together with the very low standard error suggests the proxy is appropriate.

observations remained with value of distance shipped recorded as zero and not being associated with mine-mouth plants. These I recorded as missing and they are excluded from the relevant regressions.

In terms of results, with Z_1 as the dependent variable, the main interaction term of interest is insignificant, only slightly smaller in terms of magnitude. For the other three definitions however, the main interaction term is both statistically significant and, while slightly smaller, still large in magnitude. The inclusion of cost-plus contracts, thus, appears to be quite important. Another important change from the main results is that including NON-RAIL, as well as DISTANCE, gives stronger support to the non-linear relationship of pricing with respect to the dedicated assets variable.

The Kozhevnikova-Lange definition appears to be quite robust, of the right sign and highly statistically significant, albeit of smaller magnitude. Predictions from the Busse-Keohane study do not however find much support, with the estimated coefficients varying in sign and never being statistically significant on their own. In addition, the size of the coefficient are also quite meagre. If railroads were price discriminating as Busse and Keohane (2008) argue, such behavior appears to be of little importance in explaining contractual behavior between power plants and coal mines.

Table 54: Alternative interpretations of transportation changes: Z_1 as dependent variable

	Z_1	Z_1	Z_1	Z_1
PHASE1*POST90	-0.0462	-0.0262	-0.0259	-0.0261
	(0.0489)	(0.0475)	(0.0474)	(0.0476)
POST90*MIDWEST	0.0349	0.0539	0.0537	0.0564
	(0.0445)	(0.0429)	(0.0430)	(0.0427)
PHASE1*POST90*MIDWEST	0.147	0.126	0.126	0.122
	(0.0788)	(0.0783)	(0.0784)	(0.0785)
RESTRUCTURE	-0.316***	-0.317***	-0.316***	-0.317***
	(0.120)	(0.119)	(0.119)	(0.118)
NON-RAIL	0.0495**	0.0548**	0.0588**	0.0540**
	(0.0212)	(0.0230)	(0.0284)	(0.0230)
DISTANCE		9.84e-06	2.02e-05	2.03e-05
		(1.37e-05)	(4.23e-05)	(1.65e-05)
NON-RAIL*DISTANCE			-1.29e-05	
			(3.94e-05)	
WEST*DISTANCE				-9.55E-05
				(5.63e-05)
WEST	0.00339	-0.00574	-0.0147	0.110
	(0.0370)	(0.0390)	(0.0502)	(0.0874)

Table 54 Continued

	Z_1	Z_1	Z_1	Z_1
MINE MOUTH	-0.0364	-0.0370	-0.0379	-0.0343
	(0.0366)	(0.0371)	(0.0372)	(0.0369)
INTERIOR	-0.0507	-0.0528	-0.0536	-0.0382
	(0.0396)	(0.0418)	(0.0421)	(0.0434)
REPEAT	-0.0813***	-0.0834***	-0.0833***	-0.0834***
	(0.0129)	(0.0140)	(0.0140)	(0.0140)
DEDICATE	-0.0640***	-0.0605***	-0.0606***	-0.0594***
	(0.0184)	(0.0179)	(0.0179)	(0.0177)
DEDICATE_SQUARED	0.0131***	0.0122***	0.0122***	0.0122***
	(0.00375)	(0.00362)	(0.00362)	(0.00361)
BTU	0.00291	0.00138	0.00132	0.00167
	(0.00384)	(0.00369)	(0.00365)	(0.00370)
SULF	-0.0113**	-0.0123***	-0.0123***	-0.0123***
	(0.00460)	(0.00453)	(0.00453)	(0.00457)
ASH	-0.00296	-0.00194	-0.00194	-0.00215
	(0.00315)	(0.00311)	(0.00311)	(0.00310)
Constant	0.233***	0.132***	0.130***	0.118***
	(0.0360)	(0.0306)	(0.0333)	(0.0314)
Plant FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	8,021	7,744	7,744	7,744
R-squared	0.136	0.133	0.133	0.134
Number of Plants	292	290	290	290

All standard errors are clustered by plant.

Table 55: Alternative interpretations of transportation changes: Z_2 as dependent variable

	Z_2	Z_2	Z_2	Z_2
PHASE1*POST90	-0.0415	-0.0307	-0.0310	-0.0305
	(0.0412)	(0.0400)	(0.0400)	(0.0401)
POST90*MIDWEST	0.0348	0.0454	0.0457	0.0471
	(0.0379)	(0.0367)	(0.0368)	(0.0365)
PHASE1*POST90*MIDWEST	0.160**	0.149**	0.149**	0.146**
	(0.0717)	(0.0713)	(0.0713)	(0.0715)
RESTRUCTURE	-0.297**	-0.298**	-0.298**	-0.298**
	(0.118)	(0.118)	(0.118)	(0.117)
NON-RAIL	0.0477**	0.0483**	0.0455	0.0475**
	(0.0189)	(0.0196)	(0.0240)	(0.0196)
DISTANCE		5.88e-06	-1.73e-06	1.42e-05
		(1.28e-05)	(3.88e-05)	(1.43e-05)
NON-RAIL*DISTANCE			9.62e-06	
			(3.67e-05)	
WEST*DISTANCE				-7.43e-05
				(5.20e-05)
WEST	0.0102	0.00323	0.00972	0.0928
	(0.0348)	(0.0368)	(0.0478)	(0.0831)

Table 55 Continued

	Z_2	Z_2	Z_2	Z_2
MINE MOUTH	-0.0708	-0.0741	-0.0734	-0.0725
	(0.0394)	(0.0415)	(0.0413)	(0.0416)
INTERIOR	-0.0637	-0.0663	-0.066	-0.0564
	(0.0343)	(0.0359)	(0.0360)	(0.0373)
REPEAT	-0.0773***	-0.0813***	-0.0814***	-0.0814***
	(0.0123)	(0.0132)	(0.0132)	(0.0133)
DEDICATE	-0.0630***	-0.0644***	-0.0643***	-0.0635***
	(0.0177)	(0.0170)	(0.0170)	(0.0168)
DEDICATE_SQUARED	0.0128***	0.0129***	0.0129***	0.0129***
	(0.00378)	(0.00365)	(0.00365)	(0.00366)
BTU	8.02e-05	-0.00172	-0.00167	-0.00152
	(0.00344)	(0.00334)	(0.00330)	(0.00335)
SULF	-0.00849	-0.00962**	-0.00963**	-0.00953**
	(0.00448)	(0.00443)	(0.00443)	(0.00446)
ASH	-0.000819	-0.000707	-0.000693	-0.000829
	(0.00281)	(0.00277)	(0.00278)	(0.00276)
Constant	0.210***	0.234***	0.236***	0.224***
	(0.0363)	(0.0347)	(0.0368)	(0.0349)
Plant FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	9,105	8,757	8,757	8,757
R-squared	0.118	0.119	0.119	0.119
Number of Plants	297	295	295	295

All standard errors are clustered by plant.

Table 56: Alternate interpretations of transportation changes: Z_3 as dependent variable

	Z_3	Z_3	Z_3	Z_3
PHASE1*POST90	-0.0384	-0.0279	-0.0282	-0.0278
	(0.0406)	(0.0395)	(0.0394)	(0.0395)
POST90*MIDWEST	0.0369	0.0471	0.0473	0.0487
	(0.0373)	(0.0362)	(0.0362)	(0.0360)
PHASE1*POST90*MIDWEST	0.159**	0.148**	0.148**	0.145**
	(0.0713)	(0.0710)	(0.0710)	(0.0712)
RESTRUCTURE	-0.296**	-0.296**	-0.296**	-0.296**
	(0.118)	(0.118)	(0.118)	(0.117)
NON-RAIL	0.0479**	0.0485**	0.0462*	0.0477**
	(0.0188)	(0.0195)	(0.0239)	(0.0195)
DISTANCE		6.26e-06	-4.90e-08	1.42e-05
		(1.29e-05)	(3.84e-05)	(1.44e-05)
NON-RAIL*DISTANCE			8.02e-06	
			(3.64e-05)	
WEST*DISTANCE				-7.12e-05
				(5.21e-05)
WEST	0.00988	0.00256	0.00795	0.0884
	(0.0348)	(0.0368)	(0.0476)	(0.0832)

Table 56 Continued

	Z_3	Z_3	Z_3	Z_3
MINE MOUTH	-0.0715	-0.0748	-0.0742	-0.0732
	(0.0395)	(0.0416)	(0.0414)	(0.0417)
INTERIOR	-0.0631	-0.0656	-0.0654	-0.0562
	(0.0343)	(0.0359)	(0.0360)	(0.0373)
REPEAT	-0.0757***	-0.0796***	-0.0796***	-0.0796***
	(0.0120)	(0.0129)	(0.0129)	(0.0129)
DEDICATE	-0.0624***	-0.0636***	-0.0636***	-0.0628***
	(0.0174)	(0.0167)	(0.0167)	(0.0166)
DEDICATE_SQUARED	0.0126***	0.0126***	0.0126***	0.0126***
	(0.00370)	(0.00357)	(0.00357)	(0.00357)
BTU	0.000221	-0.00150	-0.00146	-0.00131
	(0.00339)	(0.00329)	(0.00324)	(0.00329)
SULF	-0.00872	-0.00986**	-0.00987**	-0.00978**
	(0.00448)	(0.00444)	(0.00445)	(0.00448)
ASH	-0.000767	-0.000637	-0.000632	-0.000744
	(0.00270)	(0.00266)	(0.00266)	(0.00265)
Constant	0.224***	0.227***	0.229***	0.217***
	(0.0329)	(0.0337)	(0.0358)	(0.0339)
Plant FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	9,264	8,913	8,913	8,913
R-squared	0.117	0.118	0.118	0.118
Number of Plants	300	298	298	298

All standard errors are clustered by plant.

