Who (Else) Benefits from Electricity Deregulation? Coal prices, natural gas and price discrimination

Jonathan E. Hughes[1] and Ian Lange[2*]

Abstract

The movement to deregulate major industries over the past 40 years has produced large efficiency gains. However, distributional effects have been more difficult to assess. In the electricity sector, deregulation has vastly increased information available to market participants through the formation of wholesale markets. We test whether upstream suppliers, specifically railroads that transport coal from mines to power plants, use this information to capture economic rents that would otherwise accrue to electricity generators. Using natural gas prices as a proxy for generators' surplus, we find railroads charge higher markups to deregulated plants when rents are larger. This highlights an important distributional effect of deregulation. Further, our price discrimination results imply changes in upstream fuel costs can have substantially different effects on downstream consumers in regulated and deregulated markets. This has important implications for policies or technologies that change the costs of electricity generation.

JEL Classification: L11, L51, Q48

Keywords: Deregulation, Price Discrimination, Electricity Markets. Procurement Contracts

---

*We thank Matthew Butner, Harrison Fell, Dan Kaffine, Pete Maniloff and the audiences at the 2016 AERE summer conference, Front Range Energy Camp, and EI@Haas summer conference for helpful comments and suggestions.

[1]Department of Economics, University of Colorado at Boulder, Box 0256 UCB, Boulder, CO 80309. Email: jonathan.e.hughes@colorado.edu. [2]Division of Economics & Business, Colorado School of Mines, Golden, CO 80401. Email: ilange@mines.edu.

1 Introduction

Many countries have deregulated large industries with the goal of improving efficiency. However, deregulated markets leave many avenues for firms to exercise market power. Further, deregulation can affect the distribution of economic surplus across consumers, upstream producers, and downstream suppliers. Importantly, deregulated markets may facilitate price discrimination by making reservation values transparent, allowing suppliers to earn larger profits than they would have in a regulated market. For example, in a deregulated electricity sector, plants bid power into a wholesale market. These transactions may make public a wealth of information about prices, marginal generation costs and potentially, the magnitude of rents available to inframarginal generators. Could input suppliers, in this case railroads transporting coal to electricity generators, use this information as the basis for price discrimination?

To answer this question, ideally one would test whether rail prices respond differently to changes in electricity prices in regulated and deregulated markets. Of course, this is impossible since regulated utilities largely lack wholesale markets. To solve this problem we use natural gas prices as a proxy for changes in the rents available to coal-fired generators.[1] For deregulated generators in wholesale electricity markets, changes in natural gas prices affect the price of electricity when gas is on margin. In regulated markets, gas prices can affect rents to coal generators through the rate setting process. The differential impact of natural gas prices on the price received by electricity generators suggests delivered coal prices should move more strongly with natural gas prices in deregulated markets.

We first test whether coal prices are correlated with natural gas prices. Then, we compare effects for spot and contract shipments. Next, we investigate whether the effects are larger for shipments to generators in deregulated markets. Finally, we explore whether this effect is larger in places and during

[1] Natural gas is not used by rail or barge firms to transport coal, it is not a large expense for coal mines, nor is natural gas transported by rail. Therefore, it is therefore unlikely to directly impact the delivered cost of coal.

time periods when natural gas is a greater share of generation or is more often the marginal generation.

To do this, we estimate a series of hedonic models for delivered coal prices similar to Busse and Keohane (2007) and Preonas (2017). Our analysis is most closely related to Preonas (2017) who uses public data for regulated power plants and a nearest neighbor matching approach to show delivered coal prices are positively correlated with natural gas prices. Because railroads optimize markups in response to changes in gas prices, Preonas (2017) shows coal consumption may not decline as much as expected due to the incomplete pass-through of the carbon tax. Here, we show how information transmitted by deregulated electricity markets exacerbates this problem, leading to even lower pass through rates to deregulated plants compared with regulated utilities.

We expand on earlier analysis by estimating the differential impact of natural gas prices on delivered coal prices for both regulated and deregulated plants using both public and restricted-access shipment level data on coal deliveries from the Energy Information Administration (EIA). We investigate the mechanisms which exacerbate or alleviate the use of market power by transportation firms in coal transactions. Similar to to Busse and Keohane (2007) and Preonas (2017), we account for factors affecting the value of the coal transported, namely coal prices and coal quality characteristics, and rail costs such that our results can be interpreted as estimates of rail markups. In a series of robustness checks we account for scarcity effects and capacity constraints using generation data and proxies for coal demand, seasonal effects and unobserved shipment-level characteristics. We have several main results.

First, we show markups for coal shipments are positively correlated with natural gas prices. This result echoes the earlier finding in Preonas (2017) for regulated utilities. Second, and in contrast to earlier work, we find a substantially larger effect at deregulated plants. In our main specification, a \$1 per Mcf (12%) increase in natural gas price is associated with a \$0.07 per ton (0.1%) *decrease* to a \$0.11 per ton (0.2%) increase in delivered prices for spot shipments to regulated plants but a \$0.78 per ton (1.8%) to \$0.93 per ton (2.1%) increase to in the delivered price of coal at deregulated plants. Third, the relationship between natural gas and delivered coal prices is larger for spot compared with contract shipments. For contract purchases, the effect is largest for deregulated plants that negotiate contracts more frequently, consistent with price increases associated with the bargaining process.[2] Fourth, the estimated effect between gas and delivered coal prices is larger in regions and during time periods when changes in gas prices are more likely to affect rents to coal-fired generators. At regulated plants this is when the share of gas generation is larger. At deregulated plants this is when the share of generation from natural gas peaker plants (*i.e.* marginal plants) is larger. Next, we provide evidence the estimated relationship between natural gas and delivered coal prices is smaller on more competitive routes where coal can be transported by barge or multiple railroads. This evidence is consistent with our price discrimination story and suggests competition from other railroads or other modes limits firms' ability to exercise market power. Taken with our prior results, this suggests better information provided by wholesale electricity markets in deregulated regions may increase the scope for price discrimination and enable railroads to capture some of the rents from inframarginal generators. Finally, the exercise of market power has important implications for policies such as carbon pricing. We estimate pass-through rates of an implicit carbon tax for regulated and deregulated plants. Consistent with Preonas (2017) we find pass through at regulated plants can be incomplete, ranging from 0.93 to ≈ 1. However, the effect of market power on pass through is magnified at deregulated plants where we find mean pass-through rates ranging from 0.80 to 0.93.

These results contribute to several literatures. First, earlier work has focused on how upstream suppliers alter their pricing to capture rents in the deregulated electricity markets. Numerous analyses of the impact of deregulation has generally found that power plants are the main beneficiaries of a deregulated market, whether through use of market power in wholesale market(Wolfram (1999); Borenstein, Bushnell, and Wolak (2002); Wolak (2003))

[2]As opposed to more mechanical mechanisms such as cost escalation clauses in existing contracts.

or through reduced input prices (Cicala (2015); Chan et al. (2017)). While we find that deregulated plants shipment prices are approximately 8% less than regulated plants, consistent with Cicala (2015) and Chan et al. (2017), our findings suggest a mechanism whereby input suppliers can capture some of generators' cost-savings under deregulation. Additionally, diMaria, Lange, and Lazarova (2018) show that the procurement contracts between mines and plants changed with deregulation as plants tried to shift risk to coal mines by requiring fixed price contracts.

Second, recent work has estimated the pass through of energy cost changes to energy prices (Fabra and Reguant, 2014; Knittel, Meiselman, and Stock, 2017; Chu, Holladay, and LaRiviere, 2017; Preonas, 2017; Muehlegger and Sweeney, 2017), or to manufactured goods prices (Ganapati, Shapiro, and Walker, 2016).[3] Relevant to our approach, Linn and Muehlenbachs (2018) find evidence that lower natural gas prices lead to lower wholesale electricity prices, implying that lower natural gas prices pass-through to wholesale electricity prices. We find rail markups respond to changes in natural gas prices, consistent with railroads raising markups when available rents are greater. This behavior leads to incomplete pass through of energy cost changes.

Third, this paper contributes to a long literature studying the impacts of railroad market power. Railroads are well known to exercise market power (Schmidt, 2001) and practice price discrimination (MacDonald, 2013). Examples in include grain shipments (MacDonald, 1987, 1989), fuel ethanol (Hughes, 2011) and coal (Atkinson and Kerkvliet, 1986). For coal shipments, Busse and Keohane (2007) show railroad use information available in environmental regulation as the basis for price discrimination in shipments of low sulfur coal. Similarly, He and Lee (2016) show rail prices take into account the availability of markets for byproducts of coal combustion. Here, we show how the information transmitted by the wholesale power market can facilitate price discrimination for coal deliveries to deregulated electricity generators. In light

[3]Recent work related to the movement of natural gas prices on fuel used in electricity generation includes Knittel, Metaxoglou, and Trindale (2015) and Cullen and Mansur (2017).

of policy makers' calls to expand energy transportation infrastructure (U.S DOE, 2015), our results have important implications for projects that increase competition in energy delivery markets.

2 Background

Coal-fired power plants became the backbone of the US electricity generation system during the 1970s. The oil embargoes of the 1970s spurred the federal government to encourage the building of large coal plants and the leasing of coal mines on federal lands as a way to ensure energy security. As a result, a wave of new coal plants were opened in the late 1970s and early 1980s.

There are two types of markets in the US for electricity. The traditional, or regulated, market is currently used by about 60% of states. Here plants are subject to cost-of-service regulation where the state regulatory agency will generally reimburse the plant for the costs of fuel purchases. While the entire US electricity sector was once regulated in this manner, a number of states passed legislation in the late 1990s to restructure their electricity markets with the goal of encouraging competition and lowering generation costs. In a restructured market plants bid to generate electricity through wholesale markets.[4] Wholesale electricity price are determined by generators' bids and market demand. In the following section we discuss how differences in the way prices are set in regulated and deregulated markets can enable price discrimination in coal transportation.

While state regulatory agencies have traditionally played a large role in the decision to open new plants, the placement is generally governed by other factors. The siting of plants has been based on proximity to water (for cooling the boiler), transmission infrastructure, and rail line access. A majority of plants receive coal deliveries through the rail network.[5] Between 1979 and 2002, approximately 60% of coal shipments were made by rail. (U.S. EIA,

[4] In the analysis below we treat any plant classified by EIA as an "independent power producer" as a deregulated plant regardless of where the plant is located.

[5] Other major options for coal delivery are by barge along a navigable waterway, truck, or conveyor belt (in the case of mine mouth plants).

2004) More recent data suggest the ratio is currently 72%, with 81% of all western coal deliveries being made by rail. (U.S. EIA, 2012) For plants in the Midwest and Appalachia, barge deliveries are common. Plants have become more reliant on the rail industry in the last 20 years in part because of the large expansion of low cost, low sulfur mines in the western US. These western mines have little alternative to transporting coal by rail given the lack of navigable waterways and the high cost of transporting large amounts of coal by truck transportation is not competitive.

