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Why Do Firms Simultaneously Purchase in Spot and Contract Markets? Evidence from the United States Steam Coal Market

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This paper studies the relationship between spot and contract markets from the perspective of firms which simultaneously purchase the same input in both markets. Our empirical analysis concentrates on a nationwide market with active spot and contract markets–the US electric utility steam coal market. We explore the empirical implications of three rationales for simultaneous participation in spot and contract markets: (1) to insure against unforeseen supply interruptions or purchase price variability, (2) to avoid the increased costs associated with spot relative to contract transactions with geographically dispersed producers, and (3) the use of spot transactions to reward or punish behavior by either side of the transaction on the contract market. We find empirical support for each of these rationales. In particular, we find a surprising degree of integration between the spot and contract market for US steam coal, although there does appear to be a fairly large, but stable, price premium on contract versus spot transactions.

1. INTRODUCTION

There are many markets where agents simultaneously transact in both the short-term, or spot market, and the long-term, or contract market. For example, the raw material supply process for most public utilities is characterized by simultaneous spot and contract transactions. In the

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case of the water utilities, water is supplied by both long-term contracts and short-term supply agreements. Electric utilities purchase coal, oil, and natural gas in both the spot and contract markets during the same time period.

Although these spot and contract markets sell the same physical commodity, because of the many stipulations on the magnitude, price, and quality of the product delivered under long-term contractual arrangements, no arbitrage relation must hold between spot and contract market magnitudes similar to those which hold between futures market and spot market magnitudes. Nevertheless, the desire of firms to maximize expected profits provides incentives for them to enter into long-term contracts only in those instances where the expected profits from engaging in a long-term supply agreement are larger than those derived from relying solely on spot market transactions. Consequently, this expected profit maximizing motive by purchasing firms should imply certain relationships between the spot and contract quantities it purchases, the prices it faces, and the suppliers it selects for each kind of purchase.

There has been some theoretical research studying the relationship between spot and contract markets. Carlton (1978,1979) studies differences in price rigidity across the two markets and the supply side of the spot versus contract market participation decision. Hubbard and Weiner (1992) construct a model with risk-averse buyers and sellers of a good traded on both spot and contract markets. In their model, the spot price and the price of buyers' downstream output are stochastic, so that buyers and sellers participate in the contract market to insure against price uncertainty. The authors derive the equilibrium share of trades carried out on the contract versus spot market. There is also a literature on the frequency of price changes under contractual purchasing arrangements, the most notable being the analysis by Stigler and Kindahl (1970). Carlton (1986) has undertaken re-examination of the Stigler and Kindahl dataset, focusing on an empirical characterization of transactions price rigidities.

The purpose of this paper is to investigate empirically the reasons a firm would simultaneously purchase in the spot and contract market for the same commodity. We concentrate on the US electric utility steam coal market, although many of our findings should provide insight into the operation of other markets with simultaneous spot and contract market transactions. We propose three distinct rationales for this behavior and examine the validity of several relationships between observable spot market and contract market magnitudes which are implied by each.

The first of our three rationales is to insure against uncertainty in the form of either supply interruptions or large spot price fluctuations. Because public utilities must, by law, supply all that is demanded at the regulated price, they do not have the ability to use price to allocate demand. To guarantee it can meet these demand obligations at the regulated price, a utility has the incentive to engage in long-term supply arrangements which ensure a stable input supply at a relatively predictable price. The regulatory process setting the output price for these utilities is not required to compensate them for all input price increases. Consequently, utilities have an incentive to enter into long-term contracts to guard against this potential for large spot price increases. We refer to this set of reasons for contracting as the risk aversion rationale.

The second rationale has to do with the geographic size of a firm's contract versus spot market. A spot transaction is more likely to fail the larger the distance between the consumer and the supplier, holding all other factors constant. A long-term supply agreement enables the supplier and consumer to explicitly account for many of the adverse contingencies which might arise due to the greater distance between these two economic agents. Consequently, the location of the consuming firm relative to all supplying firms should be an important factor in the consuming firm's spot versus contract market purchase decision.

The final rationale for simultaneous participation in both markets is as a contract enforcement device to reward or punish a contract supplier. This rationale has its roots in Williamson's (1979) transactions-cost theory of economic interactions. For this reason, we call it the "relationship-specific rationale." One can think of a consuming firm (or producing firm) as holding out the promise of favorable future spot purchases to discourage opportunistic behavior by a contract supplier (or consuming firm). In addition, there may be aspects of the supply process which somehow make spot deliveries cheaper once a long-term supply relationship has been established. For example, the existence of a minemouth plant or dedicated rail link reduces the cost of future spot market transactions between a mine and plant. All of these relationship-specific rationales imply that contract purchases from a given supplier increase the likelihood or magnitude of spot purchases from that same supplier.

While these three reasons are not mutually exclusive, they do provide a useful classification system for studying the operation of a firm purchasing in spot and contract markets for the same commodity. A preferable strategy for analysis would be to specify an equilibrium model of expected profit-maximizing supplier and demander behavior which incorporates these three rationales. However, as the above discussion illustrates, the current state of the theoretical literature on simultaneous spot and contract market participation is not far enough along to have an empirically plausible, rational-actor equilibrium model of one of the rationales. This making constructing a model simultaneously incorporating all three rationales prohibitively difficult at this time. Although formulating and estimating such a model is the final goal of this line of research, the present paper has the intermediate goal of investigating the empirical validity of these three rationales. This analysis is still an important input into our ultimate goal of a structural model of spot and contract participation. It provides a ranking for the order in which aspects of these rationales should be incorporated into a structural model of this environment. This analysis also provides an assessment of the relative importance of each of these rationales to different types of consuming firms.

The remainder of the paper proceeds as follows. In the next section we summarize the history and current operation of the US electric utility steam coal market. We then describe the data sources used to perform our analysis. This section concludes with the presentation of summary statistics on the operation of this market for our sample of monthly data for the period 1985 to 1988. Section 3 first outlines the risk aversion rationale for simultaneous spot and contract market participation and characterizes its implications for the operation of the two markets. We then present the results of our empirical analysis of these implications. Section 4 follows the same procedure as Section 3. First we outline the implications of the size-of-the-market rationale and then present our empirical investigations of their validity. Section 5 repeats this same two-step procedure for the relationship-specific rationale. Section 6 summarizes and integrates the empirical evidence from the previous three sections. Section 7 contains our answer to the question posed in the title of the paper, and then discusses some caveats associated with these conclusions. Readers wanting a short summary of findings should refer to the first part of Section 7.

2. THE US ELECTRIC UTILITY STEAM COAL MARKET

Beginning with the 1973 Arab Oil Embargo, a concerted effort was made to wean the US Electric Utility Industry from using oil to generate base load power. This prompted a search for alternative energy sources for electricity generation. Nuclear power initially emerged as the new energy source of choice for baseload power, with coal of secondary importance because of its air pollution control problems. However, the events of Three Mile Island and the ensuing increased stringency in the regulation of both nuclear plant operations and new plant construction drastically reduced the attractiveness of nuclear power. Consequently, by the beginning of the 1980s coal had emerged as the major source of energy for new base load electricity generation.

This increased desirability of coal as an energy source for electricity generation led to the rapid development of coal reserves throughout the United States, particularly in the Rocky Mountain and Great Plains regions. The most rapid expansion in coal production occurred in Wyoming where annual production increased from 45 million short tons in 1977 to almost double that amount, 86 million short tons, in 1980. The growing concern for air quality and acid rain increased the desirability of coal from the Western US because of its low sulfur and ash content. The extremely low-cost strip-mining technology used in the West makes this coal competitive with locally produced coal in regions as far away as Alabama (and certainly in Illinois and Indiana), even after accounting for substantial delivery costs.

Another aspect of the market that underwent dramatic changes during the late 1970s and early 1980s was the form of price adjustment provisions in long-term coal contracts. Because of the relatively stable coal market during the period leading up to the first Oil Embargo, contracts negotiated prior to 1973 contained very few provisions for price review (Carney, 1978). In fact, up until the early 1970s, coal production was characterized by steady productivity improvements, which were built into the contracting process, so that both producers and consumers shared in the cost-savings which resulted from the labor productivity gains (Carney 1978). However, the events of the early 1970s rendered this form of price adjustment in long-term coal contracts obsolete.

Two events of the late 1960s set the stage for the failure of the existing contract provisions. The changes in the form of the labor contracting process led to a rapid increase in the number of wildcat strikes. The passage of the Federal Coal Mine Health and Safety Act of 1969 led to the implementation of many wide-ranging regulations governing mine operations. As a consequence of these two events, average labor productivity for coal-mining actually declined from the late 1960s to the early 1970s. The inflation which followed the 1973 oil shock only intensified the magnitude of the failure of the existing contracts to adjust to current market conditions. The most telling evidence for this failure is that, for much of the remainder of the 1970s, the average (nationwide) spot price greatly exceeded the average contract price.

Contracts written in the post-1973 period contained provisions which allowed both productivity improvements and declines to be shared between consumers and producers. Various forms of price adjustment clauses were written into contracts signed during this period; these clauses allow contract prices to change because of changes in (1) transportation costs, (2) labor costs, (3) Federal or State legislation, (4) published US government statistics relevant to the coal industry, or (5) other extraordinary events unforeseen at the time the contract was signed. Joskow (1985) discusses the various price adjustment provisions in more detail. These types of contracts are referred to as base-price-plus-escalation (BPE) contracts. This contractual form has become the standard for the post-1973 period. On the quantity side of the contract market, the usual stipulation is for a target amount of annual tonnage with minimum and maximum deliveries as percentages–usually around 10 percent–of this target (Pasha Publications, 1983).

These new contract forms were designed to allow the contract market price to more closely track current market conditions. In a series of papers on long-term coal contracts, Joskow (1985,1987,1988a,1988b,1990) studied among other things, the price adjustment process for various vintages of contracts. Joskow notes that the generic form of a BPE contract uses as its basis for price escalation a weighted average of indices of input costs, primarily labor costs (Joskow, 1988a and 1990). Although

he found evidence that some individual contracts did a very poor job of tracking changing coal market conditions over the latter part of the 1970s, his general conclusion (in Joskow 1988a) was that BPE contracts quite closely tracked prevailing market conditions (as measured by the price of new coal contracts) during the 1970s. However, this time period was characterized by expanding demand for steam coal and rising costs of production. Joskow (1990) argues that, beginning in approximately 1983, the rate of growth of the demand for steam coal declined and BPE contracts signed before this slowdown did a substantially poorer job of tracking current market conditions than did those contracts negotiated post-1983. By comparing the price adjustment performance of contracts signed before 1983 with those signed in 1984 and 1985, Joskow argues that the failure of the earlier BPE contracts to adapt to the demand slowdown was due to their being indexed to input costs (which continued to increase during this period) rather than to current demand conditions. Joskow (1990) states that this demand slowdown primarily affected Midwest and Eastern coal, whereas Western coal continued to experience growth, but at a slower rate than during the late 1970s and early 1980s.

Another aspect of this market which deserves comment given the issues we study is the extent of vertical integration between coal suppliers and electric utilities. Many of the contingencies which a contract relationship insures against can be avoided by vertical integration between the utility and coal supplier. In addition, because utilities are regulated they may be able to transfer monopoly rents to their unregulated coal subsidiaries by paying inflated transfer prices for coal purchased from these captive suppliers.

These two incentives for vertical integration resulted in a trend toward vertical integration between coal suppliers and utilities immediately following the first oil price shock in 1973. This triggered concern on the part of regulators that, despite the potential for efficiency gains in electricity supply due to vertical integration, these utilities may be earning excess profits through transfer pricing. In response to this concern, the Justice Department commissioned a study to investigate this and other issues associated with the extent of competition in the coal industry (US Department of Justice, 1978). Gordon (1974), in a related study of input supply procurement patterns of electric utilities, found that the largest users of coal are most likely to use long-term contracts to procure the majority of their input supply. However, he did find that some of the coal supplied to these utilities was obtained from captive mines. Gordon explained this result by noted that mine-ownership by large utilities provided useful information to them about the coal-mining process which "might improve the utilities' abilitiy to negotiate and enforce purchase agreements" (Gordon 1974, p. 35).

Following this initial spate of vertical integration, state regulatory agencies responded by becoming increasingly harsh in their treatment of prices set for inputs sold to electric utilities by their vertically integrated coal-suppliers. Fuhr (1990) summarizes the results of many regulatory rulings on transfer pricing which proved extremely costly to utilities involved. Further evidence for the importance of the regulatory process facing a utility on its decision to vertically integrate is provided by a study of the relationship between the mode of transfer pricing allowed by a regulatory commission and the decision of the utilities under its jurisdiction to vertically integrate. For a sample of 87 US utilities in 1975, Filer et al. (1984) find that utilities in states in where transfer prices from the coal producer to the utility are determined by a mining cost plus fixed return on equity method have a higher probability of being vertically integrated into coal production.

This suspicious treatment of transfer pricing by state regulatory commissions in late 1970s and early 1980s led to very little increase in the degreee of vertical integration. At present, most vertical integration occurs in the case of minemouth power plants and only comprises a small fraction of steam coal consumed. In addition, these minemouth plants are almost exclusively located in the Western US. According to Joskow (1985), only approximately 15 percent of total coal utilization by utilities is accounted for by vertically integrated supply. Consistent with Gordon's (1974) results, Joskow finds that integrated utilities tend to be the large consumers of coal, but only a few of these obtain 100 percent of their coal requirements from captive mines. Consequently, because of unfavorable regulatory treatment and limited efficiency gains from coal mine ownership (except for minemouth plants in West), vertical integration is of minor importance to the US electric utility steam coal market.[1]

[1]To give some idea of the lack of importance of vertical integration in this market, Joskow (1985) cites the example of coal production for the coking (iron and steel) industry where 65 percent of consumption comes from integrated suppliers.