Table 57: Alternate interpretations of transportation changes: Z_4 as dependent variable

	Z_4	Z_4	Z_4	Z_4
PHASE1*POST90	-0.0383	-0.0283	-0.0284	-0.0282
	(0.0342)	(0.0334)	(0.0333)	(0.0334)
POST90*MIDWEST	0.0468	0.0563	0.0565	0.0576
	(0.0341)	(0.0333)	(0.0333)	(0.0331)
PHASE1*POST90*MIDWEST	0.155**	0.144**	0.144**	0.141**
	(0.0664)	(0.0663)	(0.0663)	(0.0664)
RESTRUCTURE	-0.293**	-0.293**	-0.293**	-0.293**
	(0.118)	(0.118)	(0.118)	(0.117)
NON-RAIL	0.0467**	0.0480**	0.0462	0.0474**
	(0.0190)	(0.0196)	(0.0241)	(0.0197)
DISTANCE		6.89e-06	1.95e-06	1.34e-05
		(1.29e-05)	(3.85e-05)	(1.42e-05)
NON-RAIL*DISTANCE			6.29e-06	
			(3.64e-05)	
WEST*DISTANCE				-5.87e-05
				(5.22e-05)
WEST	0.00823	0.000402	0.00463	0.0712
	(0.0342)	(0.0364)	(0.0476)	(0.0837)

Table 57 Continued

	Z_4	Z_4	Z_4	Z_4
MINE MOUTH	-0.0947**	-0.104**	-0.103**	-0.103
	(0.0469)	(0.0523)	(0.0520)	(0.0526)
INTERIOR	-0.0609	-0.0634	-0.0632	-0.0556
	(0.0337)	(0.0353)	(0.0354)	(0.0367)
REPEAT	-0.0780***	-0.0818***	-0.0819***	-0.0818***
	(0.0120)	(0.0129)	(0.0129)	(0.0129)
DEDICATE	-0.0721***	-0.0733***	-0.0733***	-0.0727***
	(0.0180)	(0.0174)	(0.0175)	(0.0174)
DEDICATE_SQUARED	0.0143***	0.0144***	0.0144***	0.0144***
	(0.00397)	(0.00386)	(0.00386)	(0.00388)
BTU	-0.000614	-0.00230	-0.00226	-0.00215
	(0.00316)	(0.00306)	(0.00301)	(0.00306)
SULF	-0.00891**	-0.00992**	-0.00992**	-0.00986**
	(0.00435)	(0.00431)	(0.00431)	(0.00435)
ASH	-1.26e-06	0.000141	0.000143	6.06e-05
	(0.00258)	(0.00256)	(0.00256)	(0.00255)
Constant	0.205***	0.223***	0.224***	0.197***
	(0.0341)	(0.0317)	(0.0340)	(0.0343)
Plant FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	9,719	9,361	9,361	9,361
R-squared	0.112	0.113	0.113	0.113
Number of Plants	300	298	298	298

All standard errors are clustered by plant.

Appendix IX: Other explanatory variables

In this section, I include the total tons of coal delivered, as well as the moisture content of the coal in addition to BTUs, sulfur and ash among the delivery variables. I also include, instead of DEDICATE, QUANTITY, defined as multiplying the (lower limit of) BTU content by the (lower limit of) total tons procured. This is the definition of dedicated assets employed by Joskow (1987). The problem with such a definition is that it ignores how much coal the plant procured in aggregate, or how much coal the mine produced in aggregate and so it is not clear how much dedication really takes place. Nevertheless, I replace DEDICATE with QUANTITY to test the robustness of the results.

The results are quite similar, with a slight increase in the estimated coefficient on the main interaction term of interest when moisture and tons of coal are included. There is a marginal decrease when using QUANTITY instead of DEDICATE, but otherwise the coefficient is statistically significant, of the expected sign and very similar magnitude across all the specifications discussed in this section. The only difference from the main results is that when using QUANTITY, we are unable to reject the hypothesis of a non-linear effect of dedicated assets on pricing structure[27].

[27] However, while the estimated coefficients indicate that the (conditional) function of any of the pricing variables versus QUANTITY is U-shaped, the point at which the curve changes direction appears to be rather far out.

Table 58: Additional coal characteristics

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0337	-0.0288	-0.0255	-0.0289
	(0.0585)	(0.0494)	(0.0487)	(0.0398)
POST90*MIDWEST	-0.00610	0.00778	0.00977	0.0199
	(0.0448)	(0.0376)	(0.0369)	(0.0337)
PHASE1*POST90*MIDWEST	0.186**	0.187**	0.185**	0.183**
	(0.0887)	(0.0803)	(0.0798)	(0.0729)
RESTRUCTURE	-0.247**	-0.234**	-0.233**	-0.234**
	(0.101)	(0.0978)	(0.0980)	(0.0959)
MODES	-0.00526	-0.0102	-0.00875	-0.00738
	(0.0118)	(0.0114)	(0.0110)	(0.0107)
ACCIDENTS	-0.399***	-0.387***	-0.383***	-0.412***
	(0.138)	(0.126)	(0.126)	(0.121)
MINE-MOUTH	-0.00307	-0.0220	-0.0225	-0.0227
	(0.0541)	(0.0487)	(0.0489)	(0.0513)
WEST	0.0447	0.0553	0.0547	0.0444
	(0.0477)	(0.0445)	(0.0444)	(0.0433)
INTERIOR	-0.0636	-0.0729	-0.0729	-0.0687
	(0.0482)	(0.0424)	(0.0424)	(0.0414)

Table 58 Continued

	Z_1	Z_2	Z_3	Z_4
REPEAT	-0.0850***	-0.0787***	-0.0768***	-0.0796***
	(0.0150)	(0.0140)	(0.0136)	(0.0137)
DEDICATE	-0.0941**	-0.0929**	-0.0894**	-0.106***
	(0.0430)	(0.0386)	(0.0376)	(0.0394)
DEDICATE_SQUARED	0.0311	0.0346	0.0321	0.0395
	(0.0308)	(0.0252)	(0.0244)	(0.0255)
BTU	0.00130	-0.00104	-0.000755	-0.00172
	(0.00473)	(0.00411)	(0.00406)	(0.00373)
SULF	-0.0111***	-0.00908**	-0.00919**	-0.0106***
	(0.00416)	(0.00398)	(0.00395)	(0.00396)
ASH	-0.00193	-0.00218	-0.00223	-0.00239
	(0.00327)	(0.00287)	(0.00276)	(0.00275)
TONS	-0.0081	-0.00850**	-0.00849**	-0.00818**
	(0.00461)	(0.00410)	(0.00400)	(0.00397)
MOISTURE	0.00342	0.00331	0.00332	0.00628
	(0.00527)	(0.00474)	(0.00470)	(0.00469)
Constant	0.375***	0.369***	0.359***	0.205***
	(0.0695)	(0.0638)	(0.0619)	(0.0603)
Plant F.E	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	6,468	7,330	7,474	7,880
R-squared	0.136	0.117	0.115	0.109
Plants	284	287	290	290

All standard errors are clustered by plant.

Table 59: Other explanatory variabels: Quantity of coal procured

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0530	-0.0461	-0.0427	-0.0407
	(0.0496)	(0.0421)	(0.0415)	(0.0351)
POST90*MIDWEST	-0.000274	0.00532	0.00737	0.0177
	(0.0452)	(0.0377)	(0.0370)	(0.0337)
PHASE1*POST90*MIDWEST	0.151	0.171**	0.169**	0.163**
	(0.0787)	(0.0723)	(0.0719)	(0.0668)
RESTRUCTURE	-0.307**	-0.289**	-0.287**	-0.285**
	(0.123)	(0.117)	(0.117)	(0.116)
MODES	-0.00304	-0.00866	-0.00671	-0.00703
	(0.0108)	(0.0105)	(0.0103)	(0.0100)
ACCIDENTS	-0.453***	-0.435***	-0.427***	-0.439***
	(0.139)	(0.126)	(0.126)	(0.115)
MINE-MOUTH	-0.0250	-0.0255	-0.0262	-0.0444
	(0.0411)	(0.0358)	(0.0358)	(0.0439)
WEST	0.0590	0.0537	0.0517	0.0506
	(0.0441)	(0.0415)	(0.0415)	(0.0408)
INTERIOR	-0.0259	-0.0498	-0.0504	-0.0453
	(0.0409)	(0.0353)	(0.0353)	(0.0347)

Table 59 Continued

	Z_1	Z_2	Z_3	Z_4
REPEAT	-0.0689***	-0.0679***	-0.0665***	-0.0687***
	(0.0127)	(0.0121)	(0.0119)	(0.0119)
QUANTITY	-0.00579***	-0.00323***	-0.00310***	-0.00330***
	(0.000957)	(0.000638)	(0.000611)	(0.000614)
QUANTITY_SQUARED	2.16e-05***	5.27e-06***	5.03e-06***	5.37e-06***
	(4.39e-06)	(1.13e-06)	(1.08e-06)	(1.08e-06)
BTU	0.00110	-0.000936	-0.000659	-0.00165
	(0.00387)	(0.00348)	(0.00342)	(0.00319)
SULF	-0.0113**	-0.0105**	-0.0106**	-0.0110***
	(0.00438)	(0.00420)	(0.00416)	(0.00410)
ASH	-0.00250	-0.000670	-0.000931	-0.000168
	(0.00333)	(0.00289)	(0.00279)	(0.00270)
Constant	0.263***	0.231***	0.228***	0.216***
	(0.0368)	(0.0352)	(0.0337)	(0.0327)
Plant F.E	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	7,659	8,708	8,863	9,302
R-squared	0.142	0.116	0.114	0.109
Number of Plants	292	296	299	299

All standard errors are clustered by plant.