While coal transportation options are limited, in many cases rail competition is also limited. The US rail industry is highly concentrated and dominated by seven "Class I" railroads that operate large multi-state networks and control over 90 percent of industry revenues (Association of American Railroads, 2017). The industry is geographically segmented with two firms, the BNSF Railway and the Union Pacific Railroad, in the western US and CSX Transportation and Norfolk Southern Railway in the east. Three smaller firms, the Canadian National Railway, the Canadian Pacific Railway and Kansas City Southern Railway Company, participate in the central US, and Canada. As a result of this industry concentration, the vast majority of coal-fired generators can receive coal from only one or potentially two railroads.

The pricing of freight rail has been partially deregulated since the Staggers Act of 1980. Railroads post public common carriage tariffs for shipments of different goods between origins and destinations or by shipment distance categories. The industry regulator, the Surface Transportation Board (STB), has a limited oversight role meant to protect shippers from unfairly high prices in the case of railroad "market dominance."[6] Deregulation also allowed railroads and shippers to negotiate private contracts for the movement of goods. Historically, power plants have used utilized long-term contracts with both railroads and mines for the majority of their coal purchases. Contracts negotiated during the plant citing process can help mitigate rail market power (Joskow, 1987).

[6]Shippers can bring rate cases before the STB if they feel their rates are unfairly high. Typically STB uses a rule of thumb of three times average variable cost to assess the fairness of pricing, though prices above this threshold do not necessarily imply market dominance.

However, generators still use a mix of spot and contract purchases as a means of hedging against changes in coal prices.

A final issue relates to recent changes in natural gas markets in North America. Technological advances in drilling technology, namely horizontal drilling and hydraulic fracturing have greatly expanded natural gas production in the US. As a result, wellhead prices have fallen from a peak of approximately \$8 to \$9 per thousand cubic feet (Mcf) in 2008 to approximately \$3 to \$4 per Mcf today. These changes have lead to shifts in electricity generation (Fell and Kaffine, 2018; Knittel, Metaxoglou, and Trindale, 2015) and have been utilized as a source of exogenous variation to study the impact of carbon pricing in the electricity sector (Cullen and Mansur, 2017).

3 Conceptual framework

Whether an electricity market faces economic regulation or a deregulated wholesale market affects how generators are compensated for their production. Regulated electricity markets generally contain a monopoly producer who generates all of the power for the regulated region and sells its output at a price set by the regulator. Generators submit rate cases to the state public utility commissions (PUC) either at the firm or PUC request. Often the PUC will approve rate adjustment mechanisms for the firm to recover costs that arise through their fuel procurement contracts.

Generators in deregulated regions, on the other hand, sell their power on wholesale electricity markets. The price they receive for their output is determined by market demand and generators' production decisions. We can see how these different market structures can affect rents available to coal fired generators using a stylized model for each scenario shown in Figure 1.

First, imagine four generation technologies representing nuclear, coal, gas and oil generation with marginal costs c_n, c_c, c_g and c_o, each with one unit of capacity. Ordering the generation from lowest to highest marginal cost yields a marginal cost supply curve or "merit order." Further, consider electricity demand q in some arbitrary period, and a shock to natural gas price that increases the marginal cost of gas generation from c_g to c_g'. Under regulation (panel a), the cost of electricity generation during this period increases by the vertically shaded rectangle. In the process described above, the utility may petition the regulator for a rate increase. Here, prices increase by the increase in average generation cost, shown as Δp_1. Since electricity prices are higher as a result of the rate increase, producer surplus for the inframarginal coal generator increases by the small shaded rectangle in Figure 1 (panel a).

Next, consider the case of a deregulated generator in a wholesale electricity market. For the purposes of exposition, consider electricity demand q such that natural gas is the marginal generation. In the case of competitive bidding, the price of electricity is determined by the intersection of demand and marginal cost (c_g) and shown as the lower dashed line (p_2) in Figure 1 (panel b).[7] An increase in gas price resulting in a shift in gas generation costs from c_g to c_g' increases electricity price by Δp_2. Here, producer surplus for the inframarginal coal generator increases by the shaded rectangle in Figure 1 (panel b).

In each of these cases, railroads with market power can attempt to capture some of the additional producer surplus available to coal generators as a result of the price increase. Note that in our example, the additional surplus is smaller under regulation compared with deregulation (when gas is on the margin) due to differences in how prices are set in each scenario. Further, deregulated regions have posted wholesale electricity prices, which can be observed by the railroads, giving a strong signal of the size of producer surplus increases. Taken together, this yields several testable predictions. First, if railroads exercise market power in coal transportation we expect a positive relationship between natural gas and delivered coal prices. Second, this effect should be larger in deregulated markets compared with regulated markets. Finally, in regulated regions this effect should be larger during times or in regions where natural gas generation is a greater share of generation. In deregulated regions the effect should be larger when natural gas generation is more often on the margin.

[7]Of course changes in gas prices have no impact on wholesale electricity prices if natural gas is not the marginal generation, a feature we exploit in our empirical analysis below.

4 Empirical approach

We model the delivered price of coal as a linear function of the value of the coal itself, transportation cost, and a proportional markup term.[8] We assume a competitive mining sector such that markups reflect differences in transportation markets across regions and over time. Following Busse and Keohane (2007), we use mine mouth prices and coal characteristics, *e.g.* heat and sulfur content, to capture the value of the coal being shipped. Transportation costs are modeled as the product of shipment size in ton-miles, diesel price and a constant.[9] Finally, markups are assumed proportional to natural gas prices, consistent with our theoretical framework. More formally, the delivered price of coal ($Pcoal_{it}$) for shipment i in reporting month t is:

$$Pcoal_{it} = \alpha[Pmine_{bt} + X_{it}] \times tons_{it} + \beta \times tons_{it} \times miles_{it} \times Pdiesel_t + \gamma \times Png_{it} \times tons_{it} \tag{1}$$

where $Pmine_{bt}$ is the mine mouth price of coal from basin b in reporting month t and X_{it} is a vector of coal characteristics. Shipment distance ($miles_{it}$) is the estimated distance shipment i travels between the reported mine and power plant. Diesel and natural gas prices are represented by $Pdiesel_t$ and Png_{it}, respectively.

Since each term on the righthand side of Equation 1 depends on the quantity of coal transported ($tons_{it}$) we can, without loss of generality, represent delivered coal prices on a per ton basis (cpt_{it}) as:

$$cpt_{it} = \alpha_1 Pmine_{bt} + \alpha_2 X_{it} + \beta miles_{it} \times Pdiesel_t + \gamma \times Png_{it} + \epsilon_y + \epsilon_{it} \tag{2}$$

where we model time-varying unobservables common to all shipments at the year level as mean effects ϵ_y. Finally, ϵ_{it} is an idiosyncratic error term.

[8] The EIA data report delivered prices where the price includes both the value of transportation services and the coal itself.

[9] This approach captures diesel expenditures and other costs from line haul movements but excludes switching or loading and unloading costs. Further, the discussion above focuses on fuel costs. In our empirical results below we account for other rail costs that vary with distance using rail cost adjustment factors from the Association of American Railroads.

In our main results below we are interested in the differences between how changes in natural gas prices are related to changes in delivered coal prices for plants in regulated versus deregulated states. Because coal value and transportation costs may be passed through differently to regulated and deregulated plants, our results below allow the parameters of (2) to vary by regulatory status. Finally, in various specifications below we attempt to account for other possible explanations of the observed relationship between natural gas and delivered coal prices. Specifically, to Equation 2 we add proxies for coal transportation and electricity demand. We also explore whether the relationship between natural gas and coal prices varies by contract type, contract duration, electricity generation mix, rail or barge competition.

5 Data

We exploit confidential transaction-level data on coal deliveries to US power plants from EIA Form 423/923 during the period from 2002 to 2012. Importantly and in contrast to publicly available data, we observed shipments to both regulated and deregulated plants. Each observation reports the shipment quantity in tons, shipment cost, the county where the shipment originated, the power plant purchasing the coal, the heat, sulfur and ash content of the coal purchased. In addition, we observe the year and month of each transaction and whether the shipment is a spot or contract purchase. If the purchase is under an existing contract, the contract expiration date is reported. Beginning in 2008, EIA revised its survey form and added additional information on each shipment. In particular, for 2008 onward we observe the primary and secondary transportation modes of each shipment.

We augment these data with additional information on fuel prices, railroad costs, rail distances, electricity generation and railroad participation. Diesel prices are US monthly average on-highway prices from the U.S. Energy Information Administration (2014b). Natural gas prices are monthly state-average prices for industrial users from the U.S. Energy Information Administration (2014a). Mine mouth coal prices for Central Appalachia, the Illinois Basin, Northern Appalachia, the Powder River Basin and the Uinta Basin are from the U.S. Energy Information Administration (2018).[10] All prices are adjusted for inflation (constant 2009 dollars) using GDP implicit price deflators from the U.S. Bureau of Economic Analysis (2018). For rail costs we use "rail cost adjustment factors" excluding fuel from the Association of American Railroads (2015).

Figure 2 plots mean monthly coal prices for spot deliveries to regulated (panel a) and deregulated plants (panel b) during our sample. We see the price series appear correlated throughout the sample including both before and after the Great Recession and fracking boom beginning around 2008. However, one potential explanation for this correlation is that all energy prices are correlated due to economic shocks that affect the demand for energy. To see this, Figure 3 plots mean monthly prices for natural gas, diesel, mine mouth and delivered coal prices for regulated and deregulated plants. We see that indeed there are periods when the different energy price series move together. Therefore, our empirical model separately accounts for changes in diesel and coal prices that affect shipment costs and value while separately identifying the relationship between natural gas prices and rail markups.

Another potential confounding factor relates to rail congestion or demand shocks. In several specifications we include proxies for railroad congestion and electricity demand shocks. For the former, we aggregate the EIA shipment-level data to monthly totals for coal shipments between pairs of states or originating from particular coal mining states. For the later, we use the EIA form 923 data to construct monthly electricity generation by state for both regulated and deregulated plants.

Our theoretical framework suggests changes in natural gas prices affect delivered coal prices when natural gas electricity generation is more important. In several specifications below we use the electricity generation data from form 923 to identify periods when total natural gas generation or "peaker" gas

[10]Because EIA only reports historical prices for three years at a time, these data were complied from the EIA web site over several years. A complete price series is also available from https://www.quandl.com/data/EIA/COAL-US-Coal-Prices-by-Region.

generation, defined as natural gas fueled internal combustion and gas turbine generators, represents a greater share of total generation. Through the first part of our sample, 2002-2008, coal was the lower cost generation fuel relative to natural gas.[11] During the last part of the sample, 2009-2012, gas prices fell by about 65%. As a result, gas is generally believed to have been cost competitive with coal in many areas of the US during that period.

