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Dynamic capacity planning using strategic slack valuation

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ABSTRACT

In this paper we analyze a particular aspect of capacity planning that is concerned with the active trading of production facilities. For a homogenous product market we provide a theoretical rationale for the valuation and trading of these assets based on a metric of strategic slack. We show that trading production assets with non-additive portfolio profitability involves complex coordination with multiple equilibria and that these equilibria depend on the foresight in the planning horizon. Using the concept of strategic slack we have analyzed the dynamics of market structure, the impact of asset trading on the level of production of the industry, and to derive boundaries on the value of the traded assets. Moreover, through computational learning, the formulation is applied to a large oligopolistic electricity market, showing that plant trading tends to lead to increased market concentration, high prices, lower production and a decrease in consumer surplus.

1. Introduction

The capacity planning problem has been analyzed from many different perspectives. Whereas the dominant theme of analysis has been concerned with optimal facilities expansion, following cost minimization under uncertainty (e.g. Van Mieghem, 2003 and Julka, Baines, Tjahjono, Lendermann, & Vitanov, 2007), the implications of capacity decisions on market price formation is an important consideration in profit maximizing plans. Thus, Bish and Wang (2004) have examined the capacity expansion problem with endogenous prices for a monopoly with demand uncertainty, whilst Goyal and Netessine (2007) looked at strategic capacity investment in a competitive product market as a game of technology choice. In this article we also analyze the capacity planning problem from a strategic aspect, but in the context of competitive, profit-maximizing companies trading production facilities amongst themselves, as distinct from investing in new capacity.

Our motivation for this formulation is primarily taken from events in the electricity industry. Until the 1990s, capacity planning in the electricity sector was undertaken by long-term, least cost optimization modeling (Bloom, 1983). With the prospect of steady growth in demand and regulated returns on assets, risks were low and the planning issues were mainly about optimizing the operational mix of technologies. New capacity would be built in time to meet rising demand at least cost and old capacity would be retired at obsolescence. But, with the advent of deregulation and competitive markets in many regions since the 1990s, capacity planning became more focused upon optimizing a portfolio of production facilities, and companies often traded assets amongst themselves to increase profits, manage risks and perhaps influence market prices. Thus, Bunn (2004) documents 22 trades of power stations between companies in the British market from 1995–2004, and observes that their declining asset values followed, as expected, the declining wholesale electricity prices. Similarly, Downward, Young, & Zakeri, (2011) assert that the “swapping of assets is relatively common in power markets” and proceed to discuss how asset rearrangements (either divestures to a new firm or swaps between existing firms) in electricity markets may benefit the producers. By 2014, with some developed countries facing flat, or declining long-term projections for electricity demand (Eurelectric, 2013), and with many governments incentivizing energy sustainability, conventional capacity planning in the power sector had, in these situations, become less about expansion and more about divestment and adjusting the existing asset portfolios. Thus, Ernst and Young (2014) report 70 asset trades globally in power generation in 2012, up from 60 in 2011.

In general, there are many factors that may help in understanding the process of plant trading as a capacity planning strategy. For instance by acquiring a plant a firm may enter a market niche only available to that technology and offer different operational options to the owner (as with intermittent renewable energy, e.g., Wu & Kapuscinski, 2013). In a more general context, the prospects of operational synergies or product variety, scale economics, opportunistic accounting, strategic positioning, different attitudes to

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risk, can all motivate plant trading (e.g., Aydemir & Schmutzler, 2008; Banal-Estanol & Ottaviani, 2006), as well as asset divestures imposed by regulation (e.g., Bunn, 2004; Bunn & Oliveira, 2007, 2008; Downward et al. 2011). However, theoretical results upon whether acquisitions increase or decrease profits are still mixed (e.g., Daughety, 1990; Farrell & Shapiro, 1990; Nilsson, 2005; Salant, Switzer, & Reynolds, 1983), and furthermore, market complexities may create substantial scope for interaction, experimentation, learning and co-evolution in asset ownerships. Thus, path-dependency may be an emergent property of asset-trading dynamics through the influence of initial and distinctive resource-bases (e.g., Nelson & Winter, 1982).

Thus, the emergence of heterogeneity in the ownership of production facilities, in markets where resources are readily transferred between competitors, has motivated several avenues of research, including asymmetric market structure (Reynolds & Wilson, 2000), out-of-equilibrium rents (Klepper & Graddy, 1990) as well as real-option valuations in the presence of development opportunities and search costs (Williams, 1993, 1995) and with alternative technologies (Siddiqui & Fleten, 2010). Setting aside the usual framing of this problem in the context of market entry and innovation, we address the apparently simpler question of why, in the absence of any financial distress, the same real asset, in the same product market, should apparently be worth more to one company than another and thereby motivate a trade. In our analysis of the emergence of market heterogeneity through asset trading, we draw upon two main concepts, namely, *complexity* in the decision to trade an asset and the *strategic slack* associated with the tradable asset, the value of which varies by firm.

