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Burning wood pellets for US electricity generation? A regime switching analysis

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ABSTRACT

Applying a regime switching model under the theoretic framework of real options, we inspect the optimal timing boundaries for coal and coal mixed wood pellets as two alternative fuels for a power plant in Georgia, United States. Results indicate that cofiring wood pellets with coal is generally not a commercially viable option. However, lower-level (with wood pellets < 15%) cofiring could have been feasible during the infancy period (2009–2011) when wood pellet price was declining. Sensitivity analysis shows that our conclusions are robust and the most important factors are relative prices of coal and mixed fuel. Therefore, we reject the null hypothesis that cofiring is economically feasible and suggest using policy vehicles to stimulate the bioenergy market and meet the greenhouse gas emission reduction target. In particular, a subsidy of $1.40/mmbtu to the 10% mixed fuel or a tax of $1.50/mmbtu on coal would prompt the conversions of coal-only power plants to cofiring ones, and a subsidy of $0.45/mmbtu to the 10% mixed fuel or a tax of $0.50/mmbtu on coal would maintain existing cofiring power plants in the status quo.

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1. Introduction

Historically, coal is the major fuel type for power plants. Electricity generated from coal-fired power plants accounts for >40% and 39% globally and within the United States, respectively (EIA, 2016). On a per-unit energy basis, coal is one of the largest emitters of carbon dioxide among all fossil fuels, and coal-fired power plants represent a major source of man-made carbon dioxide emissions. To reduce greenhouse gas (GHG) emissions, most countries have set reduction targets. The world-leader in this effort is the European Union (EU) with the United Kingdom (UK) as an EU leader. In recent years, the EU in general and the UK in particular have burned an increasing amount of biomass for electricity generation. In 2015, the United States launched the Clean Power Plan aimed to lower carbon dioxide emitted by electrical power generation by 32% within 25 years relative to the 2005 level. The plan is focused on reducing emissions from coal-burning power plants, as well as increasing the use of renewable energy, and energy conservation.[1] Given the fact that electricity produced from renewable resources is <7% in the US (EIA, 2016), there remains a great expansion potential in the bioenergy market.

A typical coal-fired power plant bears a huge capital investment with a design life of 20 to 50 years. Therefore, it is usually not economical to totally abandon a coal-fired power plant and replace it with cleaner technology prior to the end of its useful life. Nonetheless, it is feasible to substitute some portion of the coal by biomass (cofire coal with biomass) so as to reduce carbon emissions. In particular, wood

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[1] Specifically, the Environmental Protection Agency requires individual states to implement their plans by focusing on three building blocks: increasing the generation efficiency of existing fossil fuel plants, substituting lower carbon dioxide emitting natural gas generation for coal powered generation, and substituting generation from new zero carbon dioxide emitting renewable sources for fossil fuel powered generation. This study focuses on the last one.

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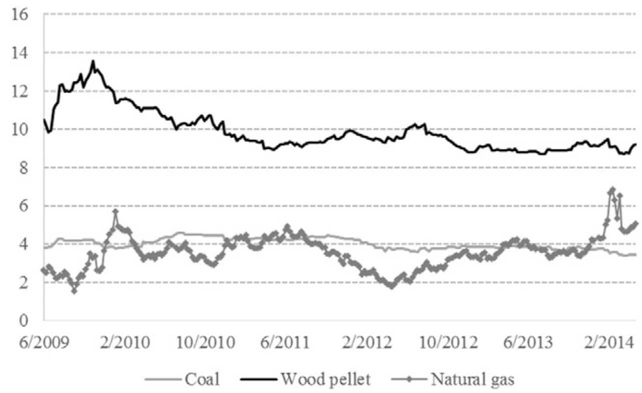

Fig. 1. Weekly real energy prices ($/mmbtu) for 06/05/2009–04/25/2014. Deflator: PPI for crude material, base time period January 2013.

pellets[2] are easily adaptable to automated combustion systems and the cost to convert existing coal boilers to mixed fuel burning is less prohibitive than plant retirement (Zhang et al., 2010). The saving of GHG emissions from wood pellets ranges from 72.6% to 82.4% for each kWh of electricity (Dwivedi et al., 2011). Within the EU and specifically in the UK, many power plants are cofiring wood pellets with coal as a transition option toward a carbon-free power sector. This has created a rapidly growing international market for wood pellets. Given the high productivity of the forest sector in the US Southeast, much of this market is supplied by southeastern wood pellet mills (Spelter and Toth, 2009). Forisk Consulting (2015) projects that US wood pellet production could grow from about 5 million tons in 2009 to near 18 million tons by 2018, of which, 97% would be intended for export markets.

