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

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Abstract

Do discriminating contract structures imply systematic differences in performance? While causal mechanisms that explain the type of contract chosen are now well detailed, however, considerably less is known about the performance implications of these choices. To answer this question, I investigate the performance effects of coal procurement behavior over two decades by electric utilities in the US. I find prices to be lower under fixed price contracts, by between 7% to 20% of the total transaction price . Renegotiations are less likely under escalator contracts, but cannot be interpreted as opportunistic under any contract structure. Supplier productivity appears to increase substantially under fixed price contracts. Contract choices appear consistent with a trade-off between establishing incentives ex-ante and lowering negotiation costs ex-post, with relationship specific investments making such a trade-off compelling.

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1 Introduction

Holding the boundary of the firm constant, do alternative contractual arrangements imply tangibly different performance outcomes? 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. [1] A contracting perspective has also been fruitful toward assessing seemingly inefficient or unfair practices when the contractual nature of the problem is not obvious at the outset. [2] The incomplete contracting approach pioneered by Oliver Williamson has particularly held up well against empirical evidence.

A central prediction of the incomplete contracting literature is that contracts are chosen on the basis of the lowest cost, with "cost" being interpreted liberally to include ex-post negotiation or adaptation related costs. Most empirical studies only test this prediction indirectly by including proxies for those variables argued to increase costs (asset specificity, transaction complexity or uncertainty), but do not ask whether the predicted choices indeed correspond systematically to lower costs. Far less is known about the existence or size of such differences, and although recently there has been increasing attention paid to measuring such effects, by far the majority of

[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.

[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.

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's analysis of price rigidity (Joskow 1988, 1990) is an early example. To repeat, holding the boundary of the firm constant, do alternative contractual arrangements imply tangibly different performance outcomes?[3]

To answer this question, I study the effects of coal procurement choices made by US electric utilities, focusing on the pricing structure within the contracts used to procure coal. I employ a dataset that contains 14,777 distinct contracts for coal procurement by US electric utilities, covering a period of twenty years from 1979 to 2000. These contracts change significantly in structure over this time period, making them a good candidate for the question at hand: 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 (Figure 1). The majority of the replacement is by fixed price contracts, which account for more than 50% of the total contracts in 2000.

There are other reasons why examining contractual performance is of interest, aside from incomplete contracting theory. First, there may be important implications for electricity regulation, at least in the US. Most available data on coal prices aggregates together information from different contracts,

[3]In the setting I examine - contractual relations between utilities and coal mines in the US - the boundary of the firm is arguably constant, as there is very little vertical integration between mines and power plants. Only 1.5% of the total number of observations are recorded as "mine-mouth": that is, mines built very close to plants. It is likely such plants and mines function in an integrated manner, but even here it is not necessarily so.

irrespective of their pricing structure.[4] Consequently, analyses of the energy markets within the US that use coal prices (Busse and Keohane 2007, Fabrizio et al 2007, Cicala 2015) are unable to distinguish whether and to what extent their results are driven by procurement changes. Given the dominant role of coal in the US energy industry, if performance varies systematically by procurement choice (Bajari and Tadelis 2001), this concern is a significant one.

Second, procurement related changes appear at least as large as those associated with deregulation of the electricity sector. Cicala (2015) offers estimates of the impact of deregulation on procurement decisions. I find similar sized impacts but these come from the change in procurement choices, which as I argue below and elsewhere (Kacker 2014), owes primarily to the structure of investment decisions made by utilities and coal mines rather than the regulatory environment they operate under.

Third, as also noted by Cicala (2015), the sheer size of coal procurement by the electricity sector in the US makes the results interesting in their own right. On average, each shipment in the data I have delivers half a million tons of coal. At this scale, even a small shift in prices can end up having large effects.

I find that where fixed price contracts are chosen, transaction prices fall by $4 per ton. Correcting for possible endogeneity raises this estimate to around $7.5 per ton of coal shipped. Counterfactual estimates of prices also follow patterns consistent with historical work (Joskow 1988 1990).

[4]This is not a new point, Joskow (1990) makes a similar argument on the grounds of contract length. It bears repeating nevertheless.

One may question why suppliers would accept these lower prices. Relatedly, I find that fixed price contracts are subject to increased renegotiation. Suppliers may accept lower prices knowing they can call upon renegotiations to extract rent later on. If so, these price reductions cannot be necessarily interpreted as gains to utilities. Counter to this, I find renegotiations under fixed price contracts to be insignificant in driving price, quantity or quality of the shipped coal. Indeed, renegotiation under the alternate - escalator contracts - typically entail significant changes in quantities, but not prices. The systematically different nature of renegotiation under the two contract types is evidence of investment choices governing procurement choices.

