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Forward contracts in electricity markets and capacity investment: *A simulation study*

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ABSTRACT

This simulation study analyzes the effect of the introduction of forward markets to mitigate cyclical price behavior in electricity markets from a dynamic extended Cobweb model. We pay particular attention to the effect of lags in investment decisions and the effect of not fully replacing retired capacity in electricity markets. In line with previous research, the introduction of forward markets decreases price variability in comparison to a spot market. However, we also observe that lags in investment decisions and the failure to fully replace retired capacity create capacity investments cycles even in the presence a forward market.

1. Introduction

Nowadays, almost all activities of any given society are based on electricity. We expect to have electricity supply 24/7, and access to electricity for all communities. A major threat to security of supply is the occurrence of cyclical behavior, i.e. sustained fluctuations of over- and under-capacity, which is an important feature of electricity markets (Arango and Larsen, 2011). Such cycles not only affect security of supply but also increase uncertainty regarding the revenues of electricity companies and electricity prices. Periods with low reserve capacity margins are more vulnerable to uncertainties due to severe droughts in hydro-dominated systems, gas supply shocks, etc. Electricity cycles started with the introduction of deregulation, where generators with limited (local) information and myopic expectations, acting under market conditions, made wrong-timing investments, subsequently causing cyclicality. Cycles have initially been hypothesized based on simulation models and analogies with other industries, and were then tested both through laboratory experiments and empirical evidence (Arango and Larsen, 2011).

System stability and sufficient and timely investment are desirable. A number of policies and mechanisms have been proposed to stabilize markets. However, there is no agreement on this issue. Some mechanisms, such as mothballing (Arango et al., 2013), procurement for long-term strategic reserves contracting, and centralized auctioning for capacity contracts (Lara-Arango et al., 2017). This paper focuses on one of these mechanisms –forward markets–, as a way of dampening cycles in electricity markets using simulation.

Since Ezekiel's seminal paper on the cyclical behavior of commodity prices and the Cobweb theorem, several theories have been proposed in an attempt to explain this behavior (Ezekiel, 1938). Nerlove was the first to introduce the model of adaptive price expectations, in which strong cycles were reduced from the original Cobweb theorem, although fluctuations in price did not disappear (Nerlove, 1958). The theory of rational expectations proposed by Muth allowed for the inclusion of random variables, removing the potential for endogenous cycles, at least in their most idealized form (Muth, 1961). Further studies have integrated additional elements into the Cobweb model in order to consider more general aspects and increase design complexity.

Arango and Moxnes (2012) show the emergence of cycles when investment delays and a lifetime of installed capacity are included in the Cobweb model that resembles an electricity market. Through experimentation Arango et al. (2013) extend the original design to analyze the mothballing effect as a stabilization mechanism in electricity markets. Experimental results confirmed predictions as to the effect of the inclusion of mothballing. Capacity and price cycles were observed in the absence of mothballing, as well as a price increase.

The case of electricity markets is particularly interesting. Electricity markets are capital-intensive industries, wherein there are long lags in the adjustment of production (generation) capacity. The main reason for such lags is the delay in investments decisions due to high uncertainty regarding future prices and the long time required to build new electric facilities (Larsen and Bunn, 1999). In such conditions,

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capacity cycles in electricity markets can be expected (Bunn and Larsen, 1992; Ford, 1999; International Energy Agency, 1999; Lomi and Larsen, 1999; Olsina et al., 2006). These speculations have been confirmed by recent empirical evidence of cyclicality after more than 20 years of deregulation (Arango and Larsen, 2011). Moreover, such cyclical behavior is also expected for ancillary services under market condition such as black start in the electricity system, as suggested by a simulation model (Carvajal et al., 2013). This behavior leads to periods of excess capacity and low prices followed by periods with capacity scarcity and correspondingly high prices (Cramton and Ockenfels, 2012). The uncertainty this generates among investors and consumers leads, in many cases, to concerns over the future security of supply (OFGEM, 2013).

In the electricity market, a number of different mechanisms have also been introduced in an attempt to ensure that cycles are kept at a minimum level, from the Value of Loss of Load (VLL) in the initial English and Welsh systems (Bunn and Larsen, 1992), to capacity mechanisms (Finon and Pignon, 2008) and forward markets. While we are herein focusing on electricity markets, the results are relevant for all commodity markets that share the characteristic long delays in investments and uncertainty in replacement capacity, e.g., agriculture, where rubber and coffee are subject to significant delays between planting and production.

Through simulations, the present study extends the work by Arango and Moxnes (2012), which considered the introduction of a ***forward market*** as a stabilization mechanism for cyclic prices in electricity (commodity) markets. That is, investment decisions are simulated in a market that includes the possibility of selling in a forward market ahead of the spot market. The effects of forward markets on reducing short-term price volatility have already been discussed in the literature, as well as the incentives of strategic behavior, for example in Allaz and Vila (1993) and Green (1999), among others, as discussed in the next section.