This short history brings us to our sample period from the beginning of 1985 to the end of 1988. Before describing the general features of the market over our sample period, we first describe the data sources used in this analysis. The major source is the monthly coal transactions data compiled by the Federal Energy Regulatory Commission (FERC) Form 423, *Monthly Reports of Cost and Quality of Fuels for Electric Plants.* Each month, electric utilities are required to submit a detailed summary of coal deliveries received. For each transaction they must list the mine of origin of the coal, the mine type (surface or underground), whether it is a spot or contract purchase, and, if it is a contract transaction, several characteristics of the form of the long-term contract. In addition to the price and quantity associated with each transaction, characteristics of the coal delivered–BTU, Sulfur, and Ash Content by weight–are also reported. For the purposes of Form 423 (and our analysis), spot transactions are defined as any "shipments under purchase orders or contracts of less than one year duration" (FERC Form 423). Contract purchases are defined as the complement event in terms of the length of the contract. These data also identify the generating facility consuming the coal purchased. Using information collected from the Energy Information Adminstration (EIA) Form 767, *Steam-Electric Plant Operation and Design Report,* we can determine the operating characteristics of the plants receiving coal. The most important piece of information for our purposes, collected by Form 767, is the latitude and longitude of the plant. We have also collected information on the latitude and longitude of each mine in the sample. [2] From this information, we can compute the straight-line, air-distance between any coal mine and power plant. This transportation distance information is essential to our study of the size-of-the-market rationale for spot and contract market participation.

We now summarize the performance of the US Steam Coal Market over our sample period. Figures 1 and 2 give a time series plot of the average monthly spot and contract delivered prices and quantities. Average delivered prices are computed as quantity weighted averages over all monthly

[2]Our algorithm for assigning latitudes and longitudes to mines uses the precise latitude and longitude of the mine when available, and when unavailable the values for the county seat of the county in which the mine is located.

transactions prices for all 363 generating plants in our sample. As is clear from the figures, the market downturn referred to in Joskow (1990) continued for much of our sample. From 1985 through the end of 1987, the average monthly amount of contract coal delivered in millions of BTU rose only slightly, whereas the average delivered price fell steadily over this same time period.[3] The average spot market quantity delivered increased at a slightly higher rate over the sample. This is captured by the increasing spot market share over time plotted in Figure 3. Nevertheless, the spot market share over the entire sample period is very close to the historical level of 15 percent referred to by Joskow (1987), although there is substantial heterogeneity across plants in their spot market share. In fact, there are a small number of plants purchasing all of their coal on the spot market, and a larger number purchasing all of their coal on the contract market.

Another feature of the graphs is that the prices in the contract market appear to track price movements in the spot market closely. In addition, the contract market price exhibits a fairly stable, approximately 20 percent, premium over the spot price throughout the sample, despite declining spot prices. In the next section we present a statistical test of the null hypothesis that the quality-adjusted spot and contract prices moved together over our sample period.

To provide a broad assessment of the differences in the degree of integration between the spot and contract markets across regions of the country, which we exploit in our empirical analysis, we first divide the US coal market into nine different regions. Figure 4 gives these regional definitions. We chose this classification scheme for the following reasons. First we tried to group regions according to the type of coal consumed, as classified by its heat, sulfur, and ash contents. In addition, we also chose regions so as to have coal-importing regions with little production taking place within their boundaries, as well as coal-exporting regions which primarily produce coal. The final two constraints were geographic proximity of the states chosen to comprise each region and economy in the total number of regions.

[3]For the purposes of this paper quantity of coal is measured in millions of BTU, rather than the perhaps more familiar unit of thousands of tons, because utilities purchase BTU's (total heat energy) in spite the fact that they must pay transport costs on the basis of the number of tons shipped.

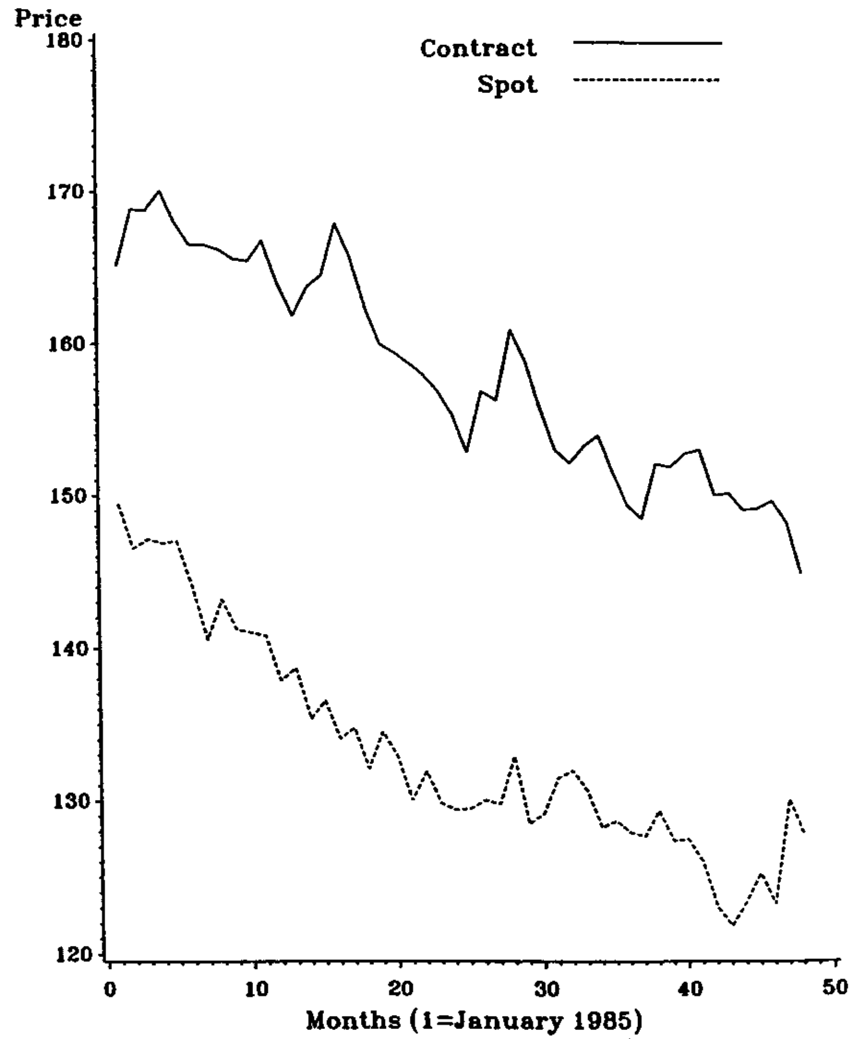

Figure 1: Quantity Weighted Average Spot and Contract Prices (Cents/Million BTU)

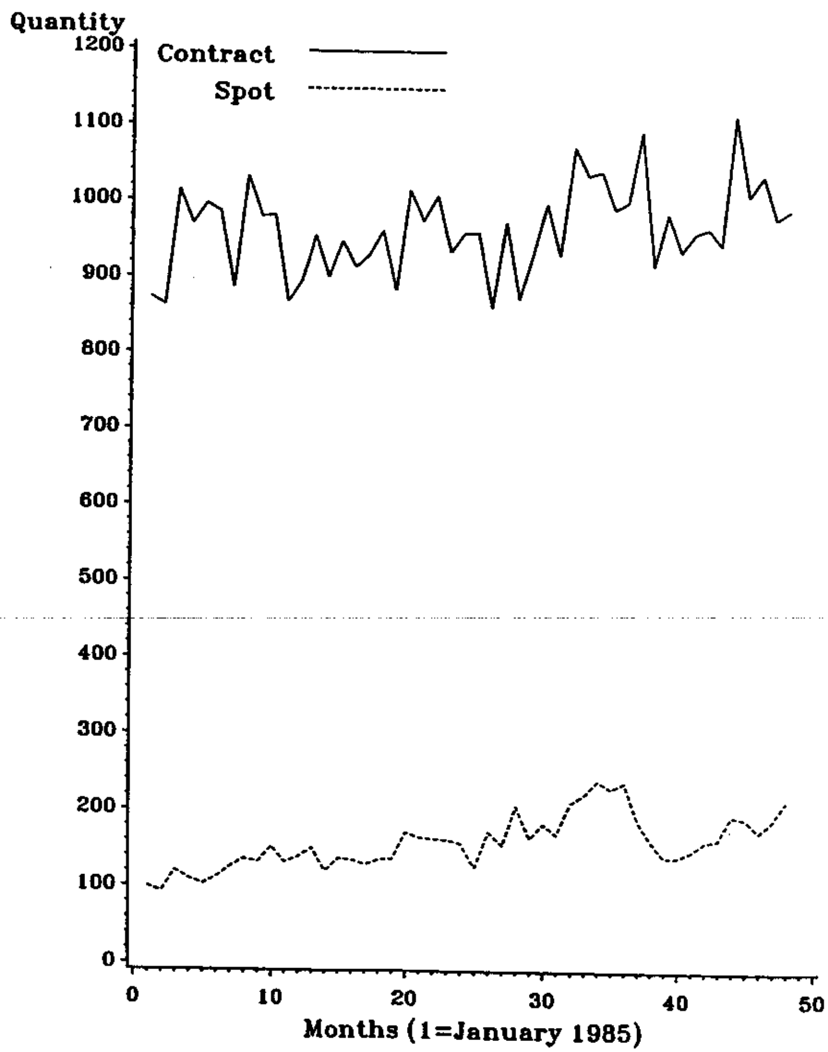

Figure 2: Total Quantity of Coal Delivered on Spot and Contract Markets (Trillions of BTU)

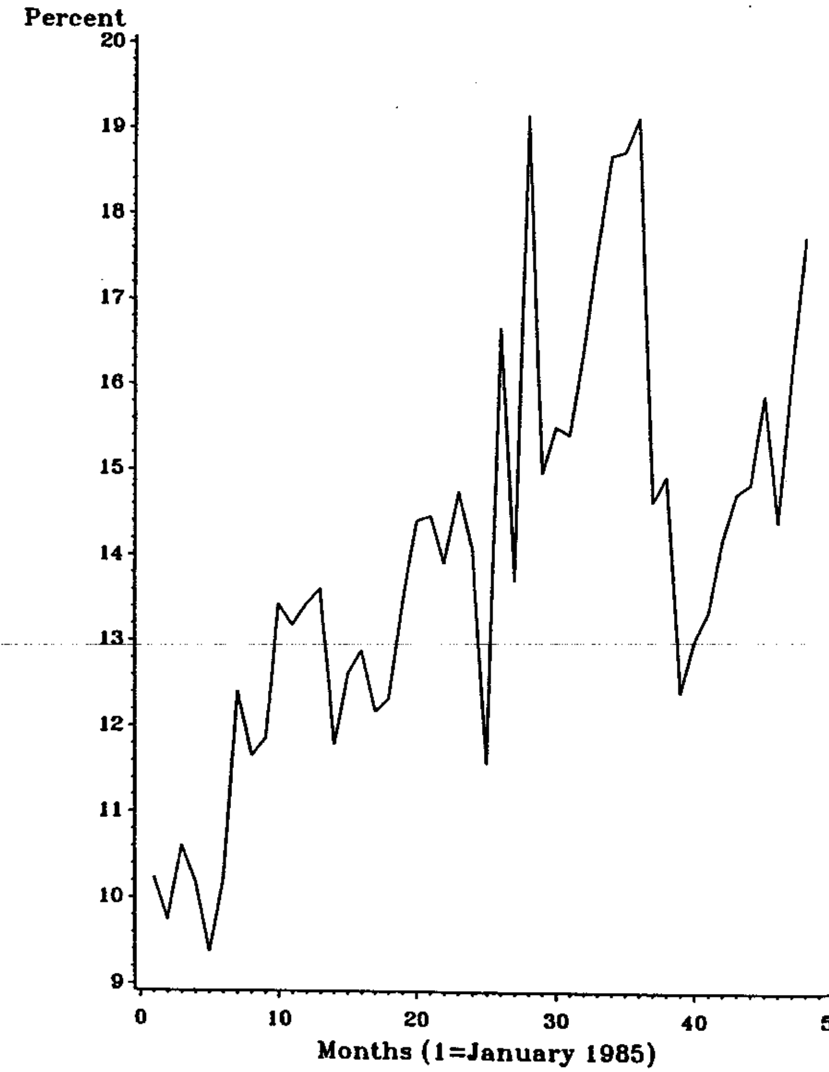

Figure 3: Share of Total Quantity Delivered on Spot Market

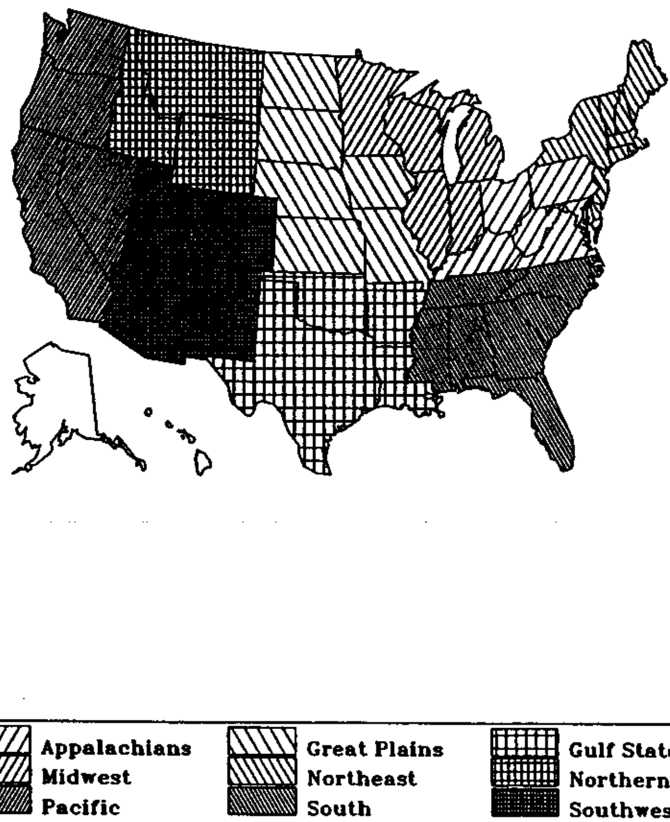

Figure 4: Coal Regions

Although there are substantial inter-regional flows of steam coal- - primarily from the west to the east–there is evidence that the US steam coal market is composed of several autonomous regional markets rather than a single national market. In particular, under the "Little in From Outside" (LIFO) criterion for geographic market definition described in Elzinga and Hogarty (1973), the Southwest, Northern Mountain, and Appalachia regions are candidates for separate markets. (LIFO is defined as the percent of total BTUs consumed within the region during our sample period which is mined within the region.) Under their "Little Out From Inside" (LOFI) criterion, all but the Appalachia, Midwest and Northern Mountain regions exhibit evidence of being distinct markets. (LOFI is defined as the percent of total BTUs produced in the region during our sample period which is consumed within the region.) Table 1 presents both of these market definition measures for all nine regions.