The price reductions may, however, simply imply a transfer of rents from coal mines to electric utilities and not amount to real welfare gains. Examining the supplier side in more detail, I document whether the changed contract structure invoked a change in mining technique. The adoption of fixed price contracts leads to more efficient production decisions: thicker coal seams are chosen and labor productivity increases when these contracts are used. These effects vary by coal sourcing regions within the US: thicker coal seams are chosen only by western coal mines, while labor productivity increases are found amongst both Appalachian and western coal mines. Last, they are concentrated amongst surface mines within western coal and amongst underground mines for Appalachian coal. These results indicate the switch to fixed price contracts realized welfare gains, arguably by providing better incentives (Bajari and Tadelis 2001) in a manner consistent with underlying geological constraints (Buessing 2014).

Overall, the pattern of results supports the interpretation of contract choice in this industry balancing renegotiations and incentives, with specific investments in particular making this tradeoff acute. Di Maria et al (2014) also study the effect of different procurement choices in this industry. Their main focus, however, is on the impact of deregulation on these choices, and following that, the consequences of these choices. By contrast, as the data I have extends until 2000, the impact of deregulation would only come into effect toward the end of the sample period while the switch in contracts begins in 1990.[5] Additionally, I also analyze comprehensively the behavior of transaction prices and renegotiation structure under different contractual arrangements, which Di Maria et al (2014) do not. 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.

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.

[5] Texas was the first state to deregulate in 1995. Most states that did attempt deregulation did not start until 1997.

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[6].

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[7], which is costly to the buyer.

When there are significant investments specific to the relationship, therefore, 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 sourc-

[6]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.

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

ing 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 (Joskow 1988, Kacker 2014). 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. [8]

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 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, and concludes that although the contracts showed some rigidity in adjusting upward, the adjustment was quite rapid.

Demand was expected to increase, and prices expected to rise, in the early 1980s but these expectations did not materialize. 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)

[8] Bajari and Tadelis (2001) argue that when adaptations are required, suppliers are likely to know the costs better, and can consequently use this information to their advantage in the renegotiation. Similar arguments can be made for the buyer side as well. Viewed bilaterally, it is cheaper to ex-ante decide on responses rather than leave the decision for later.

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 2014). 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. Therefore, the renegotiations that took place should be mostly in re-specifying contractual terms, 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 was announced 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[9]. These changes imply substitution toward fixed price contracts (Kacker 2014), and if such contracts do encourage more efficient production, lower prices. I now turn to the behavior of these prices, differentiated by contract type.

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 1 shows this trend, and Table 1 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

[9] 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.

reduction in price. Table 2 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, and there is still a wide gap in the prices under a fixed price contract compared to the escalator/cost plus contracts. 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[10], 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.

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.

[10] 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.

4 Price performance of contracts

Table 3 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[11].

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.

[11] 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.

We can see, as argued earlier, that there are many missing observations for prices paid at the mine. The use of prices paid at the plant allows estimation from a much larger sample, and for reasons argued above, are likely to be more reliable. I will therefore take price paid at the plant to be my main dependent variable. 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[12]. I expect prices to be lower for fixed price contracts, and so expect a negative coefficient on FIXED when prices are the dependent variable.

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[13]. 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.

[12]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.

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

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 allows for greater economies of scale. I expect Interior coal to show a similar pattern, but since the differences are less pronounced[14], 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[15] 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[16] 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-

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

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

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

section[17], 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 supply can take place; we may expect that where the number of such routes is smaller, the prices are likely to be higher. ACCIDENTS measures insititutional 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[18].

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

[17] 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.

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

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 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 4 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[19].

[19]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.

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[20]. 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 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 5. 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[21]. 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

[20]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.

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

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 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. 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 6, I report the results considering the specifications in Columns (4) and (5) in Table 5, 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[22].

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.

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

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 further details). I use the two-step procedure as the maximum likelihood method failed to converge[23].

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[24]. 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,

[23]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.

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

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[25]. 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 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)[26]. 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-

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

[26]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.

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 [27].

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 2014), 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

[27] See Joskow (1988) for the difficulties associated with defining a norm for market prices, in the face of specialized investment.

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

Table 7 shows the results with the probability of choosing escalator/cost plus contracts 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 8, 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)[28].

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.[29]

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

[29]These results offer mixed confirmation of the Busse-Keohane findings, and it is par-

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 specifications, 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 ef-

ticularly interesting that the opposite effect shows when considering delivered prices.

fects, 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.

4.2 Counterfactual predictions for Prices

I use the models from Table 8 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 9 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[30]. 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 replaces by fixed price contracts, the utility would save approximately \$4 per ton of coal shipped. On the other hand, fixed price contracts replacing 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 escalator contracts is greater than for fixed price 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? Recall that escalator contracts are argued to safeguard investments specific to a buyer-supplier relationship. If so, replacing them by fixed price contracts runs the risk of raising negotiation costs. And if such investments are significant, such costs could offset the lower prices.

As I have argued elsewhere (Kacker 2014), such investments were significant until the announcement of the Clean Air Act Amendment in 1990, after which their importance declines. I will further this argument below by

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

showing that the pattern of renegotiation under escalator contracts differs from that under fixed price contracts in a manner that supports this interpretation. Before I discuss renegotiation, however, it may be instructive to analyze these predicted prices as they move across the 20 year period.