Corresponding to the expanded supply, real wood pellet prices have been generally declining from 2009 to 2012 and since stabilized (Fig. 1). In the same period, coal prices have steadily declined, primarily because of the competition from declining natural gas prices, resulting from the advent of commercially viable hydraulic fracturing technologies and horizontal drilling methods. In terms of price volatility, both wood pellet and natural gas exhibit higher variations than coal. Therefore, an intriguing question for coal power-plant managers is how to make the optimal decision on fuel selection. In the energy economics literature, a few studies have examined this issue. Specifically, applying real options analysis, Pederson and Zou (2009) evaluate ethanol plant investments; Lee and Shih (2010), Lima et al. (2013), and Monjas-Barroso and Balibrea-Iniesta (2013) study solar- and wind-energy projects; Song et al. (2011), and Gazheli and Corato (2013) examine the conversion option of traditional farmland for energy crops; Bednyagin and Gnansounou (2011), Detert and Kotani (2013), and Zambujal-Oliveira (2013) investigate the investment decisions among combined-cycle, coal-fired, wind, solar, and nuclear power plants; Cheng et al. (2011) assess the clean-energy mix policy; and Siddiqui and Fleten (2010) analyze the staged commercialization and deployment of alternative energy technologies.

Past research on wood pellets mainly focuses on decentralized household heating systems (e.g., Claudy et al., 2011; Hyysalo et al., 2013; Michelsen and Madlener, 2012). Studies on wood pellets for electricity generation, however, have been limited. Steininger and Voraberger (2003) employ a computable general equilibrium model of the Austrian economy and demonstrate that fostering the use of cofiring could lead to a decline in both gross domestic product (GDP) and employment. Ehrig and Behrendt (2013) assert that cofiring wood pellets with coal represents one of the most cost-attractive ways to reach the EU-2020 carbon targets. Dwivedi et al. (2014) reveal that the use of wood pellets for electricity generation could reduce the UK's GHG emissions by 50–68% relative to fossil fuels. Xian et al. (2015) account for uncertain energy markets and examine the economic feasibility of cofiring wood pellets with coal for electricity generation. In this study, we apply a regime switching model under the framework of real options analysis to investigate the economic boundary conditions between coal and coal mixed with wood pellets as the fuel for power plants. We intend to contribute to the current literature by considering reciprocal switch options between coal-only and cofiring for a power plant, and incorporating the switch cost explicitly as a function of the energy prices. Considering the shifting energy patterns in the US market (Fig. 1), we conduct analyses on two distinct periods in addition to the whole sample period. One is the infancy period (2009–2011), which is the early stage when coal prices are relatively high and wood pellet prices are declining because of initial rapid supply expansion. The other is the substitution period, when cheap natural gas undermines coal's dominance as the fuel for US power plants. The null hypothesis is that both coal-only and cofiring are economically viable options for US power plants, which solely depends on contemporary market situations but not government involvement.[3]

2. Method

Based upon the classic real options approach proposed by Dixit and Pindyck (1994), Adkins and Paxson (2011) examine the reciprocal energy-switching options and provide a quasi-analytical solution for the case of two competing energy inputs. Extending their analysis, we adopt a general regime switching model, which incorporates price uncertainty of two alternative fuels to investigate a power plant's optimal choice of the fuel type. Consider an active, perpetual operating power plant that turns the chemical energy in coal into electricity and has an option to exchange the incumbent fuel (coal) with a substitute fuel (coal mixed with wood pellets). The switch is reciprocal and incurs a known sunk cost K_{ij}, $i, j \in \{c, m\}$ and $i \neq j$.[4] Gains from a switch include the net cost saving from using cheaper fuel and the option value of switching back.

Price for fuel X_i, $i \in \{c, m\}$, is assumed to follow a geometric Brownian motion,

$$dX_i = \alpha_i X_i dt + \sigma_i X_i dz_i \tag{1}$$

where α is the drift rate, σ is the volatility rate and dz is the increment of a standard Wiener process. Correlation between the two price variables is described by $\rho(|\rho| \leq 1)$, so that $\text{cov}(dX_c, dX_m) = \rho\sigma_c\sigma_m dt$. To state the valuation relationship in terms of one unit of output, price for each fuel can be adjusted by a conversion factor.[5]

The function $F_i(X_c, X_m)$, $i \in \{c, m\}$, denotes the plant value from using fuel i and the embedded switch option, which depends on prices of both the incumbent and substitute fuels. Using the dynamic programming approach, the following partial differential equation can be

[2] Wood pellets are small nuggets of compressed, sawdust-sized wood fiber that have higher energy density and lower moisture content than their raw input. The sustainability of wood pellets as feedstock for energy is largely a matter of carbon cycle calculations, which depends on the origin and type of trees used for wood pellets. We believe that burning wood pellets locally for energy is more carbon efficient than burning coal, even after accounting for the emissions for collecting and processing biomass.

[3] The EU biomass market is driven by government mandates. The same has not been mirrored in the US.

[4] Letter c for coal and m for mixed fuel (coal mixed with wood pellets). K_c denotes the conversion cost from coal to mixed fuel and K_m denotes the conversion cost from mixed fuel to coal. For example, for a coal-burning power plant to burn wood and meet emission requirements, some accommodations to facility operation and physical structure are necessary, including ash and air emission control, hard coating cleaning, wood storage, and grinding and blowing systems.

[5] 1 kWh = 0.0034 mmbtu.