This potential for geographically distinct coal markets allows for a greater variability across regions in plant-level spot versus contract market purchasing behavior. We exploit these across region and plant differences in our analysis of the validity of the three rationales for simultaneous spot market and contract market participation. We now summarize several features of these regional differences which we explain in terms of our three rationales in Sections 3 through 5.

Table 1
Market Definition Summary Statistics

Region	LIFO	LOFI
Appalachians	98.6	56.0
Great Plains	26.5	99.3
Gulf States	31.6	95.4
Midwest	40.0	62.7
Northeast	0.0	n/a
Northern Mountain	100.0	16.3
Pacific	19.4	100.0
South	18.3	99.4
Southwest	91.5	81.0

Notes: No coal is produced in the Northeast region.
LIFO = Percentage of coal consumed in region which is produced within region.
LOFI = Percentage of coal produced in region which is consumed within region.

In both the Gulf States and Southwest, the spot price is extremely volatile relative to the contract price (see Figures 5 and 7). Inspection of the time series of average delivered monthly spot quantities (Figures 6 and 8) reveals an extremely thin spot market in both regions. These results are consistent with Carlton's (1979) observation that high spot price volatility is associated with a less active spot market. For consumers in these regions, the spot market appears to be only a supply source of last resort, rather than the sizeable and smooth functioning market which operates in the other seven regions.

In the Northeast region where little, if any, coal is actually produced, there is a large spot market share. Figures 9 and 10 present the spot and contract prices and quantities for this region. Given the relative abundance and local availability of sources of coal in the Midwest, Appalachia, and the South, it is no surprise that the spot market comprises a noticeable fraction of coal delivered in these regions. Figures 11 and 12 present the spot and contract prices and quantities for the Appalachia region. These graphs are very similar to the those for the South and Midwest.

3. THE RISK AVERSION RATIONALE

This section first describes the risk aversion rationale for simultaneous spot and contract market participation. We then examine the validity of several of the implications of this rationale. The risk aversion rationale is easiest to understand for a regulated public utility, although similar logic applies to firms operating in unregulated environments. We concentrate on the case of a regulated utility and then discuss how the logic is modified for an unregulated firm.

3.1. The Impact of Price and Quantity Risk

There are two sources of input supply risk facing a firm: (1) price risk and (2) quantity risk. By price risk we mean variability in the prices paid by the firm for input supply. Quantity risk is variability in the quantity supplied. The most important type of quantity risk faced by a firm is largely unobservable to both the utility and the researcher. This is the risk of supply interruption–the purchasing firm is unable to satisfy the input requirements necessary to meet the demand for its output. To minimize the probability of this event, a utility engages in long-term contractual arrangements for input supply.

Because of the economic environment in which it operates, a regulated firm providing electricity, natural gas, or water finds it particularly important to insure against input supply interruptions regardless of its risk preferences. For these firms, the regulatory process requires that once the price of the utility's output is set for the period, it must by law, satisfy all demand at the mandated price. Consequently, the utility's output is exogenously set and it cannot, outside of exceptional circumstances, increase its output price to allocate a scarce supply in the event that it has a shortfall in a vital input to the production process. In addition, the production process for public utilities usually allows very little short-run substitution possibilities between capital or labor and the primary raw material input to the production process. For the case of natural gas and water utilities, the short-run technology allows very little variability in the ratio of primary input used to output produced. However, for electric utilities there are more short-run substitution possibilities, by utilizing different generation technologies (within the firm) depending on the availability and relative prices of raw energy sources.

For the case of electric utilities, one aspect of the regulatory process reduces the importance of input price risk to the utility. The presence of fuel price adjustment clauses allows a large portion of the fuel price increases faced by a utility to be passed on to the utility's customers in the form of higher rates in the future. This partial insurance against fuel cost increases allows utilities to be less concerned about energy price risk than they would be in its absence.

Although our discussion has focused on public utilities, the logic for the risk aversion rationale goes through for unregulated firms as well. These firms can raise price to allocate a lower level of output caused by input supply shortages, but depending on the elasticity of demand for the firm's output, this price increase may result in severe total revenue reductions. Firms facing very elastic demands for their output may be reluctant to follow this strategy for dealing with supply shortfalls, and should therefore have an incentive to engage in long-term contractual arrangements for input supply.

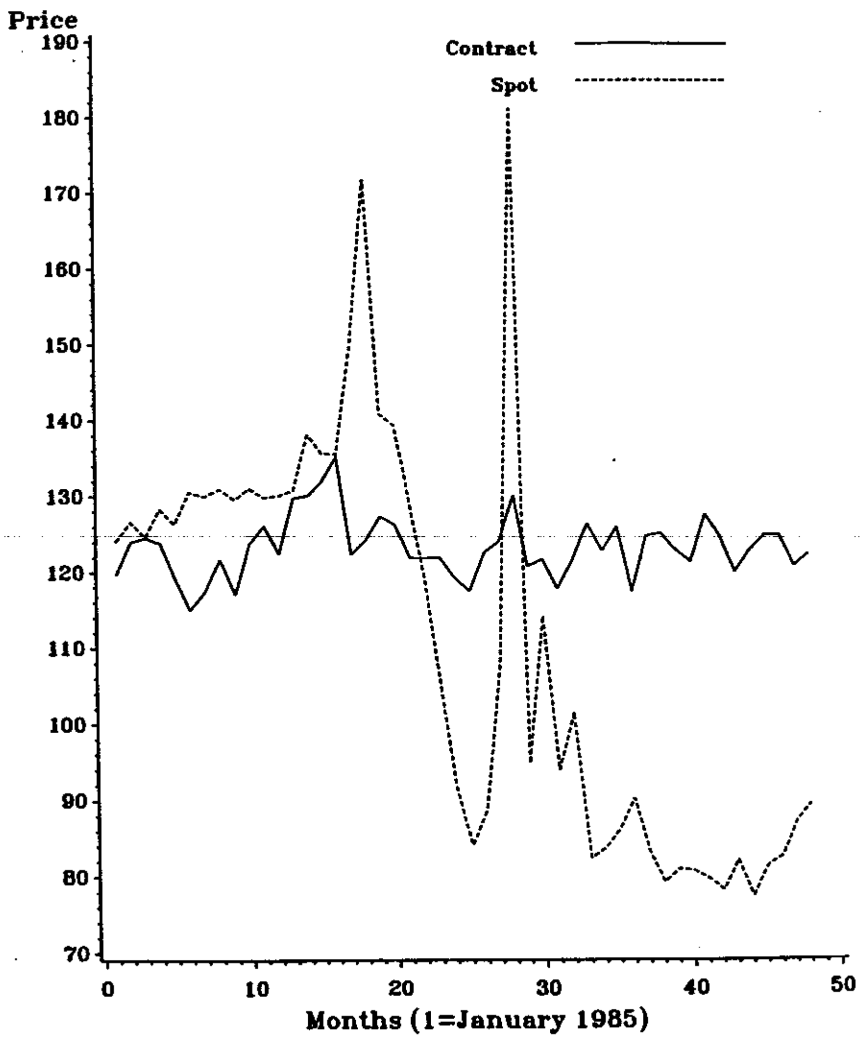

Figure 5: Quantity Weighted Average Spot and Contract Prices Region = Southwest (Cents/Million BTU)

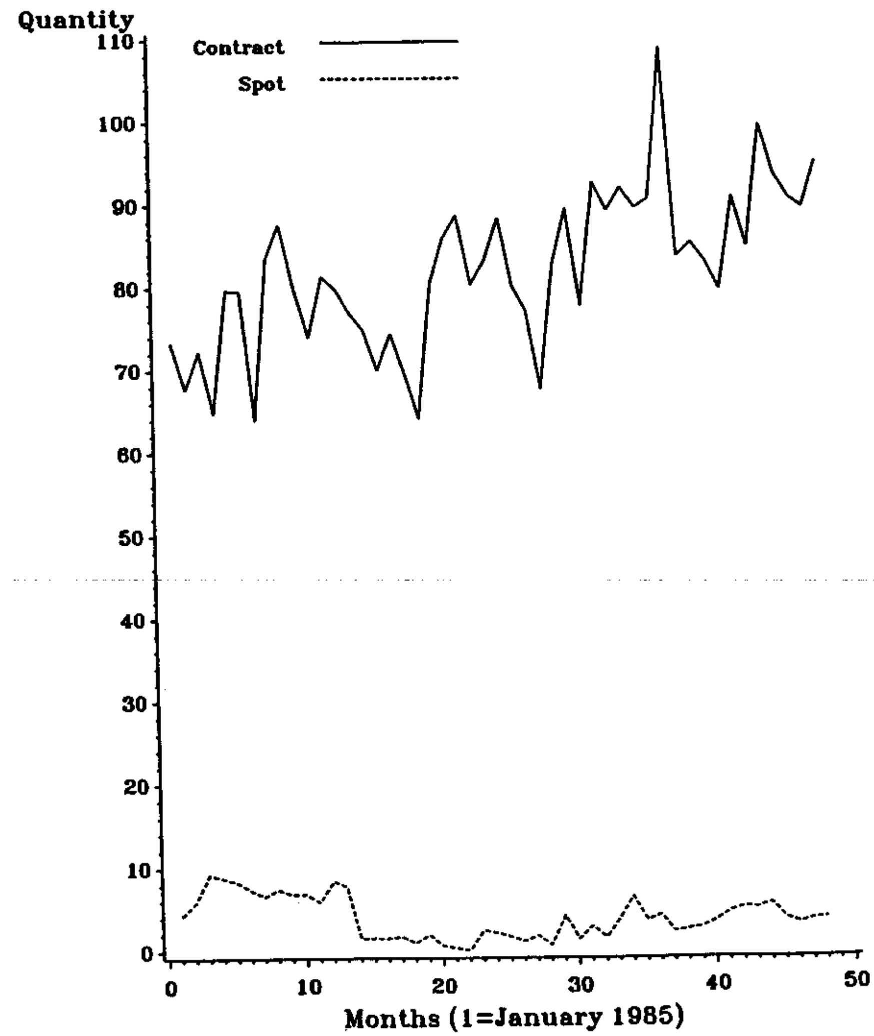

Figure 6: Total Quantity of Coal Delivered on Spot and Contract Markets Region = Southwest (Trillions of BTU)

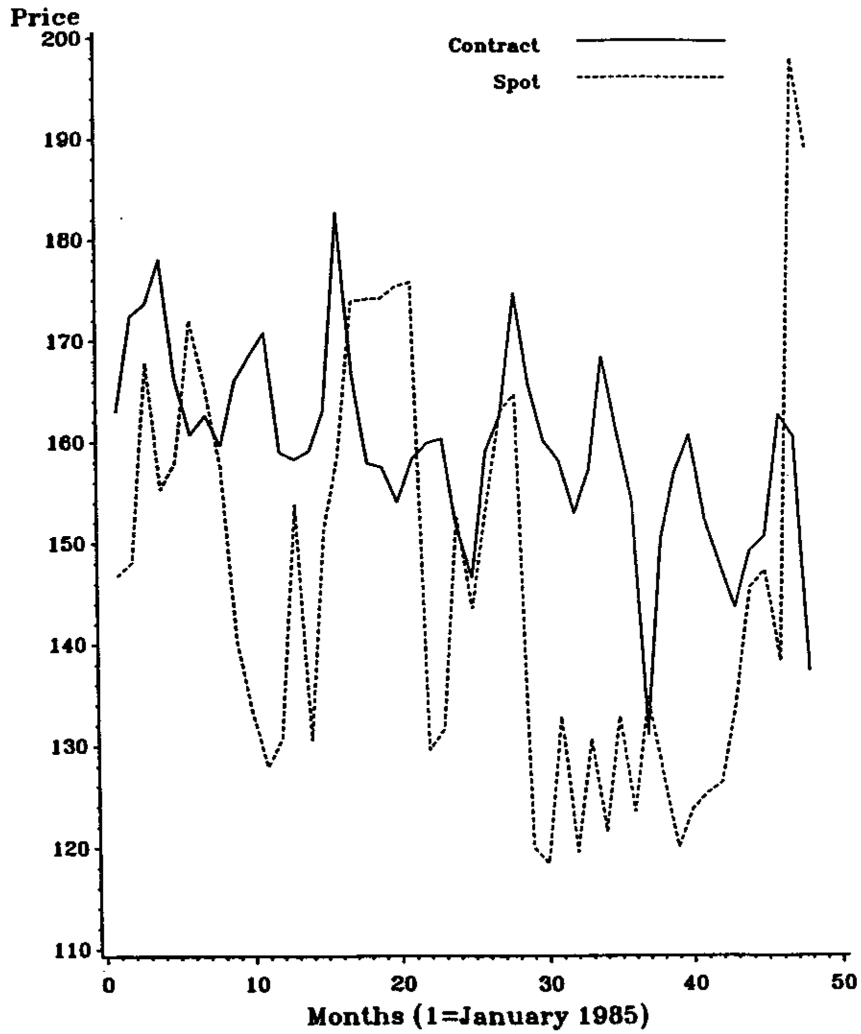

Figure 7: Quantity Weighted Average Spot and Contract Prices
Region = Gulf States (Cents/Million BTU)

