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

Danny McGowan[*][†]

May 2015

Abstract

This paper tests whether product market competition affects vertical integration through the price channel. The identification strategy exploits data on ownership structure and deregulation of the US railroad sector as a source of exogenous variation in competition within the coal mining industry. We document a 28% reduction in the incidence of vertical integration among the treatment group following exposure to more product market competition. Consistent with recent organizational economics theories this effect stems from product market competition increasing industry supply and reducing market prices. This decreased the returns to integration and triggered a significant reduction in the frequency of mergers.

Keywords: Vertical integration, product market competition, market prices.

JEL Codes: D23, L22, L23, L72

---

[*]I am grateful to Ron Chan, Masakazu Ishihara, Richard Kneller, Konstantinos Serfes, Chrysovalantis Vasilakis and participants at the International Industrial Organization Conference 2015 for helpful comments and suggestions. I thank Denny Ellerman for providing data. Samuel Bottom provided excellent research assistance.

[†]University of Nottingham. Email: danny.mcgowan@nottingham.ac.uk. Tel: +44 (0)155 846 7420.

1 Introduction

Why do firms own production chains? Understanding the determinants of organizational design and the choice between interacting inside a firm or through arms-length transactions typically focuses on internal factors such as incentives and firms' technological features. Although bargaining frictions and asset ownership may help determine the relationship between constituents in a supply chain, a recent class of organizational economics models predict that the impetus for vertical integration can also come from elements of the external operating environment.

Legros and Newman (2013) and Conconi et al. (2012) develop a theory of vertical integration in which equilibrium ownership structure depends upon prices. In the model, managers of perfectly competitive firms must decide how to organize production of a final good. Vertical integration enhances productivity by improving coordination between suppliers but imposes high private costs on managers.[1] Under non-integration managers' private costs are low as they retain decision-making authority, but production activities are poorly coordinated leading to low output. Organizational design therefore depends on how much the managers value the extra output integration generates. At low prices the productivity gains of integration translate into low revenue that does not adequately compensate managers for the high costs they must bear. But at higher prices managers choose to integrate as the additional revenue more than offsets the high private costs.

Market forces that change prices can therefore provoke widespread organizational restructuring. Conconi et al. (2012) outline a model to study the ownership implications of product market liberalization. Freeing trade in goods leads to a lower degree of vertical integration. The mechanism works as follows. Product market competition increases supply in the industry which reduces prices. At lower prices non-integration becomes the optimal ownership structure as managers are not willing to forgo their private interests to achieve a small increase in revenue.[2]

[1] Despite being beset by significant identification challenges Kosova et al. (2013), Forbes and Lederman (2010), and Hortacsu and Syverson (2007) present robust evidence of a positive link between vertical ownership and productivity. The theoretical literature has identified numerous ways through which organizational design affects firm performance. Where relationship-specific investments are important but the division of surplus is fraught with bargaining frictions, integration reduces the costs of opportunistic behavior (Williamson, 1975, 1985; Klein et al., 1978; Joskow, 1987). Property rights theories identify alignment of investment incentives with better performance (Grossman and Hart, 1986; Hart and Moore, 1990). Vertical integration can also incentivize multi-tasking (Holmstrom and Milgrom, 1991), and improve coordination (Hart and Holmström, 2010). Moral hazard models highlight productivity gains due to alignment of incentives to exert effort and the rewards of those efforts (Lafontaine and Slade, 2001).

[2] Legros and Newman (2013) also highlight that organizational design may be a function of competition. Alfaro et al. (2014) provide evidence that prices matter for firms' vertical integration decisions.

In this paper, we assess the salient predictions emanating from Conconi et al. (2012) and Legros and Newman (2013) to study how vertical integration responds to product market competition. We depart from existing literature in two respects. One important contribution of our work is to go beyond correlations between measures of product market competition and organization structure to establish causal identification. We also provide new evidence on the precise underlying mechanism. Most studies proceed somewhat more in the transactions cost tradition and find that competition reduces the incidence of vertical integration by eliminating bargaining frictions (McLaren, 2000; Grossman and Helpman, 2002; Acemoglu et al., 2010). Our evidence highlights the importance of the price channel and the associated effects on merger activity. Our tests therefore constitute a proving ground for Organizational Industrial Organization theories (Conconi et al., 2012; Legros and Newman, 2013, 2014; Alfaro et al., 2014; Serfes, 2015).

Identifying the effect of product market competition on firm boundaries presents a steep empirical challenge because firms may integrate to foreclose rivals and soften competition (Salinger, 1988; Hart and Tirole, 1990). To establish causal inferences we leverage a natural experiment in the US coal mining industry. This is a good setting from which to derive more generalizable conclusions. The model states that in a situation where vertical integration increases productivity, it does so at a cost, and the cost is independent of market prices, we expect increasing product market competition to lower the degree of vertical integration. In the case we study, these assumptions are satisfied and we indeed observe less vertical integration.[3] It appears from the data that price declines are especially important.

The heart of our identification strategy is the Staggers Rail Act of 1980 (SRA) which dramatically reduced railroad transportation costs. Pre 1980 the railroad industry was heavily regulated under the 1887 Interstate Commerce Act to prevent operators from exercising monopoly power. This stringent set of measures denied railroads freedom to independently set prices. Railroads were forced to follow a pricing structure established in the 1920s that set high prices for freight and low prices for agricultural goods. This archaic arrangement meant that the cost of transporting coal was high. Electricity plants, the principal consumers of coal, therefore purchased locally to minimize procurement costs: Eastern plants bought coal from Eastern mines whereas Western electricity providers purchased from mines in the West. As a result, pre 1980 the source of competition for Eastern (Western) coal producers were other Eastern (Western) mines.

As we document below, the SRA was triggered by an unanticipated shift in the regula-

[3]Moreover, in the model vertical integration enhances productivity by improving coordination between firms. This appears to be true in coal mining (Buessing, 2014; Coal Age, 2014).

tory body's attitude towards deregulation. Railroad firms were allowed to independently set prices and restrictions on investment were lifted. Between 1980 and 1987 the real cost of transporting coal fell 34% relative to pre 1980 levels. As trains are the principal shipping mode between coal mines and power plants, a by-product of railroad deregulation was a remarkable change in competition within the Eastern coal market. Lower freight rates led Eastern electricity plants to start sourcing coal from Powder River Basin (PRB) mines located on the Montana-Wyoming border.[4] No such change in competition took place in Western markets where geographical proximity enabled Western producers to supply power plants at lower cost than PRB mines. At the same time, the geographic remoteness of the Eastern and Western markets meant there was no market expansion effect for these producers.[5] We can therefore observe the organizational effects of a supply shock in one market and construct a counterfactual using producers in a similar but unaffected market. Our identification strategy therefore relies on difference-in-difference estimations that compare the incidence of vertical integration within the treatment (Eastern mines) and control (Western, non-PRB, mines) groups before and after the competitive shock introduced by the SRA.

There are several reasons why this laboratory is well suited to studying the determinants of vertical integration. First, the SRA constitutes an exogenous shock to competition. This change was driven by presidential appointments of reform-minded members to the railroad regulatory body. The appointments were unrelated to the organization of coal mines, or matters in the wider coal mining industry which at the time accounted for a small share of railroad shipments. Railroad deregulation was also unexpected, even by individuals inside the regulatory agency (Derthick and Quirk, 1985). Second, our setting contains well-defined upstream and downstream sectors. Coal mines excavate coal, but they rely on preparation plants for cleaning services before it may be sold to power plants. Unlike other approaches in the literature that infer vertical integration based on the goods a firm produces in each of its plants and aggregate input-output relationships among those goods, we can directly observe vertical integration.[6] Finally, our data set contains detailed information on shipments between mines and power plants. This provides information on

[4]In this paper PRB mines are not considered to be part of the Western market. Later we outline why this is the case.

[5]The geographic distance between Eastern and Western markets is large, making it prohibitively expensive to ship coal between the two regions. Only PRB producers may ship to both markets and their propensity to do so depends largely on transport costs.

[6]One concern regarding the input-output approach is that recent studies find little evidence of trade flows between plants of the same firm (Atalay et al., 2014; Ramondo et al., 2013). Unlike in other settings, evidence shows that shipments do take place between coal mines and their preparation plants. In addition, where there is measurement error in the dependent variable this attenuates the average treatment effect.

the free on board (FOB) price, quantity, and quality of each coal shipment purchased by power plants in different states and allows us to hone in on whether prices affect ownership structure. Additionally, in the mine-level data we can pinpoint mergers and divestitures to examine the mode through which firms restructure the supply chain.

From this exercise we provide several novel findings that support the theoretical predictions. Our results show that the exogenous increase in competitive pressure felt by Eastern mines caused a decrease in vertical integration. The magnitude of this effect is economically large, highly statistically significant, and robust. Depending on the specification, we obtain estimates of the average treatment effect that range between 28% and 36%. The reduction in vertical ownership is driven by a significant decrease in the frequency of mergers. Using data on coal shipments we find the competitive shock caused a 24% decrease in Eastern coal prices. We also find that the average coal-fired power plant reduced the quantity of coal purchased from Eastern mines by between 3% and 10%. Our results are therefore consistent with the idea that price shocks driven by market forces impact firm boundaries (Legros and Newman, 2008; Conconi et al., 2012; Legros and Newman, 2013; Alfaro et al., 2014; Serfes, 2015).

Firms could restructure in the face of product market competition for other reasons. In the transaction-cost economics paradigm, competition leads to fragmentation because an increase in the number of input suppliers reduces ex post bargaining inefficiencies due to holdup threats (Stigler, 1951; Williamson, 1975, 1985; Klein et al., 1978; McLaren, 2000; Elberfeld, 2002; Grossman and Helpman, 2002; Acemoglu et al., 2010). Alternatively, in more competitive environments firms may decentralize decision making to managers with greater knowledge of local operating conditions (Marin and Verdier, 2003; Alonso et al., 2008a,b, 2009). Other reasons for restructuring could be to reduce slack and increase productivity by closing down the least productive parts of the production chain (Schmidt, 1997; Melitz, 2003; Bernard et al., 2010). We explore these alternative mechanisms but find little support for them in the data. We also do not find a U-shaped relationship between integration and competition as suggested by Aghion et al. (2006). A host of additional robustness tests affirm our key results, exogeneity of treatment, and falling prices as the transmission mechanism.

Our 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.

Existing theories on the competition-vertical integration nexus tend to draw more heavily from the Williamsonian tradition. For example, McLaren (2000) and Grossman and Helpman (2002) develop search models in which competition increases the number of potential input suppliers available to a downstream producer. By thickening the market competition reduces the need for vertical ownership as firms face lower expropriation threats.[7] Aghion et al. (2006) develop a model that predicts a U-shaped relationship between competition and vertical integration. They find supportive associations using UK data. Acemoglu et al. (2010) find that the correlation between competition and the degree of vertical integration differs according to whether competition is felt in the upstream or downstream sector. A larger number of upstream firms reduces hold-up problems and reduces the likelihood of vertical integration, whereas a larger number of downstream firms increases it.[8]

The rest of the paper is structured as follows. Section 2 provides a summary of the theoretical literature which undergirds our empirical analyses. Section 3 outlines the institutional details and our economic laboratory. Section 4 describes the data. In Section 5 we discuss our empirical strategy and report econometric results. Section 6 deals with potential threats to identification. Section 7 concludes.

2 Related Literature

To motivate the empirical analysis and help interpret the results we provide a brief overview of the theoretical apparatus that underpins our paper.

Legros and Newman (2013) and Conconi et al. (2012) embed the model of Hart and Holmström (2010) in a product market setting.[9] Final goods are produced using complementary inputs supplied by two perfectly-competitive firms. Each firm comprises a risk-neutral manager whose utility is a function of monetary profits and non-contractible private costs of effort associated with the firm's organizational design. Production of the final good requires that the two input suppliers enter into a relationship. Managers then make non-contractible production decisions. The problem managers face is that decisions that suit one party will be inconvenient for the other and vice versa. Each manager

[7] In a related study Thesmar and Thoenig (2000) develop a model in which firms' organizational choices are influenced by instability in the product market.

[8] The related decentralization literature shows that delegation is more likely to occur if competition is intense as firms delegate decision-making authority to better informed lower-level managers with greater market knowledge (McAfee and McMillan, 1995; Marin and Verdier, 2003, 2008; Alonso et al., 2008b, 2009; Rantakari, 2011). Bloom et al. (2010) find that competition is associated with more delegation. Guadalupe and Wulf (2010) document that competition causes firms to flatten their organizational hierarchies.

[9] See also Alfaro et al. (2014), Legros and Newman (2014) and Serfes (2015) for similar price theories of vertical integration.

therefore finds it privately costly to accommodate the other's approach.[10]

There exist two possible ownership structures: non-integration and vertical integration. Under non-integration managers retain control of their assets and make independent production decisions. Because managers place too much emphasis on private costs, coordination between suppliers is poor, resulting in low output. Alternatively, managers can choose to vertically integrate. Under vertical integration managers sell their assets and transfer decision rights to a third-party headquarters (HQ) in return for a stake in the business. HQ values profit but has no direct concern for managers' private costs. As HQ values output she enforces a compromise solution that imposes private costs on both managers but improves coordination which raises output relative to non-integration. The private managerial costs embody the private effort related to coordinating production schedules across suppliers, administrative expenses, legal costs, etc.[11] Non-integration therefore has incentive problems as managers place private benefits before organizational goals. Integration on the other hand is a more efficient mode of production but imposes high costs on managers.

