Digging Deep to Compete: Vertical Integration, Product Market Competition and Prices

Danny McGowan*†

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Abstract

This article establishes a causal effect of product market competition on vertical integration. I exploit a hitherto unexplored natural experiment in the US coal mining industry and a unique mine-level organizational data set. Following an exogenous increase in product market competition the incidence of vertical integration fell by 33% within the treatment group relative to the counterfactual. I find novel evidence that transition to the lower degree of vertical integration is driven by competition reducing market prices by 32% which decreased the incentive to conduct vertical mergers. I discuss several possible interpretations of these changes.

Keywords: vertical integration, product market competition, market prices.
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†University of Nottingham. Email: danny.mcgowan@nottingham.ac.uk. Tel: +44 (0)155 846 7420.

1 Introduction

Understanding the boundaries of the firm typically focuses on internal factors such as incentives or bargaining frictions between suppliers (e.g. Williamson (1975); Grossman and Hart (1986)). Although transactions costs and asset ownership may help determine the relationship between constituents in a supply chain, the impetus for vertical integration can also come from elements of the external operating environment. One such factor identified by several authors is competition (McLaren, 2000; Thesmar and Thoenig, 2000; Aghion et al., 2006; Vroom, 2006; Acemoglu et al., 2010; Conconi et al., 2012; Legros and Newman, 2013). This focus is natural considering that over the past few decades a number of economic forces have strengthened competition in product markets. Declining transport costs, falling tariffs and myriad episodes of trade liberalization have increased international competition. Competition in domestic markets has intensified due to deregulation. At the same time, firms have tended to become less vertically integrated as outsourcing and offshoring have become more prevalent. However, despite the extensive theoretical literature there is little empirical evidence to support the claim that competition affects vertical integration.

In this article, I investigate whether changes in product market competition affect vertical integration using a natural experiment in the US coal mining industry. In this industry mines rely on preparation plants for cleaning services that are essential before coal can be shipped to power stations. To the best of my knowledge, this is the first article to use a credible identification strategy to show that exposure to competition leads to changes in vertical integration and to establish a clear causal mechanism driving changes in firm boundaries. I also find novel evidence that competition matters for organizational design through its effect on market prices.

The heart of my identification strategy is the Staggers Rail Act of 1980 (SRA) which deregulated the railroad sector. Before 1980 railroads were forced to follow a regulated pricing schedule established by the Interstate Commerce Commission (ICC) during the 1920s. This complex arrangement set freight rates above market clearing levels and denied railroads the right to independently set rates. As a result, pre 1980 the cost of transporting coal was high and power stations purchased from local mines to minimize procurement costs. Eastern mines (Appalachia and Illinois basins) therefore competed with one another to supply Eastern power stations whereas Western mines (Powder River Basin (PRB) and Unita basins) served Western power stations.

Deregulation granted railroads freedom to independently set freight rates. As the market rate was below the regulated rate this caused a large fall in transport costs. Low-cost PRB coal therefore became competitive in the Eastern market leading to more intense competition as Eastern mines began competing with PRB mines to supply Eastern power stations. However, there was no change in competition in the Western market because the less developed Western rail network and the proximity of the Unita basin to power stations in the region meant that PRB coal did not become more competitive there. Moreover, due to geological idiosyncrasies the marginal cost of production is much higher for Eastern and Unita mines compared to PRB producers. Despite the fall in transport costs it therefore remained uneconomic to ship Eastern coal to Western power stations. Likewise shipments of Unita coal to Eastern power stations remained uneconomic. These features ensure that neither Eastern nor Unita producers experienced improvements in market access.

In essence, I study vertical integration at an upstream point of the production chain where mines rely on preparation plants for cleaning inputs. Pre-1980 the Eastern coal market was competitive in the sense that mines lacked market power (Joskow, 1987). The major change post-1980 was not that market power was removed, but that more efficient suppliers entered the Eastern market and were likely to increasingly enter in future. This set-up is somewhat different from existing theories of vertical integration where elimination of market power plays an important role.

My identification strategy exploits the natural experiment using difference-in-difference estimations applied to unique mine-level organizational data. To establish causality I leverage two sources of exogenous variation. First, time series variation in product market competition comes through railroad deregulation. Deregulation was triggered by an unexpected switch of the regulatory body's attitude towards regulation and was exogenous with respect to coal mines' organizational design. Second, the geographical distance between the Eastern and Unita basins means there are two separate, yet similar, coal markets. I use this cross-sectional variation to construct treatment (Eastern) and control (Unita) groups. The estimations then compare the cross-time evolution of vertical integration within treated mines with that in observationally similar control mines. Identifying the causal effect of product market competition also requires that the control group constitutes a valid counterfactual. To this end, I demonstrate that the treatment and control groups display parallel trends.

I obtain the following key findings. Product market competition causes a 33% decrease in the probability that a treated mine is vertically integrated relative to the counterfactual. The estimate is highly statistically significant and robust to a host of considerations. Clearly, one would expect the reduction in vertical integration to be largest among mines that lie in closest proximity to the PRB for whom competition is most fierce. The data support this view. Moreover, the transition to a relatively lower degree of vertical integration derives from a reduction in the frequency of vertical mergers within the treatment group.

Next, I examine the underlying transmission mechanism. Falling market prices in the face of competition appear to be key. Using difference-in-difference estimations applied to detailed information on monthly shipments from coal mines to electricity power stations I find that, relative to the control group, the free-on-board (FOB) price per million British thermal units (mBtu) fell by 32% in the Eastern market following the competitive shock.[1] Moreover, power stations reduce the quantity of coal purchased from Eastern mines by around 43%. These effects are consistent with an inward shift of the Eastern market demand curve as power stations substitute Eastern for PRB coal. Overall, the estimates suggest that competition triggers changes in organizational choices because it reduces market prices and the incentive to vertically integrate.

This article's main purpose is not to discriminate between competing theoretical explanations, but to establish a robust causal relationship and transmission mechanism between product market competition and vertical integration. Nevertheless, I discuss possible interpretations of these findings. The idea that shocks to market prices provoke widespread organizational restructuring throughout an industry is central to nascent Organizational Industrial Organization (OIO) theories (Conconi et al., 2012; Legros and Newman, 2013; Serfes, 2015; Alfaro et al., 2016). In these models vertical integration enhances output but imposes higher non-contractible private effort costs on managers. At high prices, the additional output translates into high revenue which offsets the high effort costs. But at low prices the increase in revenue does not sufficiently compensate firms for the additional costs they must bear. Hence, it could be that in more competitive environments firms prefer non-integration because the market price is too low for integration to be profitable.

Perhaps the most closely related article to this one is that by Alfaro et al. (2016). Using a large cross-country, cross-industry firm-level data set they find evidence that vertical integration is positively related to market prices. My setting complements their research and offers important advantages. Focusing on a narrowly defined industry allows direct observation of whether a firm is vertically integrated. In contrast, Alfaro et al. (2016) rely on firm-level vertical integration indexes which are computed based on the industry codes of the plants that belong to a firm and aggregate input-output relationships. Vertical integration indexes potentially contain measurement error where shipments between plants are low, leading to attenuation bias in the average treatment effect. A second advantage of my set-up is that shipments do take place between mines and the preparation plants they own whereas in other industries integration is a device used to transfer intangible inputs rather than facilitate shipments between plants (Atalay et al., 2014).

Relatedly, the results are also consistent with a broad class of models in which vertical

[1] Measuring prices in mBtu terms ensures that I compare the same good (a standardized quantity of heat content) across all shipments. The data also contain detailed quality information for each shipment. The panel structure also allows me to include month-year fixed effects to eliminate all time-varying confounds.

integration requires fixed costs (McLaren, 2000; Grossman and Helpman, 2002; Antras and Helpman, 2004). Elements of both explanations are operative in the coal mining industry. As I show below, vertical integration allows mines to increase output by scheduling more production shifts. But integration also raises operating costs and incurs fixed costs. Transition to the lower incidence of vertical integration might therefore reflect competition reducing market prices such that the revenue gained from the additional output is insufficient to offset the integration costs. This argument is consistent with the reduction in merger activity I observe among treated firms following the strengthening of competition. However, the results also support any model in which vertical integration depends on the level of quasi-rents and lower output prices erode those rents (Williamson, 1975; Klein et al., 1978; Baker et al., 2002).[2]

Restructuring could also be driven by other economic forces. In the transaction-cost paradigm, competition leads to fragmentation because an increase in the number of input suppliers reduces ex post bargaining inefficiencies due to holdup threats (Williamson, 1975; Klein et al., 1978). Alternatively, in more competitive environments firms may restructure by decentralizing decision making authority to managers with greater knowledge of local operating conditions (Marin and Verdier, 2003; Alonso et al., 2008; Guadalupe and Wulf, 2010). Other reasons for fragmentation could be to reduce slack and increase productivity by closing down the least productive parts of the production chain (Melitz, 2003), or collinear energy shocks, macroeconomic factors and environmental legislation that differentially affect the treatment and control groups. I explore these alternative mechanisms but find little support for them in the data. A host of additional robustness tests affirm the key results and exogeneity of treatment.

My study bridges two literatures: organizational economics and market structure analysis in industrial organization. Bresnahan and Levin (2012) and Legros and Newman (2014) recognize that uniting these distinct but complementary disciplines is a fruitful area for research, and highlight the importance of empirical tests.

A small number of empirical studies have found associations between measures of competition and vertical integration but emphasize non-price reasons for why these phenomena are linked. For example, Balakrishnan and Wernerfelt (1986) highlight competition's role in enhancing market thickness which reduces bargaining frictions leading to less vertical integration. Using a large data set of UK manufacturing firms Aghion et al. (2006) find a non-monotonic relationship between competition and vertical integration and pinpoint the role of transactions costs and property rights. Such effects are muted in the coal mining industry where mines cannot relocate and investment incentives do not change through

[2] Property rights models in the Grossman and Hart (1986) tradition could also explain the observed evidence under certain configurations of the parameters driving marginal costs.

time.

Finally, my article relates to the pioneering work of Joskow (1987, 1990). Whereas he studies how physical asset specificity affects contract duration between mines and power stations, I focus on vertical integration at a different point of the production chain. Joskow (1987) presents evidence that power stations sign longer contracts with Western mines, in part because they must make relationship-specific boiler investments depending on which basin they source coal from. I find evidence consistent with Eastern power stations making investments to allow them to burn PRB coal following the SRA and that this behavior was motivated by the price advantages of PRB coal.

The rest of the article is structured as follows. Section 2 outlines the institutional details and the economic laboratory. Section 3 describes the data. In Section 4 I discuss the empirical strategy and report econometric results. Section 5 deals with robustness tests. Section 6 concludes.

2 Institutional Setting

This section provides an overview of the coal production chain, the contractual problems vertical integration alleviates and background information on the legislative reforms that underpin the identification strategy.

2.1 The US Coal Mining Industry and Production Chain

Figure 1 shows the areas where coal mines are located. In the east the Appalachia basin stretches continuously from Pennsylvania in the north to Alabama in the south. The other Eastern coal basin is the Illinois basin. In the West mines are located in two basins: the Unita basin (Arizona, Colorado, New Mexico, Utah) and the Powder River Basin (situated on the Montana-Wyoming border).[3]

[Insert Figure 1]

Coal production takes place either in underground or surface mines.[4] The material mines excavate is called run-of-mine (ROM) coal. This contains approximately 60% coal ore with the remainder made up of contaminants such as rock, clay and mining equipment that breaks off during excavation. The high non-ore content means that ROM coal must undergo a series of cleaning procedures at a preparation plant before it can be shipped

[3] I exclude lignite mines from the analysis on the grounds that lignite's characteristics and production methods are not the same as for coal.

[4] The choice of mining process is a function of the stripping ratio: the number of tons of non-coal material (overburden) that must be removed in order to mine one ton of coal. Where stripping ratios are high surface mining is uneconomical and underground methods are preferred.

to an electricity power station. Preparation plants are capital intensive facilities that use various machinery to separate the coal ore from the contaminants and then break it into uniform particle sizes that are suitable for burning.[5] The processed coal ore is then loaded onto unit trains, barges or trucks for delivery to a power station. Trains deliver 74% of shipments, and are more common for long-distance shipments, whereas barges (6%) and trucks (17%) are somewhat less important.

This part of the production chain is therefore very simple, comprising a single upstream (mines) and downstream (preparation plants) industry.[6] Importantly, coal cleaning markets are local in nature due to high transport costs. Owing to its high non-ore content, ROM coal is bulky which makes it prohibitively expensive to ship long distances to a preparation plant. Mines use trucks to haul ROM coal to preparation plants not further than 10 miles away although the preference is for shorter journeys (Buessing, 2014). The coal cleaning industry is therefore made up of a collection of heterogeneous local markets.