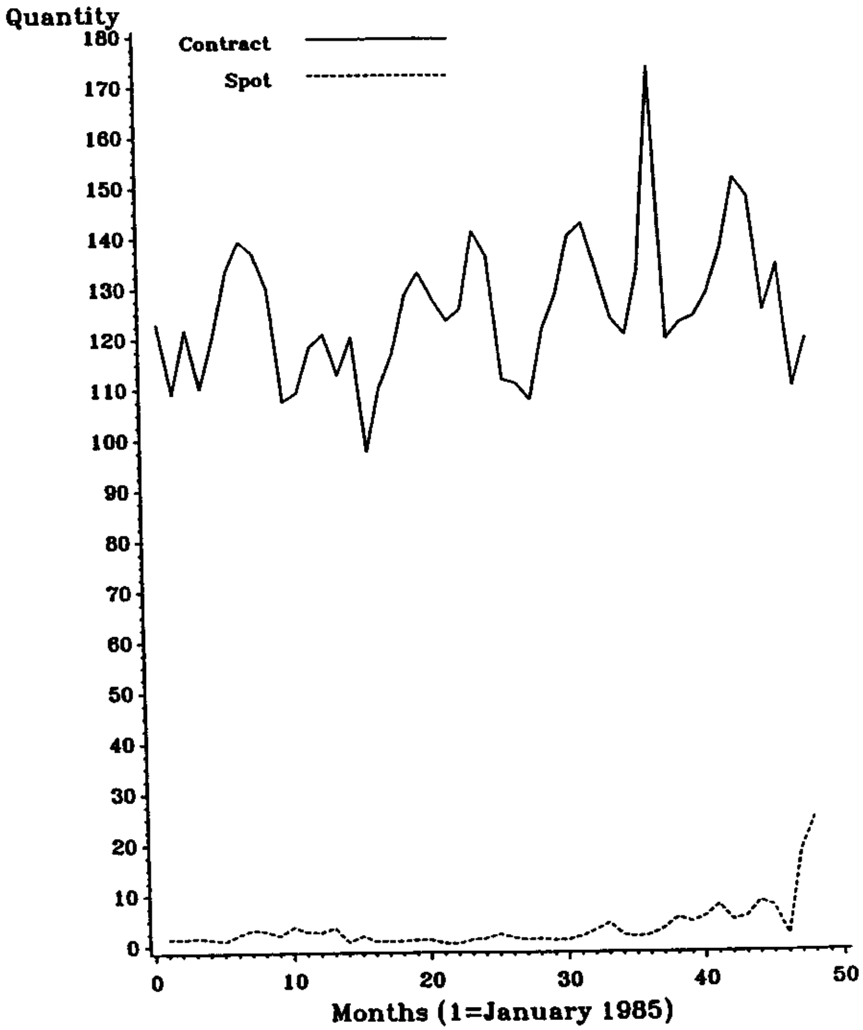

Figure 8: Total Quantity of Coal Delivered on Spot and Contract Markets
Region = Gulf States (Trillions of BTU)

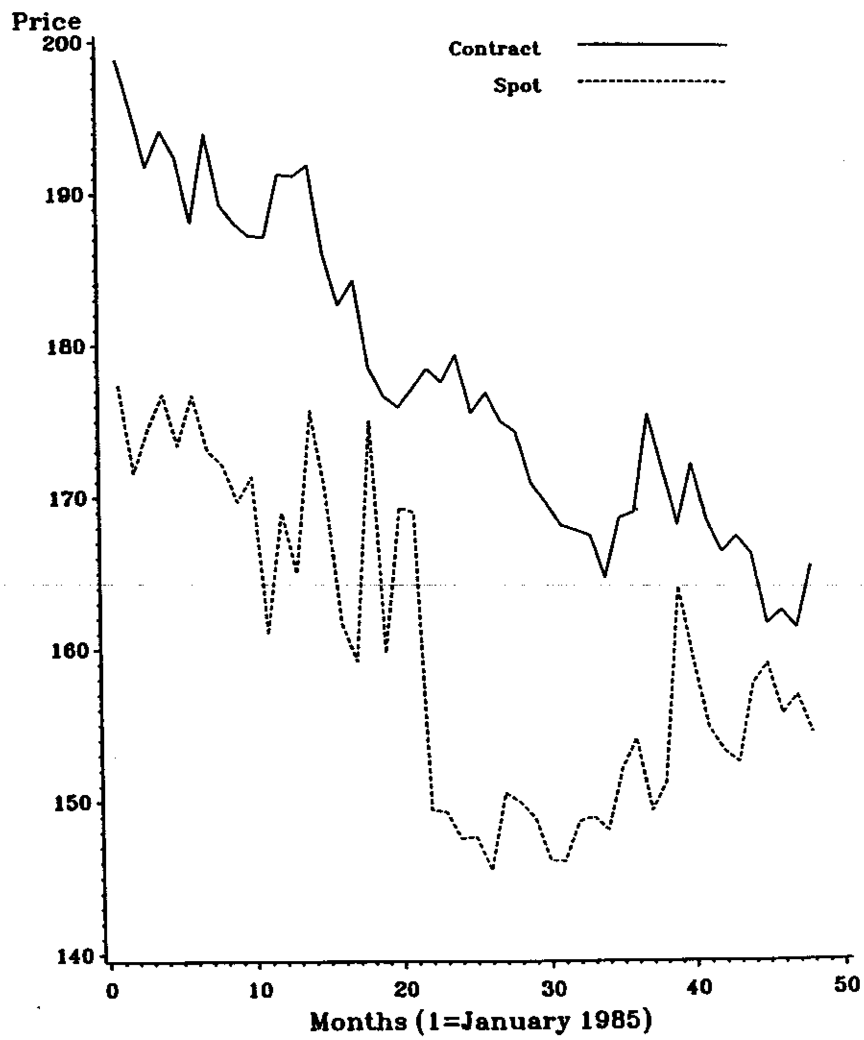

Figure 9: Quantity Weighted Average Spot and Contract Prices
Region = Northeast (Cents/Million BTU)

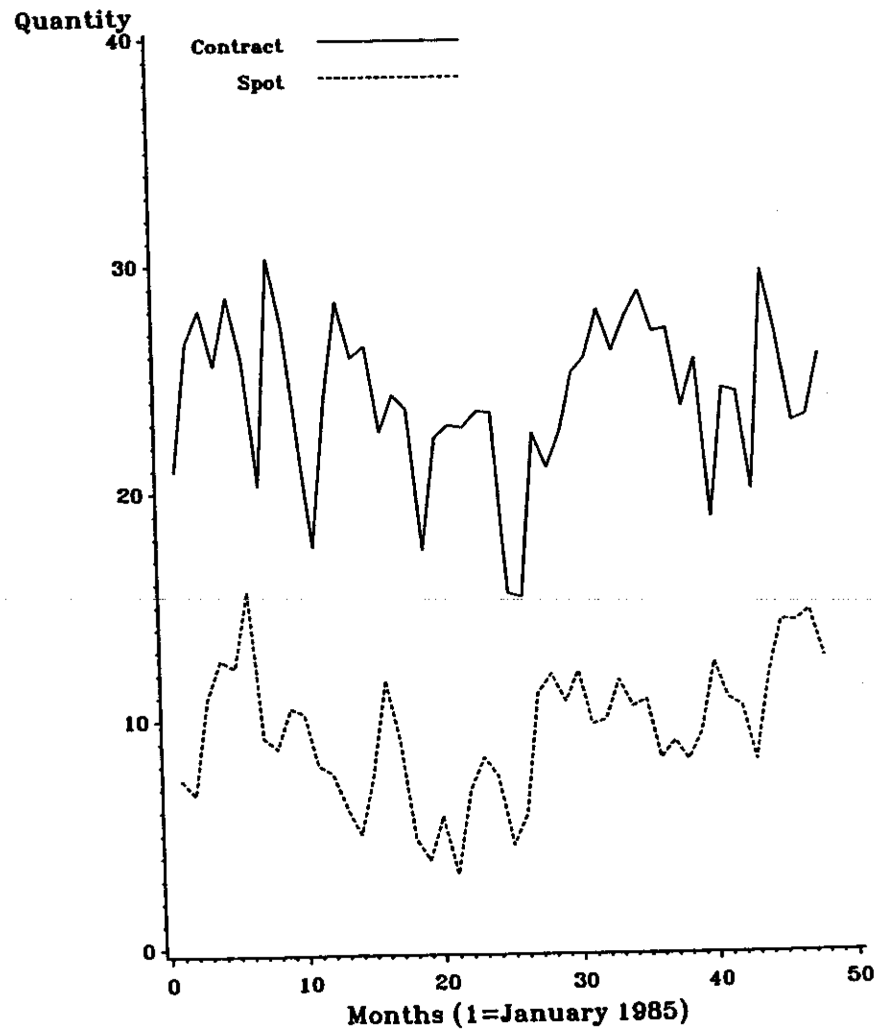

Figure 10: Total Quantity of Coal Delivered on Spot and Contract Markets
Region = Northeast (Trillions of BTU)

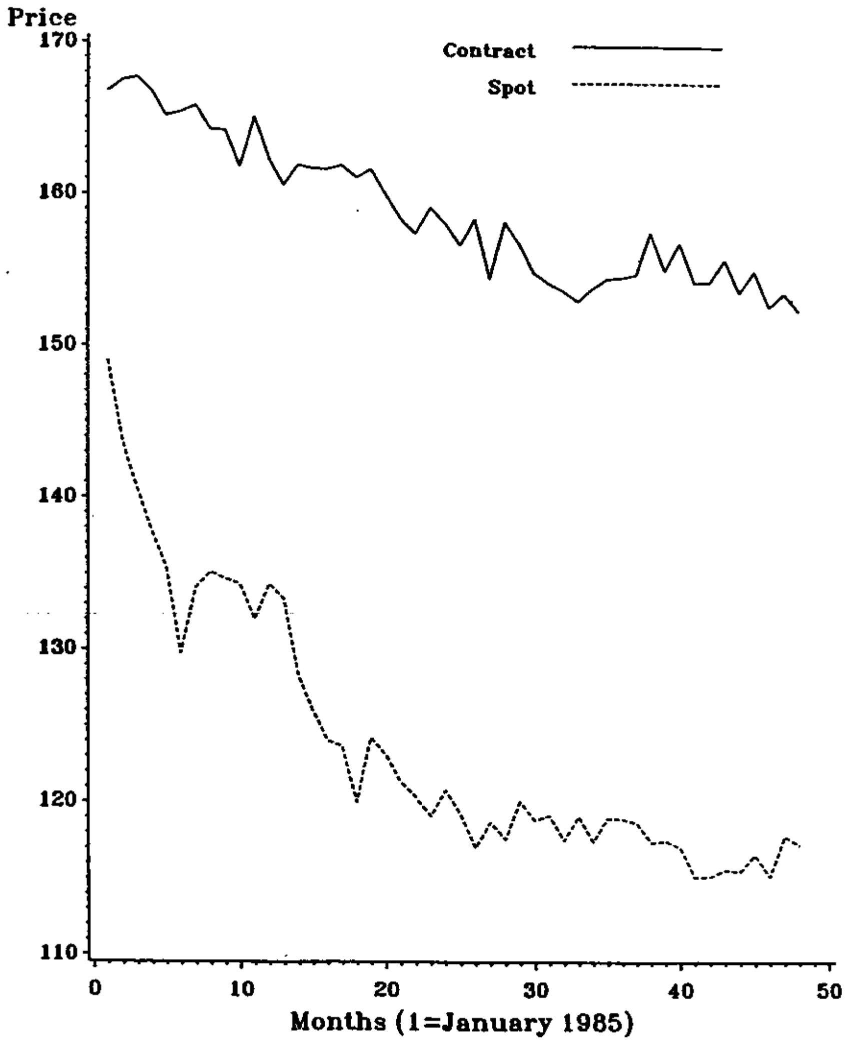

Figure 11: Quantity Weighted Average Spot and Contract Prices
Region = Appalachians (Cents/Million BTU)

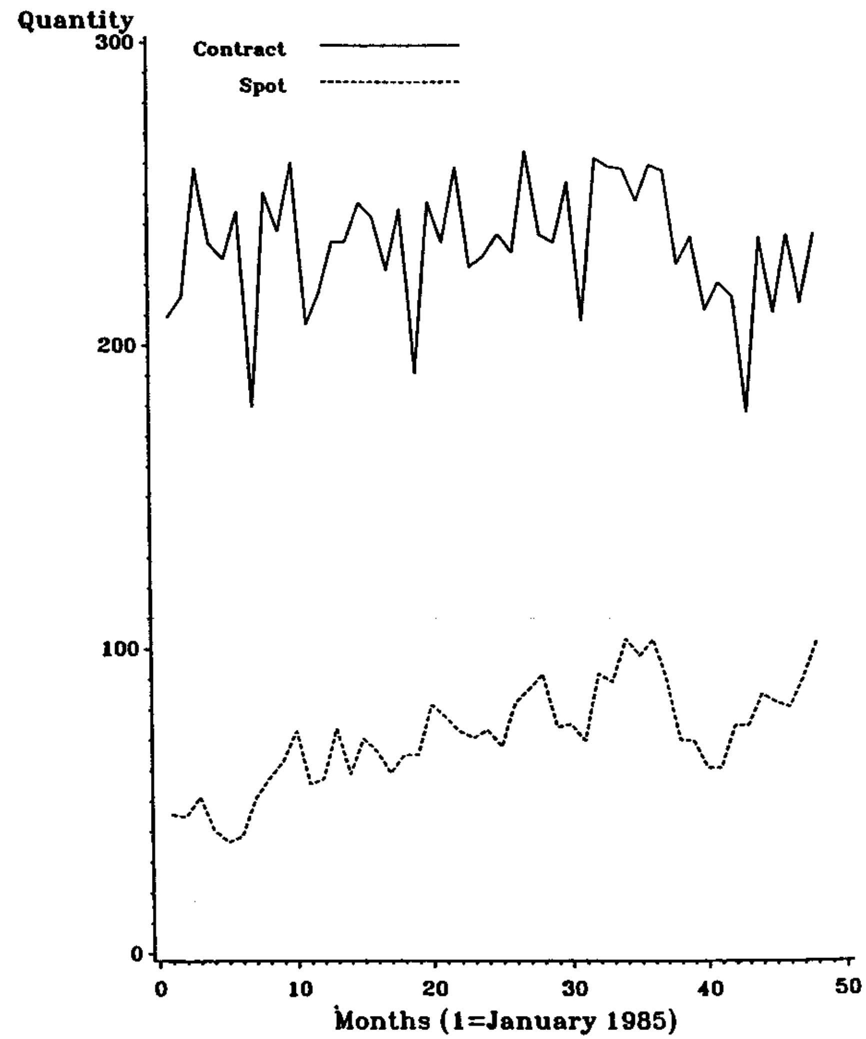

Figure 12: Total Quantity of Coal Delivered on Spot and Contract Markets
Region = Appalachians (Trillions of BTU)

3.2. Implications of Risk Aversion Rationale

There are many strategies a utility can use to insure against this risk of coal supply interruption. Although the specifics of any strategy depend on the risk preferences of the utility toward input supply interruptions and the utility's specific production technology, all of these strategies require the utility to contract or a large fraction, if not all, of its expected coal demands. The remainder of its coal demands are then obtained from the spot market or taken from its inventories. Hubbard and Weiner (1992), discussed earlier, is an example of the class of models where firms contract for a fraction of their input demands to avoid spot market price risk.