Integration decisions therefore constitute a trade-off between output and managers' private costs of effort. In this environment market prices matter because they determine the extent of the revenue gains from integration. At low prices, the additional output brought by vertical integration translates into low revenue which does not sufficiently compensate managers for the greater effort burden they must bear. But at higher prices, managers prefer to integrate because the revenue generated by the productivity gains outweighs the private effort costs.

Based on these insights Legros and Newman (2013) and Conconi et al. (2012) derive an industry supply curve that embodies not only the price-quantity relationship but also the relationship between price and ownership structure as well. This organizationally augmented supply (OAS) curve has three distinct regions shown in Figure 1. When the market price is p^* firms are indifferent between ownership structures leading to a mixed equilibrium (M) where some firms are integrated. Below p^* non-integration is the equilibrium ownership structure. Above p^* managers choose vertical integration.

[Insert Figure 1]

Equilibrium in the product market occurs at a price and quantity that equate demand

[10]An example of this incompatibility in the coal mining industry is that it is convenient for coal mines to send all coal particle sizes to a preparation plant but preparation plants find it difficult to process small particle sizes. Preparation plants are less efficient in processing small particles which necessitates specialist equipment.

[11]The models assume the private costs of vertical integration are independent of market prices.

and supply. Demand and supply shocks can therefore lead to changes in equilibrium ownership structure throughout the industry. It is possible to use the model to simultaneously perform a a supply-and-demand analysis of the comparative statics and equilibrium ownership structure. Increasing product market competition is equivalent to a rightward shift of the OAS. In Figure 1 the increase in supply shifts the OAS to $S(P)'$. Intersection between the demand and OAS curves now occurs at the lower price, $p^{*'}$. At the lower price non-integration is the equilibrium mode of organization. Tougher competition in the product market therefore triggers a lower degree of vertical integration by reducing market prices. These are the predictions we take to the data.

3 Institutional Setting

Our tests on the relationship between product market competition and vertical integration rely on a quasi-experiment in the US coal mining industry. In this section we discuss the key features of coal production and the legislative reforms that underpin the identification strategy.

3.1 The US Coal Mining Industry

Figure 2 shows the four main coal basins in the US. In the East, the Appalachian basin stretches continuously from Pennsylvania in the north to Alabama in the south. The smaller Illinois basin is the other Eastern coal mining region. In the West, mines are scattered across the Unita basin (Arizona, Colorado, New Mexico, and Utah), Oregon, North Dakota, and Washington. The Powder River Basin straddles the Montana-Wyoming border.[12]

[Insert Figure 2]

Coal extraction takes place either in underground or surface mines. 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.[13]

[12] Coal mining also takes place in Texas. These tend to be lignite mines. In the empirical analysis we remove these mines on the grounds that their output is somewhat different to producers in other regions. However, the results are robust to keeping Texas in the sample.

[13] Surface mining relies on massive earth-moving equipment such as draglines to remove the overburden. Power shovels are used to load conveyor belts and large trucks that transport coal to its next destination. These capital-intense operations tend to have low labor requirements and lower marginal costs. Underground methods are broadly split into "room and pillar" and "longwall" techniques. The "room and

The coal production chain is relatively simple, comprising coal mines (upstream producers) and preparation plants (downstream producers). Mines excavate run-of-mine (ROM) coal from the earth. This material contains coal ore as well as contaminants such as rock, clay and mining equipment that breaks off from machinery during excavation. Owing to its high non-ore content, ROM coal must undergo a series of cleaning and breaking procedures at a preparation plant to separate the coal ore from waste materials.[14] Almost all coal must be sent to a preparation plant before it can be burned (Buessing, 2014). After cleaning, the coal ore is loaded onto unit trains, barges or trucks for delivery to a power plant. Trains deliver 74% of shipments, and are more common for long-distance shipments, whereas barges (6%) and trucks (17%) are somewhat less important.

Owing to its high non-ore content ROM coal is bulky and transport costs between mines and preparation plants are high. Mines therefore rely on nearby preparation plants for cleaning services. Buessing (2014) reports that almost all shipments are to preparation plants not further than 10 miles from the mine. Trucks and conveyor belts are used to deliver the ROM coal.

3.2 Coal Prices

The delivered price of coal depends on mine prices and transport costs. Mine prices are an increasing function of heat content as the greater the heat content, the more electricity can be produced from a given quantity of coal. Heat content is measured in British Thermal Units (Btu). The heat content of Appalachian, Illinois, and Unita basin coal is fairly similar but PRB coal has a substantially lower heat content. The low heat content of PRB coal means that it retails at a discount to Eastern and Western coal.[15] Preparation

pillar" process cuts a network of 'rooms' into the coal seam and pillars of coal are left behind to support the roof. The 'rooms' are cut into the coal seam using a continuous miner machine - a large rotating steel drum equipped with teeth that scrape the coalface. Conveyor belts transport the removed coal to the surface. Longwall mining on the other hand relies on a shearing machine that moves mechanically back and forth across a wide coal seam. The coal falls on to a conveyor belt that takes the coal for removal. Longwall systems have their own hydraulic roof supports which advance with the machine as it digs deeper into the coal seam. Once the coal is removed, the roof is allowed to collapse in a safe manner. Longwall methods have become more prevalent over time, but within our sample they account for only 5% of underground operations. A larger number of workers are required in underground mines to operate the various equipment.

[14] Buessing (2014) reports that coal ore makes up approximately 60% of ROM coal. Cleaning entails washing and drying processes that remove debris. The coal ore is then broken into uniform particle sizes to facilitate efficient burning.

[15] Heat content is a geographically fixed trait that depends on coal's pore structure. Average heat content is 12,500 Btu in Central Appalachia, 13,000 Btu in Northern Appalachia, 11,800 Btu in the Illinois Basin, and 11,700 Btu in the Unita Basin. The heat content of PRB coal is 8,800 Btu. Data from the EIA

plants cannot change the heat content of coal.

Geographical idiosyncrasies also contribute to the low price of PRB coal. The PRB has uniquely thick coal seams that lie close to the surface. Stripping ratios are accordingly low, varying between 1:1 and 3:1. PRB mines are therefore surface operations that use huge excavation machinery. Together these features result in exceptionally low marginal costs of production and correspondingly low prices.

3.3 Railroad Deregulation

The Interstate Commerce Commission (ICC) was established in 1887 to regulate railroad operators.[16] The ICC was governed by a chairman and ten other commission members. Members and chairmen owed their appointments to the US president, although presidents could not remove them at will (Derthick and Quirk, 1985). To instigate reforms, chairmen had to command a majority of members' votes.

Regulation was justified by a political desire that the railways operate in the public interest. A major concern was that as the owners of the rail network operators could exercise market power by excluding rivals to set prices above competitive rates (Slack, 2013). Over time the ICC's mandate grew in power to oversee mergers, regulate entry and abandonment of routes, and to control freight rates (Eakin et al., 2010; FRA, 2011).[17] This complex set of regulations prohibited railroads from independently setting rates or negotiating private contracts with shippers. During the 1920s the ICC established a pricing structure that set high rates for freight and low rates for agriculture (Slack, 2013).[18] As a result, pre 1980 the cost of shipping coal was high and rail traffic consisted primarily of agricultural goods.

Deregulation was unexpected. Most contemporary observers expected the ICC to maintain a tight regulatory focus. Derthick and Quirk (1985) note that the ICC was not expected to reduce its regulatory oversight. Part of the reason for this was that the pro-regulation wing of the ICC commanded a handsome majority. However, both the Ford and Carter administrations favored deregulation and chose to appoint reformist members when positions became available.[19] In April 1980 three positions on the ICC committee

show that one ton of PRB coal sells for \$11 compared to \$51 for Eastern and \$37 for Western coal.

[16]Congress could have enacted detailed regulatory statutes but preferred that experts with broad delegations of regulatory authority act on its behalf (Derthick and Quirk, 1985).

[17]The 1906 Hepburn Act and 1910 Mann-Elkins Act authorized the ICC to regulate rates, removing this authority from the states.

[18]This was effectively a means of subsidizing farmers who lacked the shipment volume necessary to obtain more favorable rates (Posner, 1971; MacDonald, 1989).

[19]Beginning in the 1960s, economists' critique of regulation shifted policymakers' views on regulation (Derthick and Quirk, 1985). According to McBride (1983), the shift towards market-based solutions was

became simultaneously available and the President appointed reformist members which radically altered the balance of power and gave the deregulation wing a majority for the first time (Dempsey, 2012). This set in motion the deregulation agenda. In October 1980 these measures were codified by Congress in the Staggers Rail Act.[20]

[Insert Figure 3]

The SRA provides railroads with a high degree of freedom in setting rates (Eakin et al., 2010). This flexibility allows railroads to charge market prices that are substantially lower than those under the regulated regime.[21] The impact of the SRA on rates is clearly shown in Figure 3. Deregulation also spurred productivity innovations through rationalization, improvements to service offerings, and contracting. According to Eakin et al. (2010), 80% of the post 1980 productivity gains were passed on to shippers through lower freight rates.[22] As a result, the real cost of shipping freight by rail has fallen year on year (FRA, 2011).

4 Data

We use three novel data sets for our empirical analysis: mine-level data on ownership structure, shipments data from mines to electricity power plants, and coal transportation data. We obtain the first data set from the Mine Safety and Health Administration (MSHA) and collect shipment and transportation data from the US Energy Information Administration (EIA).

The mine data consist of annual information on employment, production, hours worked, geographical location (latitude, longitude, state, and county), owner, operation type (independently operated, operating subsidiary, or contractor), and organizational design (mine only, preparation plant, or vertical integration) from 1972 to 1987. Each mine has a unique identifier that permits tracking through time.

driven by the Chicago school's influence and the introduction of contestability theory (Baumol, 1982). Presidential views on deregulation were therefore unrelated to matters in the coal mining industry.

[20] It appears that part of the reason why ICC members advocated regulation pre 1980 was that they enjoyed a friendly relationship with railroad companies and often received benefits as a result (Dempsey, 2012).

[21] Approximately 80% of freight traffic now moves unregulated. The SRA limits the ICC's authority to set rates to instances where railroad revenues exceed 180% of variable costs and the shipper does not have an alternative railroad or transportation mode for that shipment (MacDonald, 1989).

[22] The SRA allowed railroads to rationalize their networks by abandoning unprofitable and low-density routes. Industry consolidation led to productivity gains as inefficient firms exited and their market share was reallocated to more productive survivors (Eakin et al., 2010). The remaining incumbents also capitalized on economies of scale (Slack, 2013). Liberalizing rules on investment has led to upgrading of the railroad capital stock and laying double and triple tracks along high-volume routes.

We classify a mine as vertically integrated if there is a preparation plant on site, or if its owner owns a preparation plant within a 10 mile radius of the mine. The reason for this demarcation is that ROM coal is hauled to preparation plants using conveyor belts and trucks. Trucking rates, load size regulations, and local public opinion make it costly to travel long distances (Buessing, 2014).[23] Together 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 our sample lie within 10 miles of the nearest preparation plant. The median distance is 5.7 miles.

Given that Atalay et al. (2014) find little evidence of shipments between vertically integrated cement and ready-mix concrete producers, one could question whether mines actually rely on the preparation plants they own for cleaning services. Although shipments data between mines and preparation plants is not available, reports in the annual *US Preparation Plant Census*, an industry journal published by Coal Age, indicate that mines rely heavily upon their own preparation plants. For example, accidents at preparation plants lead to disruption of production at owners' mines and preparation facilities are purchased and upgraded to accommodate production at operators' mines (Coal Age, 2013, 2014).

The shipments data are taken from EIA Form 423. This collects fuel receipts and fuel quality for each shipment to a fossil-fuel power plant with a generating capacity of 50 megawatts or more. These plants account for 95% of coal-fired electricity capacity and 96% of coal consumption.[24] Each power plant has a unique identifier and we observe every shipment to each plant. For coal shipments the data comprise variables on the quantity of fuel delivered (both tons and Btu), quality indicators (heat content, sulfur content, and ash content), FOB mine price per ton (we deflate prices in real 2009 $ values using the St. Louis Fed price index), coal mine state of origin, and coal mine type (surface or underground). This information is available across the years 1972 to 1987. A limitation of the data is that we do not observe the mine that supplied the coal, only its origin state. EIA Form 423 also contains the same variables for shipments of other energy sources such as gas and petroleum. We use this information to construct measures of demand for coal substitutes.

The final data set is the EIA Coal Transportation Rate Database (CTRD). The CTRD contains coal supply contract data and transportation-related data between mines and power plants. The data were originally collected by the Federal Energy Regulatory Com-

[23]For example, trucks hauling coal have the potential to damage roads and cause deaths or injuries in accidents (NAS, 2007).

[24]Figures are computed using EIA Form 860 data for 1980. Similar values are found for other years.

mission on Form 580, "Interrogatory on Fuel and Energy Purchase Practices", to conduct reviews of certain utility fuel and energy purchase practices as mandated by the Public Utility Regulatory Policies Act of 1978. The survey requires responses from all utilities that either operate at least one power plant of 50 megawatts or greater capacity, or have an ownership interest in a jointly-owned steam-electric station of 50 megawatts or greater capacity. Each observation in the data reports the unique contract number between a power plant (name and unique identifier) and a coal mining company and the year of the shipment.[25] In addition, information on the FOB mine price, state of origin, state of destination, tons shipped, coal quality (Btu shipped, ash content, sulfur content), transport costs, transport mode (barge, conveyor belt, truck, railroad), shipment distance, and the year the contract (between mine and power plant) was signed and expires is provided.[26] These data are available for the period 1979 to 1987.