2.2 The Costs and Benefits of Vertical Integration

Discussions with industry experts and evidence reported in industry journals indicates that preparation plants source ROM coal from several local mines to diversify the risk of disruptions to input supplies.[7] Non-integrated mines therefore compete with one another for cleaning time at local preparation plants. As a result, mines face uncertainty surrounding when their ROM coal will be cleaned which makes it harder to agree delivery schedules with power stations. This uncertainty leads mines to schedule a sub-optimal number of production shifts to avoid incurring costs related to hiring and laying off workers. Contracting cannot solve these issues because preparation plants would remain exposed to supply assurance concerns.[8]

Vertical integration helps alleviate these problems because it transfers decision making authority to mines thereby providing them with secure access to preparation plant services. Certainty surrounding cleaning time allows integrated mines to schedule more production shifts resulting in higher output. However, there are clear costs involved as well. In addition to the fixed cost of either buying or building a preparation plant, integration requires greater managerial attention to schedule deliveries to preparation plants and supervise the additional production shifts.

[Insert Table 1]

[5]ROM coal is first washed to separate the ore from contaminants. Afterwards it is dried to remove excess moisture and then broken. All coal must undergo cleaning before it can be sold (Buessing, 2014).

[6]There are very few observations of mines or preparation plants owned by power stations.

[7]Accidents are common within mines and frequently lead to extended periods of production downtime as the affected area is made safe. During this time deliveries to preparation plants are suspended.

[8]Preparation costs account for approximately 5% of the delivered price per ton of coal (Bhagwat, 2009).

Supportive descriptive evidence is reported in Table 1 which reports the within-mine responses of productivity and managerial input variables to changes in vertical integration. Column 1 shows that a mine which transitions from non-integration to vertically integrated increases the number of production shifts by approximately 0.5 per day. Given the average non-integrated mine has 0.5 daily production shifts, this is a large effect. Column 2 provides evidence that vertical integration is associated with significant improvements in mines' labor productivity: mines which integrate require 44% fewer employees to produce one thousand tons of coal. Finally, columns 3 and 4 show that transition to vertical integration leads to a substantial increase in managerial inputs, as proxied by office workers and annual office hours worked, respectively. These are strong managerial proxies as office workers are typically engaged in administering the mine's internal affairs and scheduling deliveries to preparation plants. The number of office workers and office hours worked increase by approximately 189% and 176%, respectively. Integration decisions therefore largely depend on whether the additional output (and revenue) brought by vertical integration offsets the higher costs.

Despite the advantages of vertical integration only around 9% of mines are integrated. This suggests the costs of vertical integration are high. Industry journals report that the fixed costs of building or purchasing a preparation plant range between $12m and $18m. Moreover, it is costly to employ managers. Fiscor (2010) reports that historical managerial base salaries typically started at $100,000 per annum with additional bonus payments.

2.3 Railroad Deregulation

Central to my identification strategy is an exogenous change in competition within the coal mining industry triggered by railroad deregulation. Historically, US railroads were subject to stringent regulations imposed by the ICC. To prevent operators from exercising market power the ICC established a rate schedule during the 1920s that set high freight rates and low rates for agricultural and passenger traffic.[9] This complex set of regulations prohibited railroads from independently setting rates. Moreover, because the regulated freight rate was set above the market-clearing rate, pre-1980 the cost of shipping coal was high and rail traffic primarily consisted of agricultural goods (Slack, 2013).

The ICC's decision making body comprised a chairman and 10 commission members. To instigate reforms the governing committee had to reach a majority decision. Chairmen and members were directly appointed by the US President, although the President could

[9]The 1906 Hepburn Act, the 1910 Mann-Elkins Act and the 1920 Transportation Act authorized the ICC to regulate rates, removing this authority from the states. In addition, the ICC's mandate allowed it to oversee mergers and to regulate entry, abandonment of routes and investment decisions (Eakin et al., 2010; FRA, 2011).

not remove them at will (Derthick and Quirk, 1985). Hence, new appointments could only be made when a position became available.

Both the Ford and Carter administrations favored deregulation and chose to appoint pro-deregulation ICC members when possible. Despite these efforts contemporary observers expected the ICC to maintain a tight regulatory focus as pro-regulation members commanded a handsome majority. Unexpectedly, in April 1980 three ICC positions became simultaneously available and President Carter appointed pro-deregulation members. This altered the balance of power within the ICC and gave the pro-deregulation wing a majority for the first time.

[Insert Figure 2]

The ICC quickly adopted a set of measures that were subsequently codified by Congress in the Staggers Rail Act of 1980. The SRA allows railroads to independently set rates. This led to a substantial decline in freight rates as the market rate railroads charged was substantially below the regulated rate (MacDonald, 1989). Figure 2 clearly illustrates the effect of the SRA on railroad freight rates (prices). On average, between 1980 and 1987 rates fell by 40% in real terms. Deregulation also triggered a substantial increase in railroad productivity as unproductive firms exited and their market share was reallocated to more productive survivors. Remaining incumbents capitalized on economies of scale (Slack, 2013). Eakin et al. (2010) report that 80% of the post 1980 productivity gains were passed on to shippers through lower freight rates.

2.4 Treatment Exogeneity

To gain insights into the motives behind deregulation I screen a number of historical and more recent accounts. The evidence indicates that the preferences of Presidents Ford and Carter were the key driving force. Presidential backing for deregulation derived from arguments articulated by economists showing that market-based solutions yielded superior outcomes to regulation (McBride, 1983; Slack, 2013). Derthick and Quirk (1985) highlight that both Presidents' views were partly shaped by contestability theory and a view among economists that regulations were contributing to unjustifiable costs. For example, regulated railroads were prevented from abandoning low-density and unprofitable routes and were mandated to employ excess labor such as firemen. Deregulation was considered to be a means of eliminating such inefficiencies and creating better incentives to innovate and maintain the rail network (Winston, 2005).

MacDonald (1989) highlights that appointments of pro-deregulation members to the ICC governing body were central to instigating deregulation. Deregulation was nevertheless unexpected. Political scholars such as Derthick and Quirk (1985) highlight that, "No one seems to have anticipated that criticisms of regulatory policy would actually result in substantial reform," and that the agency was not expected to reduce its own powers. Even ICC insiders did not envisage reform.[10] The reason for such skepticism was that pro-regulation members commanded a handsome majority of the ICC governing committee and this was not expected to change. However, when three positions unexpectedly became available in April 1980 President Carter exercised his authority to appoint pro-deregulation members and provide the deregulation wing with a majority for the first time (Derthick and Quirk, 1985).

These sources indicate that the impetus behind railroad deregulation were Presidential views on the benefits of deregulation on the railroad industry and an unanticipated shift in the composition of the ICC governing committee. Neither vertical integration within coal mines nor developments in the coal mining industry more generally played a role in motivating deregulation or its timing. Observers at the time also did not foresee deregulation having much effect on freight rates or the coal mining industry (Winston, 2005; Caves et al., 2010).

3 Data

I use three data sets in the empirical analysis: mine-level data on ownership structure, information on shipments from mines to electricity power stations, and coal transport cost data.

3.1 Organizational Data

The Mine Safety and Health Administration (MSHA) release annual mine-level data on employment, production, hours worked, geographical location (latitude, longitude), owner name, delegation status (independently operated, operating subsidiary, or contractor) and union status. Each mine has a unique identifier that permits tracking through time and data are available from 1972 to 1987. In total this provides an unbalanced panel containing 4,147 mines and 21,525 observations.

The MSHA release similar information for preparation plants and the data also contain an identifier variable. I classify a mine as vertically integrated if there is an on-site preparation plant (the mine and preparation plant identifiers match) or if the mine owns a preparation plant within an 10 mile radius. The reason for this demarcation is that ROM coal is hauled to preparation plants using trucks. Trucking rates, load size regulations, and local public opinion make it costly to travel long distances (Buessing, 2014). Together

[10] Derthick and Quirk (1985) quote an ICC staff member as saying, "In the ICC, the rate of change was more than anybody dreamed possible."

these factors place a geographic limit on the area from which preparation plants source coal to not much more than a 10 mile radius, although Buessing (2014) notes that the preference is over a shorter distance. Consistent with previous evidence 85% of mines in the sample lie within 10 miles of the nearest preparation plant. The median distance is 5.7 miles.[11]

[Insert Table 2]

Panel A of Table 2 tabulates the mine-level variables used in the econometric analysis. On average, approximately 9% of mines are vertically integrated and 12% undergo vertical reorganizations during the sample period. In total 418 mines vertically integrate (merger) whereas 121 become non-integrated (divest). Approximately 28% of mines are unionized while 33% belong to multi-plant firms (firms owning more than one mine). The average level of labor productivity in the sample is 2.49 tons per worker hour and the average mine produces around 0.24 million tons of coal per annum. 47% of mines are delegated, that is, operated either by a subsidiary or contractor rather than directly by the corporate headquarters.

I also merge in a number of variables which capture elements of the external operating environment. For example, to capture demand conditions I use the the generation capacity of coal-fired power stations and the real (2009 US$) average price per mBtu of coal, oil and gas in the mine's state. These variables are taken from the Energy Information Authority (EIA). Mine entry and exit rates within each mine's market (defined as a 10 mile radius) are included to capture other competitive forces. I proxy bargaining frictions using the mine-to-preparation plant ratio (weighted by capacity) within the mine's market. Higher values correlate with more severe frictions as preparation plants have greater outside options. There are 6.58 mines per preparation plant within the average mine's market.

Finally, the data contain variables such as the year the mine first opened and seam height in the mine to proxy extraction costs. State-level measures of proximity to the PRB (estimated using a gravity model and discussed later), distance to the PRB and ash content of coal (%) are included. I also retrieve the GDP growth rate in the mine's county (BEA), the volume of bank lending in the county (Chicago Fed) and dummy variables capturing whether the state a mine is located in has deregulated intra- and inter-state bank branching (FDIC). There are no obvious trends in the control variables. For further details on the variables and their construction see Online Appendix A.

Two important advantages of the coal mining laboratory are noteworthy. First, I can directly observe vertical integration based on a preparation plant's owner. This eliminates

[11]The findings are robust to excluding mines located further than 10 miles from the nearest preparation plant.

attenuation bias arising through measurement error which is possible when firm-level vertical integration indexes are constructed based on the goods a firm produces in each of its plants and aggregate input-output relationships among those goods. A second advantage is that vertically integrated mines ship ROM coal to the preparation plants they own. In this setting integration is not simply a device used to facilitate transfers of intangible knowledge capital (Atalay et al., 2014).[12]

3.2 Coal Shipments Data

Data on coal shipments from mines to power stations are taken from EIA Form 423. This source collects fuel receipts and fuel quality for each shipment to a fossil-fuel power station with a generating capacity of 50 megawatts (MW) or more. The data are highly representative given these power stations account for 95% of coal-fired electricity capacity and 96% of coal consumption. For each shipment I observe the power station that bought the coal, the quantity of fuel delivered (both tons and mBtu), the ash and sulfur content (measured in %) of the coal, the real FOB mine price per mBtu (in 2009 US$ values), coal mine state of origin, and the type of mine that supplied the coal (surface or underground). This information is available at a monthly frequency across the years 1972 to 1987. Panel B of Table 2 shows the average price per mBtu is 3.65 (ln); the sulfur and ash content in the mean shipment is 0.52% and 2.52%, respectively; 30% of shipments are from underground mines.

I also calculate the total quantity of coal each power station purchases from each state by aggregating the shipments data to the power station-state level. That is, for each power station I calculate the total amount of coal purchased from mines in state s in each month-year. The average power station buys 27.87 (ln) mBtu and 10.94 (ln) million tons of coal.

3.3 Transport Costs Data

Transport cost data is available through the EIA Coal Transportation Rate Database (CTRD). Using this information I calculate the real delivered price per mBtu (FOB mine price + transport costs) from each basin to the Eastern and Western markets. The CTRD

[12] Reports in the annual *US Preparation Plant Census*, an industry journal published by *Coal Age*, show extensive shipments from mines to their locally owned preparation plants. Further evidence of trade flows can be found in Fiscor (2013, 2014) who reports that accidents that cause downtime at preparation plants disrupt production at owners' mines and vice versa. Although these reports are for recent periods, discussions with industry experts indicate the evidence applies to earlier years as well. Moreover, unreported regressions show that accidents within a mine reduce employment, a key factor of production in preparation plants, in the owners' local preparation plants reinforcing the evidence that mines rely upon their preparation plants for cleaning services.

reports shipments from mines to power stations with a minimum generating capacity of 50 MW. For each shipment information is provided on the coal mine that supplied the coal, the purchasing power station, the FOB mine price per mBtu, tons and mBtu shipped, the year of the shipment, the state where the coal mine is located, the destination state, transport mode (rail, barge, truck), transport costs, contract duration and contract type.[13] These data are available for the period 1979 to 1987.