This class of input supply strategies has several implications for spot and contract prices and quantities. Williamson (1986, p. 182) characterizes the generic problem of contracting to protect transactions-specific assets. He argues that the price for contract transactions (where safeguards which protect these transactions-specific assets are present) should exceed that for spot transactions (where these safeguards are absent). In the present case, because of the increased cost to the supplier of guaranteeing delivery of large amounts of the input on a regular basis, the contract price facing a utility should be larger than the expected value of the spot price facing that utility.[4]

Extending this logic further implies that larger delivered contract quantities may initially cost the supplier more per unit (because of the necessity of larger safeguards to establish this contractual relationship), and should also be more valuable to the consuming firm.[5] This intially increased cost of guaranteeing large deliveries should offset by the long-run marginal cost reductions due to the economies to scale in producing and delivering the product, so that the net effect increased quantity supplied

[4] A supplier might also be willing to accept a lower price for the stable demand for its output provided by a long-term contract. The cost of a temporary output shortfall (due to insufficient energy input) to a generating facility (for example, brownouts or blackouts) is far greater than the cost to supplier of a temporary shortfall in the demand for its output. Consequently, the increased value to the consumer of a stable supply should dominate the increased value to the supplier of stable demand and therefore result in a higher price for contract transactions relative to spot transactions.

[5] The major source of these increased unit costs of larger contract quantities comes in the form of a one-time increase in transportation expenses. Frailey (1989) notes that the technology of delivering large quantities of coal from a single supplier requires the use of specialized unit trains to transport the coal and the installation of complementary unloading facilities at the utility designed to handle unit trains. He also states that substantial upgrading of a railroad's tracks is required to handle the increased load associated with these unit trains.

on the delivered contract price is theoretically indeterminant. The relationship between the size of the shipment and the price paid for a spot transaction is also an empirical question. If the spot market obeys the law of one price, then the size of a shipment, controlling for the quality of the product, should have no effect on the price paid for the input by a consuming firm. However, the gains from opportunistic behavior (as described in Williamson (1979) and Klein, Crawford, and Alchian (1978)) by a spot supplier should increase with the size of the spot shipment. Consequently, larger spot transactions may require that a premium be paid to suppliers to discourage this kind of behavior. In addition, if the very-short-run coal supply curve is upward sloping, we would also expect higher spot prices for larger transactions sizes.

In terms of the variability of prices and quantities in both markets, the risk aversion strategy implies that the period-to-period percentage change in contract supply should be substantially smaller relative to the same percentage change in spot supply. This follows from the observation that the maximum variability in the amount supplied over an entire year (for a specific contract) is contractually fixed, even though many plants contract with multiple suppliers. For most plants participating in the contract market, some, if not all, of the coal obtained on the spot market is purchased because of unexpected events--either because the plant finds a particularly favorable price or because it has an unexpectedly high demand for coal during a given period. Consequently, the residual nature of spot demand should increase the variability in its period-to-period growth rate relative to that for contract demand.

The BPE contractual form causes variability in the contract price of coal over time, as input prices, transportation costs, or government regulations change. The presence of fuel-price escalation clauses in the regulatory process enables the utility to be relatively indifferent to fuel price changes (although not completely so, as discussed in Joskow and Schmalensee (1986)) and to whether they occur in the spot or contract market. However, because contract market prices automatically change according to BPE clauses, regulators are less apt to disallow the increased fuel costs which result from these price changes versus those which occur on the spot market. (If a contract was initially deemed "prudent" by the regulatory process, it would be difficult for the regulatory commission to subsequently reverse this judgement.) Consequently, although they prefer price stability, utilities may be more tolerant of price volatility on the contract versus spot market.

The residual nature of the spot market implied by the risk aversion rationale and the current contractual form of long-term coal supply arrangements allows plants the possibility of switching a portion of their purchases between spot and contract markets depending on the relative prices and quality available in each market. Long-term contracts usually specify an annual target quantity with minimum and maximum annual amounts as a percentage of this target amount. Therefore, we would expect that when the spot price facing a plant is low relative to the contract price it faces, the plant will take the minimum it can on the contract market and purchase its remaining demand on the spot market. Similarly, when the spot price is high relative to the contract price, the firm should take all it can on the contract market and only what it must on the spot market. The same logic should also apply to the relative quality of spot versus contract purchases.

3.3. Empirical Results

We now examine the validity of these implications. From the time series plot of average transaction-level spot versus average transaction-level contract prices in Figure 2, the expected spot price appears to lie below the contract price. These plots do not control for differences in the quality of coal purchased and, as shown in the price plots for the Southwest and Gulf States, the average spot price exceeds the average contract price for several time periods. In order to control for the impacts of quality differences and exploit the transactions-level nature of our data, we estimate a hedonic price regression for coal where one of the characteristics of the coal is whether it is purchased on the spot or contract market–the dummy variable SPOT, where SPOT = 1 denotes a spot market transaction. The quality characteristics we control for are BTU, sulfur, and ash content. Sulfur and ash content are measured in terms of tons (of sulfur or ash) per million BTUs of coal, and BTU content is measured in millions of BTUs per ton of coal. Table 2 gives the means and standard errors of all of the variables used in our analysis. To address the question of the differential impact of shipment size across spot and contract transactions, we also compute a price regression which includes the size of the shipment in mega-BTUs (millions of BTUs) and the size of the shipment interacted with the spot/contract dummy.

We include both plant– and time-specific fixed effects in all regressions. Because our focus is the purchasing plant's decision to participate simultaneously in the spot and contract markets, we would like to control for the impact of any time-invariant differences across plants–for example, geographic location or generation technology–in our regressions. A plant's geographic market may have a permanent effect on the value of the dependent variable. The plant-level fixed effects control for this possibility. We include time-effects to control for changes in market conditions over time which are common to all plants, such as the aggregate level of economic activity or market conditions in other energy markets. The inclusion of plant-level and time-specific fixed effects imply that the regression coefficients measure the average plant-level impact of the regressor on the best linear predictor of the dependent variable. The time effects here and for the remainder of the paper are on a quarterly basis and are denoted by QDJ, $J = 1, \cdots, 16$.[6] The assumption implicit in including these consuming plant fixed effects is that once all observable characteristics of the coal are controlled for (BTU, sulfur, and ash content, transport distance, quantity purchased, and date purchased), each utility still pays a distinct expected price for a million BTUs of coal. This assumption imposes some economic rationality on the behavior of the purchasing utility, but does not impose the less reasonable assumption that all utilities pay the same transport distance-adjusted and quality-adjusted price. This less general assumption is implicit in a model which does not include plant-specific fixed effects. There are 363 individual plants in our sample and 16 quarters, so we must estimate a large number of parameters for this specification. However, because our sample contains 74,579 individual transactions, this presents only a computational problem, not a degrees of freedom problem. Table 3 presents the results of these regressions with and without the quantity and SPOT-quantity interaction. Because we find evidence of heteroscedastic errors for all regressions in this section, all standard errors are computed from the heteroscedasticity-consistent

[6] Although our data is available on a monthly basis, we found that price regressions with quarterly dummies were not statistically significantly different from models with monthly dummies. For computational ease and to reduce the size of the tables of regression output, we standardized on quarterly time dummies for the entire paper.

covariance matrix estimator given in White (1980).

Table 2
Means and Standard Errors for Variables Used in Analysis

Number of Observations = 74,579 heightVariable Name	Mean	Standard Deviation
QUANT = Size of Transaction in 10^{12} BTU	0.722	1.345
SULFUR = Sulfur Content in Tons of Sulfur/ 10^6 BTU	6.40	4.24
ASH = Ash Content in Tons of Ash/ 10^6 BTU	43.8	19.1
BTU = Heat Content in 10^6 BTU/Ton	23.7	2.58
PRICE = Price of Coal in Cents per 10^6 BTU	151.7	41.8
DISTANCE = Transport Distance in Miles	227.3	235.5
SPOT = Spot Contract Dummy (Spot = 1)	0.44	0.50

Table 3
Hedonic Price Equation Estimates (74,579 Transactions)[a]

Dependent Variable = Delivered Price of Coal in Cents per Million BTU				
	$R^2 = 0.3987$		$R^2 = 0.3986$	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
BTU	1.83	.137	1.83	.135
SULFUR	-1.13	.039	-1.13	.038
ASH	-.099	.010	-.101	.010
DISTANCE	.026	.002	.026	.002
QUANT	.15E-06	.19E-06		
QUANT*SPOT	.14E-05	.41E-06		
SPOT	-34.5	.254	-34.2	.194
QD1	22.5	.459	22.4	.459
QD2	19.3	.451	19.3	.451
QD3	16.8	.421	16.8	.421
QD4	16.4	.431	16.4	.432
QD5	14.2	.409	14.2	.409
QD6	11.5	.446	11.4	.446
QD7	8.69	.394	8.67	.394
QD8	6.56	.382	6.54	.382
QD9	6.42	.393	6.42	.393
QD10	4.76	.401	4.77	.401
QD11	3.06	.441	3.06	.441
QD12	3.45	.378	3.43	.377
QD13	3.32	.467	3.29	.467
QD14	.855	.424	.846	.424
QD15	-.222	.406	-.233	.406

[a]Standard Error estimates computed from heteroscedasticity-consistent covariance matrix estimate.

At this point we should emphasize that these regressions as well as all other regressions in this paper have no structural and causal interpretation. We instead interpret these regressions as estimating best linear predictor functions of the dependent variable given the vector of regressors. A regression coefficient therefore measures the increase in the best linear predictor of the dependent variable (given all of the regressors) brought about by a one unit change in the associated regressor. Consequently, these regressions are useful to investigate the empirical validity of the reduced-form, comparative statics implications of our three rationales for simultaneous spot and contract market participation. Because our goal is to estimate parameters of best linear predictor functions which embody a specific comparative statics prediction rather than forecasting future values of the dependent variables, we are less interested in the fit for these regressions. Nevertheless, we do provide the R^2 for each regression, in order to allow an assessment of the precision with which a regression coefficient forecasts the best linear prediction of the change in the dependent variable resulting from a one unit change in the associated regressor.

The regression results, for the most part, are consistent with the implications of the risk aversion rationale. A higher heat content is associated with higher prices, and higher sulfur and ash contents with lower delivered prices. Quality adjusted, the mean spot price is still more than 20 percent lower than the mean contract price. Although transaction size does not seem to help predict the contract price, larger spot transactions are associated with significantly higher transactions prices. This is consistent with the view that greater spot market risk is associated with larger transactions, or that the very-short-run coal supply curve for an individual mine is upward sloping. The increased risk associated with higher spot quantities necessitates a higher price premium paid to suppliers to insure against potential opportunistic behavior which can be explicitly dealt with on the contract market; hence the lack of a price premium for larger transactions on this market. Under the upward sloping very-short-run supply curve view, this premium does not arise for contract purchases because mines operate along their long-run supply curve for these deliveries, and this supply curve is essentially flat for our sample period. Finally, the time fixed effects show a steady decline in the quality-adjusted price of coal over the sample.

We now address the question of whether this price decline is the same across the spot and contract markets. More generally, we test the hypothesis that prices in the two markets move together over time. Our null hypothesis is that time dummies in the price regression are the same across spot and contract transactions except for the fixed mean shift embodied in the spot/contract dummy. The alternative hypothesis is that time dummies for spot prices are significantly different from those for contract prices. We test this hypothesis by running our price regressions with additional dummy variables which are interactions of SPOT with the time dummies. If these new dummies are not jointly significant from zero, then we can conclude that the time series properties of the quality-adjusted spot and contract prices are statistically insignificantly different. Table 4 presents these regressions for the two models considered in Table 3. The variables QDSJ, $J = 1, \cdots, 15$ denote the interaction of QDJ with the dummy variable SPOT. The Wald test for the null hypothesis that all of the coefficients associated with QDS1 to QDS15 are zero are: 210.02 for the estimates and their standard errors in the first two columns of Table 3, and 210.67 for those in the second two columns of Table 3. Both statistics exceed the chi-squared with 15 degrees freedom critical value for all conventional levels of significance. By inspection, we can see that for all but the first quarter of our sample, the average spot market price fell by a larger dollar amount than the contract price. We estimated this same model for ln(PRICE) and found approximately the same pattern of signs for the QDJ and QDSJ, $J = 1, \cdots, 15$ and obtained the same overwhelming rejection of the null hypothesis of equal patterns of price changes across the spot and contract markets. By either the ln(PRICE) or the PRICE regression, we find that the quality-adjusted spot price of coal fell at a slightly higher rate than did the contract price over the majority our sample period. This result reinforces Joskow's (1990) conclusion, based on a comparison of the prices of old versus new coal contracts, of a very slack coal market during our sample period.