[Insert Table 1]

A summary of the variables used in the econometric analysis is provided in Table 1. Panel A of Table 1 presents summary statistics for the variables used in the mine-level regressions. 8% of mines in the sample are vertically integrated although the standard error of 0.27 indicates considerable variation. A summary of the EIA Form 423 shipment data variables is reported in Panel B. Panel C contains an overview of some county-level variables we use in robustness tests. A detailed discussion of the variables and their construction may be found in Appendix A.

5 Empirical Results

The econometric analysis proceeds in four steps. First, we explore whether the theory's assumptions are present in our data. Next, we outline the identification strategy. We then test the theoretical predictions. Finally, we study potential mechanisms underlying the main findings.

5.1 Diagnostic Tests

The theory states that in an environment where vertical integration increases productivity, it does so at a cost, and the cost is independent of market prices, we expect increasing product market competition to lower the incidence of vertical integration. We first inspect

[25]It is possible to observe multiple shipments between the same mining company and power plant under a given contract during a given year.

[26]Transport costs are split into fixed charges and transport costs per mile.

whether the models' assumptions are met in our case study. If so, then it is more likely we can derive generalizable conclusions.

Turning first to the productivity effects of vertical integration, we estimate the following reduced form equation

$$\varphi_{it} = \alpha + \beta vi_{it} + X_{it}'\gamma + \phi_i + \phi_t + \varepsilon_{it}, \tag{1}$$

where φ_{it} is productivity in mine i during year t; vi_{it} is a dummy variable equal to 1 if a mine is vertically integrated, 0 otherwise; X_{it} is a vector of control variables; ϕ_i are mine fixed effects; ϕ_t are year fixed effects; ε_{it} is the error term.

The analysis contains two caveats. First, our data set does not contain information on mines' capital stocks or material inputs. We are therefore forced to proxy productivity using output per worker per hour. Reassuringly, Darmstadter (1997) reports that within the coal mining sector labor productivity and TFP are fairly highly correlated. Moreover, using a physical-output productivity variable obviates the potential biases that arise when productivity is estimated using revenue and firm-specific prices are unobserved. Second, we do not claim that estimates of β are causal. However, our design takes several steps to mitigate endogeneity bias. We include mine fixed effects in the estimating equation. The productivity effects of vertical integration are therefore identified through within mine responses to changes in organization. Moreover, we append the model with state-year and county-year fixed effects in subsequent regressions to mitigate potential omitted variable concerns. The latter constitute the tightest specification as they difference away all time-varying confounds that are specific to all producers in a given county. This list may include changes to tax policy, technological developments in the industry, and local infrastructure improvements. It is difficult to envisage what the omitted variable might be. Our approach to eliminating endogeneity bias is therefore similar to the design employed by Hortacsu and Syverson (2007) to investigate the consequences of vertical integration within the cement and ready-mix concrete industries.

[Insert Table 2]

The results in Table 2 indicate support for the model's first assumption. In column 1 vertical integration is estimated to increase productivity by approximately 0.20 tons per worker hour, equivalent to an 8.3% productivity gain relative to the mean. The coefficient estimate is also statistically significant. Buessing (2014) reports that vertical integration enhances productivity through better coordination between mines and preparation plants. Including state-year effects in the estimating equation has little impact on our conclusions. In column 2 we continue to find vertically integrated mines to be significantly more productive. The coefficient now implies a 6.2% productivity increase suggesting that time-varying state-specific shocks account for around one quarter of integrated producers' productivity advantages. Finally, when we condition on county-year effects in column 3 we find vertically integrated coal mines to be 5.9% more productive relative to non-integrated producers. For the average mine in the sample, this equates to an additional 26,000 tons of coal produced annually or $1.43 million in revenue.

Testing for the costs of vertical integration is trivial: if integration is productivity enhancing and costless, all firms would choose integration by default. Given only 8.8% of mines in the sample are vertically integrated it appears integration involves substantial costs. Existing evidence suggests these costs embody both non-contractible costs related to managerial effort provision and monetary factors. For example, Buessing (2014) reports that integrating mining and preparation activities improves coordination between producers but requires greater managerial attention. Data from Coal Age (2009), an industry journal, indicate that the capital costs of preparation plants are substantial. Constructing an average-size plant requires between $8m and $12m. Acquiring one is similarly costly.

Do integration costs correlate with market prices? This does not seem to be the case. According to Coal Age (2009) the main cost determinants are technological factors and idiosyncratic mine-specific attributes related to its location.

Although our inferences are drawn from a quasi experiment, the evidence above indicates that the practical features of the coal mining industry closely overlap OIO models' key assumptions. This raises the likelihood that our findings can be generalized to other settings.

5.2 Identification Strategy

Our strategy to assess the causal impact of product market competition on organizational structure is to use deregulation of the US railroad sector as a natural experiment. As argued in the introduction, this led to an increase in competition between PRB and Eastern coal producers that is exogenous to firm boundaries.

[Insert Table 3] [Insert Table 4]

Key to this approach is the effect of railroad deregulation on transport costs. In Table 3 Panel A we report the results of t-tests that examine the difference in the cost of shipping coal between the pre- and post-treatment periods using the CTRD freight rate data. The data indicate that, on average, real freight rates fell by approximately 60 cents per million Btu after 1980, equivalent to a 30% reduction relative to pre-treatment levels.[27]

[27] The size of this effect is consistent with other estimates and the patterns observed in Figure 3. Eakin et al. (2010) find a 40% decline between 1980 and 1993. Winston (2005) reports a 3.3% annual decrease in coal freight rates between 1982 and 1989.

The effect of these changes on the delivered price of 1 million Btu of coal are evident in Table 4. Before 1980 location was paramount because the costs of shipping coal were high relative to its value at the mine. Despite an FOB price of approximately $1.24, the hypothetical delivered price of PRB coal to Eastern markets was $11.91 whereas Eastern mines could supply the same power plants for $6.74.[28] The large reductions in transportation costs post 1980 led to convergence in the delivered price of coal to Eastern markets. PRB and Eastern mines could now supply Eastern power plants for $1.90 and $1.94 respectively. Darmstadter (1997) highlights that PRB-Eastern transport costs fell more relative to other routes because of significant increases in both track miles and the number of double and triple track miles laid by the two railroads that haul coal from the PRB.

In the West, the pre 1980 delivered price of PRB and Western coal was $4.32 and $0.54 respectively. Despite the innovations in the railroad sector, post 1980 this picture did not change dramatically as PRB coal continued to retail at a substantial premium to Western coal. The main reason for this is the less developed rail network and the geographical proximity of Western coal mines to power plants in the region. This is consistent with the evidence in Panel B of Table 3 that indicates no significant difference in either the number of tons or Btu shipped from the PRB to Western markets between the two periods.

Despite significant reductions in freight rates post 1980 there was no market expansion effect for either Eastern or Western (non-PRB) mines. Even with lower freight rates, the distance between the two regions is too great for transportation to be economically feasible.[29] We briefly explore whether market size, defined as the generation capacity of coal-fired power plants, differentially changed between the Eastern and Western regions through time. In Appendix B we investigate this issue using a difference-in-difference estimator. We find that generation capacity in the two regions evolved in similar fashion and there were no significant differences in market size between the regions post treatment. This implies that demand for coal in the two regions evolved in a very similar way through time. The principal effect of railroad deregulation was therefore to increase product market competition in the Eastern coal market.

Eastern and Western mines appear similar along observable margins. Appendix Table 13 shows broad similarities in the share of underground mines, unionization, and the

[28]Owing to a lack of data, the hypothetical price of PRB-Eastern coal deliveries is calculated using the pre-1980 cost per mile of delivering PRB coal and extrapolating this to calculate the cost of delivery to Eastern markets 1,000 miles away.

[29]The Alchian-Allen conjecture predicts that high quality goods should be shipped furthest. Despite the higher heat content of Eastern coal, transport costs render it infeasible for Western power plants to source coal from Eastern mines, and vice versa.

degree of multi-plant ownership across the regions. Western mines are somewhat more productive due to larger surface mines. We include controls for these variable in the regression equations to ensure that our estimates do not capture differences in, or shocks to, observable characteristics between the treated and control groups.

To assess the effects of product market competition on mines' organizational structure we use a standard difference-in-difference (DID) approach. The essence of our empirical strategy is to leverage the observational equivalence between Eastern and Western (non-PRB) mines and use the SRA as an exogenous shock to product market competition. We then compare the incidence of vertical integration within the treatment (Eastern mines) and control (Western mines) groups before and after 1980. Eastern mines are those located in the Appalachian and Illinois basin states (Alabama, Illinois, Indiana, Kentucky, Ohio, Pennsylvania, Tennessee, West Virginia). We designate Western mines as those in Arizona, Colorado, New Mexico, North Dakota, Oregon, Utah, and Washington. The findings are however robust to using only Unita Basin (Arizona, Colorado, New Mexico, and Utah) mines as Western mines. Accordingly, our empirical specification is the following equation

$$vi_{it} = \alpha + \beta Competition_t + \gamma Eastern_i * Competition_t + X_{it}'\delta + \varphi_i + \varphi_t + \varepsilon_{it}, \qquad (2)$$

where vi_{it} is a binary dependent variable equal to 1 if a mine is vertically integrated, 0 otherwise; $Competition_t$ is a dummy variable equal to 1 for the years 1980 onwards, 0 otherwise; $Eastern_i$ is a dummy variable equal to 1 if a mine is located in either the Appalachian or Illinois coal basin, 0 for Western mines; X_{it} is a vector of control variables; φ_i are mine fixed effects; φ_t are year fixed effects although we also experiment with underground-year effects; and ε_{it} is an error term. The main coefficient of interest, γ, captures the causal effect of competition on vertical integration.[30] Later we show the results are robust to using probit estimations.

5.3 Treatment Exogeneity

Clean identification in this setting relies on on the SRA being an exogenous shock to competition. To meet this criteria, the legislation must be uncorrelated with difficult to observe omitted variables contained in the error term in equation (2). Furthermore, railroad deregulation must not have been undertaken with the objective of changing coal mines' organization structure.

The evidence indicates that the key driver of railroad deregulation was presidential appointments of reform-minded ICC members. The centrality of new ICC appointments is

[30]The Eastern dummy is perfectly collinear with the mine fixed effect and is therefore omitted from the specification.

backed up by MacDonald (1989) who notes that it was, "with the appointment of a reform-minded chairman and commissioner, that the ICC began to move aggressively in the direction of deregulation." Presidential backing for deregulation derived from arguments articulated by economists showing that market-based solutions yielded superior outcomes to regulation (Derthick and Quirk, 1985).[31]

It seems implausible that matters within the coal mining industry triggered the reforms. Pre 1980 farm products and other agricultural commodities accounted for the bulk of rail freight traffic; coal shipments were relatively unimportant (Eakin et al., 2010). Moreover, Caves et al. (2010) report that in 1980 the eventual tremendous growth in coal traffic could not have been anticipated. Part of the reason for this was the massive capital investment required by railroad operators to serve the coal industry would not have been cost effective pre 1980. The reason these investments were made was because the SRA legalized private railroad-shipper contracts which provided railroads with certainty surrounding future revenues.

Railroad deregulation was also 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. Derthick and Quirk (1985) quote an ICC staff member as saying "In the ICC, 'the rate of change was more than anybody dreamed possible'." In addition, contemporary observers did not foresee the large declines in freight rates following deregulation (Winston, 2005).

Together this battery of evidence indicates that the SRA serves as an exogenous shock to product market competition within the coal mining industry.

5.4 Results

The identifying assumption central to a causal interpretation of our DID estimates is that the treated and control mines share parallel trends. We compute this test by estimating the equation

$$vi_{it} = \alpha + Year_t + \gamma_t Eastern_i * Year_t + \varphi_i + \varepsilon_{it}, \quad (3)$$

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

[31] Many economists had become convinced that regulations were contributing to inflation, imposing unjustifiable costs, and reducing growth. Both President Carter and Ford espoused views consistent with this analysis. See Derthick and Quirk (1985) for further details and exact quotes.

Our tests in Figure 4 show that the pre-treatment trends in vertical integration within the treatment and control groups are indeed indistinguishable. During the pre-treatment period there are no significant differences in the degree of vertical integration between the treatment and control groups in any year.

[Insert Figure 4]

The question is, as in any DID set-up, whether the post-treatment trends would have continued to evolve in tandem had there been no increase in product market competition. Our empirical design takes several steps to mitigate this concern. First, we condition on mine fixed effects that eliminate any unobservable time-invariant, mine-specific factors such as managerial quality that may determine organization structure. Second, we include underground-year fixed effects. The source of identification in the model therefore comes through comparing treated and control mines at the same point in time within the same industry segment. This eliminates unobserved time-varying shocks that differentially affect vertical integration across surface and underground mines. Finally, a set of time-varying mine-level variables purge the remaining realistic omitted variables. These design choices deal with mine-level and external challenges to the parallel-trends assumption.

The descriptive evidence in Figure 4 illustrates that organizational structure within Eastern mines began to change following treatment. From 1983 onwards we observe divergence in ownership structures between the two markets with a lower incidence of vertical integration among Eastern mines. Although this constitutes first informal evidence that increasing product market competition leads firms to reorganize the production chain, it prompts the question, why did organizational form not respond immediately to the SRA? The main 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). Data from the Association of American Railroads in Figure 3 shows that freight prices (productivity) began to decrease (increase) from 1983. Once these changes took effect, PRB producers began shipping coal to the Eastern market, and product market competition in the coal mining sector increased.

Although Figure 4 depicts the evolution of vertical integration between the two groups over time, it does not account for mine characteristics, or unobserved heterogeneity. For this we turn to our regression analysis. In Table 5, we report the estimation results of the effect of competition on vertical integration using equation (2). The standard errors are bootstrapped with 100 replications, although the results are no different when various clustering permutations are used instead. We prefer bootstrapping methods to clustering at the market level (a 10 mile radius round each preparation plant) as mines may be present in two or more markets.

