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Can price volatility enhance market power? The case of renewable technologies in competitive electricity markets☆

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ABSTRACT

This paper develops a two-stage model with endogenous capacity and operations to assess the practicality of photovoltaic technology (PV) in competitive electricity markets. Applying our model to stylized data of California's electricity market we demonstrate that electricity price spikes are higher and more frequent the higher the PV capacity. Consequently, the average electricity price rises when construction costs of PV capacity decline due, for example, to technology improvements, bestowing market power and excessive profits on producers employing fossil-using technologies. We also show that an increase in the number of PV-using firms and higher CO_2 tax reduce consumer surplus.

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1. Introduction

Generating electricity from renewable energy sources is believed to be one of the main remedies for the fast-increasing problems of greenhouse gases (GHG) and air pollution (Tol, 2006; Weyant et al., 2006; Lior, 2010; Friedman, 2011).[1] Research on renewable energy suggests, however, that the road to a "green world" is not yet fully paved and the potential and limits of renewable energy remain insufficiently explored and understood (Badcock and Lenzen, 2010; Lior, 2010; Trainer, 2010; Blumsack and Fernandez, 2012; Borenstein, 2012). It also points out that the high costs of producing electricity from renewable energy will likely raise electricity prices substantially, unless new technologies of electricity generation are developed and adopted (Odenberger and Johnsson, 2007; Borenstein, 2012).

This paper demonstrates that integrating renewable energy such as photovoltaic technology (PV) into the electricity market may indeed lead to higher electricity prices.[2] Unlike previous research, we show that higher price volatility, not higher production costs, is the culprit, as it bestows market power on fossil-using electricity producers, and more so the lower the costs of PV capacity (due to PV technology improvements, say) and the greater the number of PV-using producers in the market. More specifically, we show that electricity price spikes are higher and more frequent the higher the PV capacity, and that this phenomenon will be exacerbated by the introduction of CO_2 taxes.[3] Consequently, the average price paid by electricity customers will likely increase when construction costs of PV capacity decline due, for example, to PV technology improvements, yielding market power and excessive profits to electricity producers employing the fossil-using technology (CCGT).[4] We also demonstrate that consumer surplus decreases whereas overall welfare may increase or decrease when the CO_2 tax rate and/or the number of PV-using producers increase. Finally, we show that the choice of market structure (the number of generation technologies that can be constructed by each producer) may significantly affect price volatility, the average electricity price, industry profits, and welfare.

Our results are derived in the context of a two-stage decision-making process aimed at disentangling the intricate relationships among the costs of capacity construction and electricity production by fossil-using and renewable technologies, the optimal generation capacity mix, and electricity price volatility and price level.[5,6] We consider two types of generating technologies: (1) "regular", fossil-using, technologies such as combined cycle gas turbines (CCGT); and (2) weather-dependent renewable technologies in the form of photovoltaic cells (PV). In the first stage of the model, when only the probability distribution functions of future daily electricity demands and weather conditions are known, profit-seeking producers maximize their expected profits by determining the capacity to be constructed from each technology. In the second stage, once daily demands

[1] Other means to reduce air pollution and greenhouse gases are, for example, conservation, demand-side management, better use of transmission and distribution systems and smart grids. In fact, the smart grid enables better use of transmission and distribution systems as well as demand-side management. A significant increase in nuclear power in electricity generation is unlikely in the near future (Lior, 2010; Renewables, 2011; Dittmar, 2012; The Economist, 2012) and new construction of hydroelectric power is limited to specific countries (Renewables, 2011).

[2] To simplify the exposition, our model only employs combined cycle gas turbines (CCGT) and PV plants. Our methodology and results apply equally to other fossil-dependent technologies as well as weather-dependent renewables such as wind, solar-thermal technologies, and sea waves.

[3] Effective use of renewable energy depends on the tradeoff between the higher cost of electricity from these sources versus the benefits they deliver in abating local pollution and mitigating greenhouse gases (Borenstein, 2012). Thus, research and public policy debates in the coming decade will likely focus on strategies and technologies aimed at increased conservation and on the development of renewable energy to displace the use of fossil fuels (Lior, 2010; Trainer, 2010; Traber and Kemfert, 2011).

[4] The phenomenon of higher price volatility implying higher profits was observed in Tishler (2008), who demonstrated, for linear demand and constant marginal cost, that the R&D project with the highest variance yields maximal expected profits for risk-neutral firms.

[5] Substantial price volatility due to sudden and unexpected change in wind generation is reported by ERCOT in Texas (Hardy and Nelson, 2010).

[6] Analysis of demand volatility in electricity markets with renewable energy is not new. See, among others, Holland and Mansur (2008) and Chao (2011).