Figure 2 shows the prices predicted under the two contract types for delivered 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 are greater for fixed price contracts than for 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. It is around 1984/1985 that there appears to be a marked inflation in the prices under escalator/cost plus contracts. This reduces by 1986/1987 so much so that the prices in 1987 are statistically insignificantly different. Possibly this pattern reflects the results of modifications introduced earlier.

Did 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, escalator/cost plus contracts show great downward rigidity. One way therefore utilities could have adjusted to the diverging prices, in the face of 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, that is those contracts for which the year of signing equals the year the contract is recorded as being in force.

Figure 3 shows the results from running the models in Table 8 and Table 7 for newly signed contracts with delivered prices as the outcome. Two trends are apparent: one, there is a difference between the two contract types that widens over the mid-1980s. Two, this difference reverses itself fairly quickly. By 1987, predicted prices under the two contract types appear virtually identical. This is in sharp contrast to the overall sample, where by 1990 the two sets of prices are not just different in terms of averages, but also in terms of statistical significance. It appears that utilities and coal mines did adjust their contracts by negotiating lower prices in newer contracts.

4.3 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 10. 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

[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.

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, 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:

[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.

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 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

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

[35] First stage results are reported in Table 11. 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.

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 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 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 fixed price contracts reduces prices by approximately $7.5 per ton.

To sum up all the results so far, I present estimates from the three models - the OLS, Heckman and IV - in Table 12. 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.

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

5 Renegotiation and welfare implications

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. If this were true, the lowered prices cannot be interpreted as gains to utilities.

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 13 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 13 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 13, 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 necessary 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, as these contracts are supposed to safeguard relationship specific investment . 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, for two reasons. One, it was when these contracts were the majority choice that slack demand materialized. Two, as above, such contracts are argued to support relationship specific investment.

In Table 14, I show results of regressions with prices (columns (3) and (4)) and quantities (columns (5) and (6)) 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[37]. Further, the interaction of MODIFY with FIXED also yields no statistically significant effect. 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 of coal actually shipped, modification exerts a statistically significant effect

[37] I use delivered prices for two reasons. One, as above, they arguably pick up better information. Two, there are too few observations for mine prices when considering modified contracts.

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 that endeavor to protect the utility-coal mine relation. This pattern of renegotiation is consistent with the idea that such contracts were drawn up in responses to investment specific to each transactional relationship.

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 14. 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 more likely to take place with new suppliers 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[38].

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 15, 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

[38]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.

5.1 What's in it for the suppliers?

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 3, of newly signed contracts. [39]

When faced with a demand slowdown, escalator contracts were found by Joskow (1988, 1990) 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 4 I show the mean and 95% confidence intervals of predicted delivered

[39]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.

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 is statistically significant for five years, and the trend is clearly towards a lengthening difference. A similar pattern does not hold for fixed price contracts (Figure 5): 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.[40]

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

[40]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.

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 16. 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 16 along with the control variables used in earlier regressions: these 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 16, 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.[41] This is very strong evidence that escalator contracts were doing a much worse job

[41] 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.

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. [42]

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

5.2 Transfers or gains? Productivity and Mining Behavior

I have so far argued that the price drop associated with fixed price contracts was not compromised by opportunistic supplier behavior and can therefore

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

be interpreted as implying real gains to the utilities. Although escalator contracts play an important role in protecting specific investment, evidence for which I have drawn from the reneogtiation patterns and from earlier work (Kacker 2014), they also do increasingly worse at tracking prices once these investments fall in importance, making the move to fixed price contracts more attractive. It is still debatable whether the gains from lower prices were real gains or simply transfers from mines to utilities, if escalator contracts allowed suppliers to keep some information rents for themselves. In addition, fixed price contracts are argued to provide for high-powered incentives and thereby improved performance (Bajari and Tadelis 2001). If fixed price contracts do improve performance as well, then the price drop can be understood as implying real gains for both sides of the markets.

To understand whether such behavior can indeed be tracked, I use data from the Mine Safety and Health Administration (MSHA) over the period 1984 to 2000. The MSHA record, for each coal county, total production of coal and labor hours involved in mining the same. In addition, it also includes information on the seam height of the coal seam being mined. These data also allow for a decomposition of the information into surface and underground mines, which as we will see turns out to be important. I match this information to the contract dataset using the coal county recorded in the contract dataset.

In Table 17, I show the results of both OLS and instrumental variables models of the impact of fixed price contracts, with the outcome variable being production divided by labor hours. Columns (1) to (3) show results for the overall data, while columns (4) to (6) use data only from surface mines and columns (7) to (9) only for underground mines.