The results in column 1 of Table 5 correspond to a simple specification that conditions only on mine and year fixed effects. Notably, the competition variable is positive. This indicates a higher incidence of vertical integration within the control group post 1980.[32] But this pattern is not mirrored in Eastern mines. Rather, as the theory predicts, the coefficient on the interaction term is both negative and highly statistically significant. This suggests that in the face of greater competition Eastern firms chose either not to integrate their mines and preparation plants or to fragment the production chain. The economic magnitude of this effect is large. Given the pre-treatment incidence of vertical integration in the East (4.41%) and the 32 percentage point increase in integration within the control group, this translates into a 31% decrease in vertical integration among treated mines.

[Insert Table 5]

Central to our empirical strategy is that developments in the railroad sector trigger changes in competition within the coal mining industry. To verify that falling railroad transportation costs drive the change in product market competition, in column 2 of Table 5 we proxy competition using the annual railroad TFP index from Schoech and Swanson (2010). The intuition behind this is that increasing railroad TFP captures investments and innovations that lead to falling transport costs and greater product market competition in the Eastern market. Accordingly, we find that as railroad TFP increases Eastern producers are significantly less likely to vertically integrate.[33]

Next, we conduct a series of validation exercises to ensure our findings are not driven by observable and unobservable determinants of vertical integration omitted from the previous specification. When we introduce mine-level controls in column 3, we continue to observe a significant reduction in vertical integration among Eastern mines following the competitive shock. This indicates that the change in competition is essentially random at the mine level, such that the entry of PRB producers into Eastern markets does not coincide systematically with changes in mine characteristics. Economically, the mine-level controls have quite important effects. Mines belonging to multi-plant firms are about 9 percentage points more likely to be integrated whereas the degree of integration is 14 percentage points lower within unionized mines. Conditional on these factors, labor productivity has only a modest impact and the coefficient is imprecisely estimated.

[32] The competition variable is statistically insignificant in subsequent columns of Table 5 suggesting that the control group were unaffected by the shock. The statistical significance of the competition variable in column 1 therefore reflects omitted mine-specific characteristics and time-varying shocks that differentially affect the underground or surface segments of the industry.

[33] This finding is robust to including control variables and underground-year fixed effects in the model. The TFP Rail variable is perfectly collinear with the year fixed effects and hence does not appear in the regression output.

To assess the effect of prices on mines' organizational choices, column 4 includes the mean FOB price per ton of coal in the mine's state-year as a control variable. This yields an estimated sensitivity of 4 percentage points to a one standard deviation increase in prices. Consistent with the predictions made by Conconi et al. (2012) and Legros and Newman (2013), prices correlate positively with vertical integration. Later, we dig deeper into this result. The next set of tests deal with demand-side fundamentals. A unique feature of the EIA Form 423 data is that we are able to observe the price and quantity of coal purchased by power plants across different markets. The estimated coefficient on the coal demand variable shows that demand shocks can induce organizational restructuring. A one standard deviation increase in demand is estimated to increase vertical integration by 1.6 percentage points. This accords with the Legros and Newman (2013) prediction that demand shocks lead firms to vertically restructure because they impact the market price. Specifically, an outward shift of the demand curve increases prices in the industry leading to a higher degree of vertical integration. Given this coefficient is estimated conditional on prices, the demand variable is capturing the quantity effects of demand shocks. Based on the estimated coefficients it therefore appears that prices are quantitatively more important for integration decisions than quantity effects.

Column 5 of Table 5 examines the effect of demand shocks due to changes in the use of substitute fuels. Not all power plants rely exclusively on one type of fuel to generate electricity. Changes in the market price of substitutes may therefore lead power plants to switch to alternative fuel sources or trigger construction of new power plants that do not use coal. Two of the most important competing fossil fuels are gas and petroleum. We find a positive and highly significant correlation between demand for gas and vertical integration within the coal sector, but no effect from petroleum demand. However, both of these variables become insignificant determinants when we include underground-year fixed effects in the model. In column 6 we include coal's heat content as an additional explanatory variable to measure product quality.[34] We uncover a significant positive association between product quality and vertical integration. A likely explanation is that quality is positively correlated with price and in turn vertical integration.

To capture differential trends and developments that asymmetrically affect underground relative to surface mines through time, we append equation (2) with underground-year fixed effects. The average treatment effect estimate in column 7 is nearly identical to the previous findings, despite flooding the model with these dummy variables.

Throughout these specifications we find that including additional control variables in the estimation equation has little effect on the magnitude of the average treatment effect.

[34] Heat content is proxied by the heat content of coal shipments to power plants within the mine's state-year.

This lends further support to the view that the SRA was an exogenous competitive shock: it neither correlates with mine characteristics nor coincides with developments in the wider industry. The average treatment effect we estimate is therefore specific to the reaction of Eastern mines to the increase in product market competition.

Could the observed sensitivity of ownership structure to product market competition simply be random? The standard errors suggest not. Alternatively, are the average treatment effects picking up pre-treatment industry trends or spurious forces? Another way to test the exogeneity assumption is to generate placebo shocks as in Bertrand et al. (2004). We therefore generate a dummy variable $Post - 76$ (equals 1 for the years 1976 to 1979, 0 otherwise) and interact it with the Eastern dummy variable. Since competition did not change until after the SRA was implemented, we know that the null of zero effect on the Eastern x Post-76 interaction is true. This is the case in column 8 where the magnitude of the placebo interaction coefficient is close to zero and statistically insignificant. This is also the case in unreported regressions when we use placebo treatments over longer and shorter horizons during the pre-treatment era.

5.5 Prices

The results of our natural experiment show that greater product market competition causes a reduction in the degree of vertical integration. The next stage of our analysis explores the underlying transmission mechanisms.

OIO theories predict that the organizational effects we observe are driven by reductions in market prices. The models' basic premise is that vertical integration decisions are chosen to mediate conflicts between organizational goals such as profit, and private non-contractible objectives such as managerial effort. Because profits depend on prices, the shock to product market competition reduces prices, leading firms to reorganize the production chain. If the theory is correct, we should therefore be able to document a decrease in the price of Eastern coal post treatment.

To examine this hypothesis we rely on the EIA Form 423 shipment data. The first test isolates the pricing effects of product market competition. We continue to use the SRA as a treatment and estimate the equation

$$price_{ipst} = \alpha + \beta Competition_t + \gamma Eastern_s * Competition_t + X_{it}'\delta + \varphi_p + \varphi_s + \varphi_t + \varepsilon_{ipst}, \quad (4)$$

where $price_{ipst}$ is the price per ton of shipment i to power plant p from origin state s in year t. As before, we include the dummy variable $Competition_t$ and an interaction between $Competition_t$ and $Eastern_s$ to capture the impact of competition on prices in the treatment group. X_{ipst} is a vector of control variables containing information on the heat, sulfur, and ash content of the coal, and a dummy equal to 1 if the shipment was from an underground mine, 0 if from a surface mine; φ_p, φ_s, and φ_t are power plant, mine state of origin, and year fixed effects respectively; ε_{ipst} is the error term.

[Insert Table 6]

The results of these tests are provided in Table 6. In column 1 we find that the price of coal increased by approximately \$30 per ton within the control group post 1980. This finding helps explain the rising incidence of vertical integration within the control group post 1980 in some of the ownership structure tests. However, we find significant differences in the rate of price change according to whether a market was exposed to more competition. The coefficient on the interaction term is negative and highly statistically significant, indicating that prices increased by \$4.34 less per ton in Eastern markets. This translates into an average treatment effect of -6.6%.

Including control variables has very little impact on the coefficient estimates. In Table 6 column 2 the interaction coefficient is -\$5.32, or -8.2%. The relationships among the control variables also make sense. Prices are higher for coal with a greater Btu content, reflecting the fact that high-Btu coal generates more electricity. Sulfur content is negatively associated with prices. This probably reflects power plants searching to use low-sulfur coal to curb greenhouse gas emissions and offset environmental charges imposed by the Clean Air Act of 1970. We find no relationship between ash content and prices, but underground mines receive a somewhat higher price for their output than surface operators. In columns 3 and 4 we repeat the analysis but use the price per million Btu shipped as the dependent variable. The results are unchanged in this specification.

If the price reductions we observe are indeed driven by the entry of PRB suppliers into the Eastern market, we should also be able to document a decrease in the quantity of coal Eastern power plants purchase from Eastern mines post 1980. To implement this complementary test we examine the quantity effects of the supply shock on Eastern producers. We estimate the equation

$$quantity_{pst} = \alpha + \beta Competition_t + \gamma Eastern_s * Competition_t + X'_{ipst}\delta + \varphi_p + \varphi_s + \varphi_t + \varepsilon_{pst}, \quad (5)$$

where $quantity_{pst}$ is either the total number of tons of coal or Btu purchased by power plant p from mines in state s during year t.[35] Including power-plant fixed effects means that the average treatment effect is identified through variation within power plants over

[35] Because of some data irregularities we exclude the years 1972 and 1973 from the sample. The results are, however, qualitatively similar when these years are included.

time.[36]

The results of this test are reported in the remaining columns of Table 6. In column 5 we use total tons of coal shipped as the dependent variable. As in the pricing regressions, the interaction coefficient is estimated to be negative and statistically significant. We find that the average power plant reduced the number of tons purchased from Eastern mines by about 10%. The magnitude of the quantity effect is somewhat smaller when we use Btu shipped as the dependent variable in column 6. Here we find a smaller average treatment effect equal to a 3.6% contraction. Together these findings indicate that increased product market competition precipitated a reduction in final goods' prices in the Eastern coal market as power plants in the region substituted Eastern for PRB coal.

5.6 Mergers and Divestitures

[Insert Table 7]

Although the results in Section 5.4 demonstrate the importance of product market competition in determining firm boundaries, they do not show how resources are transferred. The underlying theory suggests that the lower degree of vertical integration is brought about by integrated suppliers transitioning to non-integration. However, lower prices might also lead non-integrated firms to decide against vertically integrating production, especially where the cost of integration is high. The question of how the change in equilibrium ownership structure comes about is therefore an empirical matter.

The next set of tests examines the market for corporate control. In Table 7 we examine how mergers and divestitures are affected by the competitive shock. The results in column 1 indicate a significant decrease in the probability of mergers. Following the increase in competition Eastern mines were approximately 6% less likely to merge with a preparation plant. This finding is in line with the theoretical prediction that competition lowers the incentive to integrate production. In column 2 we find no effect of competition on divestitures: the interaction coefficient is not significant at the 5% level. This result does not match the theory's prediction of a higher rate of divestitures.

Why might competition have asymmetric effects on the mode of adjustment? One possibility is that mergers incur sunk costs that divesting firms do not face. For example, mergers require large capital outlays to purchase an upstream producer. A reduction in prices lowers expected future profits and makes it more difficult for firms to afford the

[36] In unreported regressions we conduct the analysis at the market-year level. The estimates of the average treatment effect using this setup are quantitatively and qualitatively the same as in the power plant-level regressions.

monetary costs associated with acquiring a target firm. Mergers may also impose non-contractible private costs on managers that divestitures do not. For example, the cost of assimilating corporate cultures, learning about production techniques in the downstream industry, and dealing with frictions arising from subordinating managers in the corporate hierarchy. Such frictions may dissipate through time and are less likely to exist within an already integrated firm. If so, the trade-off between revenue and the managerial quiet life becomes less important.

In columns 3 and 4 of Table 7 we consider whether the integration effects were driven by Eastern mines choosing to build fewer preparation plants or idling existing facilities. The results indicate that this was not the case. In Appendix Table 15 we explore in greater detail how industry dynamics were affected by the competitive shock. Increasing product market competition is likely to reduce expected profits leading to lower entry rates and lower hold-up constraints. However, we do not find this to be the case.

6 Threats to Identification

Our analysis shows that changes in product market competition influence firms' decisions to vertically integrate production. Before we can conclude that the effect of competition is mediated through prices, we need to rule out alternative explanations. Perhaps the biggest threat in this setting is that ownership changes are driven by coincidental changes to ex post bargaining power or decentralization of decision making responsibility. We tackle these issues head on. Some of our tests are also methodological. For example, we consider alternative clustering procedures and how departures from the linear probability model affect the results.

6.1 Market Thickening and Hold-up Problems

According to the transactions-cost view, vertical integration is a solution to contract incompleteness and ex-post bargaining inefficiencies. An upstream producer knows that under market transactions it is more likely to be "held up" when the intermediate input it supplies to a downstream firm must be customized to some extent. The extent of the hold-up threat depends on the number of alternative buyers. Where there is only a limited number of firms on one side of the market, hold-up is more likely and firms vertically integrate to solve bargaining frictions (McLaren, 2000). In the mining context hold-up is more likely in areas with a limited number of preparation plants. In such an environment mines have few outside options which may lead to higher prices for cleaning services.

A potential alternative explanation for our results could be market thickening and attendant decreases in hold-up threats. Prior research has found evidence of a negative correlation between competition and vertical integration through this channel (Hubbard, 2001; Acemoclu et al., 2009). If such effects exist in our data we may wrongly conflate falling prices with market thickening.