4 Empirical Results

4.1 Identification Strategy

Key to the identification strategy is the effect of falling transport costs triggered by railroad deregulation on the delivered price (mine price + transport costs) of coal. Before 1980 transport costs were high as railroad operators followed the 1920s rate schedule. It was therefore expensive to ship coal over long distances and power stations relied on local mines to minimize procurement costs. Consequently, Eastern (Western) mines competed to supply Eastern (Western) power stations meaning there were two distinct coal markets with no trade between them. The evidence in Panel A of Table 3 shows why this was the case. An Eastern power station could source 1 mBtu from an Eastern mine for $6.74 but there are no shipments from other basins to Eastern power stations indicating the delivered price was yet higher.[14] There are no observations of shipments between Eastern (Unita) mines and Western (Eastern) power stations indicating that it was not economic to ship coal between the separate markets.[15]

[Insert Table 3] [Insert Figure 3]

Deregulation allowed railroad firms to independently set rates. As the market rate was lower than the regulated rate this led to lower transport costs (Darmstadter, 1997). The only effect of this change was to make PRB coal competitive in the Eastern market. Panel A in Table 3 shows that post 1980 the delivered price per mBtu to an Eastern power station fell to $1.90 and $1.94 from a PRB and Eastern mine, respectively. Eastern mines

[13] Contract type reports whether the contract is a fixed price, escalating price or other.

[14] When I calculate a hypothetical pre-1980 delivered price of PRB coal to Eastern power stations using data on PRB shipments to Western power stations and distance between the PRB and the average Eastern power station the value is $11.91 per mBtu. For Unita mines the value is even higher.

[15] Differences in mine-level prices across basins partly reflect differences in extraction costs due to geological idiosyncrasies. For example, PRB coal seams are uniquely thick and lie close to the surface resulting in low extraction costs and low prices. In contrast, Eastern seams are often thin and lie underground. While coal seams are thicker in the Unita basin they are not comparable to the PRB and the majority are underground. Hence, while Unita basin prices are low they still far exceed PRB prices.

therefore experienced an increase in competition from PRB suppliers.[16] PRB coal became competitive in the Eastern market because unlike other basins PRB coal is exceptionally low cost to excavate due to the area's geological idiosyncrasies which allow the use of more efficient extraction methods.[17] FOB mine prices are sufficiently low such that declining transport costs made PRB coal a viable substitute to Eastern coal.

Despite the fall in transport costs there were no changes in the pattern of shipments to other basins. The marginal cost of producing Eastern and Unita coal is higher relative to PRB coal. Hence, the fall in transport costs did not make it economic to ship coal from Eastern (Unita) mines to Western (Eastern) power stations: the delivered price remained above power stations' reservation price. Moreover, there was no change in the quantity of PRB coal shipped to Western power stations because, 1) the less developed Western rail network inhibited deliveries, and 2) Unita mines lie in close proximity to Western power stations. Both factors meant that Unita mines could deliver 1 mBtu to Western power stations more cheaply than PRB producers both pre and post 1980. The data in Panel A of Table 3 confirms this. Further evidence that Unita mines did not experience a change in competition post-1980 is provided in Panel B of Table 3. Using t-tests I compare the volume of shipments from the PRB to Western power stations between the pre- and post-1980 periods. There is no significant change in the quantity of coal shipped between periods irrespective of whether I measure quantity in tons or Btu shipped. PRB shipments to the Western market were therefore stable through time and Unita mines did not experience any changes in competition following deregulation.[18]

Hence, the only effect of railroad deregulation on the coal mining industry was an increase in product market competition for Eastern mines following the entry of PRB producers. Unita basin mines experienced no such competitive shock nor did they or Eastern mines experience improvements in market access. Figure 3 provides a succinct depiction of the identification strategy.

Isolating the organizational effects of product market competition relies on the following difference-in-difference model

$$vi_{it} = \alpha_i + \beta Post_t + \gamma East_i * Post_t + \delta X_{it} + \varphi_t + \varepsilon_{it}, \quad (1)$$

[16]Power stations' boilers have to be customized to a certain degree depending on the characteristics of the coal used. Table H.1 in the Appendix shows that Eastern power stations made investments to retrofit their plants to take PRB coal.

[17]The PRB has uniquely thick seams that lie close to the surface. Mines can use huge surface-mining equipment such as draglines and bucket excavators which are more technically efficient in extracting coal compared to underground and even surface operations in the Unita and Eastern basins. Marginal costs and prices are therefore considerably lower in the PRB relative to other basins.

[18]In unreported regressions there are no significant differences between Unita basin mines' market share in year $t \in 1973, 1987$ and the base year (1972), reinforcing the view that the control group did not experience a change in competition across time.

where vi_{it} is a binary dependent variable equal to 1 if a mine is vertically integrated, 0 otherwise; $Post_t$ is a dummy variable equal to 1 for the years 1980 onward, 0 otherwise; $East_i$ is a dummy variable equal to 1 if a mine is located in either the Appalachia or Illinois basin, 0 for Unita mines; X_{it} is a vector of controls; α_i are mine fixed effects; φ_t are year fixed effects although I also experiment with underground-year effects; ε_{it} is the error term.[19] PRB mines are excluded from most of the analysis because they receive a positive demand shock which could potentially bias the implied counterfactual.[20]

Establishing causality rests on the SRA being exogenous with respect to firm boundaries. Meeting this criteria requires that $Post_t$ is uncorrelated with difficult-to-observe omitted determinants of coal mines' vertical structure contained in the error term of equation (1). From the discussion in Section 3 it is clear that the SRA was introduced for reasons unrelated to coal mines' integration status or matters in the industry more generally. Moreover, the SRA was not introduced due to coal mines' organizational form. Rather deregulation was an unanticipated shock triggered by Presidents' desire to eliminate railroad inefficiencies and create better incentives to maintain the rail network (Eakin et al., 2010; Caves et al., 2010). Both facts rule out the possibility that estimates of γ are contaminated by endogeneity bias. Consistent with the absence of simultaneity bias, the parallel trends and falsification tests reported below clearly demonstrate that anticipation effects are not present.

While the SRA was an unanticipated shock there are a number of other shocks which may have affected coal mines during the 1980s. For example, there was a major recession which differed in its severity across regions, oil prices changed dramatically in response to the oil crises and there were changes to environmental legislation and natural gas generating capacity, a substitute fuel. I include controls for such confounds in X_{it} in equation (1).

Following Bertrand et al. (2004) the standard errors are block bootstrapped at the mine level to account for possible autocorrelation in ownership structure. However, the results are no different when I cluster the standard errors at the mine, basin, or double cluster at the mine and basin-year levels.[21]

[19] See Online Appendix Table B.1 for a summary of the treatment and control groups' observable characteristics.

[20] For example, given that PRB mines experience a positive demand shock post 1980 one would expect them to become more vertically integrated. Including them in the control group therefore risks prejudicing the implied counterfactual as there will be some mines (the PRB ones) which will also react to the treatment post 1980. In turn this will bias the average treatment effect estimates.

[21] See Online Appendix Table C.1 for further details. Bertrand et al. (2004) highlight that block bootstrapping and clustering at the mine level are appropriate in dealing with autocorrelation in the dependent variable in a difference-in-difference framework.

4.2 Results

The validity of difference-in-difference estimation also requires that the control group represent a valid counterfactual. That is, in the absence of treatment organizational design within the treatment group would have evolved in a similar fashion to that in the control group. In other words, the treatment and control groups should have parallel trends. To test this identifying assumption I estimate the equation

$$vi_{it} = \alpha_i + Year_t + \gamma_t East_i * Year_t + \varepsilon_{it}, \quad (2)$$

where α_i are mine fixed effects; $Year_t$ are year dummy variables; ε_{it} is the error term. The coefficients γ_t indicate whether there were significant differences in the incidence of vertical integration between the treatment and control groups in year t.

Figure 4 shows that the pre-treatment trends in vertical integration within the treatment and control groups are indistinguishable, indicating that the control group represent a valid counterfactual. However, there is a clear divergence in ownership structure post-1980. From 1983 onward Eastern mines become significantly less vertically integrated. Considering how abrupt this change is, one may question why did organizational form not respond immediately to the SRA. The reason is that it took time for railroad firms to instigate changes to their own operations and for the increase in competition to manifest (Winston, 2005). The data in Figure 2 shows that freight prices began to fall from 1983. Once these changes took effect, PRB producers began shipping coal to the Eastern market and product market competition intensified.

[Insert Figure 4] [Insert Table 4]

It is also critical that both the treatment and control groups had similar opportunities for vertical integration as otherwise any relationship may be mechanical.[22] Column 1 in Table 4 shows that this was not the case. The incidence of vertical integration in the two groups is very similar before 1980. However, the divergence in ownership structure between the treatment and control groups post 1980 is again evident. The patterns in columns 2 and 3 of Table 4 also convey first evidence that the reduction in vertical integration is driven by competition preventing treated mines from integrating.

Although the diagnostic tests constitute first informal evidence that increasing product market competition leads to a reduction in vertical integration, they do not pin down a precise estimate of the average treatment effect. I therefore turn to regression analysis. In Table 5 I report the estimation results of the effect of competition on vertical integration

[22]For example, if all mines in the treatment group were already integrated before 1980 they would have no integration possibilities and any relationship would be driven by developments within the control group.

using equation (1). The results in column 1 of Table 5 condition only on mine and year fixed effects. The Post coefficient is positive and statistically significant, indicating that vertical integration increased within the control group through time. This reflects the increase in demand for Western coal as coal-fired electricity capacity generation capacity expanded in the region, shown in Figure 5. Following Legros and Newman (2013) one would expect the higher demand to lead to higher market prices and an increase in the incidence of vertical integration. This pattern is clearly illustrated in Figure 6.[23]

The economic magnitude of the East-Post coefficient is equal to -0.11 in column 1 of Table 5. The average treatment effect is highly statistically significant and translates into a 33% decrease in the probability of vertical integration among treated mines relative to the counterfactual. Hence, more intense product market competition causes a reduction in vertical integration. Considering the similarities in demand patterns shown in Figure 5 it seems plausible that absent the SRA Eastern mines would have tended to become more vertically integrated as demand from Eastern power stations increased through time. However, the increase in competition acted to lower the incidence of vertical integration in the East compared to this counterfactual.

[Insert Figure 5]   [Insert Table 5]

Next, I introduce mine-level covariates into the regression model. The estimates in column 2 of Table 5 continue to show a negative and statistically significant reduction in vertical integration among treated mines following the competitive shock. The change in competition is therefore essentially random at the mine level such that the entry of PRB producers into the Eastern market does not systematically coincide with adjustments to mine characteristics. Economically, some of the mine-level controls have quite important effects. Unionized mines are approximately 11% less likely to be vertically integrated. The point estimate on the multi-plant firm variable indicates that mines belonging to firms with more than one mine are 8% more likely to be vertically integrated. Labor productivity is positively associated with vertical integration but only at the 10% significance level.

To assess the importance of other market forces, the results in column 3 include controls for demand-side forces. A one standard deviation increase in the price of coal is associated with a 4.8% increase in the probability that a mine is vertically integrated. Vertical integration is also more likely in environments where demand is high. Specifically, generation capacity is positively and significantly associated with integration. I include the oil

[23] A related possibility is that Western mines responded to competition from PRB producers by making investments to improve efficiency. Better organization of the production chain is one means through which they may achieve efficiency gains. In unreported regressions I investigate whether the volume of PRB shipments to a state explain vertical integration and labor productivity within Western mines. I find no significant associations in any of the specifications, reinforcing the view that Western mines were unaffected by the SRA.

and gas price in mine i's state as control variables to ensure that the average treatment effect of product market competition is not simply capturing developments in the wider energy sector rather than a change in competition within the Eastern coal market. For example, changes in substitute fuel prices may lead power stations to switch from using coal to another fuel source or vice versa. Although both the oil and gas price coefficients are positive and statistically significant, the key finding remains robust to including these variables in the model.

The estimates in column 3 of Table 5 also condition on mine entry and exit rates to capture other sources of competition. Vertical integration is positively related to entry and negatively related to exit and both coefficients are statistically significant. The direction of the effects are consistent with entering mines amplifying bargaining frictions by increasing preparation plants' outside options whereas exit has the reverse effect. Online Appendix Table C.2 shows that the results are also robust to adding additional controls for preparation plant entry and exit rates in the mine's market.

To capture differential trends and developments that asymmetrically affect underground relative to surface mines through time, I append equation (1) with underground-year fixed effects. These eliminate any time-varying forces that differentially affect underground and surface mines' organization structure, such as the introduction of new technologies. The results in Table 5 column 4 are robust to this change.