The relationship between second moments of prices in the spot and contract markets can be analyzed by taking the residuals squared from each of the regressions in Table 4 and regressing them on the coal quality variables and the spot/contract dummy. This regression is useful in determining the impact of quality on the predictability of the transactions price of coal and on assessing whether there is a significant difference in the variance of transactions prices across the two contractual forms. Using heteroskedasticity-consistent standard errors for these regression coefficients we can perform an asymptotically valid test for differences in the conditional variance across spot and contract transactions. Table 5 presents the results of these regressions. Based on these t-statistics, there is a significantly smaller conditional variance in the price of spot transactions relative to contract transactions. In addition, larger transactions predict a smaller variance of price on either market, whereas greater transport distances predict an increase. We also ran this regression with plant fixed effects and time fixed effects and obtained similar results for the impact of SPOT and DISTANCE on the conditional variance of price. Hence, our finding of a smaller spot market price conditional variance does not appear to be due to plant heterogeneity in the variability of prices faced.

Figure 13 presents histograms of spot and contract transactions sizes. Although there are some very large spot transactions, the vast majority of spot transactions are smaller than the average size contract transaction. The mean spot transaction delivers approximately one-fourth the number of BTUs as the mean contract transaction. The contract market transactions size density exhibits significantly less positive skew than does the spot market density.[7] These differences in distributional shapes are consistent with the residual nature of the spot market and expected demand nature of the contract market implied by the risk aversion rationale. By this logic, the average size of a contract transaction depends on the plant's expected demand for coal, which, in turn, depends on the capacity and expected net generation of the plant. Because most spot market transactions arise as a result of unexpected circumstances, the vast majority of these transactions should be quite small, satisfying the energy demand left over after contract purchases are made. In rare instances, a very large transaction should occur when the plant is short of contract coal by a large amount.

[7]The contract density in Figure 13 has been truncated at 2 million mega-BTUs, in order to graph both densities on the same plot. The maximum contract transaction size is 5 million mega-BTUs.

Table 4
Hedonic Price Equation Estimates (74,597 Transactions)[a]

Dependent Variable = Delivered Price of Coal in Cents per Million BTU

Variable	$R^2 = 0.400$ Coefficient	Standard Error	$R^2 = 0.400$ Coefficient	Standard Error
BTU	1.83	.136	1.83	.135
SULFUR	-1.13	.039	-1.13	.039
ASH	-.099	.011	-.099	.011
DISTANCE	.026	.002	.026	.002
QUANT	.15E-06	.19E-06		
QUANT*SPOT	.14E-05	.40E-06		
SPOT	-31.1	.605	-30.7	.584
QD1	22.2	.656	22.2	.656
QD2	19.8	.658	19.8	.659
QD3	18.1	.629	18.1	.629
QD4	17.9	.658	17.9	.658
QD5	16.0	.626	16.0	.626
QD6	13.1	.698	13.2	.701
QD7	11.0	.611	11.0	.612
QD8	9.53	.594	9.54	.594
QD9	7.88	.607	7.90	.608
QD10	7.05	.620	7.06	.620
QD11	5.26	.601	5.28	.602
QD12	5.08	.619	5.10	.619
QD13	5.06	.758	5.08	.759
QD14	2.95	.640	2.95	.640
QD15	1.13	.637	1.13	.638
QDS1	1.80	.877	1.74	.877
QDS2	-.165	.842	-.233	.842
QDS3	-2.73	.800	-2.78	.800
QDS4	-3.39	.818	-3.44	.818
QDS5	-4.10	.779	-4.18	.779
QDS6	-3.78	.824	-3.85	.828
QDS7	-5.29	.757	-5.36	.757
QDS8	-6.58	.737	-6.66	.737
QDS9	-3.26	.758	-3.31	.759
QDS10	-5.12	.772	-5.13	.773
QDS11	-4.79	.852	-4.84	.854
QDS12	-3.63	.747	-3.71	.746
QDS13	-3.89	.890	-3.97	.891
QDS14	-4.85	.807	-4.87	.807
QDS15	-3.02	.782	-3.04	.783

[a]Standard Error estimates computed from heteroscedasticity-consistent covariance matrix estimate.

Table 5
Conditional Price Variance Equation Estimates[a]

Dependent Variable = Squared Residual from Price of Coal Regression

Variable	$R^2 = 0.0008$ Coefficient	Standard Error	$R^2 = 0.0007$ Coefficient	Standard Error
C	1532.0	808.4	1098.6	646.5
BTU	-44.4	27.2	-30.1	21.8
SULFUR	-1.96	10.0	-.981	10.1
ASH	.899	1.86	1.06	1.79
DISTANCE	.343	.193	.362	.185
SPOT	-305.1	77.5	-234.7	51.5
QUANT	-.71E-04	.26E-04		
QUANT*SPOT	.81E-04	.77E-04		

[a]Standard Error estimates computed from heteroscedasticity-consistent covariance matrix estimate.

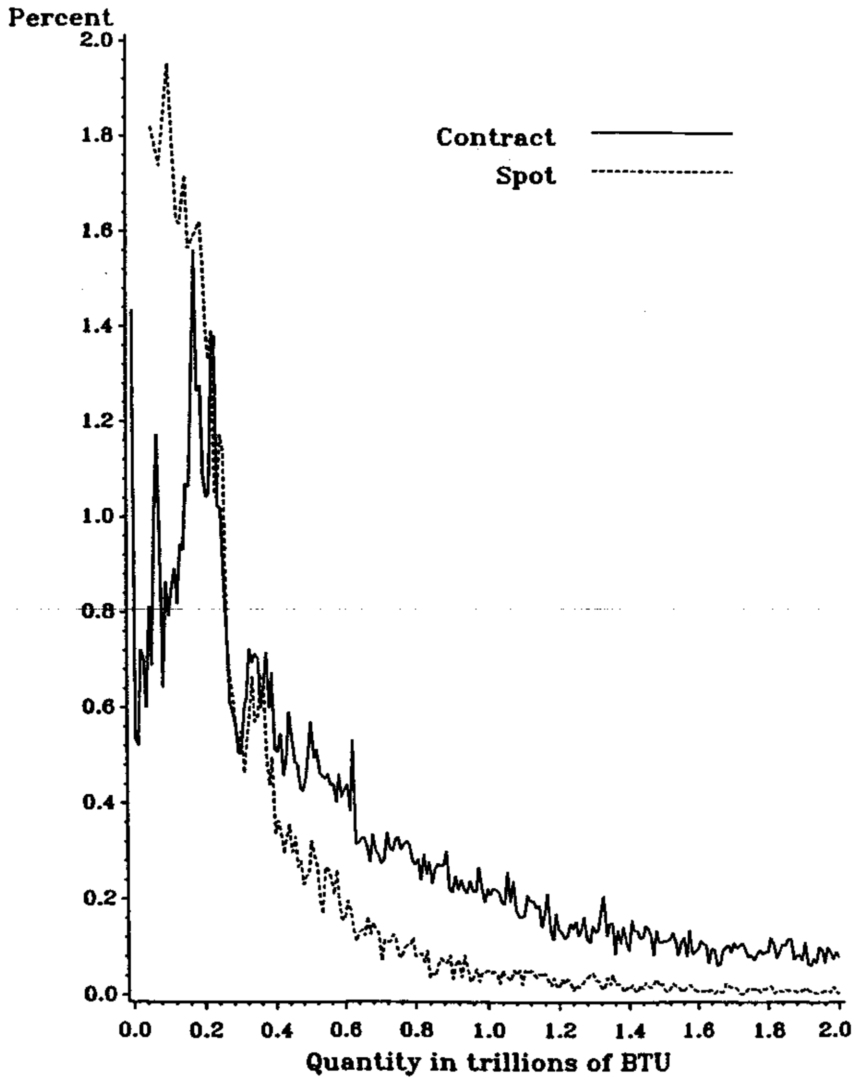

Figure 13: Histogram of Transaction Sizes for Spot and Contract Markets

The very large average size of contract transactions relative to spot transactions implies a larger unconditional variance of the contract transaction size. However, once we control for the impact of this larger expected size of contract transactions, the risk aversion rationale implies that contract transactions should have a smaller variability relative to spot transactions. We examine this implication first by computing a regression of transaction size on plant and time fixed effects and the dummy variable SPOT. This regression, given in Table 6, shows a substantially smaller spot mean transaction size across plants. To examine the relative variability question, we hypothesize the following relationship for ϵ_k^2 the square of the disturbance from this transaction size regression:

$$\epsilon_k^2 = \delta_0 + \delta_1(X_k'\beta) + \delta_2 SPOT_k + \eta_k \quad (3.1)$$

where $X_k'\beta$ denotes the best linear predictor of the transaction size for transaction k from the regression in Table 6. Substituting the fitted value from the regression given in Table 6 for $X_k'\beta$, we run the above regression (1) with the residual squared from the transaction size regression in place of ϵ_k^2. Because using the estimated best linear predictor function in this regression as opposed to the true best linear predictor function induces measurement error in this regressor, we used instrumental variables techniques with the QDJ ($J = 1, \cdots, 15$) as instruments for the estimated best linear predictor function. These results are given in the second part of Table 6, with the heteroscedasticity-consistent standard errors reported alongside the coefficient estimates. These results show that once the predicted level of transaction size is controlled for, variability in transaction size is higher for spot transactions relative to contract transactions.

To assess the variability in the monthly percentage change in quantity delivered across the two markets, we first compute total spot market deliveries (Q_{it}^s) and the total contract market deliveries (Q_{it}^c) in units of millions of BTU for each month (t) and each plant (i) in the sample. Using these magnitudes, we then compute $y_{itk} = \ln(Q_{it}^k/Q_{it-1}^k)$, $k = s, c$, which is the continuously compounded percentage change in Q_{it}^k during time period t. We then regress y_{itk} on a set of plant dummies and a spot/contract dummy variable to measure the difference in the average percentage change in Q_{it} across the two contract forms. To assess the relative variability in this rate of change, we take the residuals from this regression and regress them on a constant and the spot/contract dummy. These regressions, presented in Table 7, show that the average rate of growth in monthly plant-level spot deliveries is not significantly different from that for the total monthly contract deliveries, whereas the variability in the spot deliveries growth rate is more than twice as large as the variability in the contract deliveries growth rate.

We now examine the evidence in favor of the market switching strategy outlined above. To do this, we first compute the following magnitudes: BTU^k_{it}, SULFUR^k_{it}, ASH^k_{it}, PRICE^k_{it}, which are the transaction-size-weighted average monthly BTU, sulfur, and ash contents and the delivered price for both contract forms (k=spot, contract) for each plant (i) and month (t) in which the plant participated in both markets. We then perform the following regression.

$$\begin{aligned}\ln(Q^s_{it}/Q^c_{it}) &= \alpha_i + \lambda_t + \beta_1 BTU^s_{it} + \beta_2 SULFUR^s_{it} + \beta_3 ASH^s_{it} \\ &+\beta_4 PRICE^s_{it} + \beta_5 BTU^c_{it} + \beta_6 SULFUR^c_{it} + \beta_7 ASH^c_{it} \\ &+\beta_8 PRICE^c_{it} + \xi_{it},\end{aligned} \tag{3.2}$$

where $E(\xi_{it}) = 0$, α_i denotes the plant effects, λ_t denotes the time effects and Q^s_{it} and Q^c_{it} are defined above. Table 8 presents the results of this regression. The results are consistent with the market switching strategy based on $PRICE^s_{it}$ versus $PRICE^c_{it}$. A higher spot price predicts a smaller spot/contract ratio, and a higher contract price predicts an increased ratio. The hypothesis of market switching based on quality differences also finds some support from our data. A higher contract BTU predicts a reduction in the total spot deliveries to contract deliveries ratio, while spot BTU has an insignificant effect. Increases in spot sulfur are associated with smaller values of this ratio, whereas increases in contract sulfur are associated with increases. The major anomaly is the negative coefficient on contract ash. Since ash content is a relatively unimportant quality characteristic relative to sulfur and BTU content, this is not particularly troubling. Nevertheless, the data appear to show significant monthly market switching based on relative prices, with some evidence of market switching based on quality.

Table 6
Transaction Size Regression (74,579 Transactions)[a]

$R^2 = 0.060$		
Dependent Variable = Transaction Size in 10^{12} BTU		
Variable	Coefficient	Standard Error
QD1	-.012	.017
QD2	.026	.018
QD3	.021	.017
QD4	-.003	.017
QD5	-.010	.017
QD6	-.016	.017
QD7	.001	.016
QD8	-.005	.016
QD9	.019	.017
QD10	.017	.016
QD11	.047	.016
QD12	.033	.016
QD13	-.009	.017
QD14	-.017	.017
QD15	.010	.017
SPOT	-.487	.007
Variance of Transaction Size Conditional on Mean Transaction Size[a]		
Dependent Variable = Squared Residual from Conditional Mean Regression		
Instrumental Variables Estimation-Instruments = (C, SPOT, QD1-QD15)		
Variable	Coefficient	Standard Error
C	-1.144	.407
PREDMEAN SIZE	1.879	.371
SPOT	.869	.321

[a] Standard Error estimates computed from heteroscedasticity-consistent covariance matrix estimate.

Note: PREDMEAN SIZE = Predicted transaction size (fitted value from transaction size regression given in above).