It is worth noting that market thickening is likely to be muted in our context. Preparation plants must purchase ROM coal within their vicinity and coal mines cannot relocate to serve them. We therefore test whether there was a significant change in the mine-preparation plant ratio within a 10 mile radius of each mine. The intuition behind this variable is that the mine-preparation plant ratio captures the degree of product substitutability. At high ratios, preparation plants can source coal from several mines and bargaining frictions are therefore greater than at low ratios where the preparation plant must buy a mine's coal to produce any output. Mines therefore face a more credible hold-up threat and may choose to vertically integrate accordingly. To check if the hold-up threat changed through time we estimate equation (2) using the mine-preparation plant ratio as the dependent variable. In column 1 of Table 8 we find the Eastern-Competition interaction term to be statistically insignificant. Hence, there were no changes in bargaining frictions within the treatment group when competition increased. In Table 8 column 2 we also include the mine-preparation plant ratio as a control variable in the vertical integration regression. Our main findings are robust to this change. However, we do not find the mine-preparation plant ratio to be a significant determinant of organization structure at conventional significance levels.

Our inferences remain robust.

[Insert Table 8]

In Appendix D and E we approach this problem from a variety of different angles. For example, we examine industry dynamics to ascertain whether hold-up problems changed due to differential rates of entry and exit within the upstream and downstream sectors. Related to this we investigate if trucks began to haul coal from further afield which may have reduced nearby mines' bargaining power. We also check whether fragmentation is driven by competition forcing low-productivity producers to exit (Melitz, 2003; Asplund and Nocke, 2006). The test results in Appendix Table 15 decisively refute the idea that the changes in ownership structure we observe reflect any of these forces.

6.2 Decentralization of Decision Making

Evidence indicates that when firms face greater competition and lower profit margins they delegate authority to improve efficiency arising from the informational advantages of lower level managers with greater local market knowledge (McAfee and McMillan, 1995). Fragmentation of the production chain in the face of greater competition could therefore reflect subcontracting.

Our mine-level data contain information on each mine's company type. Specifically, we know whether the mine is independently operated, an operating subsidiary, or a contractor. Independent operators are either single-mine firms or managed directly by a corporate headquarters. Subsidiaries on the other hand are delegated decision making authority but are owned by a headquarters. For example, some mining companies own independent mining operations but subcontract to subsidiaries as well. Contractors are hired by coal operators to extract coal, often using equipment leased from the operator. These ownership structures allow us to test directly for changes in decision making.

The first test examines whether the increase in competition differentially affected the incidence of subcontracting between the treatment and control groups. We create a subcontractor dummy sc_{it} (equals 1 if a mine is operated by a subsidiary or contractor, 0 otherwise) and use this as the dependent variable in equation (2). Column 3 of Table 8 shows a significantly lower incidence of subcontracting within Eastern mines after 1980. In column 4 we include the subcontractor dummy in the vertical integration estimation equation to check whether this underlies our main results. The results show it does not. In fact the average treatment effect remains very similar to before and subcontracting is found to be an insignificant determinant of vertical integration. Given the results in column 3 we go further in column 5 and include interaction terms between the subcontractor dummy and the Eastern and Competition variables to rule out differential trends within these groups post treatment. All of the interaction terms are insignificant. The organizational restructuring we observe is therefore not due to delegation of decision-making responsibility in the face of competition.[37]

6.3 Relationship Specificity

A fundamental insight of property rights models is that the boundaries of the firm are chosen to align asset ownership with the incentive to make relationship-specific investments. Because parties can write contracts that are ex ante incomplete but can be completed ex post, bargaining considerations dictate that ownership should be assigned to the party responsible for the most important relationship-specific investments.

Could changes in the relative importance of mines' and preparation plants' relationship-specific investments explain our findings? This seems an implausible explanation as there

[37]In unreported regressions we repeat the specification in column 5 using the mine-preparation plant ratio. All the interaction terms are again statistically insignificant and the main findings are remain robust.

were few changes in operating procedures within both sectors during the sample window. However, environmental reforms under the Clean Air Act of 1970 mandated that power plants reduce particulate emissions. Some power plants responded by installing scrubbers: air pollution control devices that can be used to remove particulates and gases from industrial exhaust streams. Coal ash is one of the main contributor to particulate emissions (Blaschke, 1996), and reducing ash content is one aspect of coal cleaning. Installation of scrubber technology could therefore diminish the importance of investments made by preparation plants leading to changes in organization structure.

We collect state-level data on the share of coal-fired power plants that have installed scrubber technologies from EIA Form 860.[38] We use this as a proxy for relationship-specific investments: higher values indicate a greater incidence of scrubbers and a lower importance of investments by preparation plants. When we include the CAA coverage variable in the regression equation, the main results are unchanged. In column 6 of Table 8 the Eastern-Competition coefficient is similar in magnitude to the baseline specification at -0.0980 and remains statistically significant. However, the CAA coverage variable is negative and significant. Mines in areas where power plants installed scrubber technologies are less likely to be vertically integrated. One explanation could be that the technology mitigates the importance of some cleaning activities undertaken by preparation plants, thereby weakening their bargaining power and reducing the need for vertical integration.

6.4 Demand Shocks

Legros and Newman (2013) predict that demand shocks can spur industry-wide organizational restructuring. Demand shocks that coincide with the SRA are therefore a plausible threat to clean identification in our quasi-experiment. The most salient possibility is that environmental legislation triggered changes in demand according to coal's characteristics such as its sulfur content. Notably, there were no such environmental reforms during our treatment period.

However, some reforms did take place before 1980. The Clean Air Act of 1970 limited emissions from power plants built after 1971 (Tietenberg, 1992). This standard could be met by burning low-sulfur coal. In 1977 Congress amended the Clean Air Act by mandating a 90% cut in sulfur emissions (Hoag and Reed, 2002). All new plants henceforth require scrubbers. This again made high-sulfur coal a viable alternative. If there is time-series variation in regulatory enforcement of the rules, or the composition of power plants (srubbers versus non-scrubbers), these legal changes may introduce other demand shocks.

[38]Data limitations make it impossible to calculate the share of generation capacity that is affected by scrubbers.

Because Eastern coal has a higher sulfur content relative to Western coal, any changes in demand patterns induced by the legislation that are collinear with the SRA will bias the treatment effect of competition. To tackle this problem we include the average sulfur content of coal shipped in each state-year as an additional control variable in the organizational regression. Two features of the results in Table 8 column 7 stand out. First, including sulfur content has little effect on the main findings. The Eastern-Competition interaction coefficient is estimated to be -0.10 which is similar to the baseline estimates, suggesting that sulfur-induced demand shocks are orthogonal to the increase in competition. Second, the sulfur content variable is positive and statistically significant. Mines operating in areas with higher sulfur content are therefore more likely to be integrated. Why this might be is not entirely clear as evidence suggests preparation plants can do little to influence the sulfur content of coal Blaschke (1996). But as the 1977 Clean Air Act Amendments increased demand for high-sulfur coal, a plausible explanation could be that we are capturing positive demand shocks that increase prices and the incentive to vertically integrate.[39]

Another potential source of variation in demand is changes in electricity plants' generating capacity. As shown in column 8 of Table 8 including state-level generating capacity in the estimating equation has no effect on our core finding. However, increasing generating capacity is found to be positively associated with vertical integration. Again, this suggests that increasing demand for coal to meet higher electricity output fosters vertical integration within the coal mining sector. When we include both demand shock variables in the estimating equation the main results are again unchanged (column 9).

6.5 Productivity Effects

At least since Machlup (1967) the literature has investigated the disciplining effects of competition on managers. Although not all studies support this simple intuition (Scharfstein, 1988), Schmidt (1997) outlines a theory in which product market competition leads to a threat-of-liquidation effect which unambiguously induces the manager of inefficient firms to work harder to improve the productivity of her firm.[40]

One way to increase productivity is to vertically integrate. We therefore check whether our results are biased upwards by firms with the greatest managerial slack redesigning

[39] Given the Clean Air Act Amendments were passed in 1977 our average treatment effect estimates could be biased downwards if mines instigated changes before the SRA became effective. This does not seem plausible as the placebo test in Table 5 column 7 shows no change in vertical integration within the treatment group over the period 1976-1980. Repeating the placebo test using 1977-1980 as the placebo treatment yields the same results.

[40] See Schmitz (2005) for empirical evidence.

their ownership structure in response to the competitive shock. To implement this test we winsorize the labor productivity distribution at the 10th percentile and exclude the lowest productivity firms from the regression. If product market competition did lead these producers to vertically integrate to improve productivity we would expect that excluding them from the model would result in smaller average treatment effects. This is not the case in Table 8 column 10. Indeed, the results are near identical when we exclude the lowest quartile of the labor productivity distribution.

6.6 Financial Development

[Insert Table 9]

Existing evidence is mostly inconclusive about the relationship between financial development and vertical integration (Acemoclu et al., 2009). However, credit constraints have been shown to affect organizational design (Nocke and Thanassoulis, 2014), while improvements in financial development may trigger changes in the degree of vertical integration though its impact on the entry of new firms (Macchiavello, 2012). Our sample spans a period of history when important changes to financial development took place in the US as several states lifted restrictions on interstate commercial bank branching that increased lending to the private sector (Jayaratne and Strahan, 1996; Black and Strahan, 2002). Including measures of financial frictions has little bearing on our key results. Column 1 in Table 9 uses total bank lending within the county to proxy access to finance.[41] However, we find no effect of lending on ownership structure.

6.7 U-Shaped Relationship

Aghion et al. (2006) suggest that the relationship between competition and vertical integration is U-shaped. A small increase in competition reduces a firm's incentive to integrate by improving the outside option of non-integrated suppliers and in turn raises their incentive to make relationship-specific investments. However, a large increase in competition raises the firm's incentive to integrate by allowing non-integrated suppliers to capture most of the surplus.

We test for potential non-linearities in the competition-integration relationship using the ratio of PRB to total Btu shipments to mine i's state in year t. Hence, higher ratios indicate more product market competition. Unlike the difference-in-difference setup that

[41] We retrieve bank lending from quarterly Call Reports provided by the Chicago Fed. For each county we aggregate bank lending to the county-year level. Call Report data are available from 1976. Counties are chosen based on evidence that suggests lending relationships are local in nature.

uses the SRA as a treatment, this approach provides a continuous measure of product market competition. To provide overlap with the previous econometric strategy we interact the PRB shipments variable with the Eastern dummy variable. The assumption is that changes in PRB shipments are due to falling transport costs due to the SRA and are therefore exogenous to firm boundaries.

In Table 9 column 2 we find that greater exposure to competition from the PRB significantly reduces the likelihood that a mine is vertically integrated. A one standard deviation increase in PRB shipments reduces the probability of vertical integration by 5.5%. The interaction term is negative and statistically significant. This reinforces our previous finding and provides direct evidence that competition from the PRB led to organizational change within Eastern mines.

To explore potential non-linearities in the competition-vertical integration relationship we generate a squared PRB shipments variable and repeat the analysis. The findings in column 3 of Table 9 show that only the first-order interaction is statistically significant whereas the Eastern times PRB shipments^2 term is insignificant. Why might our findings differ from Aghion et al. (2006)? One explanation could be that their correlations capture omitted variables. This does not appear likely given the large contestability literature that finds lower entry barriers (their competition variable) increase competition. A more plausible explanation is that Aghion et al. (2006) are capturing market thickness effects, whereas in the current setting increasing competition leads to an ever lower market price and a smaller integration surplus.

We therefore re-estimate the pricing regression but use the PRB shipment ratio to measure competition. The results of this regression are reported in Table 9 column 4. A one standard deviation increase in PRB shipments decreases prices by approximately 10%. When we include the interaction between the second-order polynomial expression and the Eastern dummy in the estimating equation we continue to find only the linear interaction to directly affect FOB mine prices (although including both the linear and quadratic terms introduces collinearity into the pricing regression). This supports our conjecture that in this setting a U-shaped relationship between competition and vertical integration does not hold because increasing competition serves only to further reduce the market price. In turn, this lowers the incentive to integrate production.

6.8 Alternative Clustering

[Insert Table 10]

Difference-in-difference estimates are invariably scrutinized based on clustering of the standard errors. Bertrand et al. (2004) highlight that in cases where the dependent variable is serially correlated through time, the DID approach will yield too small standard errors. To counter this possibility we bootstrap the standard errors, but our findings are robust to alternative clustering, such as by market, treatment group-year, state-year and county-year.[42] The results for these tests are reported in Table 10. This exercise suggests that, if anything, the bootstrapped standard errors are conservative.

6.9 Non-Linear Models

[Insert Table 11]

Methods of dealing with discrete dependent variables are well known, particularly within the vertical integration literature given the discreteness of the organization decisions firms make. A natural question is to what extent our results are robust to non-linear estimation techniques. The first point to consider is that in the presence of heteroskedasticity a linear probability model (LPM) will yield inefficient estimates whereas a probit model would produce inconsistent estimates. The most simple remedy is therefore to estimate an LPM with a correction for heteroskedasticity (Lafontaine and Slade, 2007). Our bootstrapped models deal with this problem. Nonetheless, in Table 11 we provide probit estimation results in case the true functional form is a probit. Our main finding is robust to the change in estimation method.[43]

The main issue with the LPM is that it is linear and unbounded whereas the data generating process may be non-linear and the outcome is bounded between 0 and 1. While this may lead to predictions outside the 0-1 range, this only bites when looking at continuous covariates. Because the DID estimator relies on dummy variables which are all bounded between 0 and 1, the treatment effect also has to be bounded between 0 and 1. Although the possibility of overpredictions becomes more complicated with continuous covariates, this does not seem to be the case in our setting as the predicted probabilities lie between 0 and 0.93.

7 Conclusions

Modern organizational economic theory states that market forces have important implications for firms' internal ownership structure. The theoretical literature proposes that firm boundaries are chosen to mediate conflicts between profits and managerial effort. Elements of the external operating environment can therefore provoke organizational restructuring

[42] Markets are defined as a 10 mile radius around each preparation plant.