Could the average treatment effects be picking up anticipation effects? Another way to test the exogeneity assumption is to generate placebo shocks. I therefore create a dummy variable $Post75$ (equals 1 for the years 1975 to 1979, 0 otherwise) and interact it with the East dummy variable. As competition did not change until after the SRA was implemented, the null of zero effect on the East-$Post75$ interaction is true. This is the case in column 5 where the placebo interaction coefficient is close to zero and statistically insignificant. This reinforces the view that the shock to product market competition was exogenous: Eastern mines did not begin to change their organizational design in anticipation of the treatment.

A concern might be that mines in the East are older, have higher costs or lower recovery rates. Such factors might generate a trend towards less vertical integration through time if maintaining a steady supply of ROM coal to preparation plants is an important motive for integration. To control for these effects I interact the Post dummy with a vector of mine characteristics. In addition to the union, multi plant and labor productivity variables I also use the mine's opening year and seam height, both of which are time invariant. The intuition behind these variables is that mines that have been in use for a long time or have thin seams of coal have higher operating costs or lower recovery rates. Despite including these additional controls the results in column 6 of Table 5 show that competition remains an important and statistically significant determinant of vertical integration.

Column 7 of Table 5 provides estimates based on a sample that also includes PRB mines. The effect of competition on vertical integration remains unchanged from before.

[Insert Table 6]

Central to the empirical strategy is the claim that the SRA triggered an increase in product market competition within the coal mining industry. Here I present further evidence that competition lies at the heart of the results.

Column 1 in Table 6 presents estimates of equation (1) using mines' output as the dependent variable. The results show that following the increase in competition production decreased significantly within treated mines relative to control mines. On average, output contracted by 0.25 million tons in the average Eastern mine post-1980. This is equivalent to a decrease of 48% of a standard deviation. In column 2 I find a significant relative reduction in the number of hours worked within treated mines following the competitive shock. This equates to a decrease of 13% of a standard deviation. As expected, in the more competitive environment treated mines reduced production and employment as power stations began purchasing coal from PRB mines. Both findings are consistent with a large increase in competition and help explain the magnitude of the organizational average treatment effect.

Intuitively, one would expect heterogeneous treatment effects as mines that are closest to the PRB would be be most severely affected by the increase in competition because PRB producers can more easily access these markets. Accordingly, I use the following model to study whether this was the case

$$vi_{it} = \alpha_i + \beta_1 Post_t + \beta_2 Post_t * Invdistance_i + \delta X_{it} + \gamma_t + \varepsilon_{it} \tag{3}$$

where all variables are defined as before except $Invdistance_i$ which is the inverse of the distance between mine i and Gillette, Wyoming (the rail terminal for PRB coal), measured in thousands of miles. One would expect mines that lie closer to the PRB experience a larger change in the probability of vertical integration post 1980 because competition increases more in markets where the cost of transporting coal is lower for PRB producers.[24]

Consistent with a priori expectations, column 3 of Table shows that mines located closer to the PRB experienced a larger reduction in the probability of vertical integration post 1980 compared to more distant mines.

[24]Using the inverse of distance eases interpretation of β_2. For instance, the inverse distance value is equal to 1 for a mine that lies 1,000 miles from the PRB terminal. For that mine post 1985 the effect of the SRA on the probability of vertical integration is simply β_2. But for a more distant mine, located say 2,000 miles from the PRB, the effect is 0.5 * β_2.

While distance to the PRB largely captures supply-side forces, such as transport costs, which determine the level of competition, it ignores the role of demand fundamentals in determining shipments of PRB coal. I therefore construct a state-level proximity index which is based on a gravity model outlined in detail in the Appendix. In this case proximity to the PRB is a function of both distance and market size, measured as the coal-fired generating capacity of power stations in mine i's state. Next, I estimate equation (1) with the modification that I use the proximity index rather than the $Post_t$ dummy variable to measure competition. The identifying assumption is that proximity varies exogenously through time. This seems reasonable because proximity to the PRB is a function of the exogenous shock caused by the SRA and because power stations' capacities are unlikely to be a function of local mines' organizational structure. The coefficient on the East-Proximity interaction term is negative and significant in column 4 of Table 6. Hence, the largest reduction in vertical integration is among Eastern mines that are most exposed to competition with PRB producers.[25]

4.3 Prices

A possible explanation for why competition affects vertical integration is because competition leads to lower market prices (Baker et al., 2002; Legros and Newman, 2013). I therefore test whether exposure to competition triggered reductions in the market price of Eastern coal. These tests also help affirm whether the intensity of competition increased post 1980. If so I should be able to document a decrease in Eastern relative to Western market prices.

Before reporting formal empirical tests, I provide descriptive evidence on the suggestive patterns within the raw data. Figure 6 illustrates the evolution of market prices within the treatment and control group across the sample period.[26] Both series trend upward between 1972 and 1980. After 1980 the market price in the control group continues to increase. However, this pattern is not mirrored within the treatment group. Soon after the SRA was signed into law the Eastern market price peaks at \$1.57 per mBtu and then begins to fall steadily from 1983 onwards reaching a low of \$1.19 per mBtu in 1987, suggesting that the entry of PRB producers into the Eastern market coincided with a substantial fall in Eastern prices.

To formally test the effect of product market competition on prices I use the shipments-

[25] As a further validation exercise, I show that developments within the railroad sector are the key driving force behind the increase in competition. See Online Appendix E for further details.

[26] Differences in the level of coal prices pre 1980 mainly stem from differences in the capacity of power stations across the regions.

level data from EIA Form 423 and estimate the following equation

$$price_{ipst} = \alpha + \gamma East_s * Post_t + \delta X_{ipst} + \varphi_p + \varphi_s + \varphi_t + \varepsilon_{ipst}, \qquad (4)$$

where $price_{ipst}$ is the price, measured in cents per mBtu, of shipment i to power station p from mines in state s in month-year t (for example, March 1985). $East_s$ is a dummy variable equal to 1 if a shipment comes from an Eastern basin mine, 0 if from the Unita basin. X_{ipst} is a vector of shipment level covariates and φ_p and φ_s are power station and origin state fixed effects, respectively. As information is provided on shipments by month-year, I also include a set of month-year fixed effects, φ_t. These capture any time-varying shocks that affect coal prices more generally, such as oil price shocks and energy legislation. They also have the attractive property that the average treatment effect is estimated based on variation in the reaction of the treatment and control groups to the competitive shock within the same month-year of the data set.

[Insert Figure 6] [Insert Table 7]

The results of these tests are provided in Table 7. In column 1 I find that, relative to the control group, Eastern market prices decrease significantly following the increase in product market competition. The magnitude of the average treatment effect is economically large at -32%. The evidence in column 2 of Table 7 shows that the size of the treatment effect is unaffected by controlling for characteristics of the coal in each shipment. Coal with a higher sulfur content tends to have a lower price, reflecting power stations' preference for low-sulfur coal to meet their environmental obligations under the Clean Air Act. Shipments from underground mines tend to have a higher price due to higher marginal costs within underground mines. Ash content is insignificant at conventional levels.

If the observed price reductions are indeed driven by the entry of PRB suppliers into the Eastern market, there should be a corresponding decrease in the quantity of coal power stations buy from Eastern mines post-1980. To compute this test I estimate the equation

$$q_{pst} = \alpha_p + \gamma East_s * Post_t + \delta X_{pst} + \varphi_s + \varphi_t + \varepsilon_{pst}, \qquad (5)$$

where all variables are defined as before. Quantity, q_{pst}, is measured either in mBtu or tons. The vector of control variables, X_{pst} contains the mean ash and sulfur content of shipments from state s to power station p during month-year t and the share of shipments from underground mines. α_p, φ_s and φ_t are power station, mine state and month-year effects, respectively.

The findings in columns 3 to 6 of Table 7 show a significant reduction in the quantity of coal purchased from Eastern mines post 1980. The East-Post interaction coefficient estimate in column 3 indicates a 44% decrease in mBtu shipments relative to the counterfactual. This result is robust to the inclusion of control variables in column 4. Although I prefer to measure quantity in mBtu as this provides a homogenous quantity, the results are very similar when quantity is measured in tons purchased in columns 5 and 6. Together this evidence shows that following the increase in competition from PRB mines, power stations reduced the quantity of Eastern coal they purchased leading to a decline in Eastern prices. The evidence is consistent with power stations substituting Eastern coal for PRB coal and an inwards shift of the Eastern market demand curve post 1980.

Could the reduction in prices be driven by changes in mines' vertical integration status? If competition causes firms to adopt more productive organizational structures prices may fall because of reorganization rather than increased competition. To isolate this effect I append the price regression with a variable that measures the share of mines that are vertically integrated in each state-year and an interaction between this and the East dummy variable. If the hypothesis is correct, including these control variables should render competition insignificant. However, the results in column 7 of Table 7 show that this is not the case. The effect of competition remains negative and highly statistically significant whereas both the vertical integration share and interaction term enter insignificantly.

Ultimately, what we are interested in is whether the reductions in price we observe are directly related to mines' vertical integration status. I therefore use an instrumental variables strategy where the second stage equation is

$$vi_{it} = \alpha_i + \beta Price_{it} + \delta X_{it} + \gamma_t + \varepsilon_{it}, \tag{6}$$

where $Price_{it}$ is the price of coal in mine i's state during year t (in natural logarithms); and all other variables are as in equation (1). I instrument $Price_{it}$ using the SRA dummy. The results of this test are reported in column 8 of Table 7. The coal price coefficient is equal to 0.1580 and is statistically significant at the 1% level. The evidence therefore supports the previous findings and lines up with Alfaro et al. (2016) who find that prices are positively related to vertical integration. The diagnostic tests also provide strong support for the relevance of the instrument. The Kleibergen Paap F-statistic comfortably exceeds the informal critical value of 10 and the unreported first stage coefficient (t-statistic) on the SRA variable is 0.8314 (142.62). Hence, the reduction in prices caused by the competitive shock triggered changes in mines' organizational structure.

4.4 Sources of Vertical Reorganizations

Beyond the immediate organizational effects that arise from the competitive shock, it is critical to document the source of these vertical reorganizations. I therefore conduct a series of complementary tests to hone in on how the competitive shock triggered changes in vertical integration. Column 1 in Table 8 shows a significant decrease in the probability that mines in the treatment group merge with a preparation plant following the increase in competition, relative to the counterfactual. In columns 2 and 3 of Table 8 I find no significant relationship between competition and the probability that an Eastern mine divests (switches to non-integration) or builds an on-site preparation plant, respectively. Hence, the reduction in the incidence of vertical integration among Eastern mines stems from a decrease in mergers with preparation plants.

[Insert Table 8]

Overall, the evidence from Section 4 demonstrates that in an environment where competition is strengthening non-integration becomes the preferred organization structure. The mechanism behind this transition is different from previous studies. Competition matters for organizational design because it reduces market prices which diminishes the incentive to conduct vertical mergers. The evidence suggests that at low prices the output gains brought by vertical integration do not sufficiently offset the higher costs firms must bear under integration.

5 Robustness Testing

Perhaps the most serious identification concern is that the increase in product market competition coincides with shocks to other factors that are not accounted for in equation (1) and differentially affect the treatment and control groups. I would then misattribute the average treatment effects to product market competition when in fact other forces are responsible for the changes in equilibrium ownership structure.

A potential alternative explanation could be reductions in bargaining frictions. For example, if transactions costs between mines and preparation plants fall relatively more in the Eastern market than in the Unita basin post 1980, hold-up is less likely and mines do not need to vertically integrate to solve bargaining frictions (McLaren, 2000; Hubbard, 2001). Because of the local nature of coal cleaning markets the data contain a natural proxy for transactions costs: the capacity-weighted number of mines to preparation plants within 10 miles of each mine (MP ratio). The intuition is that at higher values bargaining frictions are more pronounced as preparation plants have more outside options. I therefore control for transactions costs by including the MP ratio variable in equation (1). Despite this change the East-Post interaction term remains statistically significant in the results reported in column 1 of Table 9.[27]

[Insert Table 9]

Property rights models in the Grossman and Hart (1986) tradition argue that firm boundaries are chosen to align asset ownership with investment incentives. There is little evidence that upstream or downstream producers' investment incentives changed through time. However, the Clean Air Act of 1970 stipulated a reduction in particle emissions. One aspect of coal cleaning is reducing ash content. Hence, the decrease in vertical integration could be driven by the increasing importance of preparation plants' investments. To rule out this possibility I interact the $Post_t$ dummy variable with the ash content of coal in the mine's state and include this as a control in equation (1). The findings in column 2 of Table 9 are robust to this change.