Appendix X: Robustness to the exclusion of Texas

Texas is a unique case, with an electricity grid that is little connected to the rest of the country, in contrast to every other state within the US. Importantly, it is the only state that, by the year 1995, had approved of a move toward restructuring their electricity markets. It is, thus, the only state for whose power plants the RESTRUCTURE variable equals one. We had seen earlier that including an additional year of data resulted in statistical insignifance of the coefficient on RESTRUCTURE, suggesting the strong negative correlation of RESTRUCTURE with the pricing variables was only a temporary effect. I examine the robustness of this result further, by excluding all plants in Texas and carrying out two tests.

In the first, I test the main specification including years up to 1996. In the second, I examine the main specification; as Texas is excluded, RESTRUCTURE drops out as there is no variation in this variable (no other state moved toward an agreement to restructure their markets for electricity by 1995). The main goal is to see how much the inclusion of Texas plants affects the results. The results, as we can see from the following results, is that they are barely altered. The major implication is that restructuring appears to have at best a temporary negative effect on contractual relationships between the plants and mines under study.

Table 60: The effect of excluding Texas (data includes the year 1996)

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0836	-0.0693	-0.065	-0.0575
	(0.0485)	(0.0404)	(0.0397)	(0.0329)
POST90*MIDWEST	-0.0179	-0.0116	-0.00933	0.00822
	(0.0448)	(0.0371)	(0.0362)	(0.0323)
PHASE1*POST90*MIDWEST	0.211***	0.217***	0.214***	0.202***
	(0.0809)	(0.0736)	(0.0729)	(0.0680)
RESTRUCTURE	0.0222	0.0281	0.0286	0.0201
	(0.0957)	(0.0932)	(0.0882)	(0.0784)
MODES	-0.0102	-0.0149	-0.0135	-0.0143
	(0.0107)	(0.0104)	(0.0101)	(0.00985)
ACCIDENTS	-0.424***	-0.417***	-0.410***	-0.423***
	(0.137)	(0.125)	(0.124)	(0.112)
MINE-MOUTH	-0.0179	-0.0289	-0.0264	-0.0488
	(0.0438)	(0.0376)	(0.0370)	(0.0478)
WEST	0.0132	0.0304	0.0291	0.0274
	(0.0412)	(0.0390)	(0.0391)	(0.0384)
INTERIOR	-0.0540	-0.0621	-0.0612	-0.0578
	(0.0417)	(0.0355)	(0.0355)	(0.0348)

Table 60 Continued

	Z_1	Z_2	Z_3	Z_4
REPEAT	-0.0896***	-0.0860***	-0.0846***	-0.0887***
	(0.0133)	(0.0126)	(0.0123)	(0.0125)
DEDICATE	-0.0739**	-0.0728**	-0.0698**	-0.0879**
	(0.0375)	(0.0350)	(0.0342)	(0.0352)
DEDICATE_SQUARED	0.0265	0.0279	0.0257	0.0338
	(0.0257)	(0.0225)	(0.0219)	(0.0225)
BTU	0.00216	-0.00110	-0.000789	-0.00145
	(0.00374)	(0.00342)	(0.00337)	(0.00313)
SULF	-0.0101**	-0.00852**	-0.00846**	-0.00848**
	(0.00443)	(0.00416)	(0.00412)	(0.00409)
ASH	-0.00154	-0.000359	-0.000303	8.90e-05
	(0.00329)	(0.00287)	(0.00276)	(0.00262)
Constant	0.171***	0.185***	0.179***	0.194***
	(0.0326)	(0.0305)	(0.0301)	(0.0288)
Plant F.E	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	8,091	9,196	9,357	9,831
R-squared	0.133	0.114	0.112	0.105
Plants	293	296	298	298

All standard errors are clustered by plant.

Table 61: The effect of excluding Texas (main specification)

	Z_1	Z_2	Z_3	Z_4
PHASE1*POST90	-0.0498	-0.0422	-0.0389	-0.0365
	(0.0494)	(0.0417)	(0.0410)	(0.0346)
POST90*MIDWEST	0.00873	0.0111	0.0128	0.0248
	(0.0454)	(0.0375)	(0.0367)	(0.0335)
PHASE1*POST90*MIDWEST	0.167**	0.178**	0.177**	0.170**
	(0.0811)	(0.0735)	(0.0731)	(0.0682)
RESTRUCTURE				
MODES	-0.00262	-0.00820	-0.00709	-0.00755
	(0.0111)	(0.0107)	(0.0104)	(0.0102)
ACCIDENTS	-0.427***	-0.424***	-0.421***	-0.430***
	(0.137)	(0.124)	(0.124)	(0.111)
MINE-MOUTH	-0.0262	-0.0399	-0.0403	-0.0625
	(0.0428)	(0.0367)	(0.0367)	(0.0469)
WEST	0.0183	0.0320	0.0316	0.0292
	(0.0441)	(0.0413)	(0.0413)	(0.0406)
INTERIOR	-0.0618	-0.0702**	-0.0701**	-0.0665
	(0.0417)	(0.0352)	(0.0352)	(0.0345)

Table 61 Continued

	Z_1	Z_2	Z_3	Z_4
REPEAT	-0.0806***	-0.0757***	-0.0741***	-0.0773***
	(0.0133)	(0.0125)	(0.0122)	(0.0123)
DEDICATE	-0.0748**	-0.0757**	-0.0733**	-0.0883***
	(0.0347)	(0.0328)	(0.0322)	(0.0335)
DEDICATE_SQUARED	0.0215	0.0239	0.0222	0.0286
	(0.0228)	(0.0204)	(0.0199)	(0.0205)
BTU	0.00337	0.000499	0.000685	-0.000190
	(0.00392)	(0.00348)	(0.00342)	(0.00319)
SULF	-0.0105**	-0.00855**	-0.00863**	-0.00914**
	(0.00450)	(0.00428)	(0.00424)	(0.00419)
ASH	-0.00271	-0.00163	-0.00162	-0.000877
	(0.00320)	(0.00283)	(0.00273)	(0.00262)
Constant	0.255***	0.250***	0.242***	0.226***
	(0.0380)	(0.0362)	(0.0350)	(0.0353)
Plant F.E	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Observations	7,629	8,678	8,833	9,272
R-squared	0.124	0.108	0.106	0.102
Plants	289	293	296	296

All standard errors are clustered by plant.

Appendix XI: Using the instrumental variables technique of Kozhevnikova-Lange

Kozhevnkinova and Lange (2009) study contract length and attempt to account for many of the same explanatory variables as the present study. Their main motivation, however, is not to examine the endogenous nature of the specificity-contract relationship but to account for contract changes using transaction cost theory. They include a variable measuring the amount of completeness in the contract by the nature of the pricing structure contained within the contract, with a cost-plus contract being highly incomplete and a fixed price contract being the "most" complete contract type. Given that pricing is a choice variable, identification of this variable is required.

Kozhevnikova-Lange choose an instrumental variables technique. They construct z-statistics measuring for each coal county the extent of variation for different coal characteristics. The intention behind the construction of these statistics is that they reflect the ability of the supplier to extract rents. The higher the value of the statistic, the more varied the coal found, and the greater the probability that the supplier can hold-up the plant since there is a greater threat of not fulfilling the buyers demand. In response, more complete contracts will be written to ensure such behavior is kept to a minimum.

There a few problems with this explanation. It is not clear how the exclusion restriction is valid. A major reason to write long term contracts is to minimize haggling costs that arise through supplier hold-up, which is precisely the same motivation Kozhevnikova-Lange give for the instruments.

In addition, completeness of a contract is not only a response to potentially problematic behavior by the supplier (or buyer) but constructed in response to exogenous variation in *transaction* characteristics, not just individual propensities to engage in opportunistic behavior. Last, as I have argued in the main paper, the employment of pricing as an explanatory variable for length (or vice versa) confuses effect for cause, and is therefore an incorrect specification.

Nevertheless, I mimic their regression and report the results in this section. I find very little evidence to support the use of the instrumental variables approach. I also fail to find any statistically significant effect of pricing on length, supporting my argument that it is incorrect to seek for either length or pricing structure an explanation in each other. There are, however, some important differences between my estimation and that carried out by Kozhevnikova-Lange.

I include year dummies and plant fixed effects (as we have seen, including such controls varies results greatly); Kozhevnikova-Lange do not. I also pool the data for all coal suppliers (in terms of western/interior/Appalachian), since the explanation I advance relies on switching *between* suppliers; Kozhevnikova-Lange estimate separate models for each supplier type. For these reasons, comparisons between the results I report and those in Kozhevnikova-Lange must be made with care, since the basic model being tested is different (and cannot be made similar).

