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The degree of technological innovation: A demand heterogeneity perspective

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ABSTRACT

A perennial question posed by work in the technology management domain is whether a firm should deploy a technology more advanced than its current one. While past research has provided us with a better understanding of the firm-level decision to invest in new technology, the degree of this advancement (relative to the technology inherent in existing company product offerings) remains a nascent phenomenon that the field has not fully addressed. Data on global flat panel display makers from 1995 through 2011 are analyzed to understand how competitive standing in distinct intra-industry technology segments affects a firm's degree of technological innovation. We adopt a demand heterogeneity perspective to develop hypotheses relating the degree to which more advanced technology is deployed to a firm's competitive share of a particular segment. Our findings demonstrate how segment share (a more refined unit of analysis than overall market share) encourages a firm to advance its technology and how intra-segment competition moderates this direct effect. The current study provides evidence that demand heterogeneity is operative not only at different stages of the technology life cycle, but also in different segments populated by users with divergent technological requirements.

1. Introduction

Organizations are the primary agents of creative change in economies (Hagedoorn, 1996; Schumpeter, 1942, 1949) and the incentives for and constraints on firm-level innovation are therefore critically important topics — both in and of themselves and as relates to the industries and nations of which they are part. Most firms, however, struggle to determine the extent to which they should advance their technology (Lee et al., 2011; Lerner, 1997). Technologically leading firms innovate at the cutting edge of the market to stay ahead of the competition, while technologically lagging firms take strategic steps in hopes of catching up to these leaders (Lerner, 1997). Organizations may be driven to innovate by different incentives, depending on such characteristics as their competitive position within the industry, the heterogeneity of consumer preferences they face (Adner and Snow, 2010; Windrum et al., 2009), and the existing stock of complementary assets available to deploy towards technological change (Wu et al., 2014). Given the undeniable importance of technological innovation, then, what factors might influence the degree of firm-level innovation? Stated differently, what determines the extent of increase in technical sophistication of a new process refinement realized by the firm?

Of the numerous innovation drivers acknowledged by scholars, market share is one of the most widely studied (Chandy and Tellis,

2000; Eggers, 2014; Mas-Ruiz and Ruiz-Moreno, 2011). Yet the extant literature provides mixed findings on the role of market share as an impetus in deploying advanced technology (Aboulnasr et al., 2008). Sorescu et al. (2003) find evidence from the pharmaceutical industry that dominant firms (with dominance measured partly through market share standing) introduce significantly more radical innovations and technological breakthroughs than do their non-dominant counterparts. High market share has been found to lead to more innovations due to economies of scale that make R & D expenditures relatively more affordable for market-leading firms (Mas-Ruiz and Ruiz-Moreno, 2011); market power benefits conferred by commercialization of new offerings (Blundell et al., 1999; Chandy and Tellis, 2000; Nicholas, 2003); and incentives to continue to capitalize on the quality signals conveyed by market leadership (Caminal and Vives, 1996). However, there is also evidence of the opposite effect — namely, that market share actually discourages or at least slows innovation (Dutta et al., 1995). Christensen and Bower (1996) describe the tendency for leading disk drive manufacturers to focus primarily on the needs of existing customers for relatively modest technological advancements, to the exclusion of more disruptive technologies. A high market share firm may innovate less due to concerns over cannibalization of existing sales (Chandy and Tellis, 2000) and complacency or inertia resulting from past successes and incumbent position (Aron and Lazear, 1990).

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We believe that these conflicting results related to the influence of market share on technological innovation can be reconciled by considering in greater detail the nature of intra-industry technology segments and the attendant expectations of their particular customers.¹ Industries are typically characterized by heterogeneous demand environments such that customer sets in different segments of the market will express distinct preferences in terms of both the minimum performance level expected of a given technology and the willingness to pay for products that achieve this baseline threshold (Adner and Levinthal, 2001; Adner and Snow, 2010; Amankwah-Amoah, 2016; Qian and Soopramanien, 2015). These varying customer preferences, in turn, create divergent incentives to innovate on the part of firms catering to these dissimilar segments (Klepper, 1996). Demand-side research, which attempts to identify how major strategic moves yield ongoing benefits related to value creation (Priem et al., 2012; Ye et al., 2012), is thus eminently applicable to the research that we undertake in this paper. Importantly, demand-side research also helps to account for advanced industries characterized by co-existence of new and old technology, wherein some firms engage in a strategy of “technology retreat” (Adner and Snow, 2010) to reposition old technology in a heterogeneous demand environment.