As we can see, the adoption of fixed price contracts is associated with an increase in productivity (as defined by the number of tons mined per hour of labor), by about 38% when evaluated using the average productivity of surface mines. Once again, instrumental variables estimates are significantly larger than the OLS estimates, and we can see they pass all the tests for relevance and validity. Both the pattern and size of these results is very much in line with Cicala (2014), whose focus is on the impact of deregulation. If anything, the present estimates are larger, implying that the changed structure of contracts had a larger impact than the deregulation of the electricity sector, at least as per Cicala's estimates.

Importantly, as shown by columns (4) to (9), the productivity increase in concentrated amongst surface mines. In fact, the coefficient estimate for underground mines is statistically insignificant. Such a pattern is sensible because underground mines are typically limited in terms of how much production can be expanded (Buessing 2014). In addition, this result is in line with Cicala (2014) who finds much larger productivity gains amongst surface mines following deregulation.[43]

Further evidence that there were real production changes following the adoption of fixed price contracts is in Table 18. Here I present results with coal seam height as the outcome variable. A larger coal seam height indicates

[43] A possible explanation for these results could be that the mix of labor and capital was altered, which need not necessarily correspond to productivity improvements. I have explored this issue by looking first at total production, then at total hours, and find the adoption of fixed price contracts leads to an increase in both suggesting strongly the increased production-to-labor ratio does indicate more productive labor. I do not include these results, but they are available on request.

a more productive mine, or part of a mine, as it implies more coal from a single dig. Once again, we see instrumental variable estimates that are much larger than OLS estimates, and once again, the effect appears concentrated around surface mines. The coefficient estimates imply a 30% increase in average coal seam height for surface mines. Once more, these estimates are comparable to those Cicala (2014) finds.

These set of results indicate very strongly that the shift over to fixed price contracts constituted substantial change in mining strategy, with increased productivity of existing resources and a shift over to more productive mines following the contractual change. With this shift, it is plausible that suppliers accepted lower prices partly because they were able to creatively use existing resources and mines more efficiently. Importantly, what we may conclude is that the change in contracts did not merely re-allocate surplus from suppliers to buyers (in the form of lower prices), but also lead to substantial welfare gains for all (through improved productivity, a result of which is lowered prices).

To assess the robustness of these results, it would be useful to see if the effects estimated above vary across coal deposits. The geological properties of US coal vary considerably over the country. Western coal is typically found in thicker seams closer to the surface, while Appalachian coal seams are much thinner and typically require mining to be carried out underground. As such, it may be that the effect of fixed price contracts is not homogenous across these two coal supply regions. Additionally, understanding whether such heterogenous effects are in operation allows us to see if the changed contract effects weren't simply concentrated amongst the Western mines.

As western coal seams are thicker, we may expect that the impact of the changed contract in terms of coal seams would be substantively larger for western coal mines, as there is more room to expand mining onto thicker seams. Such effects are likely to be much more constrained for Appalachian coal. In terms of labor productivity, the size of the effect is expected to be greater for western mines among surface mines, and for Appalachian coal among underground mines. Table 19 lists the results when splitting the sample by western or Appalachian coal for these outcome variables.[44]

All the results are from instrumental variable specifications, with plant fixed effects, a set of control variables, year indicator variables and contract length as an additional endogenous variable that is also instrumented for. We can see that there are indeed highly heterogenous effects in the expected directions. Labor productivity is significantly affected amongst surface mines for western coal and amongst underground mines for Appalachian coal, with the former effect more than six times that of the latter, and twice that of the pooled sample. Seam height is however significantly affected only for western coal, but note that for underground Appalachian mines the impact is positive although statistically insignificant. Again, the impact on seam height is larger for the western coal sample than for the pooled sample, by nearly three times.[45]

[44]I have also examined the full sample, but defining interactions of CONTRACT with WEST and EAST. The coefficients on these interactions are always statistically significant at the 5% level of significance, and the signs are consistent with the results reported here. The size of the coefficient is however smaller than the instrumental variable estimates presented in Table 19. I do not include these results, but they are available on request.

[45]For the western coal sample, the results shown do not include length, as the effect of length was both statistically insignificant as well as small in size. The instruments also perform worse when including length. Nevertheless, when including length (and instrumenting for it), the results on labor productivity are similar, although only surface

The presence of heterogeneity confirms that the adoption of fixed price contracts led to production changes, but only along margins that allow for these to take place. It is harder to find thick coal seams along the Appalachian belt, and so there are small and insignificant changes for these coal suppliers following the adoption of fixed price contracts along the coal seam dimension. Conversely, for western coal, there are large and statistically significant increases in coal seams. For both types of coal, though, labor productivity rises when fixed price contracts are used. The rise is much greater for western coal, and concentrated amongst surface mines, while it is concentrated amongst underground mines for Appalachian coal. These results further strengthen the interpretation that the use of fixed price contracts correspond to substantial welfare gains.

6 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 provided under a fixed price contract. The shift over to fixed price contracts appear to have followed a reduction in the relationship specificity

mine labor productivity is significantly affected. The coefficient estimate for seam height is also similar when including contract length, but the error increases, and the resulting estimate is statistically significant at the 10% level of significance with a p-value of 0.075. All the tests for relevance and validity are passed when including length. These results are available on request.

of investment, and resulted in prices lowered by between 7% to 20%.