I use two different definitions of "completeness" in terms of pricing structure: FPPPLUS and FPPLUS. These definitions, together with summary information about the variables, are given in Table 62. Out of these two definitions, the latter (FPPLUS) is very close to the Kozhevnikova-Lange definition. In addition to these variables, I also account for all the variables that Kozhevnikova-Lange use. Table 63 describe these additional variables.

Table 64 and Table 65 show the second-stage results that obtain when FPPPLUS and FPPLUS, respectively, are used as measures of contractual "completeness". In the first two columns, I show the results that obtain when I employ the main specification used in the paper, as well as with the augmented variables from Kozhevnikova-Lange (I term this specification, the "K-L" specification). For the latter, I omit DEDICATE, since it is very similar to PLANT and MINE. In the next two columns, I report results that occur when spot contracts are eliminated. I repeat that I do not doing so is valid, since an important margin of response by plants faced with reduced specialization is being dropped. Nevertheless, I include it to get as close to Kozhevnikova and Lange as possible[28].

Although in some specifications, the interaction terms of interest turn insignificant, we can also see that neither (the instrumented) FPPPLUS nor FPPLUS are ever statistically significant. This is highly suggestive that the basic model is incorrectly specified. Although the coefficient on these terms appears large, it is hard to understand what information they contain since the ordering of contracts within these two definitions is only ordinal. Nonetheless, the sign on them are, for the most part, as expected.

First stage results, shown in Table 66 and Table 67, show very scant support for the instruments Kozhevnikova-Lange use. Not only are virtually all

[28] In addition, we must ask why SPOT is included as a covariate if spot contracts are being dropped.

the instruments individually insignificant (except for BTU_z in some cases), but the very low F-statistics are highly suggestive of weak instruments, and are far below those suggested by Stock and Yogo (2005). I carry out a formal test of under-identification using the Kleibergen-Paap test. The null hypothesis under this test is that the equation is under-identified, meaning that the matrix of reduced form coefficients on the excluded instruments is less than full rank. We can see that for whichever definition of completeness we use, we can never reject this null.

In sum the instrumental variables technique employed by Kozhevnikova-Lange finds very little support. Perhaps, given the basic confusion over effect for cause, and the difficulty (both in terms of theory and in terms of regression results) of fulfiling the exclusion restriction, such a finding should not be too surprising.

Table 62: Definitions and Summary Information of Pricing Structure "Completeness" variables

	Definition				
	Value	Contract type	Observations	Mean	Standard Deviation
FPPPLUS	0	Cost Plus	13979	3.168	1.354
	1	Price Renegotiation			
	2	Renegotiation + Escalator			
	3	Escalator			
	4	Escalator + Price tied to market			
	5	Price tied to market			
	6	Fixed Price			
FPPLUS	0	Cost Plus	13372	2.126	0.871
	1	Price Renegotiation			
	2	Escalator			
	3	Price tied to market			
	4	Fixed Price			

Table 63: Additional variables used to test the Kozhevnikova-Lange specification

Variable	Definition	Observations	Mean	Standard Deviation	Minimum Value	Maximum Value
SPOT	Ratio of total coal quantity contracted on the spot market to total quantity over longer term contracts, for the particular coal type (western/interior/Appalachian)	14672	0.244	0.166	0	0.714
NON-RAIL	Indicator variable; = 1 if any delivery takes place through a mode other than rail	14672	0.261	0.439	0	1
MIN QUANT	Minimum quantity contracted for (Short Tons)	13575	953.778	1583.634	0.09	56000
STAGGER	Indicator variable; = 1 if contract signed after passage of the Staggers Act	14672	0.563	0.496	0	1
CLEAN	Indicator variable; = 1 if contract signed after passage of the Clean Air Act Amendment	14672	0.266	0.442	0	1
DISTANCE	Total distance shipped (miles)	14165	448.962	410.065	0	2643
PLANT	Ratio of total quantity of coal contracted for in the contract to total quantity for the plant as a whole, in any given year	13986	0.694	0.853	0	13.400
MINE	Ratio of total quantity of coal contracted for in the contract to total quantity for the mine as a whole, in any given year	14288	0.295	0.483	0	42.083

As can be seen, there are some observations for which *PLANT* and *MINE* take on the value of zero. Dropping these observations and estimating the regressions reported in Table 64, Table 65 and their first stages (Table 66 and Table 67) resulted in almost no changes to the estimates.

Table 64: Instrumental variables estimation following Kozhevnikova Lange: using FPPPLUS as explanatory pricing variable

Dependent Variable :	Length			
	Main Specification	K-L Specification	Main Specification	K-L Specification
			(Excluding spot contracts)	
FPPPLUS	-1.871	0.657	-4.350	-2.679
	(2.402)	(3.159)	(3.807)	(3.469)
PHASE1*POST90	0.987	0.565	1.568	1.352
	(0.752)	(0.770)	(1.218)	(1.006)
PHASE1*POST90*MIDWEST	-0.507	-0.833	-1.025	-1.156
	(1.356)	(1.256)	(1.506)	(1.197)
MIDWEST*POST90	-1.814**	-1.618**	-0.571	-0.298
	(0.726)	(0.712)	(0.956)	(0.831)
STAGGER		-0.597		-0.789
		(0.378)		(0.425)
CLEAN		0.0239		1.473
		(2.021)		(1.099)
REPEAT	0.639	0.904	-0.381	-0.264
	(0.714)	(0.679)	(0.556)	(0.479)
PLANT		1.325***		1.532***
		(0.241)		(0.366)
MINE		-0.0734		-1.291
		(0.688)		(0.683)
DISTANCE		1.39e-05		-0.000480
		(0.000758)		(0.000827)
SPOT		-3.083		-1.558
		(2.147)		(1.469)
MIN QUANT		0.00101***		0.000765**
		(0.000371)		(0.000298)
NON-RAIL		-1.136		-0.468
		(1.165)		(0.879)
MODES	0.273	-0.131	0.421	0.263
	(0.258)	(0.387)	(0.372)	(0.418)

Table 64 continued

Dependent Variable:	Length			
	Main Specification	K-L Specification	Main Specification (Excluding spot contracts)	K-L Specification
ACCIDENTS	7.219	9.703**	7.970	8.910**
	(5.058)	(4.899)	(5.314)	(4.181)
MINE MOUTH	4.414	5.048	3.460	3.637
	(3.226)	(4.065)	(2.358)	(2.414)
WEST	3.308***	0.651	3.465**	1.389
	(0.962)	(1.418)	(1.414)	(1.641)
INTERIOR	1.487	0.645	0.205	-0.331
	(1.077)	(0.941)	(1.951)	(1.640)
BTU	-0.0361	0.104	-0.108	0.0473
	(0.0833)	(0.0908)	(0.151)	(0.133)
SULF	-0.278**	-0.200	-0.236*	-0.225*
	(0.114)	(0.131)	(0.137)	(0.115)
ASH	-0.200**	-0.0678	-0.214*	-0.0629
	(0.101)	(0.0952)	(0.118)	(0.0938)
DEDICATE	3.303**		2.229	
	(1.534)		(1.628)	
DEDICATE_SQUARED	-2.860***		-2.669**	
	(1.045)		(1.090)	
Year dummies	Y	Y	Y	Y
Plant FE	Y	Y	Y	Y
Observations	7,475	7,269	5,519	5,391
Number of Plants	281	280	266	264

Table 65: Instrumental variables estimation following Kozhevnikova Lange: using FPPLUS as explanatory pricing variable

Dependent Variable :	Length			
	Main Specification	K-L Specification	Main Specification (Excluding spot contracts)	K-L Specification (Excluding spot contracts)
FPPLUS	-3.230	-0.356	-5.558	-3.135
	(2.546)	(3.334)	(3.261)	(3.126)
PHASE1*POST90	1.585**	1.249	1.843	1.518
	(0.692)	(0.647)	(0.975)	(0.808)
PHASE1*POST90*MIDWEST	-1.025	-1.295	-1.486	-1.482
	(1.231)	(1.125)	(1.403)	(1.204)
MIDWEST*POST90	-1.427**	-1.119	-0.109	0.0415
	(0.718)	(0.672)	(0.894)	(0.765)
STAGGER		-0.634		-0.712
		(0.393)		(0.439)
CLEAN		0.598		1.182**
		(1.329)		(0.591)
REPEAT	0.500	0.639	-0.315	-0.219
	(0.531)	(0.482)	(0.404)	(0.362)
PLANT		1.385***		1.595***
		(0.244)		(0.311)
MINE		-0.0858		-1.249**
		(0.600)		(0.597)
DISTANCE		-0.000152		-0.000689
		(0.000714)		(0.000795)
SPOT		-2.656		-1.487
		(1.752)		(1.425)
MIN QUANT		0.000903***		0.000751***
		(0.000307)		(0.000256)
NON-RAIL		-0.838		-0.576
		(0.910)		(0.755)
MODES	0.335	0.00718	0.421	0.236
	(0.259)	(0.319)	(0.329)	(0.346)