Since the strategic decisions made by firms in this technical environment involve precisely the types of considerations introduced by demand-side management researchers, the current paper disaggregates market share into *segment share*, a more refined unit that is particularly useful in addressing demand heterogeneity, and examines the extent to which this measure predicts a firm's degree of technological innovation. This paper conceptualizes a firm's decision to advance to higher generations of technology as a process driven in parallel by existing competitive position and the extent of rivalry within a particular segment. If technological innovation creates innovation gains, competition will generally dissipate those gains (Scherer, 2015). Yet competition within an industry is also associated with greater product and process innovation outputs (Tang, 2006). Because the severity of competition can vary greatly between segments, it is instructive to examine each segment to understand how such rivalry impacts the degree of technological innovation. For these reasons, we also explore the moderating role of intra-segment competition in the relationship between segment share and the degree of innovation. Data from the global flat panel display industry provide general support for our hypotheses. When a firm with high share in a technologically forward industry segment is able to effectively manage competition, it deploys more advanced technology in a bid to tighten its grip on that particular segment. The degree of technological innovation in this case is driven by the firm's need to enhance product performance in an effort to continue to meet the performance requirements of its demanding users. In a different vein, a firm with high share in an industry segment characterized by older technology also demonstrates a high degree of innovation — though in this case the intention is to better serve the needs of price-conscious customers.

Several contributions are made with this paper. We build upon emerging work on demand heterogeneity over the technology life cycle (Adner, 2004; Adner and Levinthal, 2001; Amankwah-Amoah, 2016) to clarify the distinct incentives for innovation created by customers in different segments of a given industry. A growing field of literature has focused on technology defined by production generation, reflecting the relevance of such a perspective to industries such as semiconductors (Leiblein and Madsen, 2009). These industries are characterized by a

leading-edge generation (which offers high performance at a premium price) that surpasses yet does not completely displace the technological variants that preceded it. The firm-level focus of much demand-side research (Priem et al., 2012) accords well with our examination of the drivers of firm innovation within the various segments of an industry. This study reconciles the conflicting findings regarding whether higher market share encourages or discourages technological innovation (Blundell et al., 1999; Caminal and Vives, 1996; Chandy and Tellis, 2000; Eggers, 2014; Mas-Ruiz and Ruiz-Moreno, 2011). We show that market share is a reliable predictor of firm innovation behavior when broken down into a more refined unit of analysis: namely, segment share.

2. Demand heterogeneity by technology segment

Technology segmentation proceeds largely on the basis of the varied markets within which the technology in question is put to use (Gruber et al., 2008). An illustrative example of this tendency can be found in the semiconductor industry, where products such as home appliances powered by low-end technology differ significantly from central processing units (CPUs) at the leading edge of development (analogous to the ‘high-end technology’ segment articulated in this paper); customers in the former segment are generally concerned only with minimal performance standards while clients in the latter place greater emphasis on high performance with comparatively less concern for the associated cost required to achieve it. All segments require the basic functionality provided by semiconductors; however, each employs different levels of technology to arrive at this end. These overall dynamics can also be observed in other sectors, including for example the disk drive industry (Christensen, 1997) and the printer industry (de Figueiredo and Teece, 1996).

The TFT-LCD and OLED technologies that characterize the flat panel industry can best be characterized as examples of technology products dominated by process innovation. While the panels are the specific products delivered to industrial customers for incorporation into their subsequent offerings, it is the underlying process innovation that determines the extent to which panels of greater size can be produced more efficiently — and that therefore drives the degree of technological innovation. In their study of technology competition and investments Lee, Kim, and Lim (2011: 721) make a similar observation regarding this industry, stating that “while the disk drive industry focuses on product innovation, the LCD panel industry focuses on the cost-reducing process innovation because the panel itself is not a final product but a key input to LCD-based consumer products such as TV, notebook, etc.”. Process innovation of this broad type can additionally be found in the hard disk drive industry, where the increase in areal density improves storage volume (Christensen et al., 1998), while the decrease in line width in semiconductors advances the clock speed of the central processing unit (Cabral and Leiblein, 2001) and the power of DRAM memory chips (Kapoor and Adner, 2012). In the following section we outline the demand characteristics pertaining to these types of technology segments.

The *high-end technology segment* is generally characterized by customers who purchase technology with superior functionalities that surpass those of existing offerings, as occurred when LCD TVs were first brought to market (Tsai, 2013). The price of a small-size LCD TV is often significantly lower than that of a new large-size LCD TV (Tsai, 2013). Firms competing to satisfy demand in this segment are often in a race to apply increasingly advanced technology to fulfill ever-expanding user needs. The *middle-range technology segment* consists of customers who tend to be less demanding than their high-end technology counterparts in terms of a product's technological performance. Middle-range technology customers as a rule have a lower willingness to pay than do high-end technology customers; witness the lower prices charged for smaller-sized monitors when compared to larger-sized monitors of the next generation (Tsai, 2013). Finally, the *low-end*

¹ Consistent with our focus on the heterogeneous preferences and expectations of business purchasers of the flat panel display inputs produced by the companies in our sample, throughout this paper we generally refer to ‘customer’ characteristics in order to avoid confusing these dynamics with those pertaining to the end-user ‘consumers’ of the resulting final product. This accords with the position that “[i]ntermediate, business-to-business purchasers in a value system are also *customers*, but they are not *consumers*” (Priem et al., 2012: 347. Emphasis in original).

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