We use geographic information system (GIS) data on US rail networks from the U.S. Department of Transportation (2018) to estimate the shipment distance for each transaction in our data. Following Hughes (2011), we assume the shortest distance path between each mine and each plant across the existing rail network.[12] Because the shipment transportation mode is unobserved prior to 2008, we take several steps to ensure our data are rail shipments. Since our shortest distance rail calculations use information on the existing rail network, our procedure effectively excludes shipments that could not have been made by rail because either the mine or power plant lacks rail access. However, in cases where both mines and plants have access to barge (or truck) transport, it is possible our data include prices for shipments using these modes. Therefore, we use GIS data on navigable waterways from the U.S. Department of Transportation (2018) to determine whether a given mine and power plant is able to ship or receive coal by barge. In robustness checks, reported below, we include an interaction term with an indicator for whether both route endpoints have barge access. Estimating separate effects for potential barge shipments does not qualitatively affect our results.[13]

Finally, to investigate the potential effects of rail competition, we use GIS

[11] Other sources of electricity that are generally cheaper than coal or natural gas are renewables and hydroelectric. However these two sources are generally not dispatchable, in that it is difficult to increase or decrease the amount of electricity from these source as the market demands.

[12] Hughes (2011) finds the shortest distance path is a good approximation for the actual routed distance.

[13] Alternatively, we could use data from 2008 onward, where transportation modes are reported, to determine routes which are served by different transportation modes. However, our initial investigation of that approach suggested the possibility of selection bias due to the types of plants and transportation modes that exited during the early portion of our sample and therefore do not appear in the later period.

data on the track ownership and leases to construct measures of rail participation. Specifically, we count the number of firms that own or lease track within a three mile radius of each power plant in the sample. We construction indicator variables for the number of firms who participate near each plant as a proxy for rail competition.

Table **??** summarizes sample means of the main explanatory variables for shipments to regulated and deregulated plants. We see delivered coal coal prices are approximately 8% lower for shipments to deregulated plants. Diesel prices, rail costs, heat content and the share of purchases from the spot market as similar between regulated and deregulated plants. Shipments to deregulated plants are somewhat shorter and sulfur and ash content are somewhat higher compared to regulated plants.

6 Natural gas and delivered coal prices

We begin by investigating the general approach outlined above leading to Equation 2. Table 2 shows results for several alternate specifications estimated separately for samples of contract and spot shipments. Robust standard errors, clustered at the plant level are reported in parentheses. The first two columns show an initial validation of the basic modeling approach using only coal price, coal quality characteristics, and shipment distance. The relationship between mine mouth coal price and delivered price is positive and statistically significant for both shipment types. An increase in mine mouth coal price of one dollar per ton is associated with a \$0.32 per ton increase in delivered price for contract shipments and an increase of \$0.63 per ton increase for spot deliveries. In terms of coal characteristics, heat content (Btu), a positive characteristic, has a positive relationship with delivered coal price. Sulfur, a negative characteristic, has a negative relationship with delivered coal prices. Evidence is mixed for ash content, also a negative characteristic, with a positive estimate for contract shipments but negative estimate for spot deliveries. Rail distance has a positive relationship with delivered coal price, consistent with higher prices for more costly shipments. An additional mile is associated with an increase of delivered coal price between \$0.015 and \$0.017 per mile (in 2009 dollars), which is roughly comparable to the Busse and Keohane (2007) estimate of \$0.009 per mile in 1995 dollars or about \$0.012 per mile in 2009 dollars.

Columns three and four show estimates of Equation 2 for the contract and spot samples. These and all subsequent specifications account for year of sample mean effects. For spot shipments, the relationship between natural gas prices and delivered coal prices is positive and statistically significant ($p < 0.10$). A one dollar per Mcf increase in natural gas price is associated with a \$0.33 per ton increase in the delivered price of coal. For contract shipments, the point estimate is positive, though, substantially smaller and not statistically significant.

Though our empirical framework uses the product of diesel price and rail distance to approximate transportation costs, one may be worried about other factors, such as congestion, that impact costs at the route level. Columns five and six replace our distance measure with route fixed-effects interacted with diesel price. The estimated relationship between natural gas and delivered coal prices are somewhat larger than the base model. A one dollar increase in natural gas price is associated with a \$0.25 per ton increase in the contract delivered price of coal and a \$0.74 per ton increase for spot shipments. The other parameter estimates are similar with the exception of mine mouth coal price for contract shipments, which is essentially zero in the results using route effects. In light of the similarity of these results, we adopt the more parsimonious distance specification of Equation 2 for the remainder of the paper. Further, route effects would subsume route-level characteristics such as modal competition, which we exploit in several specifications below.

6.1 Regulated versus deregulated markets

Our theoretical framework suggests delivered coal prices should be more responsive to changes in natural gas prices in deregulated compared to regulated markets. Table 3 estimates the price response for contract and spot shipments in regulated and deregulated markets. As discussed previously, we allow the estimated parameters to vary across regulatory regime and contract type by estimating separate regressions. For contract shipments in regulated markets, the estimated relationship between natural gas and delivered coal price is negative but not statistically significant. However, the estimate for contract shipments in deregulated markets is large, positive, and statistically significant. A one dollar per Mcf increase in natural gas price is associated with a $0.78 per ton increase in the delivered coal price. The point estimates are larger in magnitude for spot market shipments. At regulated plants, a one dollar per Mcf increase in natural gas price is associated with an increase in delivered coal price of $0.11 per ton, though not statistically significant. For deregulated plants, the estimated effect is large, $0.93 per ton for a one dollar increase in gas price. Therefore, our estimates suggest a larger effect for deregulated plants compared to regulated plants, consistent with the model in Section 3.

One concern in the results presented above is omitted variables that are correlated with both natural gas prices and delivered coal prices explain the observed correlation in prices. We investigate this possibility using several alternative specifications. First, we look at rail congestion related to coal shipments as a possible explanation. Table 4 presents results controlling for two alternate measures of coal transportation demand. Columns one through four use the total quantity of coal transported on a give route in each reporting month.[14] This specification address the possibility rail congestion occurs along rail lines, switching yards or terminals that define a given route. The second set of results, columns five through eight control for the total amount of coal originated in the mine state during each reporting month. This specification accounts for the possibility rail congestion occurs at coal loading terminals at the originating mines.

The estimated relationships between gas prices and delivered coal prices are quite similar to our base specification when we account for total coal shipments. The estimated effects are positive, statistically significant, and large for spot

[14]Where route is defined by the coal mine and plant states.

and contract shipments to deregulated plants. Interestingly, the coefficients on coal quantities are often negative and statistically significant. In the route-level specifications, an increase of one million tons per month, approximately a one standard deviation increase, is associated with between $1 and $3 per ton lower delivered price.[15] The point estimates for natural gas price are also quite similar in the specifications using state-level coal quantities.

Another possibility is that the observed correlation between natural gas and delivered coal prices reflects electricity demand shocks and increasing marginal cost of fuel supply. We investigate this possibility by accounting for monthly electricity generation at the state level. Table 5 reports two sets of results where total electricity generation enters either linearly, columns one through four, or more flexibly using indicators for the quintiles of generation, columns five through eight. Here again we see the general pattern in our estimates remains unchanged. There is a positive relationship between natural gas and delivered coal prices that is larger for deregulated plants compared with regulated plants.

As a final check, we investigate whether there exists a relationship between natural gas price and that amount of coal purchased at individual plants. Table 6 presents estimates analogous to those from Equation 2 where total coal purchases by reporting month replaces delivered coal price as the dependent variable. We may expect a a positive correlation between gas prices and coal deliveries due to unobserved energy demand shocks and increasing marginal costs of coal deliveries, for instance. However, we find no evidence of a positive statistically significant relationship between natural gas prices and coal deliveries, which casts further doubt on cost-based explanations for the observed relationship between gas and coal prices.

6.2 Gas and peak generation shares

While the results above attempt to rule out alternate explanations for the observed relationship between natural gas and coal prices, Section 3 suggests

[15]This result can be explained by economies of scale in coal transportation.

more direct tests of the predicted behavior. If railroads are responding to changes in rents available to generators, the different processes by which rates are set in regulated and deregulated markets create different mechanisms for price discrimination. In regulated markets, what matters are changes in average generation cost. Therefore, the relationship between gas and delivered coal prices should be greatest during periods and in regions where natural gas generation is a greater share of total generation. In deregulated markets, what matters are changes in gas prices when gas generation is on the margin. Therefore, we expect the estimated price effect to be larger in regions and time periods when natural gas is more likely on the margin. To test these predictions, we calculate the share of generation from natural gas generators and the share of generation from natural gas "peaker" plants by state-month. For the later, we define natural gas "peakers" as natural gas fired internal combustion and simple combustion turbine generation. To allow for non-linearity we construct indicator variables for the quintiles of natural gas generation share and natural gas peak generation share, then interact these dummies with natural gas prices. We calculate the quintiles across all states and months in the sample such the fifth quintile captures state-months with the highest share of gas generation.

Results for contract and spot purchases in regulated and deregulated markets are shown in Table 7. For regulated plants, we see that, consistent with the predictions from Section 3, the relationship between natural gas and delivered coal price is generally largest in states and months when the gas generation share is largest (columns one and three). For contract shipments in the fifth quintile of gas generation share, a one dollar per Mcf increase in gas price is associated with a \$0.52 per ton increase (-\$0.494 + \$1.007) in the delivered price of coal, compared to an estimated *decrease* of \$0.49 per ton for plants in the first quintile. For spot shipments in the fifth quintile, a one dollar per Mcf increase in gas price is associated with a \$0.54 per ton increase (-\$0.088 + \$0.628) in delivered coal price compared with a small, negative and statistically insignificant effect for shipments in the first quintile. Further, the point estimates are larger in magnitude when compared with the results using peak gas generation share (columns five and seven). While the differences between columns are not statistically significant, these results lend qualitative support to the model for regulated utilities in Section 3.

Looking at deregulated plants, the relationship between natural gas and delivered coal price is largest in states and months when the gas peak generation share is largest (columns six and eight). A dollar per Mcf increase in gas price is associated with a $1.17 increase in delivered price of coal for contract purchases at plants in the fifth quintile of peak generation share. For spot purchases, a one dollar per Mcf increase in gas price is associated with a $1.01 per ton increase in delivered price for plants in the fifth quintile of peak generation share. Overall, changes in natural gas prices matter more for coal prices when gas is a more important source of generation, either in total or as peak generation, consistent with the intuition presented in Figure 1.

6.3 Contracts

Given that contracts may respond more slowly to changes in market conditions compared with spot purchases, it is important to understand the potential mechanisms for the effects we observe. There are two main possibilities. First, rail contracts often include cost escalation provisions that increase or decrease prices based on changes in diesel price and other cost indices. These policies could be pure cost recovery mechanisms or could facilitate price discrimination. Second, existing contacts may not respond to changes in natural gas prices but railroads may push for more favorable terms when new contracts are negotiated with higher prevailing natural gas prices. The first mechanism is difficult to test for, but to the extent cost escalation provisions are indexed to fuel prices, our models that account for diesel prices account for these effects. To explore the second mechanism we investigate pricing for new contracts and the frequency of contracting activity.