Complexity is manifest as the size of the asset trading problem grows exponentially with the number of assets and firms in the market, with the consequence that decisions are likely to be made under bounded rationality. Thus, an approach based upon search methods (e.g., Williams, 1995) and computational learning is appealing (following, e.g., Chari & Agrawal, 2007; Sutton & Barto, 1998; Gosavi, 2009; Powel, 2010). Computational learning has become increasingly useful for examining the strategic behavior of competing agents interacting in markets for products or financial assets. A key ingredient in these applications of the methodology has been the stylization reflecting the market microstructure of the repeated instances of interaction, e.g. pricing and quantity decisions, from which the computational agents in the model can learn (e.g., Banal-Estanol & Micola, 2009; Bunn & Oliveira, 2008; Micola, Banal-Estanol, & Bunn, 2008; Sutton & Barto, 1998). But in the setting of market structure evolution, where agents may be acquiring, disposing or trading real assets, such as production facilities, these instances do not occur frequently, and the extensive repetitions required for learning from experience are not realistic. Furthermore, as the uncertainty in market structure evolution, due to the process of coupled search for viable asset trades, becomes unforeseeable, adaptive co-evolution will be prone to path dependency (e.g., Foray, 1997; Nelson & Winter, 1982). Modeling market structure evolution where real assets are substantially, but not frequently, traded amongst market participants, therefore, represents a challenging but relevant problem in understanding market dynamics, and in explaining the value of the traded assets.

Strategic slack is a concept that has many interpretations and functions in describing the underutilization of resources by a company, including deliberate policies for flexibility, optionality and competitive behavior (e.g., Piccolo, D'Amato, & Martina, 2008; von der Fehr & Mørch, 1992), and has an impact on the way that organizations learn to manage resources (e.g., Moreno, Fernandez, & Montes, 2009; Voss, Sirdeshmukh, & Voss, 2008) and on the real options available to the firm. We use strategic slack in the specific sense of companies choosing to underutilize real assets in order to maintain higher prices. We prove, by using this concept, that, in the context of our model: the buyers tend to be the larger firms who aim to protect their portfolios from lower prices; real asset trading increases market concentration, as firms seek to grow within their market niche; a seller may optimally sell an asset at a price below its operational profit; and the sequence of trading influences the prices of the traded assets.

A crucial aspect is the determination of the value of the assets. The value of an asset depends on its profits in the current and subsequent market states and on the implied real options that trading presents (e.g., Majd & Pindyck, 1987; Williams, 1993, 1995; Meier, Christofides, & Salkin, 2001; Smit, 2001; Smit & Ankum, 1993; Tseng & Barz, 2002; Secomandi, 2010; Shackelton, Tsekrekos, & Wojakowski, 2004; Siddiqui & Fleten, 2010; Siddiqui & Takashima, 2012). Insofar as the trading of facilities occurs, in the absence of any financial distress, the same asset must be worth more to the buyer than to the seller, yet with rational expectations, the classic "no-trade" results (following Milgrom & Stokey, 1982; Tirole, 1982) indicate that it is necessary to look beyond private information to understand the different valuations and therefore why this trading occurs.

With physical assets, the scope for externalities induced by portfolio effects, which may be transparent to all agents in the market, can induce different valuations, but this must depend upon the ability of the buyer to operate the asset more profitably than the seller, in the same product market. To the extent that the real assets are used to produce a commodity, such as electricity, and the input factors of production do not change by ownership, heterogeneous valuations and the consequent plant trading raise subtle questions on the links between asset ownership, operations and market structure in revenue formation. For example, if the asset traded is part of a portfolio, the way the tradable asset is operated to produce may depend on the other assets in the firm's portfolio. To envision the equilibrium value of an asset, therefore, requires an evaluation of all possible portfolios within which it could operate. Because of this complexity we, generally, cannot compute the ex-ante value of such a tradable asset. Nonetheless, in practice, companies will attempt a reduced-form analysis of this calculation. We have, therefore, linked computational learning to the *strategic slack* valuation.

Furthermore, the learning formulation needs to take into account multi-stage, forward looking behavior in the context of real-option games (e.g., Shackelton et al., 2004; Siddiqui & Takashima, 2012; Smit, 2001; Smit & Ankum, 1993; Williams, 1993, 1995) and it is associated with the models of search in which buyers and sellers need to find the best trading partners, as analyzed in Williams (1995). We show that foresight needs to extend several periods into the planning horizon to reflect the intricate nature of emergent strategic opportunities. This means that the buyer may buy assets that temporarily decrease the value of its portfolio, yet this trade is rational in the context of anticipating the subsequent evolution of the market.

Amongst the many manufacturing and service sectors that exhibit ownership changes in their assets, electricity is an appealing example because of the range of technologies available to produce a homogeneous product and the widespread use of a wholesale market at an intermediate stage in the supply chain. Electricity markets have been researched extensively regarding the relationship between market structure and price formation mechanisms. For example, the relationship between forward and spot energy markets relates to the ability of firms to profit from market power (e.g., Anderson & Hu, 2008a and Gulpinar & Oliveira, 2012), having substantial implications related to vertical arrangements (e.g., Aid, Chemla, Porchet, & Touzi, 2011) and on investment strategies (e.g., Murphy & Smeers, 2005). Market design, including the type of auction mechanism, such as supply function offers (e.g., Anderson & Hu, 2008b), mandatory pools or bilateral trading