Table 7
Percent Change in Total Monthly Quantity Delivered[a]

$\%\Delta Q$ = Percent Change in Quantity Delivered to Plant i and Period t		
Dependent Variable = $\%\Delta Q = \ln(Q^k_{it}/Q^k_{it-1})$		
$R^2 = 0.002$		
Variable	Coefficient	Standard Error
QD1	0.129	0.061
QD2	0.001	0.059
QD3	0.001	0.057
QD4	-0.018	0.056
QD5	-0.007	0.057
QD6	-0.015	0.056
QD7	0.031	0.055
QD8	0.004	0.054
QD9	0.004	0.057
QD10	0.005	0.055
QD11	0.049	0.053
QD12	-0.010	0.051
QD13	-0.024	0.053
QD14	0.039	0.053
QD15	-0.004	0.052
SPOT	-0.022	0.026
Variance of Percentage Change in Quantity[a]		
Dependent Variable = RES^2		
RES^2 = Squared Residual from Percentage Change in Quantity Regression		
$R^2 = 0.008$		
Variable	Coefficient	Standard Error
C	0.351	0.035
SPOT	0.385	0.057

[a] Standard Error estimates computed from heteroscedasticity-consistent covariance matrix estimate.
Note: Q^k_{it} = Average transaction size for plant i in time period t for contract form k.

4. SIZE OF MARKET RATIONALE

This section describes the size-of-market rationale for simultaneous spot and contract market participation. This rationale focuses on the impact of the location of the consuming plant relative to the supplying mines on the decision to purchase in the spot and contract markets.

4.1. Implications of Size of Market Rationale

The first implication of this rationale is that the average transport distance for a spot market transaction should be shorter than the average distance of the same quality contract market transaction because many of the contingencies which may cause a long distance spot market transaction to be unsatisfactory to either party can be explicitly accounted for in a contractual arrangement. Lower quality coal is also less likely to travel as far on the spot market because transport costs are determined on a dollar per ton basis, whereas coal consumers purchase BTUs. Consequently, as transport distance grows, low quality coal is at an increasing cost disadvantage relative to higher quality coal because of the increasing cost of transporting a given quantity of BTUs.

Another implication of the size-of-market rationale follows from the transactions-cost economics of Williamson (1979). He argues that, as the number of suppliers grows, many transactions which were once relationship-specific (and hence required contractual relations) lose that characteristic and firms can therefore rely more heavily on spot market transactions. However, the lower the degree of substitutability across input sources to produce a given level of output, the greater the relationship-specific capital involved in procuring that input, and the greater must be the reliance on contract market transactions.

For present purposes, this logic applies as follows. In areas where coal is the primary source for base load electricity generation, the fraction of coal a plant purchases on the contract market should be higher because the utility has less flexibility to diversify across generation technologies to insure against coal supply interruptions. In regions where utilities have a portfolio of possible generating technologies available, they can substitute across these technologies in their electricity supply decision depending on relative prices in the fuel markets. These utililites can afford more coal price and quantity uncertainty because coal-fired electricity generation is only one of many technologies at the utility's disposal. Many utilities have responsed to the price volatility in energy markets by adding fuel switching capabilities into their generating facilities. An increasing number of power plants have the capability to burn natural gas, oil, or coal to produce electricity (Solomon and Johnson, 1992). This is particularly true in regions where coal in not locally available. Consequently, for plants in these regions we would expect a larger fraction of its coal supply to come from spot market transactions.

By Williamson's logic, relationship-specific effects become more important if a plant only has a very small number of viable sources of supply, so it is more apt to engage primarily in contract market relations. Conversely, if a plant is located close to a large number of potential suppliers, it can afford to be less concerned with supply interruptions from specific suppliers because there are always plenty of alternate sources of supply close by.

Combining these two effects, we expect a larger number of local suppliers of coal to predict an increase in spot market participation, and a larger share of base load power from coal-fired plants in the region to predict a reduction in spot market participation.

4.2. Empirical Results

The regression used to analyze the first size-of-market question predicts transport distance. The first regression given on Table 9 uses fixed effects, time effects and a spot/contract dummy (a simple analysis of variance) to determine the difference in mean transport distances. For comparison we also present the "between" (regression of plant means over time) in addition to the "within" (regression with plant fixed effects) estimates of the mean difference in transport distance. From this table we see that, although within the firm the mean transport distance of a spot transaction is statistically significantly smaller (by 2 miles), the major difference in spot versus contract transport distance occurs across firms, where the difference is approximately 160 miles. We interpret these results as follows. Both the spot and contract market are equally geographically dispersed for a given plant; the difference of 2 miles, although statistically significant, is of no economic significance. The very large across-plant difference in average transport distance predicted by a larger average spot market share implies that those plants which have a substantially shorter average transport distance to their suppliers also take a larger fraction of their coal on the spot market during our sample period. These within versus between regression results are consistent with the view that firms near many suppliers choose a larger average spot market share than those far from their suppliers. However, despite this difference in average spot market shares, neither type of plant goes a significantly different distance for spot versus contract market supplies.

The pair of regressions in Table 10 repeats the transport distance regression controlling for quality characteristics of the coal (BTU, sulfur, and ash content), in addition to the spot/contract dummy and plant and time effects. The first of the two also includes quantity transported and the quantity transported interacted with SPOT. Both of these regressions find that the mean transport distance is statistically significantly smaller for spot transactions than for contract transactions. However, the largest this magnitude gets is 10 miles, which is still of little economic significance when considered relative to the mean transport distance of 227 miles. Figure 14 provides a graphical illustration of this point. This figure plots the histograms of both spot and contract transactions delivery distances. The two histograms are extremely similar. Consequently, the risk embodied in increasing transport distances does not seem to have an economically significant effect on incremental spot market purchases by individual generating facilities, although this increased risk does seem to be reflected in a smaller spot market share for that plant.

The regression with quantity and the spot/contract dummy interacted with quantity finds that shipment size does not predict shipping distance for contract transactions, but it does predict that larger spot transactions tend to be shipped further. This result is further evidence of the residual nature of the spot market. When a plant is faced with a large residual demand, it will go an extremely large distance to procure it, and is willing to pay (as was shown in price regressions of Tables 2 and 3) a higher per unit price for this larger quantity.

Our second size-of-market implication provides an explanation for the substantial across-region difference in spot market participation described at the end of section 2. We examine this implication in the following fashion. For each month t and plant i in our sample we first compute the fraction of coal supplied by the spot market for year t and plant i.

This quantity is regressed on the number of coal suppliers that are in the same state as that plant (INSTATE SOURCES) in that year and the percentage of that state's annual net electricity production which is coal-fired (PERCENTGEN COAL). The FERC Form 423 assigns a unique five-digit code to each source of coal. There are 3,073 distinct source codes which we allocate to states in constructing the variable INSTATE SOURCES. The value of INSTATE SOURCES in states which do not produce coal is zero. We obtain the annual fraction of net generation from coal by state from Form EIA-759, *Monthly Power Plant Report*. Our joint hypothesis is that (1) the larger the number of suppliers within the same state as the plant, the larger the fraction of that plant's deliveries coming on the spot market, and (2) the smaller the fraction of the state's annual net generation coming from coal, the greater the plant's spot market participation.

Coal units can be base loaded or operated as cycling units. Because the demand for coal by a cycling unit is less certain than that for a base load unit, we would expect these units to participate more heavily in the spot market relative to base load units. Although we do not have information on which plants are base loaded or cycled, one indicator of cycling is a low capacity factor for the plant. From our plant-level data we can compute an estimate of the average capacity factor, CAPFAC = (annual net generation)/(8760*plant capacity), where 8760 is the total number of hours in a year. We include this variable in our regressions to predict a plant's annual spot market share to control for across-plant differences in mode of operation.

Table 11 presents the results of these regressions, first for the case of just PERCENTGEN COAL and INSTATE SOURCES and then with CAPFAC added to the model. Both regressions provide statistical support in favor of our joint hypothesis, with a negative coefficient on PERCENTGEN COAL and a positive sign on INSTATE SOURCES. The sign of CAPFAC is consistent with logic given above that cycling plants, which tend to have low capacity factors, have a higher spot market share.

5. RELATIONSHIP-SPECIFIC RATIONALE

The relationship-specific rationale implies the use of spot transactions to overcome many of the incentives for either side of a transaction to shirk

its contractual obligations. This section first presents our conception of the relationship-specific rationale. Then we present the results of our empirical analysis of the implications of this rationale.

The basic idea is that there are many instances when either side of a contractual arrangement can engage in opportunistic behavior at the expense of the other side. As discussed in Klein, Crawford, and Alchian (1978) and Williamson (1979,1986), some economic institution or mechanism is necessary for punishing this type of behavior and for rewarding good behavior. The promise of future high-price spot market transactions represents one mechanism for the utility to bribe a supplier to fulfill its contractual obligations. Conversely, the promise by a supplier of future low-price spot transactions can increase the cost of opportunistic behavior by the utility in its contractual dealings with that supplier.

5.1. Implications of Relationship-Specific Rationale

The implication of this rationale that we examine is whether the existence of a contractual relationship between a supplier and consumer predicts an increased number of spot market transactions between these two agents.

We examine this implication in two ways. The first computes the total number of spot and contract transactions between supplier i and plant j over the entire sample period.[8] We then select two subsamples from this transactions sample. The first sample contains only those transactions pairs with positive contract transactions. Conditioning on this contract relationship sample, we regress S_{ij}, the total number of spot transactions between supplier i and plant j, on plant fixed effects and C_{ij}, the total number of contract transactions between supplier i and plant j. The second sample is the spot relationship sample where $S_{ij} > 0$. For this sample, we regress S_{ij} on plant fixed effects and a dummy variable DC_{ij}, which takes on the value of 1 if C_{ij} is positive (a contract relationship exists between plant j and mine i) and zero otherwise.

[8] We use the 3,073 supplier source codes to identify suppliers and the 363 plant codes to identify consuming plants in constructing the transaction-pair variables used in this section.

Table 9
Transport Distance Analysis of Variance (74,579 Transactions)[a]

Dependent Variable = Transaction Transport Distance				
Model	Between (OLS on Means)		Within (OLS with Fixed Effects)	
	$R^2 = 0.116$		$R^2 = 0.001$	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
SPOT	-163.7	46.6	-1.95	.780
QD1	-1877.3	570.9	-3.60	1.80
QD2	-427.5	442.3	-3.71	1.85
QD3	-701.1	460.9	-3.83	1.74
QD4	-791.5	696.1	-3.48	1.67
QD5	-1559.4	683.0	-5.63	1.62
QD6	-1256.9	638.4	-5.66	1.65
QD7	-804.8	741.4	-4.94	1.68
QD8	-995.5	545.8	-7.68	1.62
QD9	-2336.3	832.2	-7.96	1.58
QD10	-1183.8	873.5	-7.29	1.61
QD11	-520.2	805.1	-6.61	1.67
QD12	-1224.5	657.8	-6.26	1.65
QD13	-780.3	823.9	-7.30	1.64
QD14	-124.7	654.6	-6.66	1.85
QD15	-1329.9	820.1	-3.44	1.83
C	1317.3	438.9		

[a]Standard Error estimates computed from heteroscedasticity-consistent covariance matrix estimate.

Table 10
Transport Distance Regressions (74,579 Transactions)[a]

Dependent Variable = Transaction Transport Distance				
	$R^2 = 0.239$		$R^2 = 0.238$	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
BTU	-34.3	.897	-34.3	.901
SULFUR	-8.43	.191	-8.44	.192
ASH	-2.25	.060	-2.26	.060
QUANT	-.37E-06	.40E-06		
QUANT*SPOT	.11E-04	.15E-05		
SPOT	-10.0	.768	-6.79	.686
QD1	-3.59	1.54	-3.65	1.54
QD2	.159	1.54	.066	1.54
QD3	.255	1.46	.183	1.46
QD4	-4.15	1.42	-4.20	1.42
QD5	-4.45	1.37	-4.53	1.37
QD6	-.310	1.39	-.441	1.39
QD7	-1.22	1.41	-1.34	1.40
QD8	-6.95	1.35	-7.11	1.35
QD9	-4.81	1.33	-4.87	1.33
QD10	-4.06	1.33	-4.00	1.33
QD11	-2.59	1.37	-2.66	1.37
QD12	-2.67	1.35	-2.86	1.34
QD13	-5.95	1.36	-6.14	1.36
QD14	-1.72	1.48	-1.77	1.48
QD15	-.721	1.46	-.828	1.46

[a]Standard Error estimates computed from heteroscedasticity-consistent covariance matrix estimate.

Table 11
Regression Predicting Fraction of Quantity on Spot Market

Dependent Variable = Fraction of Annual Quantity to Plant i Obtained on Spot Market				
Sample Size(N=1412)	$R^2 = 0.049$		$R^2 = 0.058$	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
C	0.251	0.027	0.325	0.033
INSTATE SOURCES	0.00025	0.00003	0.00025	0.00003
PERCENTGEN COAL	-0.102	0.038	-0.107	0.038
CAPFAC			-0.144	0.038

Notes: INSTATE SOURCES = Number of suppliers within the same state as plant i in year t. PERCENTGEN COAL = Percentage of total annual net generation from coal for plant i's state in year t. CAPFAC = Average capacity factor of plant i in year t.