[43] The marginal effects are calculated following the method of Norton et al. (2004) that accounts for interaction terms in probit models.

because they impact market prices and in turn profits (Conconi et al., 2012; Legros and Newman, 2013). These ideas constitute a radical departure from existing theories of vertical integration that emphasize the role of bargaining frictions and investment incentives. However, there is little systematic evidence exploring these predictions.

The first contribution of this paper is to provide novel evidence that confirms some aspects of OIO theory. Specifically, we present robust empirical evidence that shocks to product market competition lead firms to reorganize the production chain and that this effect is transmitted through market prices. Our tests leverage a natural experiment in the US coal mining industry where an exogenous increase in product market competition due to deregulation of the railroad sector caused a significant decrease in the degree of vertical integration among treated firms. The magnitude of this effect is equivalent to a 30% reduction in vertical ownership. Furthermore, the data reveal that this effect stems from falling market prices due to more intense product market competition.

Our second contribution is to develop an empirical framework that establishes a causal relationship between product market competition and vertical integration. A major challenge empirical researchers in this arena face is identifying exogenous sources of variation in competition. Previous studies on this issue have found a negative correlation between competition and vertical integration and attribute this effect to how competition alleviates ex-post hold-up problems. Whereas the direction of the effect we estimate is consistent with these inquiries the underlying transmission mechanism is different.

This paper is an important step in understanding the role that elements of the external operating environment play in explaining organizational change. We contribute to a rapidly expanding body of evidence that explores how external shocks influence firms' internal organization (Akkus-Clemens, 2012; Alfaro et al., 2014; Breinlich, 2008; Buessing, 2014). While we establish a causal effect, and isolate the underlying transmission mechanism, a key objective for future research is to establish under what conditions market forces lead firms to prefer to reorganize through mergers or divestitures.

References

Acemoclu, D., Johnson, S., and Mitton, T. (2009). Determinants of vertical integration: Financial development and contracting costs. *Journal of Finance*, 64(3):1251–1290.

Acemoglu, D., Aghion, P., Griffith, R., and Zilibotti, F. (2010). Vertical integration and technology: Theory and evidence. *Journal of the European Economic Association*, 8(5):989–1033.

Aghion, P., Griffith, R., and Howitt, P. (2006). Vertical integration and competition. *American Economic Review Papers and Proceedings*, 96(2):97–102.

Akkus-Clemens, S. (2012). The impact of regulation on vertical integration and efficiency: Evidence from the dairy industry. *Unpublished Manuscript*.

Alfaro, L., Conconi, P., Fadinger, H., and Newman, A. (2014). Do prices determine vertical integration? *Harvard Business School Working Papers 10-060*.

Alonso, R., Dessein, W., and Matouschek, N. (2008a). Centralization versus decentralization: An application to price setting by a multi-market firm. *Journal of the European Economic Association*, 6(2-3):457–467.

Alonso, R., Dessein, W., and Matouschek, N. (2008b). When does coordination require centralization? *American Economic Review*, 98(1):145–179.

Alonso, R., Dessein, W., and Matouschek, N. (2009). Organize to compete. *Unpublished Manuscript*.

Asplund, M. and Nocke, V. (2006). Firm turnover in imperfectly competitive markets. *Review of Economic Studies*, 73(2):295–327.

Atalay, E., Hortacsu, A., and Syverson, C. (2014). Vertical integration and input flows. *American Economic Review*, 104(4):1120–1148.

Baker, G. and Hubbard, T. (2003). Make versus buy in trucking: Asset ownership, job design, and information. *American Economic Review*, 93(4):1328–1353.

Baumol, W. (1982). Contestable markets: An uprising in the theory of industry structure. *American Economic Review*, 72(1):1–15.

Bernard, A., Redding, S., and Schott, P. (2010). Multiple-product firms and product switching. *American Economic Review*, 100(1):70–97.

Bertrand, M., Duflo, E., and Mullainathan, S. (2004). How much should we trust difference-in-difference estimates? *Quarterly Journal of Economics*, 119(1):249–275.

Black, S. and Strahan, P. (2002). Entrepreneurship and bank credit availability. *Journal of Finance*, 57(6):2807–2833.

Blaschke, W. (1996). New trends in coal preparation technologies and equipment (recent advances in coal processing. *Gordon and Breach: New York*.

Bloom, N., Sadun, R., and Van Reenen, J. (2010). Does product market competition lead firms to decentralize? *American Economic Review Papers and Proceedings*, 100(2):434–438.

Breinlich, H. (2008). Trade liberalization and industrial restructuring through mergers and acquisitions. *Journal of International Economics*, 76:254–266.

Bresnahan, T. and Levin, J. (2012). Vertical integration and market structure. NBER Working Paper No. 17889.

Buessing, M. (2014). Vertical integration and regulation in us coal production. Boston University Working Paper.

Caves, D., Christensen, L., and Swanson, J. (2010). The staggers act, 30 years later. CATO Institute Working Paper.

Coal Age, . (2009). Several new prep plants completed in 2008. *Unpublished Manuscript*.

Coal Age, . (2013). 2013 us prep plant census. *Unpublished Manuscript*.

Coal Age, . (2014). 2014 us prep plant census. *Unpublished Manuscript*.

Conconi, P., Legros, P., and Newman, A. (2012). Trade liberalization and organizational change. *Journal of International Economics*, 86(2):197–208.

Darmstadter, J. (1997). Productivity changes in u.s. coal mining. Discussion Papers Resources for the Future DP-97-40.

Dempsey, P. (2012). The rise and fall of the interstate commerce commission: The tortuous path from regulation to deregulation of america's infrastructure. *Marquette Law Review*, 95(4):1150–1189.

Derthick, M. and Quirk, P. (1985). *The Politics of Deregulation*. The Brookings Institution: Washington.

Eakin, B., Bozzo, A., Meitzen, M., and Schoech, P. (2010). Railroad performance under the staggers act. CATO Institute Working Paper.

Elberfeld, W. (2002). Market size and vertical integration: Stigler's hypothesis reconsiderede. *Journal of Industrial Economics*, 50(1):23–42.

Forbes, S. and Lederman, M. (2010). Does vertical integration affect firm performance? evidence from the airline industry. *RAND Journal of Economics*, 41(4):765–790.

FRA (2011). Impact of the staggers rail act of 1980. Unpublished Manuscript.

Grossman, G. and Helpman, E. (2002). Integration versus outsourcing in industry equilibrium. *Quarterly Journal of Economics*, 117(1):85–120.

Grossman, S. and Hart, O. (1986). The costs and benefits of ownership: A theory of vertical and lateral integration. *Journal of Political Economy*, 94(4):691–719.

Guadalupe, M. and Wulf, J. (2010). The flattening firm and product market competition: The effect of trade liberalization on corporate hierarchies. *American Economic Journal: Applied Economics*, 2(4):105–127.

Hart, O. and Holmström, B. (2010). A theory of firm scope. *Quarterly Journal of Economics*, 125(2):483–513.

Hart, O. and Moore, J. (1990). Property rights and the nature of the firm. *Journal of Political Economy*, 98(6):1119–1158.

Hart, O. and Tirole, J. (1990). Vertical integration and market foreclosure. Working Paper 548, Massachusetts Institute of Technology (MIT), Department of Economics.

Hoag, J. and Reed, J. (2002). The impact of the clean air acts on coal mining employment in kentucky. *Journal of Regional Analysis and Policy*, 32(2):79–91.

Holmstrom, B. and Milgrom, P. (1991). Transfer pricing and organizational form. *Journal of Law, Economics and Organization*, 7(2):37–62.

Hortacsu, A. and Syverson, C. (2007). Cementing relationships: Vertical integration, foreclosure, productivity, and prices. *Journal of Political Economy*, 115:250–301.

Hubbard, T. (2001). Contractual form and market thickness in trucking. *RAND Journal of Economics*, 32(2):369–386.

Jayaratne, J. and Strahan, P. (1996). The finance-growth nexus: Evidence from bank branch deregulation. *Quarterly Journal of Economics*, 111(3):639–670.

Joskow, P. (1987). Contract duration and relationship-specific investments: Empirical evidence from coal markets. *American Economic Review*, 77(1):168–185.

Klein, B., Crawford, R., and Alchian, A. (1978). Vertical integration, appropriable rents, and the competitive contracting process. *Journal of Law and Economics*, 21(2):297–326.

Kosova, R., Lafontaine, F., and Perrigot, R. (2013). Organizational form and performance: Evidence from the hotel industry. *Review of Economics and Statistics*, 95(4):1303–1323.

Lafontaine, F. and Slade, M. (2001). *Inventive Contracting and the Franchise Decision.* Norwell, Mass: Kluwer Academic Press.

Legros, P. and Newman, A. (2008). Competing for ownership. *Journal of the European Economic Association*, 6(6):1279–1308.

Legros, P. and Newman, A. (2013). A price theory of vertical and lateral integration. *Quarterly Journal of Economics*, 128(2):725–770.

Legros, P. and Newman, A. (2014). Contracts, ownership, and industrial organization: Past and future. *Journal of Law, Economics, and Organization.*

Macchiavello, R. (2012). Financial development and vertical integration: Theory and evidence. *Journal of the European Economic Association*, 10(2):255–289.

MacDonald, J. (1989). Railroad deregulation, innovation, and competition effects of the staggers act on grain transportation. *Journal of Law and Economics*, 32(1):63–95.

Machlup, F. (1967). Theories of the firm: Marginalist, behavioral, managerial. *American Economic Review*, 57():1–33.

Marin, D. and Verdier, T. (2003). Globalization and the new enterprise. *Journal of the European Economic Association*, 1(2-3):337–344.

Marin, D. and Verdier, T. (2008). Power inside the firm and the market: A general equilibrium approach. *Journal of the European Economic Association*, 6(4):752–788.

McAfee, R. and McMillan, J. (1995). Organizational diseconomies of scale. *Journal of Economics and Management Strategy*, 4(3):399–426.

McBride, M. (1983). Spatial competition and vertical integration: Cement and concrete revisited. *American Economic Review*, 73(5):1011–1022.

McLaren, J. (2000). 'globalization' and vertical structure. *American Economic Review*, 90(5):1239–1254.

Melitz, M. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 71(6):1695–1725.

NAS (2007). *Coal: Research and Development to Support National Energy Policy.* The National Academies Press, Washinton, D.C.

Nocke, V. and Thanassoulis, J. (2014). Vertical relations under credit constraints. *Journal of the European Economic Association*, 12(2):337–367.

Norton, E., Wang, H., and Ai, C. (2004). Computing interaction effects and standard errors in logit and probit models. *Stata Journal*, 4(2):154–167.

Posner, R. (1971). Taxation by regulation. *Bell Journal of Economics*, 2(1):22–50.

Ramondo, N., Rappoport, V., and Ruhl, K. (2013). The proximity-concentration tradeoff under uncertainty. *Review of Economic Studies*, 80(4):1582–1621.

Rantakari, H. (2011). Organizational design and environmental volatility. *Journal of Law, Economics and Organization*, 29(3):569–607.

Salinger, M. (1988). Vertical mergers and market foreclosure. *Quarterly Journal of Economics*, 103:345–356.

Scharfstein, D. (1988). Product market competition and managerial slack. *RAND Journal of Economics*, 19:147–155.

Schmidt, K. (1997). Managerial incentives and product market competition. *Review of Economic Studies*, 64(2):191–213.

Schmitz, J. (2005). What determines productivity? lessons from the dramatic recovery of the u.s. and canadian iron ore industries following their early 1980s crisis. *Journal of Political Economy*, 113(3):582–625.

Schoech, P. and Swanson, J. (2010). Patterns of productivity growth for u.s. class i railroads: An examination of pre- and post-deregulation determinants. *LRCA Working Paper*.

Serfes, K. (2015). A price theory of vertical and lateral integration under two-sided productivity heterogeneity. *Drexel University Working Paper*.

Slack, B. (2013). *Rail Deregulation in the United States*. New York: Routledge.

Stigler, G. (1951). The division of labor is limited by the extent of the market. *Journal of Political Economy*, 59(3):185–193.

Thesmar, D. and Thoenig, M. (2000). Creative destruction and firm organization choice. *Quarterly Journal of Economics*, 115(4):1201–1237.

Tietenberg, T. (1992). Environmental and natural resource economics. *New York: Harper Collins*.

Williamson, O. (1975). Markets and hierarchies: Analysis of antitrust implications. *New York Free Press*.

Williamson, O. (1985). The economic institutions of capitalism. *New York Free Press*.

Winston, C. (2005). The success of the staggers rail act of 1980. *AEI-Brookings Joint Center for Regulatory Studies*.