Table 65 continued

Dependent Variable:	Length			
	Main Specification	K-L Specification	Main Specification (Excluding spot contracts)	K-L Specification
ACCIDENTS	6.409	9.452**	8.278**	10.12***
	(4.372)	(4.223)	(3.919)	(3.346)
MINE MOUTH	4.328	4.681	3.499	3.686
	(2.970)	(3.468)	(2.492)	(2.543)
WEST	3.258***	0.860	3.268***	1.395
	(0.902)	(1.348)	(1.173)	(1.571)
INTERIOR	1.404	0.698	0.463	0.116
	(0.984)	(0.888)	(1.345)	(1.228)
BTU	-0.0157	0.0602	-0.0606	0.0513
	(0.0739)	(0.0717)	(0.109)	(0.0978)
SULF	-0.279***	-0.233**	-0.208**	-0.209**
	(0.0894)	(0.0919)	(0.0957)	(0.0851)
ASH	-0.228**	-0.0989	-0.221**	-0.0664
	(0.102)	(0.0924)	(0.111)	(0.0880)
DEDICATE	2.756**		2.203	
	(1.160)		(1.310)	
DEDICATE_SQUARED	-2.531***		-2.604***	
	(0.851)		(0.994)	
Year dummies	Y	Y	Y	Y
Plant FE	Y	Y	Y	Y
Observations	7,079	6,866	5,175	5,036
Number of Plants	281	280	265	263

Table 66: Selected First Stage results for Instrumental Variables regression in Table 64 (Dependent Variable: FPP-PLUS)

	Main Specification	K-L Specification	Main Specification	K-L Specification
			Excluding Spot Contracts	
BTU_Z	0.0413	0.0296	0.04816	0.043
	(0.0335)	(0.0288)	(0.0389)	(0.0325)
SULF_Z	0.0106	0.036	0.0005	0.0174
	(0.0339)	(0.0312)	(0.0396)	(0.0360)
ASH_Z	0.0349	0.0089	0.0412	0.0198
	(0.0349)	(0.0357)	(0.0365)	(0.0362)
MOIST_Z	-0.0346	-0.0214	-0.0321	-0.0341
	(0.0347)	(0.0368)	(0.0353)	(0.0380)
F-stat	0.55	0.51	0.57	0.49
Kleibergen-Paap rk LM statistic	2.19	2.12	2.2	1.97
	[0.7004]	[0.7139]	[0.698]	[0.7417]
Hansen J-Statistic for overidentification	11.725	11.25	4.197	4.24
	[0.0084]	[0.0104]	[0.240]	[0.2367]

Notes: ** p<0.05, ***p <0.01. Standard errors in parentheses, and p-values in square brackets.
For further details regarding number of observations and plants, see Table 64.

Table 67: Selected First Stage results for Instrumental Variables regression in Table 65 (Dependent Variable: FP-PLUS)

	Main Specification	K-L Specification	Main Specification	K-L Specification
			Excluding Spot Contracts	
BTU_Z	0.0415**	0.0293	0.0533**	0.0448**
	(0.0205)	(0.0186)	(0.0230)	(0.0204)
SULF_Z	0.0087	0.0268	-0.0016	0.0114
	(0.0213)	(0.0197)	(0.0244)	(0.0222)
ASH_Z	0.0331	0.0178	0.0424	0.0306
	(0.0213)	(0.0218)	(0.0219)	(0.0217)
MOIST_Z	-0.0333	-0.0252	-0.0356	-0.0392
	(0.0215)	(0.0221)	(0.0212)	(0.0224)
F-stat	1.43	1.01	1.93	1.62
Kleibergen-Paap rk LM statistic	5.51	4.06	6.91	5.97
	[0.2388]	[0.3978]	[0.1409]	[0.2012]
Hansen J-Statistic for overidentification	9.166	10.501	3.508	4.024
	[0.0272]	[0.0148]	[0.3198]	[0.2588]

Notes: ** p<0.05, ***p <0.01. Standard errors in parentheses, and p-values in square brackets.
For further details regarding number of observations and plants, see Table 65.

Appendix XII: Reporting full results of the SUR specification

Here, I report results considering length and pricing as endogenous variables, using an SUR specification. Table 68 shows results for length in levels and Table 69 shows results in logs. For each table, the first two columns show results for a single simultaneous regression of Z_1 and length, the next two shows the same for Z_2 and length, and so on.

We can see there is comprehensive agreement with the basic hypothesis throughout these tables. As I include indicator variables for individual plants, those plants with a single type of contract are dropped. Consequently, the total number of observations is lower than for the single equation specifications.

Results from tests of joint significance are reported in Table 70. These tests, we can see, reject the null hypothesis of zero effect for the triple interaction variable at the 1% level of significance for *all* specifications.

In Table 71, I report results of the Breusch-Pagan test for whether the error terms for the twin equations of pricing and length are correlated (and therefore, whether it makes sense to estimate them simultaneously under a SUR framework). We can see all tests reject the null hypothesis of zero correlation, as the test statistic in all cases is well over what is required for rejection at the 1% level of significance[29].

[29] The statistic must be at least as large as 9.21 for the cases considered.

Table 68: Full set of results for SUR regressions (in levels)

	Z_1	Length	Z_2	Length	Z_3	Length	Z_4	Length
	1(a)	1(b)	2(a)	2(b)	3(a)	3(b)	4(a)	4(b)
BTU_Z	0.00591		0.00553		0.00592		0.00211	
	(0.00429)		(0.00383)		(0.00379)		(0.00364)	
SULF_Z	0.00306		0.00521		0.00400		0.00128	
	(0.00438)		(0.00400)		(0.00395)		(0.00385)	
ASH_Z	0.0165***		0.00834		0.00807		0.00709	
	(0.00505)		(0.00456)		(0.00445)		(0.00434)	
MOIST_Z	-0.00725		-0.00589		-0.00496		-0.00248	
	(0.00495)		(0.00447)		(0.00438)		(0.00427)	
PHASE1*POST90	-0.0221	1.992***	-0.0175	1.071***	-0.0142	1.169***	-0.0187	0.658
	(0.0223)	(0.414)	(0.0200)	(0.394)	(0.0197)	(0.396)	(0.0178)	(0.359)
PHASE1*POST90*	0.171***	-2.804***	0.175***	-1.671***	0.172***	-1.792***	0.169***	-1.156**
MIDWEST	(0.0307)	(0.571)	(0.0285)	(0.564)	(0.0281)	(0.569)	(0.0266)	(0.539)
MIDWEST*	0.00848	-1.875***	0.0199	-1.628***	0.0222	-1.534***	0.0329**	-1.907***
POST90	(0.0171)	(0.316)	(0.0158)	(0.312)	(0.0156)	(0.313)	(0.0151)	(0.303)
RESTRUCTURE	-0.231	-3.631	-0.215	-3.625	-0.213	-3.566	-0.212	-3.545
	(0.130)	(2.422)	(0.128)	(2.534)	(0.127)	(2.563)	(0.125)	(2.550)
MODES	-0.00262	0.203	-0.00817	0.0620	-0.00654	0.273**	-0.00486	0.222
	(0.00675)	(0.126)	(0.00617)	(0.122)	(0.00599)	(0.121)	(0.00588)	(0.119)
ACCIDENTS	-0.391***	7.608***	-0.381***	8.929***	-0.377***	9.662***	-0.421***	10.11***
	(0.118)	(2.207)	(0.113)	(2.244)	(0.112)	(2.266)	(0.107)	(2.176)

Table 68 continued

	Z_1 1(a)	Length 1(b)	Z_2 2(a)	Length 2(b)	Z_3 3(a)	Length 3(b)	Z_4 4(a)	Length 4(b)
MINE MOUTH	-0.0145	2.916***	-0.0348	5.078***	-0.0330	5.166***	-0.0295	5.105***
	(0.0432)	(0.796)	(0.0396)	(0.772)	(0.0392)	(0.780)	(0.0387)	(0.773)
WEST	0.0423**	2.778***	0.0524***	2.997***	0.0516***	2.860***	0.0464**	2.965***
	(0.0209)	(0.388)	(0.0195)	(0.385)	(0.0193)	(0.389)	(0.0190)	(0.385)
INTERIOR	-0.0865***	1.605***	-0.0946***	2.110***	-0.0945***	2.090***	-0.0865***	2.008***
	(0.0208)	(0.386)	(0.0191)	(0.378)	(0.0189)	(0.382)	(0.0186)	(0.378)
REPEAT	-0.0871***	0.882***	-0.0785***	1.089***	-0.0763***	1.114***	-0.0793***	1.173***
	(0.00938)	(0.175)	(0.00861)	(0.171)	(0.00843)	(0.171)	(0.00818)	(0.166)
DEDICATE	-0.130***	3.429***	-0.111***	3.689***	-0.106***	3.848***	-0.125***	4.331***
	(0.0318)	(0.592)	(0.0293)	(0.581)	(0.0290)	(0.586)	(0.0283)	(0.575)
DEDICATE	0.0596**	-2.919***	0.0486**	-2.960***	0.0452*	-3.061***	0.0545**	-3.378***
_SQUARED	(0.0268)	(0.498)	(0.0246)	(0.487)	(0.0243)	(0.491)	(0.0236)	(0.480)
BTU	0.00167	-0.0879	-0.00120	-0.0367	-0.000841	-0.00991	-0.00196	-0.0185
	(0.00320)	(0.0594)	(0.00293)	(0.0580)	(0.00289)	(0.0582)	(0.00276)	(0.0559)
SULF	-0.0114***	-0.237***	-0.00915***	-0.220***	-0.00939***	-0.209***	-0.0108***	-0.204***
	(0.00291)	(0.0539)	(0.00273)	(0.0537)	(0.00268)	(0.0540)	(0.00259)	(0.0523)
ASH	0.00191	-0.227***	0.000647	-0.0966	0.000642	-0.174***	0.00152	-0.160***
	(0.00318)	(0.0565)	(0.00292)	(0.0553)	(0.00284)	(0.0547)	(0.00273)	(0.0530)