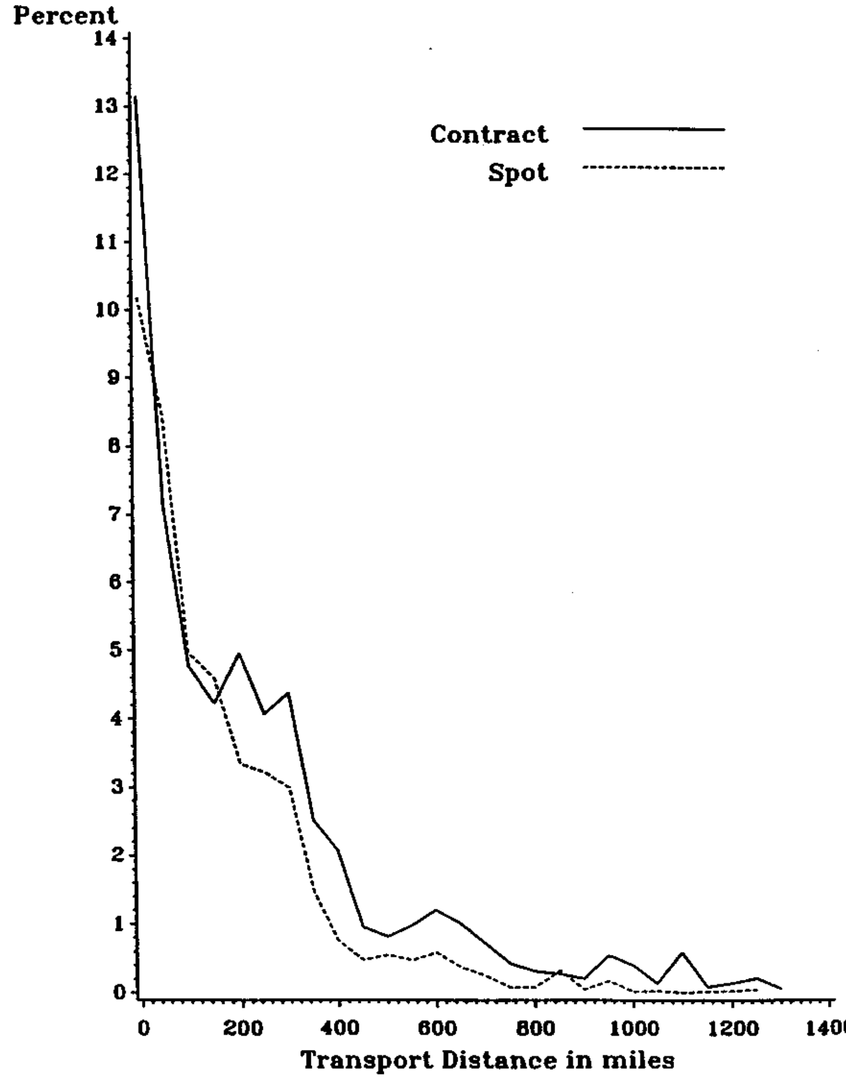

Figure 14: Histogram of Shipping Distances for Spot and Contract Transactions

Our second approach attempts to take into account the temporal dependence between a contract relationship and future spot market transactions embodied in the relationship-specific rationale. For this purpose we divide our sample into two periods. The relationship establishment period is from the beginning of 1985 to the end of 1986. For this two-year period we compute the total number of transactions (spot or contract) between each supplier-plant pair. Conditional on these pre-1987 relationships, we then compute, S_{ij}^{a86}, the total number of spot transactions between these supplier-plant pairs for the two-year post-86 sample period from the beginning of 1987 to the end of 1988. Let S_{ij}^{b87} denote the number of pre-87 spot transactions between supplier i and plant j. Define C_{ij}^{b87} in an analogous manner. With this sample of pre-87 spot or contract relationships, we regress S_{ij}^{a86} on plant dummies and C_{ij}^{b87} and S_{ij}^{b87}. Consequently, the coefficient on C_{ij}^{b87} measures the expected plant-level impact of one more pre-87 contract transaction on the expected number of post-86 transactions, controlling for the number of pre-87 spot transactions. Including the number of pre-87 spot transaction in our attempt to controls for the impacts of previous spot relations between this supplier and demander pair. A positive coefficient on C_{ij}^{b87} is consistent with the use of spot transactions to enforce contractual performance. We repeat this exercise reversing the positions of spot and contract transactions in an attempt to address the question of temporal causation between spot and contract transactions.

5.2. Empirical Results

Table 12 presents the results of the full-sample analysis with total spot transactions as the dependent variable. For both the spot relationship sample and the contract relationship sample, contract relations or transactions lead to a larger predicted number of spot transactions between the supplier and plant.

Table 13 presents results for both C_{ij}^{a86} and S_{ij}^{a86} as the dependent variable. In the regression to predict post-1986 spot market transactions (S_{ij}^{a86}), we find that even controlling for the number of pre-87 spot transactions (S_{ij}^{b87}), more pre-87 contract transactions (C_{ij}^{b87}) predict a statistically significantly larger number of post-86 spot transactions. In the regression to predict post-86 contract transactions (C_{ij}^{a86}) using the number of pre-87 contract transactions, the addition of the number of pre-87

spot transactions provides no statistically significant increase in predictive power of the regression. Consequently, the dynamics of the interaction between spot and contract relations seems consistent with the view that the existence of a contract relation makes future spot transactions more likely.

6. SUMMARY AND INTEGRATION OF EVIDENCE

In this section we summarize the evidence for and against the various rationales for simultaneous spot and contract market participation presented in the previous three sections. As is clear from the results in the previous sections, these rationales should have varying degrees of relevance to different participants in the US steam coal market. For this reason, we also discuss the relative importance of these rationales to plants operating in different regions of the US.

6.1. The Risk Aversion Rationale

The vast majority of the evidence presented in Section 3 is consistent with the risk aversion rationale. Despite the fact that the mean contract market transaction is approximately four times larger (in terms of millions of BTUs) than the mean spot market transaction, the conditional variance of the spot transaction quantity is considerably larger once the effect of this larger mean is controlled for (see Table 6). In addition, in terms of monthly growth rates, the average spot market transaction rate of growth is more than twice as volatile as the average contract market transaction rate of growth (see Table 7). We also found that the mean contract price premium is approximately 20 percent regardless of how one controls for quality or quantity in the price regression. For a wide variety of conditioning variables, we find that the spot price is less volatile than the contract price.

Taken together this evidence points to the following explanation. The most important source of uncertainty to coal consuming plants is quantity risk. These firms are willing to pay a substantial price premium for a guaranteed input supply, and are relatively indifferent to price variability in both contract and spot supply. Further evidence for the importance of quantity risk is suggested by the results of the price and distance regressions with QUANT included. There we found that larger shipments on the spot market are associated with higher prices, whereas larger shipments on the contract market are not. In addition, plants are willing to go larger distances for larger quantities on the spot market. This willingness to pay higher prices and go larger distances on the spot market (when presumably the plant has a particularly high demand for coal) is further evidence of the importance to the plant of having a sufficient supply of coal.

Although coal consumers use contracts to insure against large supply disruptions, at the margin, they appear to be both price and quality sensitive in choosing the incremental amount of spot versus contract coal to purchase in any time period. Our market switching regression results in Table 8 imply that a 30 cent price increase on the spot market results in a more than one percent decrease in the ratio of total monthly spot market deliveries to total monthly contract market deliveries, and that the same price increase on the contract market increases this ratio by a little less than one percent. The estimated quality coefficients are largely consistent with the market switching for quality logic. Although it is difficult to choose interpretable absolute magnitudes for changes in the coal quality, standardizing both quality and price to one standard deviation changes (see Table 2), we find that a one standard deviation price change results in a larger absolute effect on the spot/contract ratio than does a one standard deviation change in any of the quality attributes.

6.2. The Size of Market Rationale

The empirical evidence on this rationale uncovers perhaps the most surprising fact about the operation of this market–within a given plant, the expected distance of a spot market transaction is not noticeably smaller than the expected transport distance of a contract market transaction. However, comparing the mean transport distance of spot versus contract purchases across plants we find that average transport distance is much lower for plants with larger spot market shares. This result can be explained by the geographic distribution of active spot markets; they tend to be in the Midwest, Appalachia, and Northeast, where transport distances are relatively small, whereas the primarily contract market regions are in the Southwest, Northern Mountain, and Gulf States where transport distances are quite large (see Figures 5-12).

We provide one explanation for this geographic distribution of active spot markets in terms of a size-of-the-market rationale. If there are numerous suppliers local to a given plant, spot market participation should be high. A mitigating factor in a plant's decision to participate in the spot market is the fuel-switching capabilities of the utility (the portfolio of available electricity-generating technologies and the extent of within-plant fuel switching capabilities). We find greater spot market participation in areas with large numbers of suppliers close to both one another and the purchasing plant. We find less contract market participation in regions where demonstrated fuel-switching capabilities away from coal are low. Plants in the Northeastern region provide the best illustration of the mitigating effect of this potential fuel-switching. This region does not rely very heavily on coal power and, as a consequence it can afford a less reliable coal supply, so that it has a very active spot market participant despite the fact that no coal is actually produced in this region.[9] West Virginia is a slightly different example of these two competing effects. Despite the fact that more than 95 percent of its electricity generation is coal-fired, spot market purchases account for a sizeable share of plant coal purchases because of the large number of local suppliers.

6.3. Relationship-Specific Rationale

Although we have found evidence consistent with our conception of the relationship-specific rationale, it is very difficult to quantify how important it is in determining simultaneous participation in the spot and contract market by electricity-generating plants. Our results find that the existence of a contract market relationship is correlated with a larger than plant-average spot market relationship. Past contract market purchases are able to completely explain future contract market purchases for a given supplier-plant pair, with past spot market transactions providing no significant predictive power. Consistent with the relationship-specific rationale, even controlling for the number of previous spot transactions between a supplier-plant pair, past contract transactions are a significant predictor of a larger number of future spot transactions between this supplier-plant pair.

[9] The major energy sources for electricity generation in the Northeast region are oil and nuclear power.

Table 8
Monthly Spot/Contract Market Switching Regression

Dependent Variable = $\ln(Q^s_{it}/Q^c_{it})$		
$R^2 = 0.397$		
Variable	Coefficient	Standard Error
BTU^s	-0.050	0.031
BTU^c	-0.235	0.032
ASH^s	-0.001	0.003
ASH^c	-0.021	0.005
$SULFUR^s$	-0.036	0.018
$SULFUR^c$	0.038	0.021
$PRICE^s$	-0.004	0.001
$PRICE^c$	0.003	0.001
QD1	-0.033	0.084
QD2	-0.177	0.081
QD3	-0.063	0.078
QD4	-0.141	0.075
QD5	-0.181	0.075
QD6	-0.114	0.074
QD7	-0.071	0.070
QD8	-0.111	0.069
QD9	-0.140	0.073
QD10	-0.026	0.069
QD11	-0.041	0.065
QD12	-0.069	0.065
QD13	-0.218	0.068
QD14	-0.053	0.067
QD15	-0.071	0.064

Notes: BTU^k_{it} = Average BTU content of coal received by plant in month t under contract form k. ASH^k_{it} = Average ASH content of coal received by plant i in month t under contract form k. $SULFUR^k_{it}$ = Average sulfur content of coal received by plant i in month under contract form k. $PRICE^k_{it}$ = Average price of coal received by plant i in month t under contract form k. Contract form $k = s$ or c (spot or contract).

Table 12
Relationship-Specific Regressions for Entire Sample

Dependent Variable = Number of Spot Transactions Between Source-Supplier Pair				
	Source-Supplier Relationship Sample			
Sample	Spot (N=5811)		Contract (N=2485)	
	$R^2 = 0.006$		$R^2 = 0.018$	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
(DC) CONTRACT RELATION	1.84	0.333		
(C) CONTRACT TRANSACTIONS			0.034	0.005

Table 13
Relationship-Specific Regressions for Split Sample

Dependent Variable = Number of Post-1986 Transactions Between Pre-1986 Source-Supplier Pairs				
Model	Post-1986 Spot (S^{a86})		Post-1986 Contract (C^{a86})	
	$R^2 = 0.157$		$R^2 = 0.303$	
Variable	Coefficient	Standard Error	Coefficient	Standard Error
C^{b87}	0.370	0.013	0.589	0.013
S^{b87}	0.020	0.007	0.008	0.025

7. CONCLUSIONS AND CAVEATS

In light of the empirical evidence presented, we now provide our answer to the question posed in the title of the paper. Based on our analysis of the US electric utility steam coal market, plants participate jointly in both spot and contract markets for the following reasons.

(1) Plants enter into contractual arrangements to guarantee a stable supply source for their expected input demands.

(2) For the most part, plants use spot market transactions to satisfy residual demands due to unforeseen events and are willing to pay even higher prices for and purchase from even more distant suppliers the larger is this residual demand.

(3) Plants are less concerned with price variability relative to the probability of supply interruptions, particularly on the contract market.

(4) Once contract relationships are set, plants engage in significant switching between spot and contract markets within the contraints of their contractual arrangements based on relative price and coal quality in the two markets.

(5) Within a given plant, the average distance to its spot suppliers is not significantly different from the average distance to its contract suppliers. In other words, transport distance is not an important factor in the spot versus contract purchasing decision, conditional on a plant's location.

(6) Plants participate in the spot markets to a larger extent in regions where there are many coal suppliers, but to a lesser extent where coal is the primary energy source for electricity generation.

(7) Spot market transactions appear to be a useful tool for both plants and mines to insure against opportunistic behavior by either side of the contractual supply relationship.

7.1. Caveats

There are many caveats associated with these conclusions. We mention the ones that we feel are most important.

The first concerns the role of inventories of coal in the spot versus contract market purchase decision. Plants can (and some do) participate only in the contract market and satisfy unexpected input demand out of accumulated inventories. Unfortunately, we have no information on the level of inventories and so we cannot directly address the importance of this issue. We believe that for the majority of plants our conclusions would not be substancially different if this information were available because coal has several attributes which make its storage costs quite high, and hence reduce a plant's desire to accumulate large enough inventories to obviate the need to participate frequently in the spot market. Coal is very space-inefficient relative to oil or gas in terms of the volume required to deliver a fixed number of BTUs. Also, if coal is stored for long, it can accumulate substancial amounts of moisture which reduces its combustive efficiency. In addition, regulatory commissions have been reluctant to allow utilities to earn a return on any coal held beyond the standard 30 to 45 day inventory held to guard against short-term supply interruptions. Cross (1993) discusses the recent difficulties many utilities have faced in attempting to increase their revenue requirements in order to offset the costs of holding larger than normal coal inventories in preparation for labor strikes at coal-supplier mines.

A second caveat concerns the lack of information on production costs, or equivalently, transport costs. In our price regressions, we attribute all differences in prices (besides the additive error to the regression) to observable characteristics of the coal. However, part of the delivered price of coal to a plant may be due to supplier market power or differences in transport costs across plants. Mine-level production costs would allow us to exactly determine transportation costs. Even though delivered price is the cost of the coal to consumers, it is composed of two prices, which in most cases, are set by two independent agents, the supplying mine and the transporter. Interactions among these players can complicate any attempt to understand the reasons for spot versus contract market participation. We hope to address this caveat in future research.

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