Tables

Table 1: Summary Statistics

	Obs.	Mean	Std. Dev.	Min	Max	Aggregation	Source
A: Mine-level variables							
Vertical integration	20,995	0.09	0.28	0	1	Mine	MSHA mine-level database
Union	20,995	0.29	0.45	0	1	Mine	MSHA mine-level database
Multi-plant	20,995	0.33	0.47	0	1	Mine	MSHA mine-level database
Tons per hour	20,995	2.50	2.29	0	162.64	Mine	MSHA mine-level database
Coal price	20,995	0.68	0.23	0.04	1.18	State	EIA Form 423
Coal demand	20,995	0.13	0.07	0	0.36	State	EIA Form 423
Gas demand	20,995	12.57	8.56	-16.12	18.15	State	EIA Form 423
Petroleum demand	20,995	14.57	2.28	-16.12	18.08	State	EIA Form 423
Btu content	20,995	9.38	0.04	8.98	9.44	State	EIA Form 423
Merger	16,470	0.22	0.41	0	1	Mine	Author's calculations
Divest	16,470	0.04	0.21	0	1	Mine	Author's calculations
Prep built	16,470	0.01	0.07	0	1	Mine	Author's calculations
Prep idle	16,470	0.00	0.05	0	1	Mine	Author's calculations
Mine-prep ratio	20,955	6.47	7.46	0	85	Mine	Author's calculations
Sub contract	20,955	0.48	0.50	0	1	Mine	MSHA mine-level database
CAA coverage	20,995	0.28	0.21	0	1	State	EIA Form 860
Sulfur content	20,995	0.57	0.28	-0.97	1.15	State	EIA Form 423
Generating capacity	20,995	24.97	0.82	-18.42	25.44	State	EIA Form 423
Total loans	20,995	10.23	4.24	-2.30	17.22	County	Call Reports

Table 1: Summary Statistics Cont'd

TFP Rail	20,995	1.18	0.15	0.92	1.43	National	Schoeck and Swanson (2010)
PRB shipments	20,995	29.79	16.60	0	77.78	State	CTRD and EIA Form 423
PRB shipments^2	20,995	1163.13	848.77	0	6050.39	State	CTRD and EIA Form 423
B: Form 423 variables							
Mine price	159,076	53.81	29.60	0.55	766.57	Shipment	EIA Form 423
Mine price (mBtu)	159,076	8.30	0.57	3.88	11.09	Shipment	EIA Form 423
Underground	159,076	0.29	0.46	0	1	Shipment	EIA Form 423
Btu content	159,076	11,529.79	971.37	5,147	18,000	Shipment	EIA Form 423
Sulfur content	159,076	2.00	1.18	0	74	Shipment	EIA Form 423
Ash content	159,076	13.11	4.30	0	48.70	Shipment	EIA Form 423
Quantity (tons)	26,704	3.39	0.97	0.58	7.98	Utility	EIA Form 423
Quantity (Btu)	26,704	10.49	1.05	8.79	15.47	Utility	EIA Form 423
C: County-level variables							
Prep entry rate	1,893	0.05	0.19	0	1	County	EIA Form 423
Mine entry rate	2,475	0.16	0.25	0	1	County	EIA Form 423
Prep exit rate	991	0.00	0.02	0	0.50	County	EIA Form 423
Mine exit rate	2,045	0.00	0.02	0	1	County	EIA Form 423

Table 2: Productivity Effects of Integration

	1	2	3
vi_{it}	0.2095***	0.1541***	0.1476**
	(3.46)	(2.61)	(2.25)
Union	-0.2346***	-0.2520***	-0.2134***
	(-3.59)	(-3.28)	(-3.01)
Multi-plant	0.0341	0.0416	0.0718
	(0.35)	(0.41)	(0.62)
Coal price	1.0765**	3.0510***	2.9383***
	(2.20)	(4.60)	(4.11)
Demand	2.8244***	1.3471*	2.1477**
	(4.90)	(1.83)	(2.09)
Btu content	2.2555*	-1.3662	-4.3385
	(1.74)	(-0.51)	(-1.28)
Mine FE	x	x	x
Year FE	x		
State-year FE		x	
County-year FE			x
N	20,955	20,955	20,955
R^2	0.02	0.05	0.15

Notes: The dependent variable in all columns is the number of tons produced per worker per hour. Standard errors are clustered at the mine level and the corresponding t-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table 3: Diagnostic Tests

Variable	Pre	Post	Diff.	t-statistic
A: Freight Rates				
Freight rates	0.68	0.32	-0.36	-2.09**
	(0.17)	(0.06)	(0.17)	
B: PRB Shipments to the West				
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: Panel A reports a t-test on the null of equality between pre 1980 and post 1980 freight rates. Freight rates are measured as the real 2011 cost per mile of transporting 1 million Btu. Data are taken from the CTRD. We proxy pre 1980 values using data from 1979. Panel B reports the results of a t-test on the null of equality between pre and post 1980 PRB shipments to Western markets. Data are taken from the CTRD. Again we proxy pre 1980 values using data from 1979.

Table 4: Delivered Prices

Origin:Destination	Distance	Pre 1980	Post 1980
PRB:East	1,200	11.91	1.90
PRB:West	347	4.32	1.42
East:East	336	6.74	1.94
West:West	262	0.54	0.32

Notes: This table 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 2011 $ delivered price of coal. Data are taken from the CTRD database. The Pre 1980 delivered price of PRB coal to the East is calculated as the average mine price per 1 million Btu ($1.24) plus 1,200 times the mean cost of transporting PRB coal per mile reported in the CTRD.

Table 5: Organizational Design Results

	1	2	3	4	5	6	7	8
Competition	0.3199***		0.2601***	0.0079	0.0270	0.0883**	0.0038	0.2154***
	(9.45)		(8.94)	(0.19)	(0.61)	(2.21)	(0.08)	(6.05)
Eastern * Competition	-0.1059***		-0.0998***	-0.0768***	-0.0748***	-0.1045***	-0.1089***	-0.1024***
	(-3.50)		(-3.41)	(-2.71)	(-2.68)	(-4.26)	(-3.60)	(-3.22)
Eastern * TFP Rail		-0.4617sym***						
		(-3.75)						
Union			-0.1382***	-0.1326***	-0.1308***	-0.1299***	-0.1064***	-0.1064***
			(-9.19)	(-8.93)	(-7.67)	(-8.01)	(-6.45)	(-6.27)
Multi-plant			0.0888***	0.0897***	0.0890***	0.0887***	0.0949***	0.0949***
			(9.22)	(10.30)	(9.29)	(8.52)	(9.51)	(11.01)
Tons per hour			0.0031	0.0026	0.0025	0.0024	0.0014	0.0014
			(1.54)	(1.43)	(1.38)	(1.58)	(1.15)	(1.17)
Coal price				0.2700***	0.2380***	0.1862***	0.1961***	0.1964***
				(5.78)	(5.52)	(4.10)	(4.08)	(3.83)
Coal demand				0.3426***	0.3583***	0.2656***	0.1161	0.1137
				(5.50)	(5.71)	(4.48)	(1.61)	(1.50)
Gas demand					0.0012***	0.0010***	0.0003	0.0003
					(4.83)	(4.75)	(1.26)	(1.45)
Petroleum demand					0.0005	0.0009	0.0008	0.0006
					(0.61)	(1.22)	(0.83)	(0.72)
Btu content						0.7675***	0.7613***	0.7697***
						(5.44)	(5.65)	(6.11)
Post-76								-0.1963***
								(-4.10)
Eastern * Post-76								-0.0223
								(-0.87)
Mine FE	x	x	x	x	x	x	x	x
Year FE	x	x	x	x	x	x		x
Underground-year FE							x	
N	20,955	20,995	20,955	20,955	20,955	20,955	20,955	20,955
R^2	0.13	0.13	0.16	0.16	0.16	0.16	0.19	0.19

Notes: Standard errors are bootstrapped using 100 replications and the corresponding t-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table 6: Pricing and Demand Results

	1	2	3	4	5	6
Dependent variable:	Price (ton)	Price (ton)	Price (mBtu)	Price (mBtu)	Quantity) (tons)	Quantity (Btu)
Competition	29.6536***	30.3198***	0.7995***	0.7986***	0.2600***	0.2637***
	(51.58)	(67.61)	(77.92)	(69.91)	(13.01)	(16.18)
Eastern * Competition	-4.2371***	-5.3205***	-0.4067***	-0.4078***	-0.3815***	-0.3927***
	(-9.48)	(-9.01)	(-54.54)	(-40.42)	(-27.12)	(-24.34)
Btu content		0.0015***			-0.0000	
		(17.00)			(-1.32)	
Sulfur content		-3.0677***		-0.0739***	-0.0519***	-0.0606***
		(-25.41)		(-18.08)	(-7.30)	(-8.39)
Ash content		0.0014		0.0102***	0.0159***	0.0074***
		(0.07)		(29.73)	(7.97)	(3.69)
Underground		2.4582***		0.0066***	-0.1243***	-0.1345***
		(24.15)		(3.76)	(-23.68)	(-15.25)
Power plant effects	x	x	x	x	x	x
State effects	x	x	x	x	x	x
Year effects	x	x	x	x	x	x
N	159,076	159,076	159,076	159,076	26,704	26,706
R^2	0.76	0.77	0.75	0.76	0.73	0.73

Notes: The dependent variable in columns 1 and 2 is the price per ton of coal. In columns 3 and 4 the dependent variable is the price per 1 million Btu in natural logarithms. Columns 1-4 report results from shipment-level regressions. In these regressions Btu, sulfur, and ash content correspond to that shipment. Underground is an indicator equal to 1 if the shipment came from an underground mine, 0 otherwise. The dependent variable in columns 5 and 6 aggregates the shipment-level data to the power plant-origin state-mine type level, i.e. shipments to power plant p from state s from mine type u during year t. Btu, sulfur, and ash content are the mean value for shipments. Standard errors are bootstrapped using 100 replications and the corresponding t-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table 7: Ownership Adjustment Mechanisms

	1	2	3	4
Dependent variable	Merger	Divest	Prep build	Prep idle
Competition	1.2472***	0.1048***	0.0397**	0.0153
	(20.89)	(2.76)	(2.05)	(0.59)
Eastern * Competition	-0.0625**	-0.0248	-0.0178	-0.0243
	(-2.07)	(-1.43)	(-1.12)	(-1.39)
Control variables	x	x	x	x
Mine FE	x	x	x	x
Underground-year FE	x	x	x	x
N	16,470	16,470	16,470	16,470
R^2	0.49	0.13	0.02	0.01

Notes: We estimate the equation $y_{it+1} = \alpha + \beta Competition_t + \gamma Eastern{*}Competition_{it} + X_{it}'\delta + \varphi_i + \varphi_t + \varepsilon_{it}$, where y_{it+1} is a dependent variable equal to 1 if a mine merges/divests/builds a preparation plant/idles a preparation plant in year $t+1$, 0 otherwise. We model mergers and divestitures in period $t+1$ as it may take time for organizational changes to be implemented. The unreported control variables are the union dummy, multi-plant firm, tons per hour, coal price, coal demand, gas demand, petroleum demand, and Btu content. Standard errors are bootstrapped using 100 replications and the corresponding t-statistics are reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table 8: Robustness Testing

	1	2	3	4	5	6	7	8	9	10
Dependent variable	MP ratio	vi_{it}	sc_{it}	vi_{it}	vi_{it}	vi_{it}	vi_{it}	vi_{it}	vi_{it}	vi_{it}
Competition	-12.5856***	-0.0027	-0.0914	0.0040	0.0132	-0.0035	-0.0368	-0.0874	-0.1190**	0.0045
	(-9.91)	(-0.05)	(-0.72)	(0.09)	(0.22)	(-0.06)	(-0.66)	(-1.42)	(-2.55)	(0.09)
Eastern * Competition	0.6968	-0.1085***	-0.0449**	-0.1088***	-0.1176***	-0.0980***	-0.1046***	-0.0473*	-0.0480*	-0.0969***
	(1.48)	(-3.63)	(-2.11)	(-3.78)	(-3.12)	(-3.54)	(-3.57)	(-1.68)	(-1.82)	(-3.24)
MP ratio		-0.0005*								
		(-1.75)								
sc_{it}				0.0020	0.0144					
				(0.27)	(0.13)					
Eastern * sc_{it}					-0.0120					
					(-0.10)					
Competition * sc_{it}					-0.0150					
					(-0.28)					
Eastern * Competition * sc_{it}					0.0146					
					(0.27)					
CAA coverage						-0.0747***				
						(-3.93)				
Sulfur content							0.0959***		0.0908***	
							(5.16)		(4.34)	
Generating capacity								0.0979***	0.0905***	
								(3.84)	(3.90)	
Mine effects	x	x	x	x	x	x	x	x	x	x
Underground-year effects	x	x	x	x	x	x	x	x	x	x
Control variables	x	x	x	x	x	x	x	x	x	x
N	20,995	20,955	20,955	20,955	20,955	20,955	20,955	20,955	20,955	18,961
R^2	0.37	0.19	0.03	0.19	0.19	0.19	0.19	0.19	0.19	0.17

Notes: This table reports estimates of equation (1). MP ratio is the mine-to-preparation plant ratio within a 10 mile radius of each mine. sc_{it} is a dummy variable equal to 1 if a mine is operated either by a subsidiary or a contractor, 0 otherwise. Sulfur content is the mean sulfur content of coal shipped from mine i's state-year in the EIA Form 423 database. Generating capacity is the natural logarithm of the total megawatts of capacity at coal-fuelled power plants in mine i's state-year. Standard errors are bootstrapped using 100 replications and the corresponding t-statistics are reported in parentheses. The unreported control variables included in the regressions are union, multi-plant, tons/hr, coal price, coal demand, gas demand, petroleum demand, and Btu content. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table 9: Further Robustness Tests

	1	2	3	4	5
	vi_{it}	vi_{it}	vi_{it}	Price	Price
Competition	0.0101				
	(0.17)				
Eastern * Competition	-0.1066***				
	(-3.56)				
Total loans	-0.0006				
	(-0.30)				
PRB shipments		-0.0034**	-0.0047	-0.0561	5.8858***
		(-2.01)	(-0.54)	(-0.83)	(10.23)
Eastern * PRB shipments		-0.0056***	-0.0207**	-0.6266***	-1.1445**
		(-3.04)	(-2.17)	(-11.25)	(-2.51)
PRB shipments^2			-0.0000		-0.0539***
			(-0.55)		(-12.16)
Eastern * PRB shipments^2			0.0003		-0.0134
			(1.41)		(-1.54)
Control variables	x	x	x	x	x
Mine effects	x	x	x		
Underground-year effects	x	x	x		
Power plant effects				x	x
State effects				x	x
Year effects				x	x
N	20,955	20,955	20,955	159,076	159,076
R^2	0.19	0.19	0.19	0.52	0.52