Table 68 continued

	Z_1 1(a)	Length 1(b)	Z_2 2(a)	Length 2(b)	Z_3 3(a)	Length 3(b)	Z_4 4(a)	Length 4(b)
PHASE1	0.00361	-17.28***	-0.0192	-4.306	-0.0214	-13.82**	-0.0516	-3.950
	(0.335)	(6.246)	(0.329)	(6.449)	(0.326)	(6.602)	(0.323)	(6.492)
POST90	0.163***	-2.662***	0.130***	-3.658***	0.124***	-3.141***	0.107***	-2.716***
	(0.0190)	(0.352)	(0.0175)	(0.346)	(0.0172)	(0.348)	(0.0164)	(0.333)
MIDWEST	0.0484	-8.226	0.0241	5.185	0.0209	-4.372	-0.0131	5.501
	(0.247)	(4.595)	(0.239)	(4.634)	(0.237)	(4.796)	(0.235)	(4.664)
PHASE1*	0.0194	5.553	0.0527	-8.784	0.0563	0.583	0.0866	-9.210
MIDWEST	(0.413)	(7.060)	(0.404)	(7.265)	(0.400)	(7.428)	(0.396)	(7.313)
Constant	0.0522	17.48***	0.0866	4.381	0.0834	13.72***	0.127	3.729
	(0.242)	(4.498)	(0.236)	(4.583)	(0.234)	(4.745)	(0.232)	(4.612)
Year Indicator variables	Y	Y	Y	Y	Y	Y	Y	Y
Plant Indicator variables	Y	Y	Y	Y	Y	Y	Y	Y
Observations	6,165	6,165	6,945	6,945	7,088	7,088	7,484	7,484
R-squared	0.457	0.494	0.418	0.470	0.418	0.464	0.399	0.449

Standard errors in parentheses; ** $p < 0.05$, *** $p < 0.01$.

Table 69: Full set of results for SUR regressions (in logs)

	Z_1	Log(Length)	Z_2	Log(Length)	Z_3	Log(Length)	Z_4	Log(Length)
	1(a)	1(b)	2(a)	2(b)	3(a)	3(b)	4(a)	4(b)
BTU_Z	0.00794		0.00726		0.00790**		0.00424	
	(0.00436)		(0.00382)		(0.00377)		(0.00359)	
SULF_Z	-0.000460		0.00317		0.00198		-0.000285	
	(0.00428)		(0.00385)		(0.00379)		(0.00367)	
ASH_Z	0.0114**		0.00394		0.00452		0.00386	
	(0.00488)		(0.00434)		(0.00423)		(0.00410)	
MOIST_Z	-0.00526		-0.00393		-0.00345		-0.00101	
	(0.00480)		(0.00427)		(0.00417)		(0.00404)	
PHASE1*POST90	-0.0125	0.354***	-0.0128	0.179***	-0.0109	0.197***	-0.0168	0.0936
	(0.0226)	(0.0742)	(0.0196)	(0.0682)	(0.0193)	(0.0681)	(0.0173)	(0.0621)
PHASE1*POST90*	0.161***	-0.489***	0.166***	-0.290***	0.165***	-0.307***	0.163***	-0.181
MIDWEST	(0.0306)	(0.101)	(0.0278)	(0.0969)	(0.0274)	(0.0970)	(0.0257)	(0.0928)
MIDWEST*	0.0125	-0.260***	0.0225	-0.257***	0.0236	-0.245***	0.0287**	-0.313***
POST90	(0.0168)	(0.0549)	(0.0154)	(0.0534)	(0.0151)	(0.0532)	(0.0146)	(0.0522)
RESTRUCTURE	-0.0993	-0.116	-0.0864	-0.121	-0.0844	-0.0883	-0.0910	-0.0988
	(0.137)	(0.451)	(0.133)	(0.465)	(0.132)	(0.467)	(0.130)	(0.471)
MODES	-0.00673	0.0502**	-0.00972	0.0352	-0.00864	0.0596***	-0.00603	0.0446**
	(0.00656)	(0.0216)	(0.00593)	(0.0207)	(0.00575)	(0.0203)	(0.00562)	(0.0203)
ACCIDENTS	-0.310***	0.550	-0.272**	0.580	-0.270**	0.673	-0.338***	0.722**
	(0.114)	(0.374)	(0.107)	(0.374)	(0.106)	(0.375)	(0.101)	(0.365)

Table 69 continued

	Z_1 1(a)	Log(Length) 1(b)	Z_2 2(a)	Log(Length) 2(b)	Z_3 3(a)	Log(Length) 3(b)	Z_4 4(a)	Log(Length) 4(b)
MINE MOUTH	0.0172	0.474***	0.00582	0.623***	0.00688	0.633***	0.00958	0.621***
	(0.0413)	(0.134)	(0.0374)	(0.128)	(0.0370)	(0.129)	(0.0364)	(0.130)
WEST	0.0397	0.403***	0.0478**	0.441***	0.0471**	0.429***	0.0423**	0.445***
	(0.0204)	(0.0666)	(0.0189)	(0.0654)	(0.0187)	(0.0657)	(0.0184)	(0.0660)
INTERIOR	-0.133***	0.212***	-0.137***	0.296***	-0.137***	0.293***	-0.129***	0.275***
	(0.0208)	(0.0683)	(0.0188)	(0.0652)	(0.0186)	(0.0656)	(0.0182)	(0.0657)
REPEAT	-0.0560***	0.0576*	-0.0523***	0.0881***	-0.0506***	0.0931***	-0.0523***	0.109***
	(0.00994)	(0.0327)	(0.00899)	(0.0313)	(0.00877)	(0.0310)	(0.00846)	(0.0306)
DEDICATE	-0.0812***	0.598***	-0.0745***	0.628***	-0.0713***	0.662***	-0.0861***	0.734***
	(0.0307)	(0.101)	(0.0280)	(0.0976)	(0.0277)	(0.0978)	(0.0270)	(0.0976)
DEDICATE	0.0252	-0.524***	0.0229	-0.533***	0.0207	-0.552***	0.0282	-0.586***
_SQUARED	(0.0256)	(0.0843)	(0.0232)	(0.0809)	(0.0229)	(0.0810)	(0.0223)	(0.0807)
BTU	0.00162	-0.0161	-0.00130	-0.00334	-0.000916	-0.00138	-0.00160	-0.00304
	(0.00317)	(0.0104)	(0.00286)	(0.00994)	(0.00281)	(0.00991)	(0.00267)	(0.00963)
SULF	-0.00679**	-0.0329***	-0.00445	-0.0292***	-0.00478	-0.0275***	-0.00650**	-0.0279***
	(0.00291)	(0.00952)	(0.00269)	(0.00928)	(0.00264)	(0.00926)	(0.00253)	(0.00905)
ASH	0.00158	-0.0339***	-0.000243	-0.0140	-6.70e-05	-0.0224**	0.00116	-0.0232**
	(0.00312)	(0.00981)	(0.00283)	(0.00940)	(0.00274)	(0.00922)	(0.00262)	(0.00904)

Table 69 continued

	Z_1 1(a)	Log(Length) 1(b)	Z_2 2(a)	Log(Length) 2(b)	Z_3 3(a)	Log(Length) 3(b)	Z_4 4(a)	Log(Length) 4(b)
PHASE1	0.0791	-1.039	0.109	-1.894**	0.0733	-0.690	0.0338	1.043
	(0.306)	(0.860)	(0.245)	(0.852)	(0.294)	(0.909)	(0.291)	(1.037)
POST90	0.107***	-0.626***	0.0809***	-0.504***	0.0783***	-0.527***	0.0759***	-0.516***
	(0.0188)	(0.0627)	(0.0171)	(0.0596)	(0.0167)	(0.0591)	(0.0159)	(0.0575)
MIDWEST	0.0920	0.623	0.0908	0.00797	0.0873	0.0373	0.0469	0.764
	(0.227)	(0.726)	(0.217)	(0.755)	(0.214)	(0.759)	(0.212)	(0.746)
PHASE1* MIDWEST	0.245	0.586	0.0878	1.218	0.124	0.0161	0.328	-3.682***
	(0.336)	(0.973)	(0.324)	(0.965)	(0.361)	(1.017)	(0.317)	(1.277)
Constant	-0.0411	1.460**	-0.0135	2.109***	-0.0160	2.055***	0.0281	1.319
	(0.221)	(0.706)	(0.214)	(0.746)	(0.212)	(0.751)	(0.209)	(0.737)
Year Indicator variables	Y	Y	Y	Y	Y	Y	Y	Y
Plant Indicator variables	Y	Y	Y	Y	Y	Y	Y	Y
Observations	5,319	5,319	6,035	6,035	6,173	6,173	6,540	6,540
R-squared	0.424	0.473	0.388	0.444	0.387	0.439	0.368	0.411

Standard errors in parentheses; ** $p < 0.05$, *** $p < 0.01$.