First, the EIA data include a field indicating if a shipment occurred during the first month of a new contract. We interact this indicator variable with natural gas prices to test for any differential effect of new contracts on the estimated price relationship. These results are shown in Table 8. Columns one and two use the full samples of regulated and deregulated contract shipments. For observations during and after 2008 we also observe the primary transportation mode of each shipment. To focus on railroad behavior, columns five and six use only observations where rail is the primary mode. To illustrate the separate effect of the temporal restriction, columns three and four limit the sample to observations in 2008 and after.

The evidence here is mixed. For regulated plants, new contracts show a strong relationship between natural gas and delivered coal prices. In the full sample of contracts, the effect of a one dollar increase in gas price is approximately \$0.51 per ton and approximately \$0.47 per ton for shipments classified as "rail" during 2008 and after. For deregulated plants, there is no evidence of an incremental effect of new contracts. However, the main effect is large and consistent with our main results. Also note that while the estimated coefficient (0.950) for the later portion of our sample (column 4) is consistent with our results in the full sample, the effect is substantially larger when we limit the sample to shipments classified as "rail." Here, a one dollar increase in gas price is associated with a \$1.43 per ton increase in delivered coal price. This suggests rail markups respond more to changes in gas prices than markups on other modes.

Second, we explore the frequency of contract renewals. Unfortunately, for the majority of our sample we do not observe the contract length.[16] However, we can infer something about the frequency of contract renewals be comparing the reporting month with the contract end date. Since coal shipments occur somewhat regularly, shipments to plants that negotiate contracts more frequently should more often appear close to the contract end date. We construct a variable measuring the average difference, across plants, in months

[16]For a small number of shipments, about 1200 observations, classified as new contracts we can infer the contract length by comparing the contract expiration date with the report month. In this sample, deregulated plants have somewhat longer contracts, 25 months on average, compared with 15 months for the average regulated plants. Arkansas, Louisiana, Maryland, Michigan, New York and Ohio have mean contract lengths less than 10 months. Alabama, Tennessee and West Virginia have mean contract lengths over 30 months.

between the reporting month and the contract end date.[17] We interact indicator variables for the quintiles of this "contract time remaining" variable with natural gas prices. Shipments in the first quintile are near the end of their contract term and, based on the rational above, more likely to be to plants with shorter, more frequent contracts. Results of this specification are reported in Table 9. We see that for deregulated plants, the estimated relationship between natural gas and coal prices is largest for observations in the first quintile, *i.e.* at those plants where we infer contracting is more frequent. [18] The estimated effect is, in general, smaller for shipments at plants where the mean time remaining on contracts is longer, or again by implication, contract activity is less frequent. There is less evidence of similar behavior for regulated plants as the point estimates are smaller in magnitude, noisy and in general not statistically significant.

6.4 Competition

Finally, if railroads with market power are extracting rents from power plants, we expect the relationship between natural gas and delivered coal prices to be attenuated with increased competition. Unfortunately, it is challenging to quantify rail competition. A common approach is to proxy for competition with the number of railroads who participate along routes, origins or destinations (Schmidt, 2001; Hughes, 2011). However, in contrast with previous studies using firm-level data, we do not directly observe railroad participation in terms of shipments or reported prices. Instead, we use GIS data on the US rail network to infer participation from the routes where railroads own or lease tracks. Specifically, we count the number of Class I railroads who own or

[17]In other words, we first group plants and calculate the mean time to end of contract across all shipments to that plant. Then we construct the quintile indicators such that these variables measure the mean differences in time to end of contract across plants. Unfortunately, the generalizability of this approach is limited due to the large number of missing contract expiration dates in the data.

[18]This matches anecdotal evidence from coal companies and consultants that new contracts are often negotiated when there are large changes in the price of transportation.

lease tracks within three miles of each mine and power plant.[19] We create an indicator variable equal to one if a particular route is served by two or more railroads.[20] We construct an analogous variable for whether a particular route could be served by barge using GIS data on navigable inland waterways. We also create an interaction variable equal to one if a particular route is served both by two railroads and has barge access. Table 10 reports results where natural gas prices are interacted with each of these indicator variables.

While the point estimates are noisy, competition appears to reduce the size of the estimated relationship between natural gas and delivered coal prices. The first row of Table 10 presents estimates for the least competitive routes, *i.e.* those served by only one railroad and without barge access. Here, there are large positive and significant relationships between natural gas and coal prices for shipments to deregulated plants. Consistent with the base results, the point estimates for shipments to regulated plants are small and not statistically significant. Turning to the most competitive routes, *i.e.* those served by more than one railroad and with barge access, the is essentially no relationship between natural gas and delivered coal prices, though the estimated effects are not significant. For deregulated plants, the effect of a one dollar increase in gas price is approximately \$0.18 per ton (0.72 - 0.19 + 0.41 - 0.75) for contract shipments and \$0.00 (1.02 + 0.17 - 0.08 - 1.11) for spot shipments. For regulated plants, the estimate for contract shipments is - \$0.25 (0.04 - 0.78 - 0.13 + 0.63) but not statistically significant. For spot shipments the estimate is \$0.18 (0.16 - 0.68 + 0.16 - 0.53) but again, not statistically significant.

At least two caveats are in order when interpreting these results. First, the method outlined above for using GIS data to infer rail and barge competition is prone to measurement error. On one hand, the existence of rail lines or barge access does not guarantee firms are competing on these routes. On the

[19]We experimented with a number of different buffer sizes. Smaller buffers tend to misclassify mines or plants that we observe originating or receiving rail shipments (2008 onward) as having no rail access. Large buffer sizes are likely to include railroads that participate nearby but may not, in reality, service a particular route. That said, using buffer sizes as small as one mile or as large as ten miles produce qualitatively similar estimates.

[20]There is only one route in our sample served by three railroads.

other hand, lack of rail lines or barge access at route end points does not necessarily preclude short distance connections by truck or conveyor that would enable competition. Second, locations served by more firms or modes may be different in unobserved ways that affect delivered coal prices. Therefore, we take these results, particularly those for shipments to deregulated plants, as weak evidence competition reduces railroads' ability to adjust markups to changes in natural gas prices.

7 Pass-though of energy cost changes

The rate at which energy cost are passed through to downstream consumers will vary if firms adjust markups in response to cost changes. For instance, Preonas (2017) shows railroads that ship coal to regulated utilities vary markups in response to changes in natural gas prices that affect the demand for coal. Using his estimates he calculates the pass-through rate of an implicit carbon tax and shows average rates vary from 0.75 to 1 (full pass-through). Here we show price discrimination facilitated by deregulation magnifies this effect, leading to lower pass through rates in deregulated markets compared with regulated markets.

Using our estimates above, we first corroborate the finding in Preonas (2017). Note that we use a different estimation strategy and slightly shorter sample yet find qualitatitely similar results for deregulated plants.[21] This suggests the overall finding of incomplete pass-through is quite robust. Then, we show mean pass-through rates at deregulated plants can be substantially lower. Intuitively, since markups at these plants respond more to changes in natural gas prices, the pass-through rate for a carbon tax that changes relative fuel prices will be smaller.[22]

We calculate pass-through using the relationship derived in Preonas (2017),

[21]Recall, Preonas (2017) uses a nearest-neighbor matching approach and we rely on a simple panel fixed effect model. Further, our data end at 2012 whereas the public data used in Preonas (2017) end in 2016.

[22]Cullen and Mansur (2017) discuss conditions under which changes in relative fuel prices can mimic a carbon tax.

namely the pass-though rate (ρ) of an implicit carbon tax is given by:

$$\rho = 1 + \frac{\Delta\mu}{\Delta Z}\left[\frac{E_g}{E_c} - \frac{Z}{P}\right] \tag{3}$$

where Z and P are mean fuel prices for natural gas and coal, respectively, and $\Delta\mu$ is the change in delivered coal price (markup) from a change in natural gas price ΔZ, both in dollars per MMBtu.[23] We assume $\Delta Z = 1$ and use mean heat content values from the data to convert delivered coal prices and the parameter estimates from Table 3 and Table 7 into price changes per MMBtu.[24] Following Preonas (2017) we assume mean emission rates for gas E_g and coal E_c generation of 0.053 and 0.095 Metric tons CO_2 per MMBtu.

We begin by looking at average pass-through rates for contract and spot shipments to regulated and deregulated plants. Results using the parameter estimates for $\Delta\mu$ from Table 3 are shown in Table 11. On average, an implicit carbon tax is fully passed through for both contract and spot shipments at regulated plants. At deregulated plants the pass-through rate is substantially lower, approximately 0.86 for contract shipments and 0.82 for spot shipments. We note that these average values hide substantial heterogeneity across markets. In particular, the responsiveness of markups to changes in relative fuel prices depends in large part on the importance of gas generation in the local market.

Table 12 shows the mean pass-through rate for the quintiles of gas generation share (regulated plants) and gas peak generation share (deregulated plants) using the parameter estimates from Table 7. For regulated plants, there is approximately full pass through ($\rho = 1$) for shipments in the first quintile of gas generation share. However, the pass-through rate falls at locations and times when gas generation share is larger. In the fifth quintile the mean pass-through rate is approximately 0.93 for both contract and spot shipments. While these rates are somewhat higher than the mean rates for reg-

[23]This expression assumes full pass-through of the carbon tax to natural gas prices.

[24]We use separate average values for each category, *i.e.* regulated contract shipments versus deregulated spot shipments, etc. For natural gas, we convert Mcf to MMBtu by dividing by 1.037.

ulated plants reported in Preonas (2017), our calculations support the overall finding of incomplete pass-through for a substantial share of shipments.[25]

Turning to deregulated plants, the estimated pass-through rates are substantially lower. At the first quintile, we calculate mean pass-through rates of approximately 0.87 and 0.93 for contract and spot shipments, respectively. The pass-through rate falls as the share of peak gas generation grows, *i.e.* the price discrimination effect becomes stronger. At the fifth quintile the mean pass-through rate is approximately 0.80 for both contract and spot shipments. Taken together, these results suggest behavior consistent with earlier findings of incomplete pass-through of carbon prices to delivered coal prices. Importantly, the price discrimination mechanism coming from deregulated appears to magnify this effect, further reducing pass-through rates for shipments to deregulated plants.

8 Conclusion

We use spatial and temporal variation in natural gas prices as a proxy for rents available to coal-fired electricity generations. We find delivered coal prices are positively correlated with natural gas prices. The estimated relationships are larger for spot deliveries compared with contract shipments. Consistent with a simple conceptual model for electricity pricing and producer surplus, we find prices respond more for coal plants in deregulated markets compared with regulated areas. Further, the estimated relationships between gas and coal prices are larger in regions and during time periods when gas is either a greater share of total generation or the fraction of generation from natural gas peaker plants is larger. This suggests railroads vary markups for coal shipments in response to changes in the rents available to generators.