In this paper, we consider a simulation model which takes into account endogenous factors frequently ignored in the analysis, such as long investment lags and capacity vintages consistent with Arango and Moxnes (2012). Thus, the contribution of this study is to understand the influence that the introduction of a forward market has on price dynamics, since previous studies have noted a decrease in market prices and an increase in competitiveness as a consequence of the introduction of these types of markets.

The paper is organized as follows: Section 2 presents a review of different mechanisms to attenuate the cyclical behavior of commodity markets, including the role of forward markets. In Section 3, economic models of both spot and forward markets are developed. Section 4 identifies and explains variables in the simulation model, while Section 5 presents results obtained from these simulations, followed by a discussion and conclusions.

2. Forward markets

The first theoretical evidence that forward markets reduce price volatility was shown in models of price variability wherein spot prices stabilized after the introduction of forward markets (Danthine, 1978; Peck, 1976; Turnovsky, 1979). As mentioned above, there are different mechanisms available to reduce the cyclicality of commodity prices and, within the area of electricity in particular, a number of methods have been developed and applied. Evidence suggests that in the absence of forward markets, cycles in the Cobweb theorem persist for long periods of time (Stein, 1992). Subsequent studies have found evidence that the introduction of forward markets can stabilize prices in spot markets (Slade and Thille, 2006). In addition to this desirable attribute of forward markets, they also contribute to the organization of economic activity, easing price formation and offering risk mitigation mechanisms (Figuerola-Ferretti and Gonzalo, 2010).

Forward markets have been introduced in electricity markets to mitigate market power (Green, 1999) and to cover the associated risks of spot market price volatility (Eydeland and Wolyniec, 2003; Wilson, 2002; Wolak, 2000). Studies made by Allaz and Vila (1993); Green (1999); Newbery (1998) and Powell (1993), have applied models in which the negotiations in forward markets occurred first, followed by spot market negotiations – assuming that prices are equal in both markets, with the objective of understanding the interactions between forward market and spot market.

There is evidence that the presence of forward markets influences the reduction of price variability. Danthine (1978); Peck (1976); and Turnovsky (1979) analyzed the problem of price variability from a theoretical perspective, reaching spot price stabilization after the introduction of forward markets, or at least no increase in volatility. These studies have led to possible strategies to reduce the uncertainty in agricultural markets (Singh, 2007) and electricity markets in particular (Ausubel and Cramton, 2010).

It is well known that forward contracts mitigate the market power of electricity producers and thus, a better understanding of the mechanisms behind forward contracting can improve the design of electricity markets (Holmberg, 2011). Despite the policy activity surrounding the use of forward contracts, there has been relatively little exploration of what the optimal set of forward contract commitments might be.

Allaz and Vila (1993), and Green (1999), identify an additional effect, which Holmberg (2011) called strategic forward price manipulation. A producer can have incentives to increase its forward sales to lower the forward price and thereby the competitor's forward sales (along their committed forward supply curve) in order to soften the spot market bidding of his competitors. Green (1999) shows that the level of strategic contracting resulting from strategic forward price manipulation is higher when competitors have a more elastic forward supply, i.e., competitors' forward sales can be reduced at the cost of a low price reduction. Anderson and Hu (2012) show that strategic retailers preferring to buy on the forward market in order to reduce producer mark-ups on the real-time market results in equilibria where the forward price is higher than the expected real-time price.

Empirically, prices on forward markets would be expected to be lower than on spot markets. However, this is not always the case. For example, in the electricity markets of Pennsylvania, New Jersey, Maryland, and California, it has been shown that when demand or risk is high, forward market prices behave as an unbiased estimator of spot market prices (Bessembinder and Lemmon, 2002). In contrast, when demand is low, retailers have less incentive to participate in forward markets. Thus, when participation in forward markets is low, generators can choose to increase spot market prices so as to incentivize retailers to pay forward prices, even when they are higher than the expected spot price (Anderson et al., 2007). In fact, Anderson et al. (2007) and (Cramton and Ockenfels, 2012), have indicated that the correct usage of forward markets could have averted the electricity crisis in California, proving risk cover and ensuring enough investments to guarantee the supply under high price conditions.

This study contends that the introduction of a forward market serves as a stabilization mechanism that can be used to dampen cyclic price behavior in an electricity market. The study uses an economic model to simulate investment decisions with different values for the time to adjust capacity and various degrees of replacement for capacity depreciation. The pricing behavior of these simulated markets is analyzed in two parts: The first analysis involves only a spot market (i.e., the benchmark) and the second involves both a forward market and spot market.

3. Economic model

3.1. Base case: treatment 1 (T1)

The initial model is based on the simple design presented by Arango and Moxnes (2012), where n firms participate in a standard cournot