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The effect of coal combustion byproducts on price discrimination by upstream industries☆

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ABSTRACT

Price discrimination is often difficult to disentangle from price dispersion due to a lack of transaction level data capable of tracking sales from individual companies to quantifiably heterogeneous groups of consumers. This paper uses mine-mouth prices and transportation prices paid by regulated coal-fired power plants in the U.S. coal market during the time period 2009–2010 to study how coal mines and transportation companies practice price discrimination against electricity plants. Power plants with heterogeneous demand for coal are perfectly identified based upon their ability to market flue-gas desulfurization (FGD) gypsum, which is a byproduct produced from scrubbing SO_2 emissions. Because sulfur is the raw material for FGD gypsum byproduct production, gypsum sellers are anticipated to have a more inelastic demand for high-sulfur coal. Results indicate that coal mines and transporters charge higher prices to gypsum sellers in comparison to non-sellers for transactions originating at the same mine during the same month of the same year. Coal-fired power plants capable of selling FGD gypsum byproducts are estimated to pay a 10.3–39.6 ¢/MMBtu price premium for coal. Coal mines and transportation companies each capture a relatively equal share of the associated rents.

1. Introduction

Firms capable of segmenting consumer groups may be able to practice price discrimination by selling the same product to consumers at different prices. Price discrimination can be executed straightforwardly by checking consumer IDs (e.g. student and senior discounts on movies and food) or can be practiced indirectly by charging different sizes of products different per unit prices (see, for example, Busse and Rysman, 2005 for a discussion of volume-based price discrimination for advertisement space).

The extent of price discrimination is often difficult to measure empirically due to issues of data quality and confounding unobservables (see, Borenstein and Rose, 1994, for a discussion of the empirical difficulties for identifying price discrimination). When transaction level data are available, they seldom contain the characteristics of buyers that are necessary for identifying segmented consumer groups. In the event of volume-based price discrimination, detailed cost data are often unavailable, thereby making it impossible to precisely construct the price to cost markups necessary for measuring price discrimination. Similar problems exist when products are differentiated in quality, because it is difficult to disentangle the cost- and quality-based price variation from price discrimination. Finally, the timing of purchase adds another empirical challenge to the mix, because price differentials over time may reflect sellers' uncertainty of demand and reserves as opposed to price discrimination (see, for example, Pindyck, 1980; Dana, 1998, 1999a, 1999b for a discussion of dynamic pricing).

This paper studies the third-degree price discrimination practiced by coal mines and transportation companies against coal-fired power plants and addresses the aforementioned empirical difficulties associated with identifying price discrimination. Specifically, mines and transporters are able to perfectly segment coal-fired power plants based upon electricity plants' ability to sell their flue-gas desulfurization (FGD) gypsum byproduct.[1] Significant transportation costs, reloading costs, and asymmetric information among coal buyers likely serve as an impediment to arbitrage in the coal market. Busse and Keohane (2007) note that buyer coalition formation is rare because coal is

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[1] FGD gypsum is produced as a byproduct at plants that operate SO_2 scrubbers in order to comply with the emission requirements of the U.S. Clean Air Act Amendment (CAAA).

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generally piled outside of electricity plants upon delivery and arbitrage among buyers would impose additional reloading costs for the coal. Our data suggest that the average transportation cost is 75 cents per million British thermal units (¢/MMBtu) while the average coal price differential across gypsum sellers and non-sellers is at most 40 ¢/MMBtu (see total price differential for gypsum sellers in Tables 3 and 4). As a result of the relatively higher transportation costs, the coal-fired power plants do not have an opportunity for arbitrage. Furthermore, Jeon and Menicucci (2005) show that the presence of transaction costs for buyer coalition formation significantly reduces arbitrage opportunities in the presence of asymmetric information among buyers, and transportation fees are not publicly available for coal purchases.

Market segmentation is possible because FGD gypsum sales information is readily available to mines and transport companies from the U.S. Energy Information Administration's (EIA) public databases for form 923 and 860, the American Coal Ash Association's (ACAA) list of FGD gypsum producers, and public press releases from electric utilities.[2] Form 923 contains the most detailed annual gypsum disposition data for power plants and is released with a 7 month lag in July of the subsequent calendar year. Form 860 is released on a similar lagged schedule. The data collected on form 860 are less detailed than form 923 with respect to gypsum, but importantly, it provides coal mines and transporters with advanced notice of gypsum sales. Specifically, form 860 asks power plants to report proposed projects to recover salable FGD byproduct up to 5 years in advance of the start date along with the anticipated in-service date and whether the project is currently under construction. Finally, public press releases from the utilities are common in advance of a gypsum contract's start date particularly when the contract involves construction of a new dedicated wallboard plant adjacent to an electric plant.