Table 70: Tests of joint significance

	Z_1, Length		Z_2, Length		Z_3, Length		Z_4, Length	
	Joint test	p-value	Joint test	p-value	Joint test	p-value	Joint test	p-value
PHASE1*POST90	23.25	8.94E-06	7.61	0.02	8.81	0.010	3.97	0.13
PHASE1*POST90*MIDWEST	47.54	4.75E-11	42.04	7.42E-10	42.9	4.82E-10	42.08	7.29E-10
MIDWEST*POST90	35.36	2.10E-08	27.54	1.05E-06	24.62	4.50E-06	41.1	1.19E-09
	Z_1, Log Length		Z_2, Log Length		Z_3, Log Length		Z_4, Log Length	
	Joint test	p-value	Joint test	p-value	Joint test	p-value	Joint test	p-value
PHASE1*POST90	23.11	9.56E-06	6.91	0.03	8.37	1.00E-02	2.69	0.26
PHASE1*POST90*MIDWEST	41.81	8.34E-10	38.56	4.24E-09	39.78	2.30E-09	40.55	1.56E-09
MIDWEST*POST90	22.54	1.27E-05	23.38	8.38E-06	21.59	2.05E-05	36.34	1.28E-08

These tests are carried out for the interaction variables, after running the regressions reported in Table 68 and Table 69. Shown above are the test statistics and associated p-values from these tests.

Table 71: Breusch-Pagan test statistics for tests of correlation of errors from regressions in Table 68 and Table 69

	Z_1, Length	Z_2, Length	Z_3, Length	Z_4, Length
Correlation between residuals	-0.159	-0.145	-0.143	-0.153
Breusch-Pagan	155.86	146.35	139.43	176.03
	Z_1, Log Length	Z_2, Log Length	Z_3, Log Length	Z_4, Log Length
Correlation between residuals	-0.227	-0.220	-0.215	-0.229
Breusch-Pagan	275.54	292.66	285.95	343.15

Appendix XIII: Impact of Fixed Effects, Clustering and the impact of the main covariates

Here I detail the impact of clustering and fixed effects. From the discussion in the paper, these two are central reasons for choosing the main specification - that of a two way fixed effect linear probability model with errors clustered at the plant. This section will show the importance of clustering and including fixed effects. I consider Z_2 as the dependent variable, since it corresponds closest to the theory.

In Table 72 I start with the most basic specification considering only of the interaction terms (in column (1)). Since neither plant nor year fixed effects are included, I include the two group variables (MIDWEST and PHASE1) as well as the time variable (POST90). In column (2), I introduce clustering. We can see that the errors increase dramatically, pointing out the importance in the current context of clustering.

Introducing year fixed effects (in column (3)) lowers the standard error slightly but does not change the coefficients greatly[30]. Finally, in column (4), I introduce plant fixed effects. Here we can see that a number of the coefficients change. In addition, the standard error does fall[31].

The lowering of the standard error, and the slight change in coefficients, due to the incorporation of fixed effects is evidence of the importance of the two way fixed effect model. And clustering clearly has important effects on the errors of the estimates. In Table 73 I consider marginal additions to the model in column (4) of Table 72, until the main specification is reached.

[30] Since POST90 does not vary over individual plants, it is excluded.

[31] In this specification, all time invariant variables are differenced out, so PHASE1, MIDWEST and their interactions drop out.

We can see that the estimated coefficient on the triple interaction variable is not sensitive to these additional variables, that is, the main result is not a consequence of any one particular specification. Figure 11 graphically displays the results (for the triple interaction variable) as we move through the various specifications in Table 72 and Table 73.

Table 72: The impact of clustering and the two way fixed effect models (Z_2 as dependent variable)

	(1)	(2)	(3)	(4)
PHASE1*POST90	-0.0178	-0.0178	-0.0195	-0.0423
	(0.0165)	(0.0472)	(0.0468)	(0.0391)
MIDWEST*POST90	0.0192	0.0192	0.0206	0.0136
	(0.0134)	(0.0375)	(0.0370)	(0.0363)
PHASE1*POST90*MIDWEST	0.187***	0.187**	0.186**	0.174**
	(0.0242)	(0.0816)	(0.0808)	(0.0703)
PHASE1	-0.00933	-0.00933	-0.00779	-
	(0.00946)	(0.0130)	(0.0129)	
POST90	0.117***	0.117***	-	-
	(0.00886)	(0.0271)		
MIDWEST	-0.0256***	-0.0256**	-0.0277***	-
	(0.00807)	(0.0107)	(0.0106)	
PHASE1*MIDWEST	0.0263	0.0263	0.0284	-
	(0.0144)	(0.0194)	(0.0190)	
Constant	0.0432***	0.0432***	0.00560	0.00762
	(0.00507)	(0.00904)	(0.00392)	(0.0119)
Year FE	N	N	Y	Y
Plant FE	N	N	N	Y
Clustered standard errors	N	Y	Y	Y
Observations	10,258	10,258	10,258	10,258
R-squared	0.084	0.084	0.100	0.090
# Plants clustered over	-	309	309	-
Number of plantcode	-	-	-	309

Standard errors in parentheses

Table 73: Considering the effect of covariates (Z_2 as dependent variable)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
PHASE1*POST90	-0.0423	-0.0430	-0.0427	-0.0436	-0.0512	-0.0437	-0.0423
	(0.0391)	(0.0391)	(0.0388)	(0.0387)	(0.0389)	(0.0404)	(0.0417)
MIDWEST*POST90	0.0145	-0.00210	-0.00225	-0.00967	-0.0158	0.00115	0.0144
	(0.0364)	(0.0359)	(0.0355)	(0.0353)	(0.0352)	(0.0367)	(0.0375)
PHASE1*POST90*MIDWEST	0.173**	0.182**	0.179**	0.173**	0.182***	0.174**	0.175**
	(0.0703)	(0.0703)	(0.0701)	(0.0688)	(0.0686)	(0.0712)	(0.0736)
RESTRUCTURE	-0.217**	-0.206	-0.205	-0.2	-0.205**	-0.278**	-0.289**
	(0.107)	(0.108)	(0.108)	(0.106)	(0.0961)	(0.109)	(0.117)
MODES		-0.00344	-0.00403	-0.00870	-0.00747	-0.00726	-0.00858
		(0.00949)	(0.00950)	(0.00985)	(0.00970)	(0.0106)	(0.0106)
ACCIDENTS		-0.298***	-0.303***	-0.393***	-0.394***	-0.405***	-0.409***
		(0.102)	(0.103)	(0.106)	(0.105)	(0.122)	(0.122)
MINE-MOUTH			-0.0991***	-0.0914***	-0.0882***	-0.0544	-0.0397
			(0.0340)	(0.0334)	(0.0330)	(0.0360)	(0.0366)
WEST				0.0362	0.0360	0.0377	0.0310
				(0.0400)	(0.0397)	(0.0406)	(0.0413)
INTERIOR				-0.0703**	-0.0651**	-0.0765**	-0.0691
				(0.0330)	(0.0326)	(0.0344)	(0.0352)

Table 73 continued

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
REPEAT					-0.0686***	-0.0775***	-0.0774***
					(0.0119)	(0.0125)	(0.0126)
DEDICATE						-0.0499***	-0.0755**
						(0.0138)	(0.0328)
DEDICATE_SQUARED						0.00161***	0.0234
						(0.000327)	(0.0203)
BTU							0.000525
							(0.00347)
SULF							-0.00990**
							(0.00428)
ASH							-0.00114
							(0.00286)
Constant	0.0157	0.0276	0.0307	0.0444**	0.0635***	0.173***	0.252***
	(0.00929)	(0.0167)	(0.0167)	(0.0175)	(0.0187)	(0.0193)	(0.0361)
Year FE	Y	Y	Y	Y	Y	Y	Y
Plant FE	Y	Y	Y	Y	Y	Y	Y
Observations	10,258	9,785	9,785	9,785	9,785	8,945	8,709
R-squared	0.091	0.082	0.084	0.089	0.097	0.103	0.109
Number of plants	309	308	308	308	308	299	296

** p< 0.05, *** p<0.01. Standard errors in parentheses, and are clustered by plant.

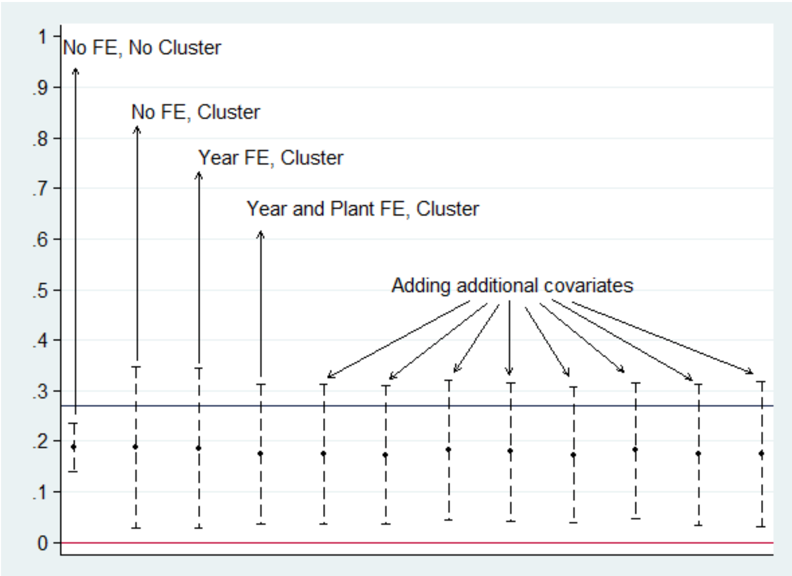

Figure 11: The impact of clustering, fixed effects and covariates

Appendix IV: Comparing measures of relationship specific investment

Three previous studies have examined coal mine-power plant contracts in the US: Joskow (1987), Kerkvliet and Shogren (2001), and Kozhevnikova and Lange (2009). It is important to ask how the estimates in this paper compare to those derived earlier. All these studies length as the dependent variable. In order to compare the present study to these, I also use length as the dependent variable, using estimates from the SUR model in the appendix available on my website[32].