Using a proposition contained in Williamson (1985), I identify a pattern of renegotiation under the two contract types (escalator and fixed price) from which I take two conclusions. One, that renegotiations follow very different paths under the two contract types, in a manner that strongly supports the argument that escalator contracts were built to safeguard relationship specific investment. Two, renegotiations under fixed price contracts, although more frequent, were unlikely to lead to significant changes in quantities, prices or coal characteristics. Di Maria et al (2014) argue that increased renegotiations from fixed price contracts may be interpreted as a welfare reducing effect of deregulation (which, they argue, promotes the use of fixed price contracts). My results suggest there is some subtlety in interpreting contract renegotiations and qualify this argument, as the increased renegotiations under fixed price contracts appear rather mild. Further, fixed price contracts appear to have also improved considerably supplier productivity, as Bajari and Tadelis (2001) argue they should.

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. 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 (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 fixed price contracts result in lower prices, due primarily to the high-powered incentives present in such contracts, it also true that escalator 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.

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Figures

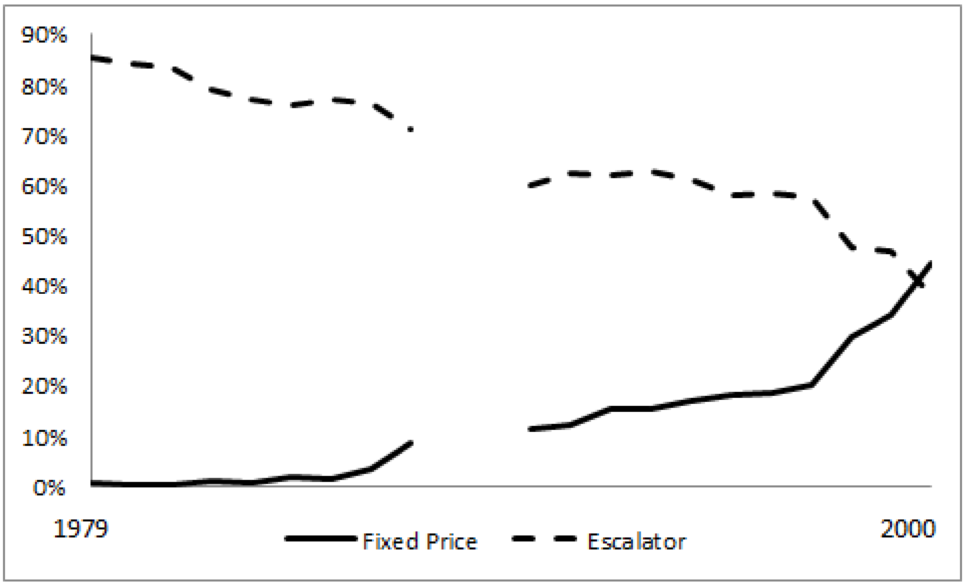

Figure 1: Rising use of fixed price contracts (Source: Coal Transportation Rate Database, Author's Calculation)