Notes: Interstate deregulation is a dummy variable equal to 1 if a state allows interstate bank branching, 0 otherwise. Standard errors are bootstrapped using 100 replications and the corresponding t-statistics are reported in parentheses. In columns 1-3 the unreported control variables included in the regressions are union, multi-plant, tons/hr, coal price, coal demand, gas demand, petroleum demand, and Btu content. In columns 4 and 5 the unreported control variables are the underground dummy variable, BTU, sulfur and ash content of the shipment. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table 10: Alternative Clustering

	1	2	3	4
Cluster level	Mine market	Treatment year	State year	County year
Competition	0.0038	0.0038	0.0038	0.0038
	(0.07)	(0.05)	(0.05)	(0.05)
Eastern * Competition	-0.1089***	-0.1089**	-0.1089**	-0.1089***
	(-5.06)	(-2.37)	(-2.16)	(-2.71)
Control variables	x	x	x	x
Mine effects	x	x	x	x
Underground-year effects	x	x	x	x
N	20,955	20,955	20,955	20,955
R^2	0.67	0.67	0.67	0.67

Notes: This table reports estimates of equation (1) but clustering the standard errors at different levels. Mine market denotes all preparation plants within a 10 mile radius of each preparation plant. Where mines overlap markets we assign them to the nearest preparation plant market. t-statistics are reported in parentheses. The unreported control variables included in the regressions are union, multi-plant, tons/hr, coal price, coal demand, gas demand, petroleum demand, and Btu content. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Table 11: Probit Results

	1
Competition	0.0852*
	(1.73)
Eastern * Competition	-0.1283***
	(-3.71)
Mine effects	x
Control variables	x
Underground-year effects	x
N	20,995

Notes: This table reports probit estimates of equation (2). The marginal effects are computed using the procedure recommended by Norton, Wang, and Ai (2004). The standard errors are bootstrapped using 100 replications and the corresponding t-statistics are reported in parentheses. The unreported control variables included in the regressions are union, multi-plant, tons/hr, coal price, coal demand, gas demand, petroleum demand, and Btu content. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

Figures

Figure 1: Organizationally Augmented Supply Curve

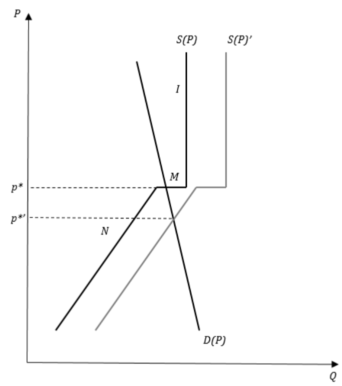
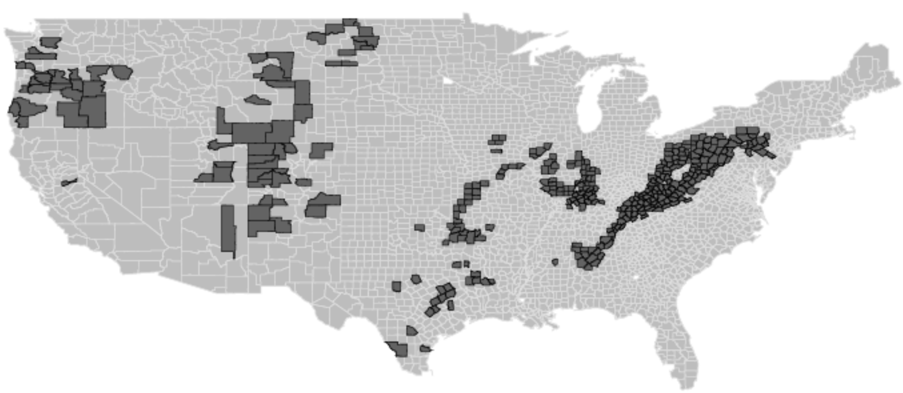
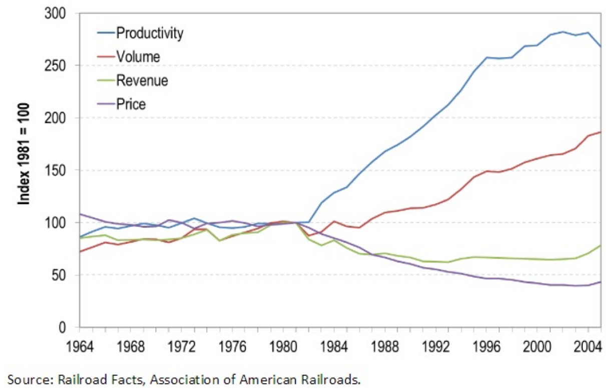


Figure 2: Location of Coal Mines



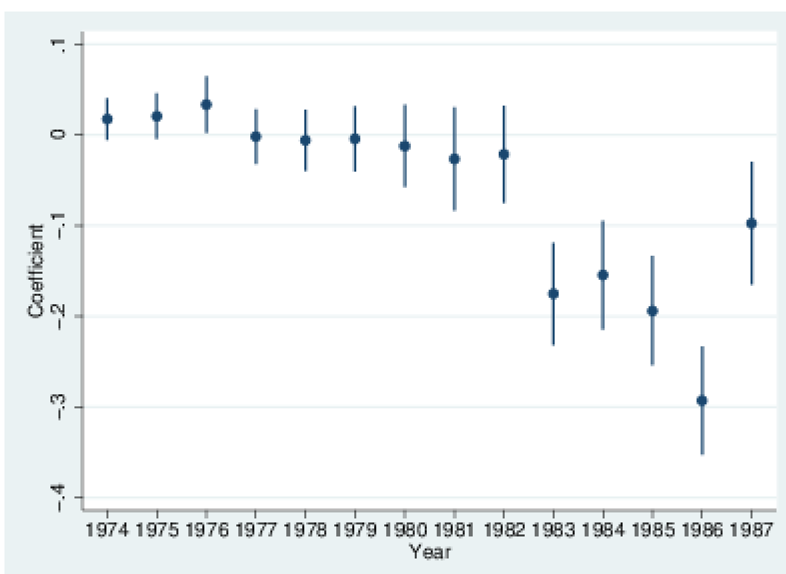
Notes: This figure shows the location of coal mines throughout the continental US. Dark counties contain at least one coal mine. Light counties contain zero coal mines. The Powder River Basin consists of the Montana counties of Big Horn, Custer, Powder River, Rosebud, and Treasure and the Wyoming counties of Campbell, Converse, Crook, Johnson, Natrona, Niobrara, Sheridan, and Weston.

Figure 3: Prices and Productivity in the Railroad Sector



Notes: This figure shows the time-series evolution of prices, productivity, revenue, and volume of shipments within the railroad sector 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 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 Eastern * Year interaction. 95% confidence intervals are denoted by vertical lines.

Supplementary Appendix

Appendix A: Variable Description

Mine-level variables

Vertical integration is a dummy variable equal to 1 if a mine owns a preparation plant within a 10 mile radius of the mine, 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.

Tons per hour is the ratio of total output to total hours worked in a mine during the year.

Coal demand is the total number of tons of coal purchased by power plants from mine i's state during year t.

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

Gas demand is the total quantity of gas purchased by power plants in mine i's state during year t.

Petroleum demand is the total quantity of petroleum purchased by power plants in mine i's state during year t.

Btu content measures the number of British thermal units per pound of coal.

Mine-prep ratio is the ratio of the number of mines to preparation plants within a 15 mile radius of mine i. We choose a 15 mile radius as a conservative threshold although the results are robust to using alternative radii.

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

CAA coverage measures the ratio of utilities operating in a state-year that have installed scrubber technologies to the total number of operating utilities.

Sulfur content is the mean number of pounds of sulfur per million Btu of shipments from mine i's state during year t.

Ash content is the percentage of ash material per ton of coal in shipments from mine i's state during year t.

Generating capacity measures the total number of megawatts of installed capacity at coal-fired power plants in mine i's state during year t. In the market size tests we use the total number of megawatts of installed capacity at coal-fired power plants in state s in year t.

Total loans is the sum of lending by banks in mine i's county during year t. Data are taken from Call Reports provided by the Chicago Fed.

TFP Rail is annual railroad TFP, taken from Schoech and Swanson (2010). Because the series only begins in 1974 we impute values for 1972 and 1973 (equal to the 1974 values) based on evidence in Slack (2013) that railroad productivity was flat over this period. The results are unchanged when we omit 1972 and 1973 from the regression equations.

PRB shipments measures the ratio of Btu shipments from the PRB relative to total Btu shipments in mine i's state during year t.

EIA Form 423 variables

Mine price is the FOB mine price per ton of shipment i to power plant p in state s during year t.

Mine price (mBtu) is the FOB mine price per million Btu of shipment i to power plant p in state s during year t.

Btu content is the number of British thermal units per pound of coal in shipment i to power plant p in state s during year t.

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.

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

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

County-level variables

Prep entry rate is the ratio of the number of entering preparation plants to the number of continuing preparation plants in county c during year t. A preparation plant is deemed to be an entrant when its unique MSHA identifier is present in year t but not in year $t-1$. Continuers are preparation plants observed in both year t and $t-1$.

Mine entry rate is the ratio of the number of entering mines to the number of continuing mines in county c during year t. A mine is deemed to be an entrant when its unique MSHA identifier is present in year t but not in year $t-1$. Continuers are mines observed in both year t and $t-1$.

Prep exit rate is the ratio of the number of exiting preparation plants to the number of continuing preparation plants in county c during year t. A preparation plant is deemed to be an exitor when its unique MSHA identifier is present in year t but not in year $t+1$.

Mine entry rate is the ratio of the number of exiting mines to the number of continuing mines in county c during year t. A mine is deemed to be an exitor when its unique MSHA identifier is present in year t but not in year $t+1$.

Appendix B: Market Size

To analyze changes in market size we calculate the total generating capacity of coal-fired electricity power plants in each state between 1972 and 1987 from EIA Form 759. States are then assigned to either the East or West as before. We then estimate the equation

$$capacity_{it} = \alpha + \beta Competition_t + \gamma Eastern_i * Competition_t + \varphi_i + \varphi_t + \varepsilon_{it}, \quad (6)$$

where $capacity_{it}$ is electricity generating capacity (in megawatts) in state i during year t; $Competition_t$ is a dummy variable equal to 1 for the years 1980 onwards, 0 otherwise; $Eastern_i$ is a dummy variable equal to 1 if a state is located in either the Appalachia or Illinois coal basin, 0 for Western states; φ_i are state fixed effects; φ_t are year fixed effects; and ε_{it} is an error term. The results of this regression are reported in Table 12.

Table 12: **Market Size**

	1
Competition	1.6150***
	(5.33)
Eastern * Competition	-0.3135
	(-0.57)
State effects	x
Year effects	x
N	333
R^2	0.67

Appendix C: Treatment and Control Group Characteristics

Table 13 shows the pre-treatment averages for several observable characteristics between the treatment and control groups.

Table 13: **Pre-Treatment Differences**

	1			
Region	Underground	Union	Multi-plant	Tons/hr
East	0.48	0.49	0.35	2.25
West	0.51	0.63	0.45	4.13

Appendix D: 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 14.

Table 14: 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 E: Additional Market Thickness Tests

The second related way we approach this problem is to examine industry dynamics. Given we estimate a negative competition-integration relationship, market thickening would be consistent with a wave of entry into the downstream sector. To address entry dynamics we generate a variable $Entry_{cjt}$. This is the entry rate in county c of sector j (mine or preparation plants) at time t.[44] The DID estimation results reported in Table 15 column 1 indicate no change in the entry rate of preparation plants in Eastern counties post 1980. In column 2 we find a modest increase in the entry rate of mines but the effect is not significant at conventional levels.

[44]The entry rate is calculated as the number of entering mines in county c at time t divided by the number of continuing mines. Similarly for 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. As before, we calculate the exit rate in each county-sector-year and re-run the analysis. In Table 15 columns 3 and 4 we find no evidence of statistically significant changes in exit rates.[45]

Our 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 travelled 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, one of the two shipping modes between mines and preparation plants. In addition, the survey contains information on the truck's state of operation.

We select only trucks that list their principal product as mining products to proxy for coal shipments. Next, we 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 we can 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 15 we 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, we 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.

[45] In unreported regressions we estimate the exit regressions using the mine-level data. Like in the county regressions, we do not find significant treatment effects. This is also the case when we use triple-interaction terms to assess whether mines were differentially affected by competition depending on their labor productivity.

Table 15: **Robustness Testing**

	1	2	3	4	5	6
Dependent variable:	Entry (prep)	Entry (mine)	Exit (prep)	Exit (mine)	Local	Miles
Competition	-0.0064	0.0553	0.0087	-0.0007	-0.1482**	2.6090***
	(-0.30)	(1.32)	(1.00)	(-1.16)	(-2.22)	(5.10)
Eastern * Competition	0.0312	0.0645*	0.0019*	0.0005	0.0176	-0.9862*
	(1.59)	(1.73)	(1.79)	(1.30)	(0.23)	(-1.83)
County effects	x	x	x	x		
State effects					x	x
Year Effects	x	x	x	x	x	x
Controls	x	x	x	x	x	x
N	1,890	2,477	1,000	2,041	1,189	1,396
R^2	0.21	0.26	0.17	0.83	0.08	0.13

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$