These results hold even when a myriad of controls are included, such as route fixed effects, coal quality, and multiple time specifications. Falsification

[25]One possible explanation of the difference is that Preonas (2017) estimates the cumulative effect on markups of natural gas price changes over several months whereas we estimate only the contemporaneous effect.

tests reveal that the mechanism through which coal prices change is not due to changes in quantity sold; leaving the mechanism of rent capture as the most plausible. Further, there is some evidence the correlation between gas and coal prices shrinks in magnitude or goes away entirely on routes where railroads face more competition, again consistent with our price discrimination hypothesis.

These findings give important insights into the distributional effects of electricity deregulation. While deregulation is widely believed to have improved efficiency, it also appears to have facilitated price discrimination by upstream suppliers, in this case railroads, who captured rents that would otherwise have accrued to generators. Further, these effects also have important implications for policies, such as carbon pricing, that change of costs of electricity generation. Consistent with earlier work in this area, we find incomplete pass-through of an implicit carbon tax due to the fact railroads vary markups in response to changes in fuel prices. We show this effect is substantially larger for shipments to deregulated plants compared with regulated plants. This suggests that while deregulation can yield efficiency gains in fuel procurement and plant operations, it can also mute price signals from policies aimed at correcting environmental externalities, creating additional challenges for policy makers.

References

Association of American Railroads. 2015. "Rail Cost Adjustment Factor Less Fuel." URL https://www.aar.org/rail-cost-indexes/. Accessed February 23, 2015.

———. 2017. "Overview of America's Freight Railroads." URL {https://www.aar.org/BackgroundPapers/Overview\%20of\%20America's\%20Freight\%20RRs.pdf}. Accessed August 19, 2017.

Atkinson, Scott E and Joe Kerkvliet. 1986. "Measuring the multilateral allocation of rents: Wyoming low-sulfur coal." *The Rand Journal of Economics* :416–430.

Borenstein, S., J. Bushnell, and F. Wolak. 2002. "Measuring Market Inefficiencies in California's Restructured Wholesale Electricity Market." *American Economic Review* 92:1376–1405.

Busse, Meghan R. and Nathaniel O. Keohane. 2007. "Market Effects of Environmental Regulation: Coal, Railroads, and the 1990 Clean Air Act." *RAND Journal of Economics* 38 (4):1159–1179.

Chan, H. S., H. Fell, I. Lange, and S. Li. 2017. "Efficiency and Environmental Impacts of Electricity Restructuring on Coal-fired Power Plants." *Journal of Environmental Economics and Management* 81:1–18.

Chu, Y., S. Holladay, and J. LaRiviere. 2017. "Opportunity Cost Pass-through from Fossil Fuel Market Prices to Procurement Costs of the U.S. Power Producers." *Journal of Industrial Economics* 65:842–871.

Cicala, S. 2015. "When Does Regulation Distort Costs? Lessons from Fuel Procurement in U.S. Electricity Generation." *American Economic Review* 105 (1):411–444.

Cullen, Joseph and Erin Mansur. 2017. "Inferring Carbon Abatement Costs in Electricity Markets: A Revealed Preference Approach Using the Shale Revolution." *American Economic Journal:Economic Policy* 9 (3):106–133.

diMaria, C., I. Lange, and E. Lazarova. 2018. "A Look Upstream: Market Restructuring, Risk, Procurement Contracts, and Efficiency." *International Journal of Industrial Organization* 57:35–83.

Fabra, Natalia and Mar Reguant. 2014. "Pass-through of emissions costs in electricity markets." *American Economic Review* 104 (9):2872–99.

Fell, Harrison and Daniel T Kaffine. 2018. "The fall of coal: Joint impacts of fuel prices and renewables on generation and emissions." *American Economic Journal: Economic Policy* 10 (2):90–116.

Ganapati, Sharat, Joseph S Shapiro, and Reed Walker. 2016. "The Incidence of Carbon Taxes in US Manufacturing: Lessons from Energy Cost Pass-Through." Tech. rep., National Bureau of Economic Research.

He, Qingxin and Jonathan M Lee. 2016. "The effect of coal combustion byproducts on price discrimination by upstream industries." *International Journal of Industrial Organization* 44:11–24.

Hughes, J. 2011. "The Higher Price of Cleaner Fuels: Market Power in the Rail Transport of Fuel Ethanol." *Journal of Environmental Economics and Management* 62 (2):123–139.

Joskow, P. 1987. "Contract Duration and Relationship Specific Investments: Empirical Evidence from Coal Markets." *American Economic Review* 77 (1):168–185.

Knittel, C., K. Metaxoglou, and A. Trindale. 2015. "Natural Gas Prices and Coal Displacement: Evidence from Electricity Markets." Tech. rep., National Bureau of Economic Research Working Paper 21627.

Knittel, Christopher R, Ben S Meiselman, and James H Stock. 2017. "The pass-through of RIN prices to wholesale and retail fuels under the renewable fuel standard." *Journal of the Association of Environmental and Resource Economists* 4 (4):1081–1119.

Linn, Joshua and Lucija Muehlenbachs. 2018. "The heterogeneous impacts of low natural gas prices on consumers and the environment." *Journal of Environmental Economics and Management* 89:1–28.

MacDonald, James M. 1987. "Competition and rail rates for the shipment of corn, soybeans, and wheat." *The Rand Journal of Economics* :151–163.

———. 1989. "Railroad deregulation, innovation, and competition: Effects of the Staggers Act on grain transportation." *The Journal of Law and Economics* 32 (1):63–95.

———. 2013. "Railroads and price discrimination: The roles of competition, information, and regulation." *Review of Industrial Organization* 43 (1-2):85–101.

Muehlegger, Erich and Richard L Sweeney. 2017. "Pass-Through of Input Cost Shocks Under Imperfect Competition: Evidence from the US Fracking Boom." NBER Working Papers 24025, National Bureau of Economic Research.

Preonas, Louis. 2017. "Market Power in Coal Shipping and Implications for U.S. Climate Policy." Energy Institute at Hass Working Paper 285.

Schmidt, S. 2001. "Market Structure and Market Outcome in Deregulated Rail Freight Markets." *International Journal of Industrial Organization* 19:99–131.

U.S DOE. 2015. "Quadrennial Energy Review-First Installment." United States Department of Energy.

U.S. Bureau of Economic Analysis. 2018. "GDP implicit price deflators." URL `https://bea.gov/iTable/iTable.cfm?reqid=19&step=3&isuri=1&1921=survey&1903=13#reqid=19&step=3&isuri=1&1921=survey&1903=13`. Accessed March 9, 2015.

U.S. Department of Transportation. 2018. "National Transportation Atlas Database." URL https://www.bts.gov/geospatial/national-transportation-atlas-database. Accessed March 23, 2018.

U.S. EIA. 2004. "Coal Rate Transportation Database." United States Energy Information Administration.

———. 2012. "Coal Rate Transportation Database." United States Energy Information Administration.

U.S. Energy Information Administration. 2014a. "Industrial Natural Gas Price." URL https://www.eia.gov/dnav/ng/NG_PRI_SUM_A_EPG0_PIN_DMCF_A.htm. Accessed February 20, 2015.

———. 2014b. "US No. 2 Diesel Retail Prices." URL https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EMD_EPD2D_PTE_NUS_DPG&f=M. Accessed August 29, 2014.

———. 2018. "Average weekly coal commodity spot prices." URL https://www.eia.gov/coal/markets/. Accessed March 23, 2018.

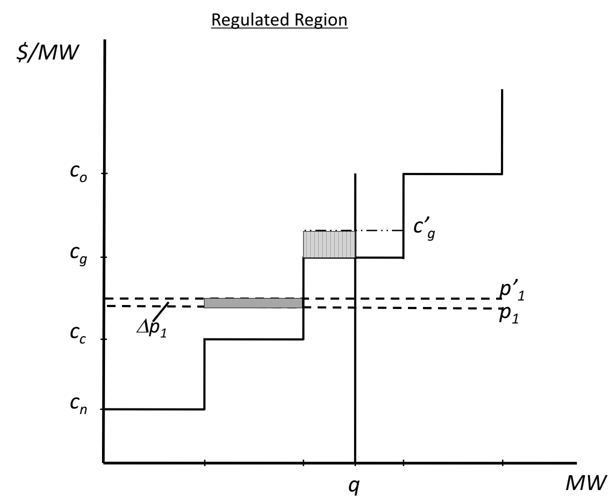
Wolak, F. 2003. "Measuring Unilateral Market Power in the Wholesale Electricity Markets: The California Market, 1998-2000." *American Economic Review* 93 (2):425–430.

Wolfram, C. D. 1999. "Measuring Duopoly Power in the British Electricity Spot Market." *American Economic Review* 89 (4):805–826.

9 Figures

Figure 1: Stylized model for prices in regulated and deregulated markets.

(a) Regulated market



(b) Deregulated market

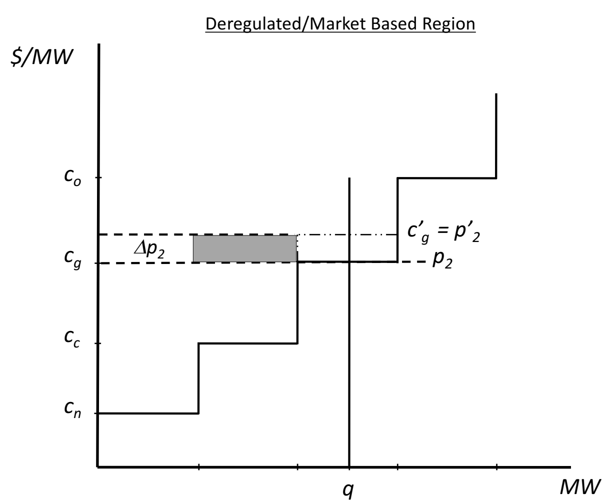
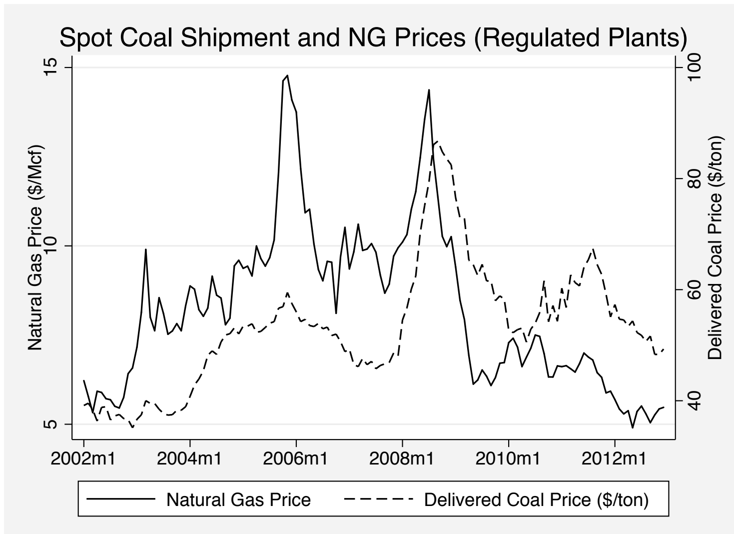


Figure 2: Natural gas and delivered coal prices in regulated and deregulated markets.