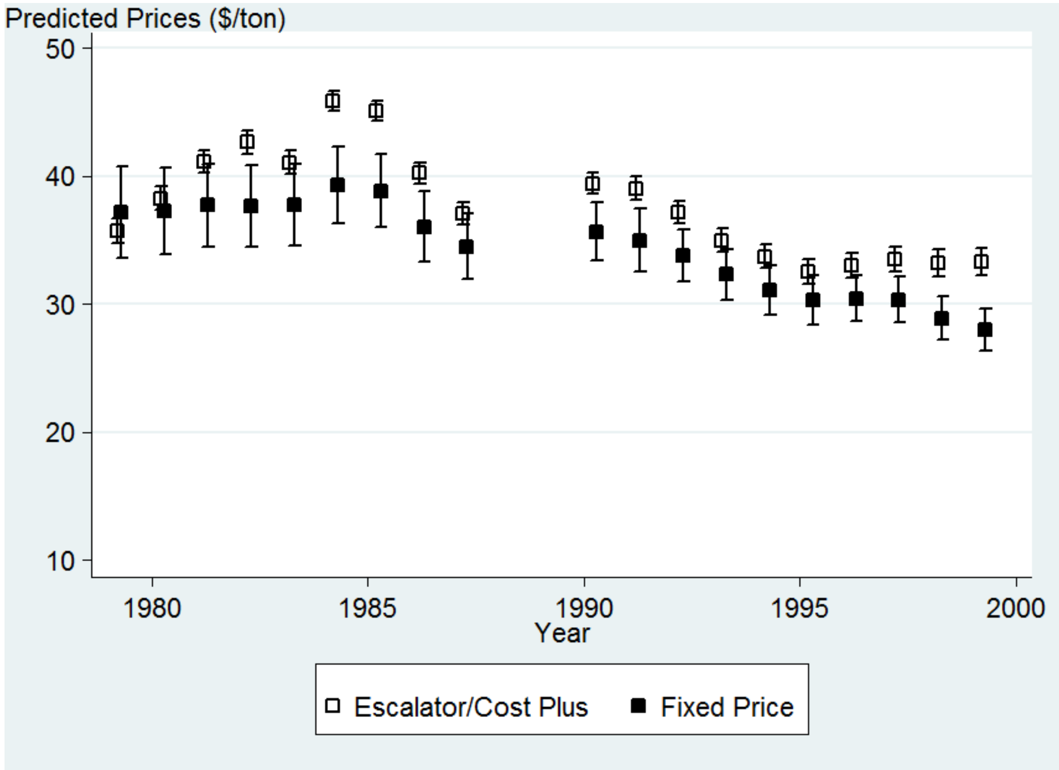

Figure 2: Predicted Prices ($/ton) from the Heckman Model

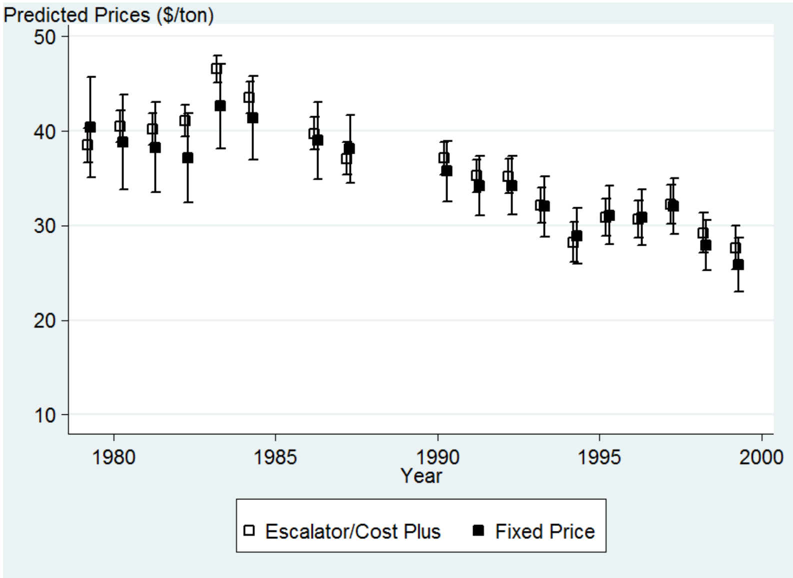

Figure 3: Predicted Prices ($/ton) for New Contracts

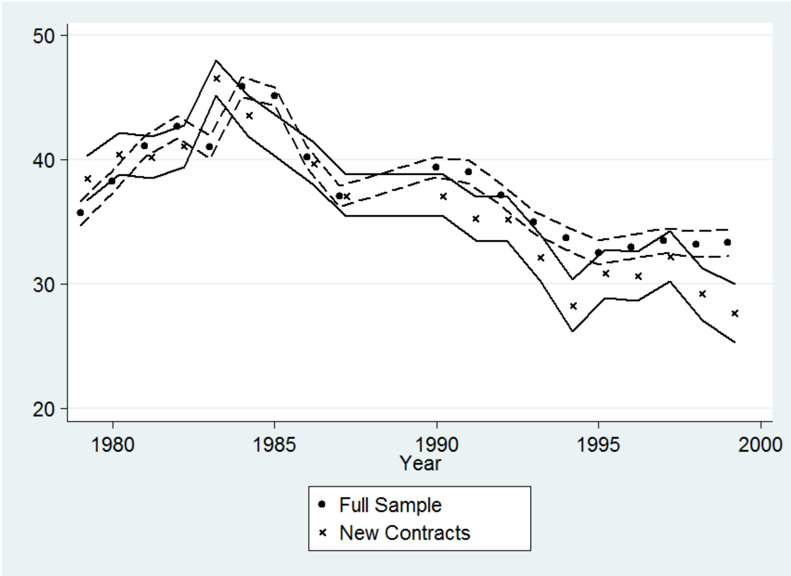

Figure 4: Comparing New Contracts to Full Sample: Escalator Contracts

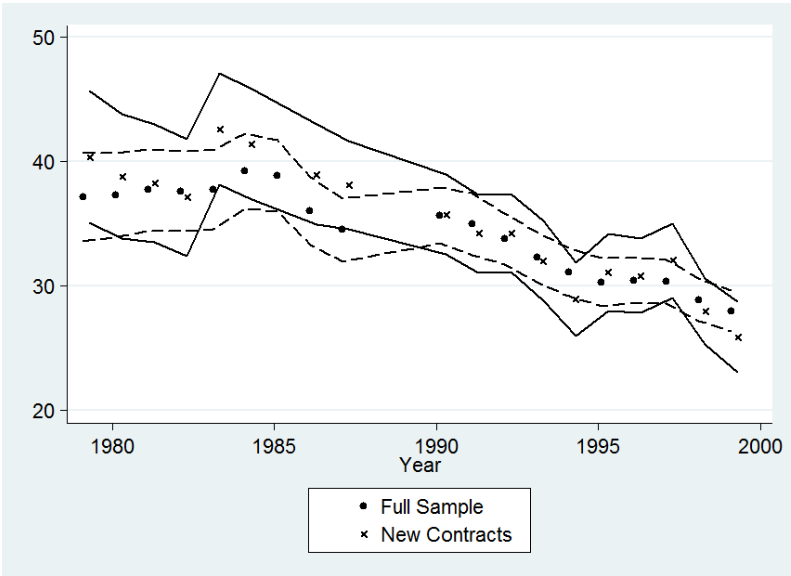

Figure 5: Comparing New Contracts to Full Sample: Fixed Price Contracts

Tables

Table 1: 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 2: 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 (9.89)	37.73 (12.41)	39.36 (11.97)
Observations	4614	10312	4607
Fixed Price	23.38 (7.36)	28.77 (11.11)	33.18 (11.97)
Observations	302	1684	302
t-statistic for difference in means	13.971	30.153	8.69

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.
The numbers in parentheses indicate standard deviations.

Table 3: Summary Statistics

Variable	Observ ations	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 3 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 3 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 4: 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 5: 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 5 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 6: 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 6 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 7: 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 7 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 8: 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 8 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 9: 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 10: 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 11: 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 12: 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 13: 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 14: What does renegotiation entail? Renegotiation, Prices and Quantities

	Probability of Multiple Renegotiation		Delivered Price ($/ton)		Tons Shipped (Millions)		Probability of Repeat Supplier	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
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	0.0375	0.0457		-3.254***		-0.171***		-0.0593**
	(0.0372)	(0.0376)		(0.583)		(0.0528)		(0.0265)
MODIFY*FIXED				-0.993		0.00414		-0.0630
				(0.554)		(0.0403)		(0.0391)
Length		0.00406						
		(0.00214)						