Previous research has found that when confronted by greater competition firms delegate authority to improve efficiency arising from the informational advantages of lower level managers with greater local market knowledge (McAfee and McMillan, 1995; Bloom et al., 2010). Non-integration could be consistent with this tendency. I therefore control for a mine's delegation status in the estimating equation. This takes the value 1 if a mine is operated by a subsidiary or contractor, 0 if by a corporate headquarters. Column 3 of Table 9 shows the effect of competition is robust to this change.

Heterogeneous firm models predict that more intense competition causes low productivity firms to exit (Melitz, 2003). A lower degree of vertical integration may therefore reflect firms closing down inefficient parts of the value chain. To rule out this explanation I use a balanced panel comprising only mines that are active during all years in the data set, thereby ensuring the results are not driven by mines closing down. Despite throwing away a large number of observations, the results in column 4 of Table 9 are similar to before and the average treatment effect remains negative and statistically significant.

Recent theory and evidence indicates that vertical integration correlates with financial development (Acemoglu et al., 2009; Macchiavello, 2012). As the sample period spans a period of time when many states lifted restrictions on the geographical scope of bank

[27] Further tests presented in Online Appendix Table F.1 show that market thickening does not explain the key finding. Columns 1 and 2 of Table F.1 show that there was no differential change in the probability of a mine entering or exiting the data set across the treatment and control groups between periods. Columns 3 and 4 repeat this exercise and find no significant effects for preparation plants. Hence, the change in ownership structure was not simply driven by competition changing market thickness through entry or exit. Columns 5 and 6 use information from the Truck Inventory and Use Survey to investigate whether preparation plants began purchasing coal from more distant mines thereby increasing hold-up threats. The data show this was not the case.

activities and legalized de novo branching statewide, I examine the robustness of my findings to including financial-sector variables. First, in column 5 of Table 9 I include the total volume of bank lending within the mine's county-year. Second, in column 6 I include an interstate and intrastate deregulation dummy that capture time-varying changes in whether a state permits interstate and intrastate branching respectively. In both cases the effect of product market competition on vertical integration remains robust.

In column 7 of Table 9 I estimate equation (1) using a probit model to ensure my findings are not simply an artefact of the linear probability model. The average treatment effect remains negative and statistically significant.

A further concern might be that there were differential shocks to coal demand between the treatment and control group as power stations idled capacity and/or switched from burning coal to another fuel or vice versa. Shifting demand patterns may therefore drive the results if, for example, Eastern mines experience falling demand. I therefore focus on how coal-fired electricity generation capacity changed through time in the Eastern and Western market using a difference-in-difference estimator applied to power station-level data reported on EIA Form 759. Column 1 in Online Appendix Table G.1 shows no significant reduction in capacity between the treatment and control group post 1980. In columns 2 and 3 I find no significant differences in the probability of power stations entering and exiting between the two groups.

[Insert Table 10]

Nevertheless, to alleviate concerns that confounding demand shocks drive the results I interact the $East_i$ dummy variable with coal-fired generation capacity in the mine's state. I then include this additional variable in the vertical integration and price regressions. The results of these tests are reported in Table 10. In both column 1 and column 2 the interaction term remains insignificant and the main findings are unaffected.

The sample period is characterized by a period of turbulence in energy markets, an acute recession which differed in severity across regions, new environmental mandates and changes to coal demand induced by the rise of substitute fuels such as natural gas. If these factors differentially affect the treatment and control groups they may confound the average treatment effect estimates. I address these concerns in the remainder of Table 10.

To rule out that cross-time changes in the price of substitute fuels, such as oil, provoke changes in coal prices and mines' organization I append equation (1) with an interaction between the $East_i$ dummy and the oil price variable. The results reported in columns 3 and 4 of Table 10 are robust to this change. Next, I deal with concerns that environmental legislation drives the results. The Clean Air Act Amendments of 1977 required that all power stations built after 1977 must be fitted with flue-gas desulfurization systems (scrubbers): a technology that reduces the sulfur content of power stations' exhaust emissions. A danger is that the introduction of scrubbers altered demand for coal depending on its sulfur content. I therefore create a variable measuring the share of coal-fired generation capacity with scrubbers to total capacity in each state-year and interact it with the $East_i$ dummy variable.[28] Including this additional control variable has little effect on the main findings in columns 5 and 6 of Table 10. To rule out differential macroeconomic trends due to the early 1980s recession I interact the $East_i$ dummy variable with the annual GDP growth rate in the mine's county.[29] The findings in columns 7 and 8 remain very similar to before. Finally, in columns 9 and 10 of Table 10 I report estimates based on a specification that considers possible differences in demand between the treatment and control group due to changes in power stations' natural gas demand. Again, the main findings are unchanged.[30]

6 Conclusions

One contribution of this article is to provide first evidence of a causal relationship between product market competition and changes in vertical integration. Using a natural experiment in the US coal mining industry, I find that following exposure to more intense product market competition the probability of vertical integration fell by approximately 30% within the treatment group, relative to the counterfactual.

The second contribution is novel evidence on the underlying mechanism. Specifically, product market competition matters for vertical integration because it changes market prices and alters the returns to operating different organizational formats. I find that the competitive shock caused a 32% reduction in market prices within the treatment group. Hence, as competition increases prices fall and the output gains brought by vertical integration translate into low revenue which no longer offset the costs of integrating. Consistent with this argument, the estimates show the transition to a lower degree of vertical integration is driven by competition reducing the frequency of vertical mergers. The transmission mechanism differs from existing explanations which emphasize the role of competition in thickening the market and reducing bargaining frictions between firms.

How might these results be interpreted? The evidence is consistent with a number of economic theories. For example, recent OIO theories offer one possible explanation (Legros

[28]The earliest year for which data on scrubber installations are reported is 1985. I therefore proxy scrubber usage using the ratio of power station generation capacity built after 1977 to total capacity.

[29]Owing to a lack of data on which county a power station is located in, the pricing regression uses state-level GDP growth rate.

[30]Finally, Online Appendix Table G.2 shows that the effect of competition is not confounded by features of contracts (share of fixed price contracts and average duration) between mines and power stations (Kacker, 2016).

and Newman, 2013). These models emphasize the role of product prices in influencing vertical integration and imply that demand shocks can provoke merger and divestiture waves. My findings could be viewed as consistent with product market competition shifting the market demand curve inward and reducing market prices. As prices fall the marginal value of output gains decrease and firms choose non-integration. Models in which there are differences in the fixed costs of operating different organization structures could also explain the results (Grossman and Helpman, 2002; Antras and Helpman, 2004). Transactions cost theories may also offer an interpretation of the evidence. In those models vertical integration depends on the level of quasi-rents (Williamson, 1975; Klein et al., 1978; Baker et al., 2002). Where rents are a function of market prices, increasing the intensity of competition erodes rents leading non-integration to become the preferred equilibrium ownership structure.

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Tables

Table 1: Organizational Characteristics

Dependent variable:	Production shifts	Employees per thousand tons	Office workers	Office hours
vi_{it}	0.4983***	-0.4390***	1.8890**	1.7581***
	(6.39)	(-10.31)	(2.33)	(2.86)
Number of VI mines	1,875	1,875	1,875	1,875
Number of NI mines	19,650	19,650	19,650	19,650
R^2	0.06	0.98	0.11	0.09
Mine FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Notes: All data are taken from the MSHA mines information database except employees per thousand tons which comes from the MSHA mine-level database. Employees per thousand tons is the ratio of mine employees to the number of tons of coal extracted (in thousands). Office workers is the number of workers employeed in the mine's on-site office. Office hours is the total annual number of hours worked by office workers at the mine. All dependent variables are measures in natural logarithms except production shifts. The estimating equation in all columns is $y_{it} = \alpha_i + \beta vi_{it} + \gamma_t + \varepsilon_{it}$ where y_{it} is a dependent variable; vi_{it} is the vertical integration indicator; α_i and γ_t are mine and year fixed effects, respectively; ε_{it} is the error term. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table 2: Summary Statistics

	Obs.	Mean	Std. Dev.	Min	Max	Aggregation	Source
A: Organizational Tests							
Vertical integration	21,525	0.09	0.28	0	1	Mine	MSHA
Union	21,525	0.28	0.45	0	1	Mine	MSHA
Multi plant	21,525	0.33	0.47	0	1	Mine	MSHA
Labor productivity	21,525	2.49	2.27	0	162.64	Mine	MSHA
Output	21,525	0.24	0.47	0	8.06	Mine	MSHA
Hours worked	21,525	0.13	0.23	0	2.66	Mine	MSHA
Divest	17,645	0.01	0.08	0	1	Mine	MSHA
Merger	17,645	0.02	0.15	0	1	Mine	MSHA
Prep build	17,645	0.01	0.07	0	1	Mine	MSHA
Coal price	21,525	0.67	0.23	0.04	1.18	State	EIA Form 423
Generation capacity	21,525	0.70	0.19	0.01	1.12	State	EIA Form 780
Oil price	21,525	1.18	0.46	0.01	2.81	State	EIA Form 423
Gas price	21,525	0.07	0.07	0.01	0.45	State	EIA Form 423
Entry rate	21,525	0.17	0.20	0	1	Mine	Author's calculations
Exit rate	21,525	0.06	0.13	0	1	Mine	Author's calculations
Delegation	21,525	0.47	0.50	0	1	Mine	MSHA
MP ratio	21,525	6.58	8.95	0	108	Mine	Author's calculations
Foreclosure	21,525	0.09	0.18	0	1	Mine	Author's calculations
Opening year	21,525	5.43	4.80	0	15	Mine	MSHA
Seam height	21,525	48.98	43.40	0.1	812	Mine	MSHA
Proximity	21,525	4.90	0.19	3.55	5.17	State	Author's calculations
Ash content	21,525	0.12	0.01	0.08	0.22	State	EIA Form 423
GDP growth rate	21,525	0.07	0.05	-0.13	0.45	County	BEA
Bank lending	21,525	0.01	0.00	0	0.03	County	Call Reports
Interstate	21,525	0.24	0.43	0	1	State	FDIC
Intrastate	21,525	0.03	0.18	0	1	State	FDIC
B: Price and Quantity Tests							
Price	179,855	3.65	0.74	-2.16	6.64	Shipment	EIA Form 423
Sulfur content	179,855	0.52	0.65	-4.61	4.30	Shipment	EIA Form 423
Ash content	179,855	2.52	0.36	-2.30	4.53	Shipment	EIA Form 423
Underground	179,855	0.30	0.46	0	1	Shipment	EIA Form 423
Quantity (mBtu)	29,643	27.87	1.45	17.04	30.82	Power station	EIA Form 423
Quantity (tons)	29,643	10.94	1.46	0.01	13.88	Power station	EIA Form 423

Table 3: Delivered Prices and Shipments

Panel A: Delivered Prices				
Origin : Destination		Distance	Pre 1980	Post 1980
PRB : East		1,200		1.90
PRB : West		347	4.32	1.42
East : East		336	6.74	1.94
Unita : West		262	0.54	0.32
B: PRB Shipments to the West				
Variable	Pre 1980	Post 1980	Diff.	t-statistic
Tons shipped	2.52	2.60	0.08	0.05
	(1.46)	(0.37)	(1.62)	
Btu shipped	28.04	20.65	-7.39	-0.80
	(8.86)	(2.09)	(9.21)	

Notes: This table uses data from the CTRD database. Panel A reports the average distance between mines and power plants according to mines' location (Origin) and power plants' location (Destination). Pre and Post 1980 denote the real 2009 $ delivered price per 1 mBtu. The Pre 1980 delivered price of PRB coal to the East is calculated as the average mine price per 1 mBtu ($1.24) plus 1,200 times the mean cost of transporting PRB coal per mile reported in the CTRD. Panel B reports the results of a t-test on the null of equality between pre and post 1980 PRB shipments to Western markets.

Table 4: Vertical Integration Incidence

	1	2	3
	Pre-Staggers	Post-Staggers	Difference
Treatment group	.0314	0.1063	0.0749
Control group	0.0438	0.1877	0.1440
Difference-in-difference			-0.0691**
			(-2.49)

Notes: This table uses the mine-level data set and reports the average incidence of vertical integration within the treatment and control groups before and after the Staggers Rail Act was introduced in 1980. t-statistic reported in parentheses. ** indicates statistical significance at the 5% level.