(a) Regulated plants



(b) Deregulated plants

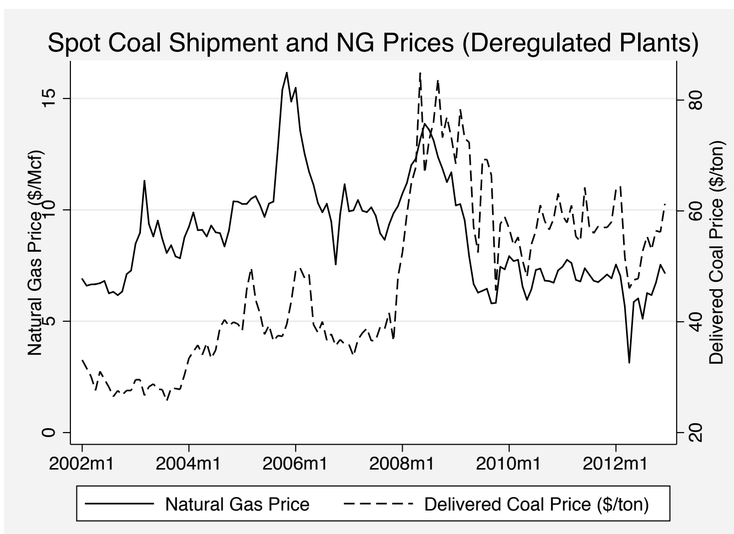
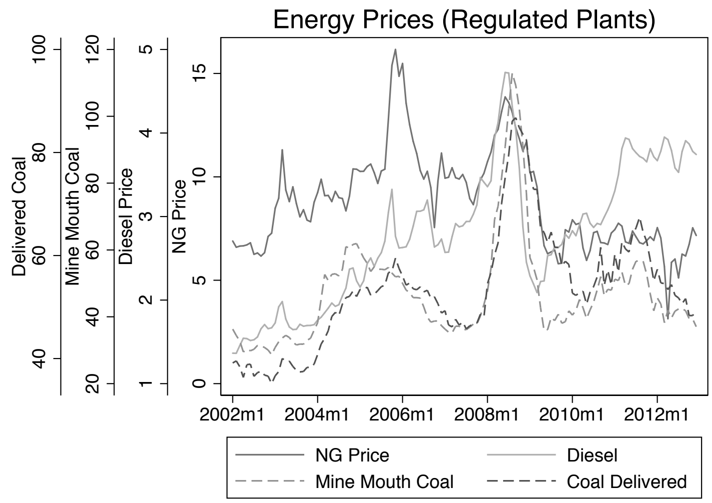
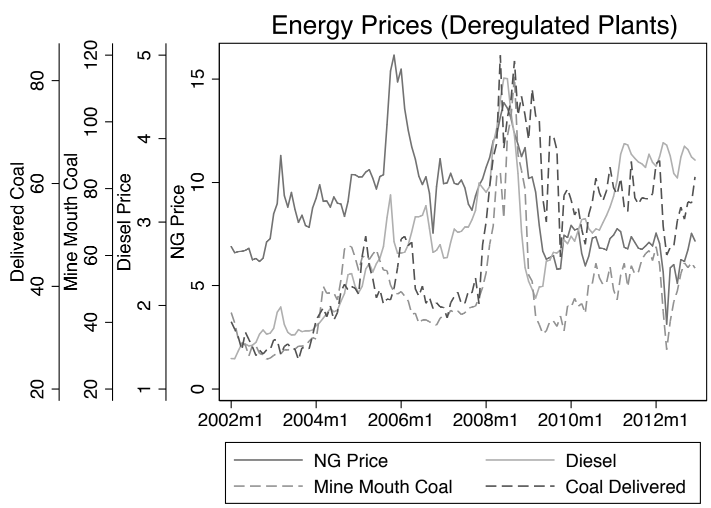


Figure 3: Energy Prices in regulated and deregulated markets.

(a) Regulated plants



(b) Deregulated plants



10 Tables

Table 1: Means of explanatory variables for regulated and deregulated plants.

Mean Values for Regulated and Deregulated Plants	Regulated	Deregulated
Delivered Cost ($/ton)	48.56	44.95
NG Price ($/Mcf)	8.23	9.14
Diesel Price ($/gal.)	2.77	2.73
Rail Cost Index	83.70	82.73
Rail Distance (miles)	578.27	456.83
Coal Price ($/ton)	43.37	46.42
Btu Content (Btu per lb.)	10977	10945
Sulfur Content (tons/ton coal)	0.011	0.016
Ash Content (% wgt.)	9.13	11.72
Spot Market Purchase	0.23	0.19

Table 2: Relationships between delivered coal prices, mine mouth coal prices, coal characteristics and natural gas prices.

Natural Gas Prices and Delivered Coal Prices (All Plants)	Contract	Spot	Contract	Spot	Contract	Spot
NG Price ($/Mcf)			0.061	0.332*	0.252***	0.744***
			(0.1910)	(0.1890)	(0.0510)	(0.1090)
Coal Price ($/ton)	0.320***	0.629***	0.203***	0.550***	0.018	0.410***
	(0.0200)	(0.0270)	(0.0200)	(0.0500)	(0.0140)	(0.0240)
Btu Content (Btu per lb.)	0.009***	0.006***	0.010***	0.007***	0.007***	0.006***
	0.0000	(0.0010)	0.0000	(0.0010)	0.0000	(0.0010)
Sulfur Content (tons/ton coal)	-437.180***	-373.351***	-608.267***	-457.731***	-505.725***	-506.674***
	(50.9100)	(60.0490)	(48.3230)	(62.6220)	(53.8990)	(41.0200)
Ash Content (% wgt.)	0.318***	-0.261**	0.544***	-0.072	0.242***	-0.215
	(0.0820)	(0.1050)	(0.0850)	(0.1510)	(0.0900)	(0.2010)
Rail Distance (miles)	0.015***	0.017***				
	(0.0010)	(0.0020)				
Diesel Price ($/gal.) * Dist. (100 mi.)			-0.033	-0.107		
			(0.0360)	(0.0950)		
Rail Cost * Dist. (100 mi.)			0.015***	0.022***		
			(0.0020)	(0.0040)		
Year Effects	No	No	Yes	Yes	Yes	Yes
Route Effects	No	No	No	No	Yes	Yes
Diesel and Route Interactions	No	No	No	No	Yes	Yes
Rail Cost and Route Interactions	No	No	No	No	Yes	Yes
Observations	129062	35839	129062	35839	154451	44980
Adj. R-sq.	0.566	0.629	0.706	0.701	0.807	0.769

Notes: Dependent variable is the delivered price of coal in dollars per ton. Standard errors clustered at the plant level. Data are FERC form 423/923 (reg. and dereg. plants), EIA State-level industrial natural gas prices, EIA national diesel fuel prices and STB rail cost index. ***, ** and * denote significance at the 1 percent, 5 percent and 10 percent levels.

Table 3: Relationships between delivered coal prices, mine mouth coal prices, coal characteristics and natural gas prices for *regulated* and *deregulated* plants.

Natural Gas Price Effects for Regulated and Deregulated Plants

	Contract		**Spot**	
	Regulated	**Deregulated**	**Regulated**	**Deregulated**
NG Price ($/Mcf)	-0.073	0.782***	0.109	0.929***
	(0.2290)	(0.1930)	(0.2000)	(0.3390)
Coal Price ($/ton)	0.188***	0.233***	0.586***	0.363***
	(0.0200)	(0.0610)	(0.0530)	(0.0510)
Btu Content (Btu per lb.)	0.010***	0.010***	0.007***	0.008***
	(0.0000)	(0.0010)	(0.0010)	(0.0010)
Sulfur Content (tons/ton coal)	-555.937***	-654.037***	-441.946***	-524.168***
	(53.1790)	(80.7230)	(74.7710)	(72.9130)
Ash Content (% wgt.)	0.681***	0.526***	-0.294**	0.145
	(0.1340)	(0.1190)	(0.1480)	(0.1350)
Diesel Price ($/gal.) * Dist. (100 mi.)	-0.051	0.055	-0.121	-0.017
	(0.0410)	(0.0980)	(0.1100)	(0.1170)
Rail Cost * Dist. (100 mi.)	0.014***	0.017***	0.023***	0.015***
	(0.0020)	(0.0050)	(0.0050)	(0.0050)
Year Effects	Yes	Yes	Yes	Yes
Observations	103853	25209	30265	5574
Adj. R-sq.	0.715	0.683	0.687	0.782

Notes: Dependent variable is the delivered price of coal in dollars per ton. Standard errors clustered at the plant level. Data are FERC form 423 data (reg. and dereg. plants), EIA State-level industrial natural gas prices, EIA national diesel fuel prices and STB rail cost index. ***, ** and * denote significance at the 1 percent, 5 percent and 10 percent levels.

Table 4: Relationship between plant-level coal quantities and natural gas prices taking into account proxies for regional coal transportation demand.