Controls	Y^a	Y^a	Y^b	Y^b	Y^c	Y^c	Y^d	Y^d
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	8,547	8,547	6,407	5,097	6,917	5,487	7,501	5,979
R-squared	0.080	0.082	0.455	0.482	0.078	0.103	0.183	0.199
# Plants	313	313	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: QUANTITY, 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) are the same as those for columns (1) and (2), except QUANTITY is not included.

(c) 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.

(d) Controls for columns (5) and (6) include: MODES, ACCIDENTS, DISTANCE, RESTRUCTURE, interactions of PHASE1, POST90 and MIDWEST, DEDICATE, and SULF

Table 15: 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 16: 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 16 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.

Table 17: Contract Structure and Mining Choices: Labor Productivity

	Overall			Only Surface Mines			Only Underground Mines		
	OLS	OLS	IV	OLS	OLS	IV	OLS	OLS	IV
	(1)	(2)	(3)[b]	(4)	(5)	(6)[b]	(7)	(8)	(9)[b]
FIXED	0.589*			0.712**			-0.0735		
	(0.305)			(0.307)			(0.112)		
CONTRACT		0.617**	3.309**		0.723**	3.578**		0.00842	0.457
		(0.310)	(1.445)		(0.310)	(1.414)		(0.0960)	(0.663)
Controls[a]	Y	Y	Y†	Y	Y	Y†	Y	Y	Y†
Plant FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y		Y	Y		Y	Y	
Kleibergen-Paap Wald F statistic			10.60			11.07			6.394
Underidentification test ‡			33.46			34.28			17.93
p-value			2.58e-07			1.73e-07			0.000455
Hansen J statistic			3.506			3.670			0.264
p-value			0.173			0.160			0.876
Observations	6,830	8,130	7,526	6,438	7,732	7,153	4,959	6,134	5,785
R-squared	0.792	0.793	0.789	0.783	0.789	0.791	0.321	0.337	0.309
# of Plants	304	310	287	295	302	281	244	251	233
Outcome Mean		8.79			9.40			3.20	

Notes: Standard errors in parentheses, clustered by plant unless otherwise indicated. *** p < 0.01, ** p<0.05, * p< 0.1.
a: Controls include COST, MODES, ACCIDENTS, Distance, Reserves, interaction of Reserves with INTERIOR and WEST, BTUs, Sulfur, Ash and Moisture Shipped, and a control variable.
b: Instruments used: DEDICATE, DEDICATE SQUARED, PLANT DEDICATE, and REPEAT.
†: Additional controls used here are year indicator variables, and contract length as an endogenous variable, which is also instrumented for using the instruments listed above.
‡: The under-identification test statistic (and the associated p-value) is the Kleibergen-Paap statistic.