Table 5: Vertical Integration Results

	1	2	3	4	5	6	7
Dependent variable: vi_{it}							
Post	0.3208***	0.2834***	0.0544	0.0235	0.2080***	-0.0181	-0.0100
	(10.41)	(9.79)	(1.51)	(0.54)	(4.89)	(-0.43)	(-0.20)
East * Post	-0.1111***	-0.1007***	-0.0999***	-0.0967***	-0.0906***	-0.0620**	-0.0757***
	(-3.75)	(-3.60)	(-4.03)	(-4.24)	(-2.95)	(-2.29)	(-3.66)
Union		-0.1147***	-0.1114***	-0.0929***	-0.0929***	-0.1243***	-0.0932***
		(-8.87)	(-7.82)	(-6.53)	(-5.91)	(-7.42)	(-7.31)
Multi plant		0.0840***	0.0849***	0.0826***	0.0826***	-0.0260	0.0808***
		(5.26)	(4.04)	(4.70)	(4.87)	(-1.48)	(5.31)
Labor productivity		0.0032*	0.0025	0.0014	0.0015	0.0040***	0.0013*
		(1.95)	(1.57)	(1.40)	(1.57)	(3.21)	(1.69)
Coal price			0.2583***	0.2123***	0.2135***	0.1160***	0.2304***
			(6.77)	(3.85)	(3.82)	(2.91)	(4.66)
Generation capacity			0.1860***	0.1428***	0.1427**	0.1426***	0.1399***
			(3.94)	(2.79)	(2.43)	(2.67)	(2.77)
Oil price			0.0004***	0.0004***	0.0004***	0.0004***	0.0004***
			(6.14)	(6.27)	(5.99)	(6.05)	(6.84)
Gas price			0.1367***	0.0902**	0.0917***	0.0845**	0.0885**
			(3.35)	(2.23)	(2.59)	(2.39)	(2.51)
Entry rate			0.0333***	0.0315***	0.0315***	0.0258***	0.0309***
			(4.84)	(3.91)	(4.84)	(3.05)	(3.85)
Exit rate			-0.0460**	-0.0459***	-0.0459**	-0.0406**	-0.0472***
			(-2.23)	(-2.90)	(-2.34)	(-2.28)	(-2.59)
$Post75$					-0.1633***		
					(-3.45)		
East * $Post75$					-0.0284		
					(-1.02)		
Union * Post						0.0553***	
						(6.87)	
Multi plant * Post						0.1242***	
						(15.40)	
Labor productivity * Post						-0.0033**	
						(-2.25)	
Opening year * Post						0.0028*	
						(1.92)	
Seam height * Post						0.0004***	
						(3.67)	
Observations	21,525	21,525	21,525	21,525	21,525	21,525	21,685
R^2	0.13	0.15	0.16	0.18	0.18	0.20	0.18
Mine FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	No	No	No	No
Underground * Year FE	No	No	No	Yes	Yes	Yes	Yes

Notes: These tests rely on the mine-level MSHA data set. t-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table 6: Further Evidence

	1	2	3	4
Dependent variable:	Output	Hours worked	vi_{it}	vi_{it}
Post	0.0702	0.0162	-0.0008	
	(0.86)	(0.64)	(-0.02)	
East * Post	-0.2522***	-0.0441***		
	(-3.34)	(-2.68)		
Post * Inv distance			-0.0628***	
			(-2.73)	
Proximity				0.3879***
				(3.86)
East * Proximity				-0.3149***
				(-3.22)
Observations	21,525	21,525	21,525	21,525
R^2	0.07	0.03	0.18	0.18
Mine FE	Yes	Yes	Yes	Yes
Underground * Year FE	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes

Notes: These tests rely on the mine-level MSHA data set. The control variables are identical to those used in Table 5 column 3. t-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table 7: Pricing and Quantity Results

Dependent variable:	1 Price (¢/mBtu)	2 Price (¢/mBtu)	3 Quantity (mBtu)	4 Quantity (mBtu)	5 Quantity (tons)	6 Quantity (tons)	7 Price (¢/mBtu)	8 vi_{it}
East * Post	-0.3237***	-0.3379***	-0.4470***	-0.4323***	-0.4741***	-0.4532***	-0.3304***	
	(-8.16)	(-7.84)	(-2.91)	(-2.60)	(-2.82)	(-3.17)	(-7.63)	
Sulfur content		-0.1166***		0.0679		0.0579	-0.1167***	
		(-3.81)		(1.55)		(1.26)	(-4.49)	
Ash content		-0.0300		0.0808		0.1773***	-0.0300	
		(-0.68)		(1.20)		(2.65)	(-0.64)	
Underground		0.0316*		0.0054		-0.0318	0.0316*	
		(1.95)		(0.09)		(-0.58)	(1.85)	
VI share							-0.0227	
							(-0.23)	
VI share * Post							-0.0849	
							(-0.43)	
Coal price								0.1580***
								(20.44)
Observations	179,855	179,855	29,643	29,643	29,643	29,643	179,855	21,525
R^2	0.87	0.87	0.77	0.77	0.77	0.77	0.87	0.16
Kleibergen-Paap F-statistic	-	-	-	-	-	-	-	20,339
Power plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Month * Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Mine FE	No	No	No	No	No	No	No	Yes
Underground * Year FE	No	No	No	No	No	No	No	Yes

Notes: The tests in this table use the EIA Form 423 database. Monthly shipment-level data is used in columns 1, 2 and 7. In the remainder of the table shipments are aggregated to the power plant-origin state level. In columns 1, 2 and 7 sulfur and ash content are the sulfur (%) and ash (%) content in a shipment. In columns 3-6 sulfur and ash content are the mean sulfur (%) and ash (%) content of shipments from state s to power plant p during month m of year t. Column 8 uses data from the MSHA mine-level database. Coal price is the market price of coal in the mine's state (measured in natural logarithms). The unreported control variables used in column 8 are identical to those used in Table 5 column 3. t-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table 8: Ownership Adjustment Mechanisms

	1	2	3
Dependent variable:	Merge	Divest	Prep build
Post	0.0744***	0.0314***	0.0159*
	(5.06)	(3.28)	(1.92)
East * Post	-0.0358***	-0.0036	-0.0073
	(-2.85)	(-0.55)	(-1.00)
Observations	17,645	17,645	17,645
R^2	0.10	0.02	0.01
Mine FE	Yes	Yes	Yes
Underground * Year FE	Yes	Yes	Yes
Control variables	Yes	Yes	Yes

Notes: These tests rely on the mine-level MSHA data set. The number of observations is lower compared to Table 5 because at least two time periods are required to generate the dependent variable. A mine's ownership status must be known in t and $t-1$ to be able to ascertain whether a merger, divestiture or preparation plant build has taken place. The control variables are identical to those used in Table 5 column 3. t-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table 9: Robustness Tests

	1	2	3	4	5	6	7
Dependent variable: vi_{it}							
Post	0.0198	0.0299	0.0199	0.1648	0.0174	-0.0679*	-0.0096
	(0.37)	(0.51)	(0.39)	(1.07)	(0.24)	(-1.79)	(-0.26)
East * Post	-0.0953***	-0.0933***	-0.0954***	-0.1022*	-0.0963***	-0.0767***	-0.0306***
	(-3.25)	(-3.39)	(-3.63)	(-1.71)	(-3.57)	(-3.20)	(-2.58)
MP ratio	-0.0004						
	(-0.14)						
Ash * Post		-0.0013					
		(-0.38)					
Delegation			-0.0005				
			(-0.07)				
Bank lending					0.0003	0.0010	
					(0.14)	(0.60)	
Interstate deregulation						-0.0187**	
						(-2.12)	
Intrastate deregulation						0.0570***	
						(2.89)	
N	21,525	21,525	21,525	2,848	21,525	21,525	21,525
R^2	0.18	0.18	0.18	0.27	0.18	0.18	-
Mine FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Underground * Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: These tests rely on the mine-level MSHA data set. t-statistics are reported in parentheses. The control variables are identical to those used in Table 5 column 3. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

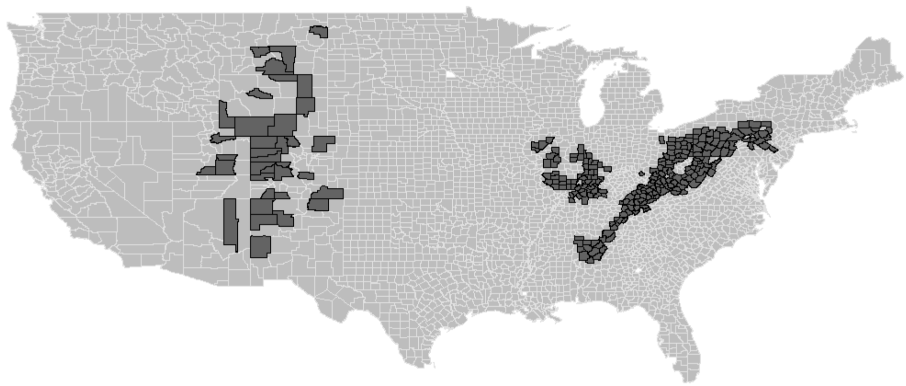
Table 10: Energy and Legislative Shocks

	1	2	3	4	5	6	7	8	9	10
Dependent variable:	vi_{it}	Price	vi_{it}	Price	vi_{it}	Price	vi_{it}	Price	vi_{it}	Price
Post	0.0230		0.0118		0.0101		0.0009		0.0178	
	(0.37)		(0.21)		(0.19)		(0.02)		(0.37)	
East * Post	-0.0990**	-0.2549***	-0.0942***	-0.2840***	-0.0757***	-0.2164***	-0.0756***	-0.2205***	-0.0854***	-0.3010***
	(-2.39)	(-3.75)	(-3.58)	(-3.29)	(-2.58)	(-3.10)	(-3.21)	(-3.88)	(-2.98)	(-3.98)
Coal generating capacity	0.1062	0.1328**	0.1713***	0.1462*	0.1649***	0.1313*	0.1463***	0.1245*	0.1622***	0.1255*
	(0.25)	(2.06)	(2.70)	(1.84)	(2.75)	(1.69)	(3.44)	(1.89)	(3.13)	(1.76)
Oil price	0.0004***	0.0001	0.0004***	-0.0001	0.0004***	0.0001	0.0004***	0.0000	0.0003***	0.0001
	(6.01)	(0.42)	(5.59)	(-1.21)	(6.22)	(0.42)	(5.61)	(0.20)	(6.13)	(0.52)
East * Coal generating capacity	0.0439	0.0030								
	(0.10)	(0.02)								
East * Oil price			-0.0009	0.0002						
			(-1.33)	(1.06)						
Scrubbers					0.0040**	-0.0055**				
					(2.16)	(-2.09)				
East * Scrubbers					-0.0033*	0.0100***				
					(-1.70)	(3.51)				
GDP growth rate							-0.3205	-0.0828		
							(-1.58)	(-0.21)		
East * GDP growth rate							0.2989	0.9206**		
							(1.45)	(2.01)		
NG capacity									-0.0428	-0.2223
									(-0.91)	(-0.82)
East * NG capacity									0.0098	0.3395
									(0.21)	(1.23)
N	21,525	179,855	21,525	179,855	21,525	179,855	21,525	179,855	21,525	179,855
R^2	0.18	0.87	0.18	0.87	0.18	0.87	0.18	0.87	0.18	0.87
Mine FE	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Underground * Year FE	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Power station FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
State FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Month * Year FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The results reported in columns 1, 3 and 5 use the MSHA mine-level data set. The results reported in columns 2, 4 and 6 use the EIA Form 423 database. *t*-statistics are reported in parentheses. The control variables in columns 1, 3 and 5 are identical to those in 5 column 3. The control variables in columns 2, 4 and 6 are identical to those in Table 7 column 2. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

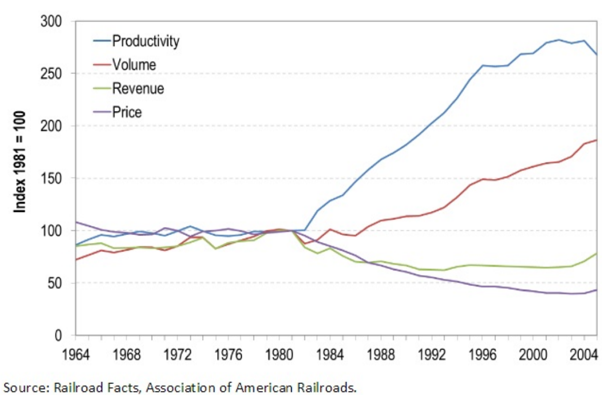
Figures

Figure 1: Location of Coal Mines



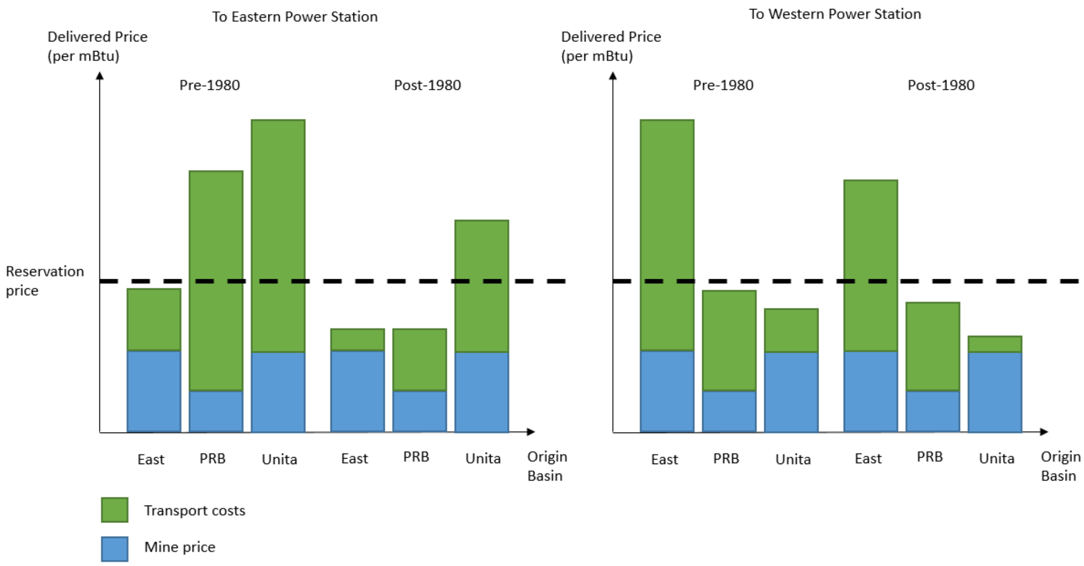
Notes: This figure shows the location of coal mines throughout the continental US. Dark counties contain at least one coal mine. Light counties contain zero coal mines.