	Capacity Constraint and Demand Proxies							
	Monthly Coal Quantities Between Mine and Plant States				Monthly Coal Quantities Transported from Mine State			
	Contract		Spot		Contract		Spot	
	Reg.	**Dereg.**	**Reg.**	**Dereg.**	**Reg.**	**Dereg.**	**Reg.**	**Dereg.**
NG Price ($/Mcf)	-0.096	0.633***	0.021	0.935***	-0.059	0.695***	0.094	0.853**
	(0.2150)	(0.2140)	(0.1920)	(0.3400)	(0.2240)	(0.2110)	(0.1890)	(0.3300)
Coal Price ($/ton)	0.193***	0.218***	0.581***	0.368***	0.189***	0.227***	0.560***	0.345***
	(0.0200)	(0.0590)	(0.0480)	(0.0530)	(0.0210)	(0.0600)	(0.0390)	(0.0520)
Btu Content (Btu per lb.)	0.010***	0.009***	0.006***	0.008***	0.010***	0.009***	0.006***	0.008***
	(0.0000)	(0.0010)	(0.0010)	(0.0010)	(0.0000)	(0.0000)	(0.0010)	(0.0010)
Sulfur Content (tons/ton coal)	-558.288***	-663.034***	-452.862***	-522.559***	-590.447***	-650.267***	-523.903***	-516.621***
	(52.6270)	(71.6120)	(70.4390)	(72.2950)	(53.6780)	(77.8030)	(79.0240)	(76.9900)
Ash Content (% wgt.)	0.615***	0.340***	-0.334**	0.174	0.559***	0.261**	-0.468**	0.073
	(0.1390)	(0.1000)	(0.1580)	(0.1220)	(0.1410)	(0.1010)	(0.1910)	(0.1170)
Diesel Price ($/gal.) * Dist. (100 mi.)	-0.037	0.027	-0.113	-0.002	-0.041	0.098	-0.144	-0.026
	(0.0400)	(0.0930)	(0.1060)	(0.1080)	(0.0400)	(0.0990)	(0.0990)	(0.1230)
Rail Cost * Dist. (100 mi.)	0.013***	0.014***	0.022***	0.016***	0.014***	0.021***	0.027***	0.018***
	(0.0020)	(0.0030)	(0.0050)	(0.0050)	(0.0020)	(0.0040)	(0.0040)	(0.0060)
Coal Quantity (Route)	-1.742***	-2.418***	-1.608***	0.409				
	(0.3460)	(0.3670)	(0.4480)	(0.7150)				
Coal Quantity (Mine State)					-0.143**	-0.474***	-0.349***	-0.177
					(0.0620)	(0.0960)	(0.1240)	(0.1510)
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	103853	25209	30265	5574	103853	25209	30265	5574
Adj. R-sq.	0.719	0.700	0.691	0.782	0.716	0.694	0.693	0.782

Notes: Dependent variable is the delivered price of coal in dollars per ton. Standard errors clustered at the plant level. Data are FERC form 423/923 (Reg. and Dereg.), EIA State-level industrial natural gas prices, EIA national diesel fuel prices and STB railcost index. Coal quantities are monthly total coal deliveries by route and mine state. In millions of tons per month. ***, ** and * denote significance at the 1 percent, 5 percent and 10 percent levels.

Table 5: Relationship between plant-level coal quantities and natural gas prices taking into account state-level electricity generation.

	Capacity Constraint and Demand Proxies							
	Monthly Electricity Generation				Monthly Electricity Generation Quintiles			
	Contract		Spot		Contract		Spot	
	Reg.	**Dereg.**	**Reg.**	**Dereg.**	**Reg.**	**Dereg.**	**Reg.**	**Dereg.**
NG Price ($/Mcf)	-0.071	0.761***	0.101	0.890**	-0.066	0.611***	0.086	0.531
	(0.2330)	(0.2040)	(0.1970)	(0.3370)	(0.2230)	(0.1670)	(0.1750)	(0.3600)
Coal Price ($/ton)	0.188***	0.227***	0.587***	0.373***	0.192***	0.227***	0.590***	0.359***
	(0.0200)	(0.0590)	(0.0530)	(0.0510)	(0.0190)	(0.0580)	(0.0520)	(0.0520)
Btu Content (Btu per lb.)	0.010***	0.010***	0.007***	0.009***	0.010***	0.009***	0.007***	0.008***
	(0.0000)	(0.0010)	(0.0010)	(0.0010)	(0.0000)	(0.0010)	(0.0010)	(0.0010)
Sulfur Content (tons/ton coal)	-556.749***	-607.885***	-435.344***	-513.185***	-559.569***	-501.167***	-440.135***	-399.556***
	(55.1380)	(58.9690)	(75.0390)	(80.1970)	(55.3280)	(54.9600)	(73.9780)	(75.5430)
Ash Content (% wgt.)	0.680***	0.485***	-0.285*	0.205	0.680***	0.442***	-0.281*	0.169
	(0.1340)	(0.1080)	(0.1490)	(0.1250)	(0.1310)	(0.1110)	(0.1510)	(0.1200)
Diesel Price ($/gal.) * Dist. (100 mi.)	-0.051	0.05	-0.12	0.01	-0.047	0.053	-0.118	-0.002
	(0.0410)	(0.0950)	(0.1100)	(0.1110)	(0.0400)	(0.0990)	(0.1080)	(0.1110)
Rail Cost * Dist. (100 mi.)	0.014***	0.017***	0.023***	0.016***	0.014***	0.017***	0.023***	0.016***
	(0.0020)	(0.0040)	(0.0050)	(0.0060)	(0.0020)	(0.0030)	(0.0050)	(0.0050)
Electricity Generation (Plant State)	0.006	-0.368***	-0.054	0.122				
	(0.0800)	(0.0900)	(0.0780)	(0.1070)				
Electricty Gen. = Quintile 2					-3.536***	-8.574***	-1.368	-7.251***
					(0.9450)	(1.4200)	(1.4270)	(2.5400)
Electricty Gen. = Quintile 3					-0.7	-9.073***	-0.481	-7.207***
					(1.1570)	(1.6120)	(1.4650)	(2.3690)
Electricty Gen. = Quintile 4					0.459	-6.356***	0.415	-1.281
					(1.2900)	(1.9740)	(1.5140)	(2.4310)
Electricty Gen. = Quintile 5					-0.442	-9.584***	-1.99	-1.442
					(1.6260)	(1.3700)	(1.7000)	(2.1740)
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	103853	25209	30265	5574	103853	25209	30265	5574
Adj. R-sq.	0.715	0.694	0.688	0.783	0.718	0.702	0.688	0.787

Notes: Dependent variable is the delivered price of coal in dollars per ton. Standard errors clustered at the plant level. Data are FERC form 423/923 (Reg. and Dereg.), EIA State-level industrial natural gas prices, EIA national diesel fuel prices and STB railcost index. Electricity generation is monthly generation by state. ***, ** and * denote significance at the 1 percent, 5 percent and 10 percent levels.

Table 6: Relationship between plant-level coal quantities and natural gas prices.

	Monthly Coal Quantities - Levels				Monthly Coal Quantities - Logs			
	Contract		Spot		Contract		Spot	
	Reg.	**Dereg.**	**Reg.**	**Dereg.**	**Reg.**	**Dereg.**	**Reg.**	**Dereg.**
NG Price ($/Mcf)	-6.1379	-9.2058	-1.3599	0.2322	-0.0183	-0.0007	0.0109	-0.0169
	(4.1983)	(8.6534)	(2.5182)	(2.3464)	(0.0214)	(0.0354)	(0.0278)	(0.0344)
Coal Price ($/ton)	0.0626	-1.8571**	0.4714**	0.0587	-0.0016	-0.0078**	0.0068**	-0.0014
	(0.5103)	(0.8618)	(0.1860)	(0.1847)	(0.0026)	(0.0037)	(0.0034)	(0.0039)
Btu Content (Btu per lb.)	-0.0342***	-0.0612***	-0.0152***	-0.0200***	-0.0002***	-0.0003***	-0.0001**	-0.0002**
	(0.0093)	(0.0201)	(0.0041)	(0.0068)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Sulfur Content (tons/ton coal)	2729.0059*	3162.6049	-297.6676	1047.1821**	11.6647	28.8928*	-9.3223	25.8801**
	(1443.4260)	(2595.4842)	(397.4573)	(523.6057)	(10.0051)	(16.3392)	(7.8622)	(11.8849)
Ash Content (% wgt.)	5.276	-5.7457	-0.0545	-3.3317**	0.0541*	-0.0399*	-0.0058	-0.0201
	(4.8254)	(4.9776)	(1.0412)	(1.3072)	(0.0301)	(0.0232)	(0.0200)	(0.0167)
Diesel Price ($/gal.) * Dist. (100 mi.)	1.2474	-2.7165**	-1.8457	-2.1691	0.002	-0.0145**	-0.0166*	-0.008
	(0.7852)	(1.3297)	(1.3262)	(1.7213)	(0.0037)	(0.0071)	(0.0096)	(0.0160)
Rail Cost * Dist. (100 mi.)	0.0362	(0.0439)	0.1031**	0.1146*	0.0003	0.0004	0.0010***	0.0015*
	(0.0514)	(0.1599)	(0.0516)	(0.0606)	(0.0003)	(0.0006)	(0.0004)	(0.0008)
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	29890	7261	11768	2045	29889	7261	11768	2045
Adj. R-sq.	0.072	0.288	0.108	0.324	0.075	0.266	0.057	0.207

Notes: Dependent variable is plant monthly coal deliveries (1000s) in levels or natural logarithms. Standard errors clustered at the plant level. Data are FERC form 423/923 (reg. and dereg. plants), EIA State-level industrial natural gas prices, EIA national diesel fuel prices and STB rail cost index. ***, ** and * denote significance at the 1 percent, 5 percent and 10 percent levels.

Table 7: Relationship between delivered coal prices and natural gas prices in areas and periods when natural gas "peakers" are more often on the margin.

	All Natural Gas Generation				"Peaker" Generation			
	Contract		Spot		Contract		Spot	
	Reg.	Dereg.	Reg.	Dereg.	Reg.	Dereg.	Reg.	Dereg.
NG Price ($/Mcf)	-0.494**	0.730***	-0.088	0.273	-0.419*	0.737***	0.099	0.379
	(0.2290)	(0.2070)	(0.1880)	(0.3070)	(0.2410)	(0.1620)	(0.2190)	(0.3870)
NG Price X Gas Quintile 2	0.385***	-0.036	0.359***	0.594***	0.319***	0.025	0.002	0.403
	(0.0730)	(0.1370)	(0.1000)	(0.1450)	(0.0880)	(0.1210)	(0.1170)	(0.2550)
NG Price X Gas Quintile 3	0.647***	0.168	0.471***	0.752***	0.358***	-0.016	0.056	0.615***
	(0.1110)	(0.1610)	(0.1330)	(0.2020)	(0.1080)	(0.1490)	(0.1520)	(0.2200)
NG Price X Gas Quintile 4	0.703***	0.376	0.286	0.751***	0.666***	0.329*	0.354*	0.487*
	(0.1790)	(0.2500)	(0.2190)	(0.2160)	(0.1210)	(0.1860)	(0.1830)	(0.2860)
NG Price X Gas Quintile 5	1.007***	0.595**	0.628*	-0.22	0.814***	0.437**	0.441*	0.632**
	(0.2140)	(0.2930)	(0.3300)	(0.4500)	(0.1390)	(0.2050)	(0.2450)	(0.2860)
Coal Price ($/ton)	0.175***	0.214***	0.572***	0.356***	0.171***	0.222***	0.569***	0.361***
	(0.0200)	(0.0640)	(0.0510)	(0.0480)	(0.0220)	(0.0560)	(0.0520)	(0.0480)
Btu Content (Btu per lb.)	0.010***	0.010***	0.007***	0.008***	0.010***	0.010***	0.007***	0.008***
	(0.0000)	(0.0000)	(0.0010)	(0.0010)	(0.0000)	(0.0010)	(0.0010)	(0.0010)
Sulfur Content (tons/ton coal)	-565.764***	-665.400***	-459.751***	-405.174***	-536.301***	-653.579***	-436.786***	-498.997***
	(49.4640)	(84.8770)	(72.8480)	(91.1260)	(51.1950)	(77.2700)	(73.3730)	(80.7260)
Ash Content (% wgt.)	0.771***	0.493***	-0.227	0.209	0.658***	0.524***	-0.271*	0.171
	(0.1240)	(0.1090)	(0.1510)	(0.1410)	(0.1280)	(0.1160)	(0.1520)	(0.1310)
Diesel Price ($/gal.) * Dist. (100 mi.)	-0.069*	0.047	-0.143	-0.073	-0.083**	-0.016	-0.161	-0.022
	(0.0410)	(0.0970)	(0.1070)	(0.1010)	(0.0410)	(0.0860)	(0.1120)	(0.1230)
Rail Cost * Dist. (100 mi.)	0.012***	0.015***	0.021***	0.022***	0.015***	0.017***	0.023***	0.016***
	(0.0020)	(0.0040)	(0.0050)	(0.0050)	(0.0020)	(0.0040)	(0.0050)	(0.0050)
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	103853	25209	30265	5574	103853	25209	30265	5574
Adj. R-sq.	0.723	0.686	0.691	0.792	0.719	0.687	0.69	0.783

Notes: Dependent variable is the delivered price of coal in dollars per ton. Peak generation is defined as NG combustion turbine and inernal combustion engine prime movers. Standard errors clustered at the plant level. Data are FERC form 423 data (regulated plant), EIA State-level industrial natural gas prices, EIA national diesel fuel prices and STB railcost index. ***, ** and * denote levels.significance at the 1 percent, 5 percent and 10 percent levels.