Such a comparison serves two purposes. First, we can see how the influence of a particular variable varies across studies. For instance, if the

[32]To be sure, only Joskow (1987) explicitly argued for the inclusion of variables that capture physical specialization, which is the central focus of this paper. Dedicated assets may however follow from physical specialization, and so I include measures of dedicated assets in what follows.

hypothesis of declining specificity is true, we should find that estimated coefficients for various measurements of relationship specific investments should be lower than Joskow (1987) or Kerkvliet and Shogren (2001), who analyzed cross sections of contracts in the early 1980s. Second, we can compare within the present study the estimated coefficients of various alternate measures of relationship specific investment. This will indicate the relative importance of using the triple difference specification.

In Table 74, I report the variables, definitions and coefficients estimated by the three papers cited above for all the variables that measure relationship specific investment. Below each variable name I include the expected sign. In Columns (1) and (2) I report the lowest and highest (in terms of magnitude) coefficients in the papers. Below these coefficients, in parentheses, I report the level of significance at which one can reject the null hypothesis that the estimated coefficient is equal to zero[33]. A lower difference between the upper and lower estimates indicates a tightly estimated relationship, irrespective of sample selection or specification differences. The differences in coefficients from earlier studies come from the differences in specifications they report. For the present study, such variation comes from the variations in defining the pricing outcome variable.

In Column (3) and (4), I report the results that obtain when I estimated the specification in the appendix on my website. The coefficients on the *Quantity* variable in Joskow (1987)[34], and the *Plant Dedicated Assets* and

[33] I tried to only include coefficients which were significant at the 5% level of significance. However, in some cases, coefficients were always insignificant in the specifications reported in the paper. For these, I include a pair of empty parentheses.

[34] Note that his *WEST* and *MIDWEST* are exactly analogous to the WEST and INTERIOR indicator variables I use.

Mine Dedicated Assets variables in Kozhevnikova and Lange (2009) are estimated by replacing the DEDICATE variable by *Quantity* and then by *Plant Dedicated Assets* and *Mine Dedicated Assets* respectively[35]. If earlier papers reported estimates with the logarithm of length, it is replicated here accordingly[36].

Comparing across studies, we can see that indeed relationship specific investment declines. While Joskow estimates that cross-regional variation (captured by *WEST* and *MIDWEST*) increased contract length by between 5 to 6 years (for WEST) and 2.5 to 3.5 years (for *MIDWEST*), I find the same variables exert far smaller influence, with the fall in size being approximately 50%. In addition, the difference between *WEST* and *MIDWEST* also falls, which is expected if cross-regional variation becomes less important.

The marginal effect of *Quantity* (in Column (1)) was derived at the average level reported in Joskow (1987)[37], while the marginal effect shown in Columns 3 was calculated for the entire sample and then averaged[38]. We see, both in levels and logs, that the marginal effect for this variable is lower. The estimate in levels is not necessarily comparable, as I use billions of BTUs while Joskow uses trillions, but in logs, the estimate was derived using a log

[35] *Quantity* in Joskow (1987) is defined as the product of the contracted BTU content with the contracted tonnage, and it is not clear whether Joskow considered upper or lower limits. *Minimum Quantity* in Kozhevnikova and Lange (2009) is defined as the lower limit of the contracted tonnage. I take as my definition of *Quantity* the product of the lower limit of the contracted BTU content with the lower limit of the contracted tonnage, and so for this reason do not include *Minimum Quantity*.

[36] I do not have the data required to estimate the two variables - *Lead Time* and *Mine Reserve* - capturing relationship specific investment in Kerkvliet and Shogren (2001).

[37] Not having access to the data that Joskow (1987) uses, I cannot calculate standard errors of the marginal effect. For the log specification, only the log of quantity was entered, so I can use the standard errors Joskow reports.

[38] This estimate is very close to the marginal effect at the average level.

specification on quantity, thus making the estimate in Column (4) directly comparable to that in (2), as this is an elasticity and so free of units. We can see that here too the impact roughly halves, indicating a fall in physical asset specificity.

Comparing to the Kozhevnikova and Lange (2009) study, we can see that the estimates in the current study are as expected by theory, a result in contrast to some of the results in the original paper. *Plant Dedicated Assets* has a positive effect on length, and in magnitude terms is similar to what Kozhenvikova and Lange (2009) find, albeit slighlty lower. *Mine Dedicated Assets* has the expected sign, but is not robust across specifications, becoming insignificant once we use the log of length.

Comparing within the present study, we see that although dedicated assets correlate strongly with increased contract length, this correlation is typically lower in terms of magnitude than specialized investment[39]. Importantly, we can see that the interaction variables are approximately as large as *MIDWEST*, and slightly lower than *WEST*. The triple interaction variable, in particular, has at its largest an effect almost as large as *WEST*. The triple interaction variable is, therefore, in terms of magnitude, meaningful to those suggested by the Joskow study[40].

Finally, we may turn our attention to the direction and variation of the coefficients themselves. The sign on all the coefficients (in the present study) are as per theoretical prediction[41]. I conclude that, even with a research design

[39]Kervliet and Shogren 2001 find a similar result.

[40]Once again, the comparison to Joskow is made because this is the only other paper that attempts to capture the influence of physical specialization.

[41]Note that for Joskow's *Quantity*, the suggested relationship is quadratic and inverse-U shaped, which makes the sign of the marginal effect depend on the size of the individual

arguably free from endogeneity concerns, relationship specific investments appear to have strong effects on contract structure. In addition, physical asset specificity exceeds the effect of dedicated assets in terms of magnitude.

coefficients. The sign may be negative if the coefficient on the square of *Quantity* is large enough. We see that in the present case this is not true.

Table 74: Comparing estimates of Relationship Specific Investment across US coal contracting studies

		Original Study		Current Study[c]	
		(1)	(2)	(3)	(4)
Variable	Definition	In Levels	In Logs	In Levels	In Logs
Joskow 1987					
WEST	Indicator variable that equals 1 if coal is sourced from Western coal region	4.89, 5.89	0.614, 0.684	2.77, 2.99	0.403, 0.445
(+)		(1%), (1%)	(1%), (1%)	(1%), (1%)	(1%), (1%)
MIDWEST	Indicator variable; equals 1 if coal is sourced from Interior coal region	2.42, 3.87	0.515, 0.578	1.60, 2.11	0.212, 0.296
(+)		(5%), (1%)	(1%), (1%)	(1%),(1%)	(1%), (1%)
Quantity[a]	Annual quantity of coal contracted for	0.363, 0.379	0.494, 0.505	0.203, 0.234	0.230, 0.266
(?)			(1%), (1%)	(1%), (1%)	(1%), (1%)
Kerkvliet and Shogren 2001					
Lead Time	Number of years between contract's first announcement and announced year of initial coal delivery	0.582, 0.914	-	Data Not Available	
(+)		(5%), (5%)			
Mine reserve	Tonnage of coal specified over the life of the contract as a proportion of mine's reserves	25.31, 37.75	-	Data Not Available	
(+)		(1%), (5%)			

Table 74 Continued

		Original Study		Current Study[c]	
Variable	Definition	(1) Level	(2) Logs	(3) In Levels	(4) In Logs
Kozhevnikova and Lange 2009					
Quantity[b]	Minimum quantity specified for delivery to the plant (1000 tons)	1.94, 5.7	-	-	-
(+)		(1%), (1%)			
Plant dedicated Assets	Ratio of quantity for individual contract to quantity for the plant as a whole	0.03, -2.08	-	1.61, 1.79	0.211, 0.238
(+)		(), (5%)		(1%, 1%)	(1%, 1%)
Mine dedicated Assets	Ratio of quantity for individual contract to quantity for the mine as a whole	0.19, -0.53	-	0.538, 0.659	0.001, 0.052
(+)		(), ()		(5%), (1%)	(), ()
Current study					
*PHASE1*POST90*MIDWEST*				-1.15, -2.8	-0.29, -0.49
(-)				(1%), (1%)	(1%), (1%)
*PHASE1*POST90*				1.16, 1.99	0.18, 0.35
(+)				(1%), (1%)	(1%), (1%)
*POST90*MIDWEST*				-1.53, -1.90	-0.24, -0.31
(-)				(1%), (1%)	(1%), (1%)

Each cell entry under Columns (1) to (4) contains the highest and lowest magnitude amongst all the specifications reported. The level of significance at which the null hypothesis can be rejected is reported in parentheses under these coefficients. The dependent variable for all specifications is length. The expected sign for each variable is given in parentheses under the variable name. Refer to the text for additional explanation regarding how the estimates shown above are calculated.

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