We are able to match this gypsum sales information to confidential coal transaction data in order to perfectly identify groups segmented by gypsum contract status. The transaction data contain detailed information on coal quality that includes average heat, sulfur, and ash content. Controlling for these confounding quality characteristics allows us to measure group price differentials for coal of statistically similar quality. The data are collected at a relatively high monthly frequency and contains unique mine and electricity plant identifiers. Because mines sell coal to multiple electricity plants within a given month, we are able to control for unobserved time varying coal mine characteristics. This feature of the data allows us to control for unmeasured time varying production costs that include uncertainty of demand and coal reserves. If the production costs for the same coal mine at the same month of the same year do not vary with respect to the coal-fired power plants involved in the transaction, then our method perfectly controls for cost differentials across consumer groups. This is particularly important because price discrimination is measured by the difference in price–cost markups as opposed to overall price dispersion.

A final benefit of the transaction data used herein is that it contains confidential coal prices measured at the coal mine-mouth (commodity price), the measured coal transportation price (delivery price), and the total price paid by coal-fired power plants (commodity price + delivery price). The partitioned pricing data allow us to first check if there is price discrimination being practiced against coal-fired power plants, and then estimate whether it is the coal mines or coal transporters who are taking the largest rents.

Non-parametric matching estimators are first used to test for significant differences in coal quality sold to gypsum sellers in comparison to non-sellers for purchases originating at the same mine and the same month of the same year. The matching estimators find no significant differences in heat content, sulfur content, ash content, quantity, or delivery distance for such transactions.

Fixed effects models and non-parametric matching estimators are then employed to estimate differences in coal prices paid by gypsum sellers and non-sellers. The results indicate that gypsum sellers pay a 10.3–39.6 ¢/MMBtu (4.2–16.0%) total price premium for coal of statistically indistinguishable quality in comparison to their non-selling counterparts.

In a similar study, Busse and Keohane (2007) find evidence of price discrimination for low-sulfur Powder River Basin (PRB) coal following the U.S. Clean Air Act Amendment of 1990 (CAAA) and attribute their findings to price discrimination on the part of transportation companies. Our estimation strategy and results differ in four key regards. First, we focus on price discrimination on the basis of gypsum contracts, whereas Busse and Keohane (2007) focus on price discrimination practiced against electricity plants operating SO_2 scrubbers. Second, our analysis focuses on all U.S. coal transactions and Busse and Keohane (2007) focus only on sales of Powder River Basin (PRB) coal. Third, the data allow us to control for detailed mine-by-month-by-year fixed effects in order to reduce concerns of unobserved excavation costs. Finally, our data include confidential mine-mouth prices and delivery prices, while Busse and Keohane (2007) only have data on overall coal prices.

The results presented herein therefore enhance our understanding of the U.S. market for coal by providing evidence for the existence of price discrimination in more competitive coal markets outside of the PRB and illustrating another market segmentation device (gypsum contract status) that mines and transport companies can use to practice third-degree price discrimination. Furthermore, the results provide the first estimates of the disposition of rents between coal mines and transportation companies and suggest that the economic rents from price discrimination are roughly evenly shared among mines (51% of rents) and transporters (49% of rents).

The remainder of this paper is organized as follows. Section 2 provides a background of the CAAA and illustrates how coal mines and transporters are able to segment consumers on the basis of their differential coal demand. Section 3 provides an overview of the data used in the analysis, and the empirical results are given in Section 4. Finally Section 5 concludes.

2. Background

Carbon, sulfur, hydrogen, nitrogen, oxygen, and other compositions are naturally contained in coal. During the combustion process at coal-fired power plants, the sulfur contents in coal react with oxygen to form sulfur dioxide (SO_2). SO_2 emissions are a precursor to acid rain and are known to have harmful effects on plants, aquatic animals, infrastructure, and human health (Spengler et al., 1990).

In order to reduce SO_2 emissions, the CAAA of 1990 established a market-based system for SO_2 emission allowances. The CAAA first set an annual cap on total SO_2 emissions and then allocated allowances totaling the amount of the annual cap to U.S. electricity plants (Schmalensee and Stavins, 2013). Power plants are free to buy or sell allowances and may choose among a variety of SO_2 abatement strategies provided that they have enough allowances at the end of the year to cover their annual SO_2 emissions. Due to the flexibility of the CAAA allowance trading program, the ultimate decision of compliance strategy depends on which abatement method yields the greatest cost savings to electricity plants. Some coal-fired power plants have reduced emissions through fuel switching alternatives such as natural gas or low-sulfur (and low heat) subbituminous coal from the western U.S. (see, for example, Busse and Keohane, 2007; Gerking and Hamilton, 2008; Schmalensee and Stavins, 2013 for a discussion of fuel switching and the CAAA). Indeed, Schmalensee et al. (1998) estimate that the majority of SO_2 emission reductions (55%) can be attributed to fuel switching for

[2] The public EIA data files for form 923 are available online at http://www.eia.gov/electricity/data/eia923/ (last accessed July 2015). Form 860 data are available online at http://www.eia.gov/electricity/data/eia860/ (last accessed July 2015). The ACAA list of gypsum producers is available at http://www.acaa-usa.org/Links/FGD-Gypsum-Producers-Products (last accessed July 2015).