Table 8: Relationship between delivered coal price and natural gas price during the first month of a new contract.

	"New" Contracts and Natural Gas Price Effect					
	All Years		**2008 and After**		**Rail Shipments**	
	Reg.	**Dereg.**	**Reg.**	**Dereg.**	**Reg.**	**Dereg.**
NG Price ($/Mcf)	-0.084	0.783***	-0.042	0.950***	-0.113	1.429***
	(0.2280)	(0.1940)	(0.3220)	(0.3580)	(0.3590)	(0.4420)
NG Price X "New Contract"	0.509***	-0.053	0.221	0.111	0.465**	0.02
	(0.1000)	(0.1500)	(0.2080)	(0.1780)	(0.1870)	(0.3190)
Coal Price ($/ton)	0.188***	0.233***	0.025	0.119	0.025	0.221
	(0.0200)	(0.0610)	(0.0250)	(0.0790)	(0.0330)	(0.1330)
Btu Content (Btu per lb.)	0.010***	0.010***	0.015***	0.014***	0.015***	0.014***
	0.0000	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0020)
Sulfur Content (tons/ton coal)	-555.524***	-654.146***	-695.399***	-755.280***	-638.266***	-816.494***
	(53.1870)	(81.0020)	(74.1390)	(149.7860)	(105.7290)	(199.3140)
Ash Content (% wgt.)	0.681***	0.526***	1.138***	1.098***	1.176***	1.188***
	(0.1340)	(0.1190)	(0.1900)	(0.1870)	(0.2460)	(0.3530)
Diesel Price ($/gal.) * Dist. (100 mi.)	-0.048	0.055	0.145***	0.337***	0.142**	0.162
	(0.0400)	(0.0980)	(0.0500)	(0.1160)	(0.0620)	(0.1100)
Rail Cost * Dist. (100 mi.)	0.014***	0.017***	0.008***	0.010**	0.006*	0.018***
	(0.0020)	(0.0050)	(0.0030)	(0.0050)	(0.0040)	(0.0060)
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	103853	25209	51059	11532	39284	6737
Adj. R-sq.	0.72	0.68	0.70	0.65	0.75	0.69

Notes: Dependent variable is the delivered price of coal in dollars per ton. Standard errors clustered at the plant level. Data are FERC form 423 data (reg. and dereg. plants), EIA State-level industrial natural gas prices, EIA national diesel fuel prices and STB rail cost index. "New contract" is an indicator variable equal to one if contract delivery began during the reporting month. ***, ** and * denote significance at the 1 percent, 5 percent and 10 percent levels.

Table 9: Relationship between delivered coal prices and natural gas prices for plants with more frequent contract renewals.

	Frequent Contracts and Natural Gas Price Effect					
	All Years		2008 and After		Rail Shipments	
	Reg.	**Dereg.**	**Reg.**	**Dereg.**	**Reg.**	**Dereg.**
NG Price ($/Mcf)	0.088	1.003***	0.080	1.352***	-0.076	1.828***
	(0.2450)	(0.1930)	(0.3500)	(0.4160)	(0.4090)	(0.5380)
NG Price X Mean Time Remaining (Q2)	0.031	-0.452**	0.178	-0.749*	0.265	-0.804**
	(0.1720)	(0.2010)	(0.2370)	(0.4440)	(0.2590)	(0.3850)
NG Price X Mean Time Remaining (Q3)	-0.252	-0.759***	-0.243	-1.052***	-0.156	-0.984***
	(0.1590)	(0.1720)	(0.2280)	(0.3130)	(0.2330)	(0.2960)
NG Price X Mean Time Remaining (Q4)	0.063	-0.372**	0.252	-0.604*	0.261	-1.287***
	(0.2100)	(0.1740)	(0.2870)	(0.3030)	(0.3070)	(0.4330)
NG Price X Mean Time Remaining (Q4)	-0.595***	-0.563***	-0.581**	-0.844***	-0.517**	-2.025***
	(0.1760)	(0.1670)	(0.2340)	(0.3050)	(0.2300)	(0.5160)
Coal Price ($/ton)	0.183***	0.220***	0.016	0.1	0.012	0.220*
	(0.0200)	(0.0590)	(0.0230)	(0.0720)	(0.0300)	(0.1220)
Btu Content (Btu per lb.)	0.010***	0.010***	0.015***	0.014***	0.015***	0.012***
	0.0000	(0.0010)	(0.0010)	(0.0010)	(0.0010)	(0.0020)
Sulfur Content (tons/ton coal)	-537.838***	-570.727***	-667.552***	-633.922***	-640.141***	-388.621*
	(55.1870)	(68.7880)	(73.2620)	(110.9300)	(112.2730)	(210.9980)
Ash Content (% wgt.)	0.669***	0.371***	1.125***	0.930***	1.180***	1.108***
	(0.1250)	(0.1280)	(0.1760)	(0.2090)	(0.2480)	(0.3720)
Diesel Price ($/gal.) * Dist. (100 mi.)	-0.049	0.056	0.140***	0.325***	0.139**	0.129
	(0.0390)	(0.0950)	(0.0490)	(0.1120)	(0.0620)	(0.1000)
Rail Cost * Dist. (100 mi.)	0.014***	0.015***	0.008***	0.009*	0.006*	0.014**
	(0.0020)	(0.0040)	(0.0030)	(0.0050)	(0.0030)	(0.0070)
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	103666	25037	50999	11532	39224	6737
Adj. R-sq.	0.72	0.70	0.71	0.67	0.76	0.72

Notes: Dependent variable is the delivered price of coal in dollars per ton. Standard errors clustered at the plant level. Data are FERC form 423 data (reg. and dereg. plants), EIA State-level industrial natural gas prices, EIA national diesel fuel prices and STB rail cost index. Mean time remaining are indicator variables for the quintiles of the time remaining between the reporting month and contract end date by plant. ***, ** and * denote significance at the 1 percent, 5 percent and 10 percent levels.

Table 10: Relationship between delivered coal, natural gas prices and implied competition.

Effect of Barge and Rail Competition

	Contract		**Spot**	
	Reg.	**Dereg.**	**Reg.**	**Dereg.**
NG Price	0.039	0.719***	0.158	1.016***
	(0.2450)	(0.1990)	(0.1950)	(0.3760)
NG Price * Barge Access	-0.779***	-0.193	-0.675*	0.172
	(0.2510)	(0.8390)	(0.3850)	(0.7330)
NG Price * Two RRs	-0.134	0.410*	0.159	-0.078
	(0.2710)	(0.2080)	(0.3500)	(0.6900)
NG Price * Two RRs and Barge	0.6250	-0.754	0.5340	-1.111
	(0.6150)	(0.9090)	(0.5350)	(1.1730)
Barge Access	0.5580	3.5490	1.8330	-4.601
	(2.6640)	(9.2950)	(3.7130)	(6.1160)
Two Railroads	-2.241	-7.621***	-2.906	-0.624
	(2.2120)	(2.2840)	(2.4430)	(5.1840)
Two RRs and Barge	-3.844	3.9790	0.2260	14.4280
	(4.6190)	(9.5370)	(4.8420)	(9.5990)
Coal Price ($/ton)	0.192***	0.234***	0.588***	0.373***
	(0.0210)	(0.0590)	(0.0520)	(0.0480)
Btu Content (Btu per lb.)	0.010***	0.010***	0.007***	0.008***
	0.0000	(0.0010)	(0.0010)	(0.0010)
Sulfur Content (tons/ton coal)	-574.354***	-661.801***	-433.146***	-508.758***
	(48.9160)	(71.6690)	(76.2710)	(89.7000)
Ash Content (% wgt.)	0.652***	0.486***	-0.289*	0.166
	(0.1260)	(0.1050)	(0.1500)	(0.1450)
Diesel Price ($/gal.) * Dist. (100 mi.)	-0.063	0.046	-0.13	-0.02
	(0.0410)	(0.1020)	(0.1100)	(0.1170)
Rail Cost * Dist. (100 mi.)	0.014***	0.016***	0.023***	0.016***
	(0.0020)	(0.0040)	(0.0050)	(0.0050)
Year Effects	Yes	Yes	Yes	Yes
Observations	103853	25209	30264	5574
Adj. R-sq.	0.72	0.69	0.69	0.78

Notes: Dependent variable is the delivered price of coal in dollars per ton. Standard errors clustered at the plant level. Data are FERC form 423 data (reg. and dereg. plants), EIA State-level industrial natural gas prices, EIA national diesel fuel prices and STB rail cost index. ***, ** and * denote significance at the 1 percent, 5 percent and 10 percent levels.

Table 11: Average pass-through rates for regulated and deregulated plants, contract and spot deliveries.

Average Pass Through Rates			
Contract		Spot	
Regulated	Deregulated	Regulated	Deregulated
1.011	0.864	0.985	0.818

Table 12: Average pass-through rates for regulated and deregulated plants, contract and spot deliveries by quintiles of gas generation share.

Average Pass Through Rates by Quintiles of Gas Generation				
	Contract		Spot	
	Regulated	Deregulated	Regulated	Deregulated
q = 1	1.072	0.872	1.012	0.926
q = 2	1.016	0.868	0.962	0.847
q = 3	0.978	0.875	0.946	0.805
q = 4	0.970	0.815	0.972	0.830
q = 5	0.926	0.796	0.925	0.802