Figure 2: Prices and Productivity in the Railroad Sector



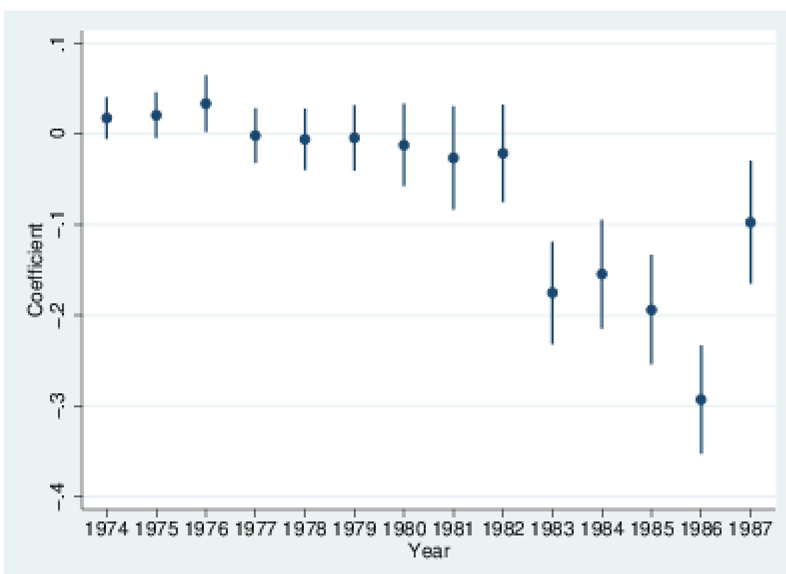
Notes: This figure shows the time-series evolution of railroad prices (freight rates), productivity, revenue, and volume of shipments between 1964 and 2004. The base year is 1981. Data are taken from *Railroad Facts* (published by the Association of American Railroads) reported by Slack (2013).

Figure 3: Essence of the Identification Strategy



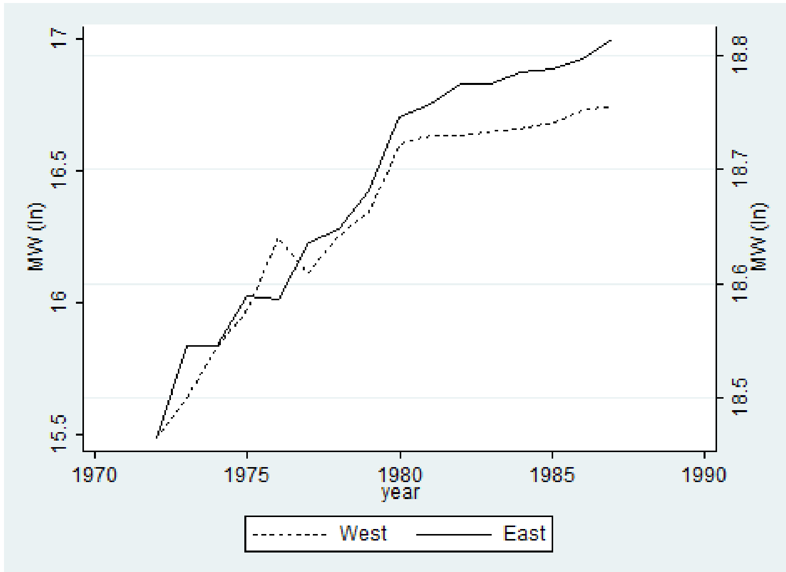
Notes: This figure provides a conceptual overview of the identification strategy. The left (right) panel shows the delivered price per mBtu to an Eastern (Western) power station from mines in each basin. The dashed line represents the power stations' reservation price - they only source coal from a basin if the price is below this level.

Figure 4: Parallel Trends Test



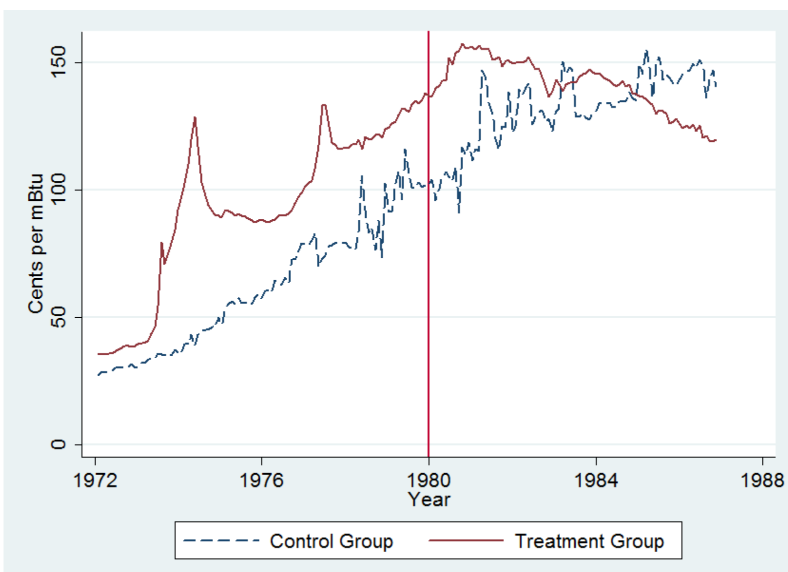
Notes: This figure presents graphical evidence on the parallel trends assumption. The excluded years are 1972 and 1973. Blue dots denote the coefficient estimate on the East * Year interactions. 95% confidence intervals are denoted by vertical lines.

Figure 5: Generation Capacity by Market



Notes: This figure shows total capacity (in megawatts) of coal-fired electricity power stations in the East and West during each year of the sample. Data are taken from EIA Form 759.

Figure 6: Market Prices



Notes: This figure plots average monthly prices (in 2009 US$'s) within the treatment and control group between January 1972 and December 1987. The vertical line corresponds to October 1980 when the Staggers Rail Act was signed into law.

Online Appendix - Not for Publication

Appendix A: Variable Description

Variables used in the vertical integration tests

Vertical integration is a dummy variable equal to 1 if a mine owns a preparation plant within a 10 mile radius, 0 otherwise. The 10 mile radius is calculated using great circle area.

Union is a dummy variable equal to 1 if the MSHA data report a union code for the mine, 0 if no union is listed.

Multi plant is a dummy variable equal to 1 if a mine belongs to a firm that owns more than one mine, 0 otherwise.

Labor productivity is the ratio of total output to total hours worked in a mine during the year.

Output total number of tons of coal produced by mine i in year t. Measured in millions of tons.

Hours worked total number of worker hours in mine i in year t. Measured in millions of hours.

Divest is a dummy variable equal to 1 if a mine divests a preparation plant within a 10 mile radius of the mine, 0 otherwise.

Merger is a dummy variable equal to 1 if a mine merges with a preparation plant within a 10 mile radius of the mine, 0 otherwise.

Prep build is a dummy variable equal to 1 if a mine builds an on-site preparation plant, 0 otherwise.

Coal price is the average price per 1 mBtu of coal purchased by power plants in mine i's state during year t.

Generation capacity is the total capacity of coal-fired power stations in mine i's state during year t.

Oil price is the average price per 1 mBtu of oil purchased by power plants in mine i's state during year t.

Gas price is the average price per 1 mBtu of gas purchased by power plants in mine i's state during year t.

Entry rate is the ratio of entering mines to continuing mines within a 10 mile radius of mine i during year t.

Exit rate is the ratio of exiting mines to continuing mines within a 10 mile radius of mine i during year t.

Delegation is a dummy variable equal to 1 if a mine is operated by a subsidiary or an independent contractor, 0 otherwise.

MP ratio is the ratio of mines to preparation plants within a 10 mile radius of mine i during year t.

Foreclosure is the ratio of vertically integrated mines to preparation plants within a 10 mile radius of mine i during year t.

Opening year is the year the mine was first observed in the database. For example, mines that open in 1972 have a value of 0 whereas mines that open in 1985 have a value of 13.

Seam height is the thickness of the coal seam in mine i (in feet).

Proximity is a measure of proximity between mines in state s during year t calculated using the gravity equation.

Ash content is the percentage of ash material per ton of coal in mine i's state.

GDP growth rate is the annual growth rate of per capita income in mine i's county during year t. Calculated using data from the Bureau of Economic Analysis.

Bank lending is the total value of loans originated by banks in mine i's county during year t. Data are taken from Call Reports issued by the Chicago Fed. Measured in billions.

Interstate deregulation is a dummy variable equal to 1 if a state allows interstate bank branching, 0 otherwise.

Interstate deregulation is a dummy variable equal to 1 if a state allows intrastate bank branching, 0 otherwise.

EIA Form 423 variables used in the price regressions

Price is the FOB mine price per 1 mBtu of shipment i to power plant p in state s during year t. Measured in dollars.

Sulfur content is the number of pounds of sulfur per million Btu in shipment i to power plant p in state s during year t.

Ash content is the percentage of ash material per ton of coal in shipment i to power plant p in state s during year t.

Underground is a dummy variable equal to 1 if the shipment comes from an underground mine, 0 if from a surface mine.

Quantity (mBtu) is the total number of Btu purchased by power plant p from mines in state s during year t.

Quantity (tons) is the total number of tons of coal purchased by power plant p from mines in state s during year t.

Appendix B: Treatment and Control Group Characteristics

Table B.1 reports summary statistics for the key observable mine-level characteristics among the treatment and control group during the pre-treatment period. The regression analysis conditions on these characteristics to ensure that, conditional on covariates, the identifying assumption that mines in the treatment and control groups are only randomly different is met.

Table B.1 Treatment and Control Group Characteristics

	$East_i = 0$	$East_i = 1$
Vertical integration	0.0424	0.0342
Union	0.6424	0.5070
Underground	0.6182	0.5118
Labor productivity	3.3526	2.2203
Production	0.8480	0.3168
Hours worked	11.7943	11.1399
Sub-contractor	0.5879	0.5261
Coal price	0.2432	0.3558

Appendix C: Clustering and Additional Results

Table C.1 reports the results of the main specification using various clustering procedures. In column 1 I cluster at the mine level. The results in column 2 are clustered at the region (i.e. basin level). Column 3 shows results based on two-way clustering. Specifically, I cluster at the mine and region-year levels to capture time-varying shocks affecting nearby mines.