Table 18: Contract Structure and Mining Choices: Seam Height

	Overall			Only Surface Mines			Only Underground Mines		
	OLS	OLS	IV	OLS	OLS	IV	OLS	OLS	IV
	(1)	(2)	(3)[b]	(4)	(5)	(6)[b]	(7)	(8)	(9)[b]
FIXED	12.62*			11.85			0.510		
	(7.575)			(7.961)			(0.862)		
CONTRACT		15.93**	48.55**		16.11**	51.59**		1.933*	12.49*
		(6.848)	(24.37)		(7.114)	(26.13)		(1.096)	(6.886)
Controls[a]	Y	Y	Y†	Y	Y	Y†	Y	Y	Y†
Plant FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y	Y		Y	Y		Y	Y	
Kleibergen-Paap Wald F statistic			11.67			13.20			7.913
Underidentification test ‡			38.75			40.92			22.93
p-value			7.84e-08			2.79e-08			0.000131
Hansen J statistic			6.255			4.618			2.374
p-value			0.0998			0.202			0.499
Observations	6,835	8,135	6,859	6,508	7,804	6,604	5,054	6,229	5,351
R-squared	0.630	0.644	0.671	0.570	0.589	0.607	0.015	0.017	0.006
# of Plants	304	310	283	298	305	278	245	252	232
Outcome Mean		162.73			168.87			60.45	

Notes: Standard errors in parentheses, clustered by plant unless otherwise indicated. *** $p< 0.01$, ** $p<0.05$, * $p<0.1$.
a: Controls include COST, MODES, ACCIDENTS, Distance, Reserves, interaction of Reserves with INTERIOR and WEST, BTUs, Sulfur, Ash and Moisture Shipped, and a constant term.
b: Instruments used: DEDICATE, DEDICATE SQUARED, PLANT DEDICATE, and REPEAT.
†: Additional controls used here are year indicator variables, and contract length as an endogenous variable, which is also instrumented for using the instruments listed above.
‡: The under-identification test statistic (and the associated p-value) is the Kleibergen-Paap statistic.

Table 19: Contract structure and Productivity: Heterogenous Impacts between Coal Supply Regions

Panel A: Labor Productivity

	Overall		Surface		Underground	
	Appalachian	Western	Appalachian	Western	Appalachian	Western
	(1)	(2)	(3)	(4)	(5)	(6)
CONTRACT	0.877**	5.600***	0.357	6.793***	1.139***	2.315
	(0.349)	(1.817)	(0.490)	(2.038)	(0.425)	(1.991)
Controls[a]	Y	Y	Y	Y	Y	Y
Plant FE	Y	Y	Y	Y	Y	Y
Kleibergen-Paap Wald F statistic	13.73	25.22	14.80	20.28	12.89	6.588
Underidentification test ‡	35.80	30.54	35.82	28.32	33.62	8.689
p-value	3.19e-07	3.80e-06	3.15e-07	1.08e-05	8.91e-07	0.0694
Hansen J statistic	5.015	4.390	5.576	3.042	6.932	1.954
p-value	0.171	0.222	0.134	0.385	0.0741	0.582
Observations	4,673	1,510	4,623	1,341	4,489	331
R-squared	0.400	0.531	0.381	0.493	0.285	0.134
# of Plants	175	107	175	98	173	37

Table 19 Continued

Panel B: Seam Height

	Overall		Surface		Underground	
	Appalachian	Western	Appalachian	Western	Appalachian	Western
	(1)	(2)	(3)	(4)	(5)	(6)
CONTRACT	6.470	101.2**	-3.759	164.3***	5.965	-6.832
	(8.214)	(43.73)	(11.98)	(57.74)	(7.865)	(7.787)
Controls[a]	Y	Y	Y	Y	Y	Y
Plant FE	Y	Y	Y	Y	Y	Y
Kleibergen-Paap Wald F statistic	8.927	25.22	9.758	19.58	8.812	6.595
Underidentification test ‡	23.43	30.54	24.37	27.60	23.98	8.685
p-value	3.28e-05	3.80e-06	2.09e-05	1.50e-05	2.52e-05	0.0695
Hansen J statistic	5.507	3.587	7.738	1.510	4.088	0.946
p-value	0.0637	0.310	0.0209	0.680	0.130	0.814
Observations	5,151	1,510	5,107	1,363	4,942	332
R-squared	0.001	0.382	0.006	0.257	0.002	0.365
# of Plants	179	107	179	99	177	37

Notes: Standard errors in parentheses, clustered by plant unless otherwise indicated. *** p< 0.01, ** p<0.05, * p<0.1. Instruments used: DEDICATE, DEDICATE SQUARED, PLANT DEDICATE, and REPEAT. In addition, SULF is used as an instrument for the labor productivity outcomes in the Appalachian coal sample.

a: Controls include COST, MODES, ACCIDENTS, Distance, Reserves, interaction of Reserves with INTERIOR and WEST, BTUs, Sulfur, Ash and Moisture Shipped, a constant term variable, year indicator variables and contract length as an endogenous variable, which is also instrumented for using the instruments listed above. Length is not included in the regressions for the Western coal sample.

‡: The under-identification test statistic (and the associated p-value) is the Kleibergen-Paap statistic.

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.