Table C.1: Alternate Clustering

	1	2	3
Dependent variable: vi_{it}			
Post	0.0532	0.0532	0.0532
	(0.68)	(0.49)	(0.01)
East * Post	-0.0986**	-0.0986**	-0.0986***
	(-2.06)	(-17.67)	(-3.63)
Union	-0.1086***	-0.1086***	-0.1086***
	(-5.04)	(-590.04)	(-6.62)
Multi plant	0.0855***	0.0855***	0.0855***
	(4.10)	(175.55)	(5.26)
Labor productivity	0.0026	0.0026	0.0026*
	(1.55)	(4.55)	(1.78)
Coal price	0.2605***	0.2605	0.2605***
	(2.72)	(1.92)	(4.37)
Generation capacity	0.1916*	0.1916*	0.1916***
	(1.92)	(11.45)	(2.84)
Oil price	0.0004***	0.0004**	0.0004***
	(4.34)	(17.38)	(6.72)
Gas price	0.1330*	0.1330	0.1330**
	(1.81)	(1.74)	(2.26)
Observations	21,525	21,525	21,525
R^2	0.18	0.18	0.18
Mine FE	Yes	Yes	Yes
Underground * Year FE	Yes	Yes	Yes

Notes: These tests rely on the mine-level MSHA data set. The table reports results based on the model used in column 3 of Table 5. t-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table C.2: Preparation Plant Entry and Exit

	1
Dependent variable: vi_{it}	
Post	0.0246
	(0.59)
East * Post	-0.0986***
	(-4.14)
Union	-0.0932***
	(-5.98)
Multi plant	0.0825***
	(4.96)
Labor productivity	0.0014
	(1.30)
Coal price	0.2086***
	(4.69)
Generation capacity	0.1467***
	(2.90)
Oil price	0.0004***
	(7.44)
Gas price	0.0820**
	(2.30)
Mine entry rate	0.0222***
	(2.91)
Mine exit rate	-0.0495***
	(-3.25)
Prep entry rate	0.0243***
	(2.83)
Prep exit rate	0.0118
	(0.94)
Observations	21,525
R^2	0.18
Mine FE	Yes
Underground * Year FE	Yes

Notes: These tests rely on the mine-level MSHA data set. The table reports results based on the model used in column 3 of Table 5. t-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Appendix D: Proximity Variable

Calculation of the proximity variable follows the trade literature. The idea is that proximity between trading partners depends on both distance and market size. Greater physical distance reduces proximity whereas larger market size leads to more trade and higher proximity. I use the following gravity model to calculate a state-level proximity index

$$Shipments_{st} = \alpha + \beta_1 Distance_s + \beta_2 Capacity_{st} + \gamma_t + u_{st}, \qquad (7)$$

where $Shipments_{st}$ is the total quantity of Btu's shipped from PRB mines to power stations in state s during year t taken from EIA Form 423; $Distance_s$ is the distance between the centroid of state s and Gillette, Wyoming (the main hub for PRB rail shipments); $Capacity_{st}$ is coal-fired generation capacity in the state taken from EIA Form 759; γ_t are year fixed effects; and u_{st} is the error term. All variables are measured in natural logarithms. The results of equation (7) are reported in Table D.1.

Table D.1 Gravity Model Results

	1
Distance ($\hat{\beta}_1$)	-1.0029***
	(-2.96)
Capacity ($\hat{\beta}_2$)	0.1042*
	(1.93)
Observations	933
R^2	0.03
Year effects	x

The coefficient estimates have the correct sign. The quantity of Btus shipped is inversely related to how far a state lies from the PRB whereas there are more shipments to states with large markets. Using these estimates I calculate proximity as a linear prediction of equation (7), that is:

$$proximity_{st} = \hat{\beta}_1 Distance_s + \hat{\beta}_2 Capacity_{st}. \qquad (8)$$

Appendix E: Railroad Deregulation and Competition

Crucial to my identification strategy is the claim that falling freight rates triggered an increase in product market competition for Eastern mines. This section provides additional support for this claim.

Eakin et al. (2010) report that approximately 80% of railroad TFP improvements were passed on through lower freight rates. This suggests that higher TFP values correlate with more intense product market competition among coal mines. I therefore interact the East dummy variable with an annual railroad TFP index provided by Schoech and Swanson (2010) and estimate the equation

$$vi_{it} = \alpha_i + \beta_1 East_i * TFP_t + \delta X_{it} + \varepsilon_{it}, \quad (9)$$

where all variables are defined as in equation (1) except for TFP_t which is the annual TFP index.

The estimation results are reported in column 1 of Table E.1 below. The evidence shows that as TFP in the railroad sector increased, the incidence of vertical integration fell among Eastern coal mines. This makes sense, as TFP increases railroads pass on the productivity gains to shippers through lower freight rates which leads to greater product market competition in the East.

Table E.1 Alternate Competition Proxies

	1	2
East * TFP Rail	-0.1188***	-0.1188***
	(-5.41)	(-4.95)
Post		0.0945***
		(3.47)
Observations	21,525	21,525
R^2	0.17	0.17
Mine FE	Yes	Yes
Underground-year FE	Yes	Yes
Control variables	Yes	Yes

Notes: These tests rely on the mine-level MSHA data set. t-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Column 2 of the table appends the regression model with the *Post* dummy variable. The key finding remains unchanged.

Appendix F: Additional Market Thickness Tests

Previously, I addressed the role of transactions costs by examining the behavior of the mine to preparation plant ratio. In this section I provide a number of additional tests to rule out the effect of changing transactions costs or bargaining frictions. For example, these margins may change depending on the number of suppliers in the market as this alters firms' outside options.

The second related way I approach the issue of transactions costs is to examine industry dynamics. Given the negative competition-integration relationship found previously, market thickening would be consistent with a wave of entry into the downstream sector. To address entry dynamics I generate a variable $Entry_{it}$. This is equal to 1 if a mine enters during year t, 0 otherwise. In addition, I generate the same variable for preparation plants. The DID estimation results reported in Table F.1 column 1 indicate no change in the probability that an Eastern mine enters after 1980. Likewise, the findings in column 2 display no sensitivity of entry to product market competition among preparation plants.

A key insight of monopolistically-competitive heterogeneous firm models is that increasing competition erodes incumbents' market share forcing low-productivity producers to exit (Melitz, 2003; Asplund and Nocke, 2006). Fragmentation of the production chain could therefore be driven by competition causing firms to shutdown their Eastern operations due to declining profitability. To address this concern I generate an exit dummy variable, equal 1 if a mine (preparation plant) exits during year t, 0 otherwise. In Table F.1 columns 3 and 4 there are no significant differences in the probability of exit among the treatment and control group post 1980.

The final strategy to assess the hold-up hypothesis relies on data from the Truck Inventory and Use Survey (TIUS). The TIUS is a repeated cross-section containing truck-level data on the principal product carried by a truck, the truck's primary range of operation, and the total annual miles the truck traveled during the past year. It covers the years 1977, 1982 and 1987. This source provides information on the distances over which coal is transported by trucking firms, the shipping mode between mines and preparation plants. In addition, the survey contains information on the truck's state of operation.

I select only trucks that list their principal product as mining products to proxy for coal shipments. Next, I create a variable $Local_{it}$ (equals 1 if the primary range of operation for truck i is less than 49 miles, 0 otherwise). The intuition underlying this test is that it is possible to infer hold-up problems from shipping distance. If preparation plants begin to ship from outside the local area this would be consistent with a reduction in hold-up problems as they can credibly threaten to purchase coal from a larger number of potential suppliers. In column 5 of Table F.1 I find that trucks transporting mining products in Eastern states did not begin to transport coal from outside local markets. The interaction coefficient is statistically insignificant indicating shipments continued to take place within the same geographical areas pre and post treatment. In addition, I experiment with the total number of miles driven during the past 12 months to see whether trucks began to ship from more distant destinations. However, the results in column 6 show that this is not the case. If anything the distance of mining shipments decreased although the interaction coefficient is imprecisely estimated.

Table F.1 Transactions-Cost Explanations

	1	2	3	4	5	6
Dependent variable:	Entry (mine)	Entry (prep)	Exit (mine)	Exit (prep)	Local	Miles
Post	-0.6757***	-0.1157	-0.0024	0.0005	-0.1482*	2.6090***
	(-9.01)	(-1.56)	(-1.46)	(0.11)	(-1.89)	(5.53)
East * Post	-0.0458	0.0069	-0.0001	-0.0008	0.0176	-0.9862*
	(-0.88)	(0.30)	(-0.80)	(-0.56)	(0.22)	(-1.86)
Observations	18,697	2,828	18,697	2,828	1,189	1,396
R^2	0.16	0.06	0.00	0.01	0.08	0.13
Mine FE	Yes	Yes	Yes	Yes	No	No
State FE	No	No	No	No	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The estimates reported in columns 1 to 4 rely on the MSHA mine-level database. The estimates in columns 5 and 6 use information from the TIUS. In columns 2 and 4 the mine FE denote preparation plant FE. *t*-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Truck Inventory and Use Survey

The Truck Inventory and Use Survey (TIUS) provides microdata on the physical and operational characteristics of the US truck population (see Hubbard (2001) for a more extensive description of the data set). The survey is a repeated cross-section conducted quinquennially that reports information on truck's state of operation, characteristics (axels, body/trailer type, engine etc.), primary range of operation, primary cargo, and many other variables. We use data from the 1977, 1982 and 1987 vintages. The earlier 1972 survey asked a more limited number of questions that do not cover some of the variables we are interested in. The data are used by Hubbard (2001) and Baker and Hubbard (2003) to study the implications of ICT technologies and the determinants of vertical integration. A summary of the TIUS variables used in the analysis are shown in Table F.2.

Table F.2 TIUS Summary Statistics

	Obs.	Mean	Std. Dev.	Min	Max	Aggregation	Source
Local	1,189	0.69	0.46	0	1	Truck	TIUS
Miles (10,000)	1,396	3.52	3.23	0	20	Truck	TIUS

Appendix G: Further Robustness Tests

Table G.1 Electricity Sector Changes

	1	2	3
Dependent variable:	Capacity	Entry	Exit
Post	0.1212***	-0.0158	0.0359***
	(2.85)	(-0.78)	(3.24)
East * Post	-0.0261	0.0159	-0.0188
	(-0.53)	(1.04)	(-1.42)
Observations	4,260	4,260	4,260
R^2	0.06	0.54	0.72
Power station FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Notes: The regressions are estimated using power plant-level data reported on EIA Form 759. East denotes power stations that lie east of the Mississippi river. The dependent variable in column 1 is capacity, in MW(ln). Entry is a dummy variable equal to 1 if a power station enters, zero otherwise. Exit is a dummy variable equal to 1 if a power station exits, 0 otherwise. Standard errors are clustered at the power plant level and the corresponding t-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table G.2 Contractual Features

	1	2
Dependent variable:	vi_{it}	Price
Post	0.0122	
	(0.27)	
East * Post	-0.0973***	-0.2274***
	(-3.56)	(-3.55)
Fixed price share	-0.0974	-5.7044***
	(-1.36)	(-3.26)
Average duration	-0.0002***	-0.0001
	(-2.91)	(-0.34)
Observations	21,525	26,884
R^2	0.18	0.83
Mine FE	Yes	No
Underground * Year FE	Yes	No
Power station FE	No	Yes
State FE	No	Yes
Month * Year FE	No	Yes
Control variables	Yes	Yes

Notes: These tests rely on the mine-level MSHA data set. t-statistics are reported in parentheses. In column 1 the unreported control variables are identical to those in Table 5 column 3. In column 2 the unreported control variables are identical to those in Table 7 column 2. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table G.2 reports the results of regressions that condition on features of contracts between mines and power stations. In both columns I include controls for the share of fixed price contracts and average contract duration (in years). Each variable is measured at the state-year level and the data are constructed using observations from the CTRD database. Although contract duration is negatively associated with vertical integration the East-Post coefficient estimate remains negative, statistically significant and similar in magnitude to the baseline regressions. The East-Post coefficient is also negative and statistically significant in column 2 of the table where price is the dependent variable. Here I find prices to be lower among mines with a higher share of fixed price contracts. Average duration is insignificant.

Appendix H: Power Station Investments

Table H.1: Power Station Investments

	1	2
Dependent variable: sulfur content (%)		
East * Post	-0.1055*	
	(-1.92)	
East * P		-0.2256***
		(-2.69)
Observations	179,861	179,861
R^2	0.55	0.56
Power plant FE	Yes	Yes
State FE	Yes	Yes
Month * Year FE	Yes	Yes

Notes: These tests rely on the mine-level MSHA data set. The table reports results based on the model used in column 3 of Table 5. t-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Power stations' boilers must be customized to a certain extent for them to be compatible with different types of coal. For example, boilers must be modified so that they can use coal with certain ash and sulfur characteristics Joskow (1987). I therefore present evidence which shows that Eastern power stations undertook investments to make their plants suitable for burning PRB coal.

Unfortunately, power station-level data is not available before 1985. However, given that power stations boilers must be customized to some extent to accept PRB coal it is possible to infer whether investments were made using data on the characteristics of coal shipments purchased by power stations. For example, PRB coal has a considerably lower sulfur content relative to other basins PRB coal has a 0.4% sulfur content versus 1.5-2% in Appalachia and 2.5%+ in the Illinois basins (sulfur content is a geologically fixed characteristic which cannot be manipulated). Investments in retrofitting boilers to accommodate PRB coal would be consistent with a reduction in the sulfur content of the coal in shipments bought by Eastern power stations.

Column 1 of Table H.1 presents evidence consistent with power stations making investments to accept PRB coal. Specifically, post 1985 the sulfur content of shipments to Eastern power stations fell by approximately 0.11 percentage points.