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The Degree of Technological Innovation: An Empirical Analysis of the Flat Panel Display Industry

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Abstract

Data on global flat panel display makers over the period 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. In this industry, product applications using new, current and old technologies determine market segmentation. We adopt a demand heterogeneity perspective to develop hypotheses relating the degree to which more advanced technology is deployed to a firm's share in 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 contributes to the literature by providing evidence that demand heterogeneity is operative not only at different stages of the life cycle as the broad-based technology in question advances, but also at different segments of a (relatively) stable market targeted by firms and populated by users whose requirements of the underlying technology diverge.

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Key words: Technology competition; Innovation; Market share; Market segment; Demand heterogeneity

INTRODUCTION

Most firms, even those at the forefront of technological competition, struggle to determine the extent to which they should advance their technology (Lee, Kim, and Lim, 2011; Lerner, 1997). Innovation, despite the benefits that it produces for both firms and industries as a whole, requires the allocation of resources in pursuit of an ultimately uncertain payoff. Furthermore, organizations may be driven to innovate by different incentives, depending on such characteristics as their competitive position within the industry. 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). In both cases, however, the degree of technological innovation – that is, the increase in technical sophistication of a new product or process refinement realized by the firm – is a key consideration. Given the undeniable importance of such creative activity, then, what factors might influence the degree of firm-level innovation?

Of the numerous innovation drivers acknowledged by scholars, market share is one of the most widely studied (Chandy and Tellis, 2000; Eggers, 2014; Lee and Kim, 2013; 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; Gilbert, 2006). 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; Lunn and Martin, 1986; Nicholas, 2003); and incentives to continue to capitalize on the quality signals conveyed by market leadership (Caminal and Vives; 1996). Market share has also been shown to be related to a greater degree of technological innovation in production (Lee et al., 2011; Lerner, 1997). However, there is also evidence of the opposite effect – namely, that market share actually discourages or at least slows innovation (Dutta, Lach, and Rustichini, 1995). A high market share firm may innovate less due to concerns over cannibalization of existing sales (Chandy and Tellis, 2000; Greenstein and Wade, 1998) and complacency or inertia resulting from past successes and incumbent position (Aron and Lazear, 1990).

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 consumers. 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 offering and the willingness to pay for products that achieve this baseline threshold (Adner and Levinthal, 2001; Adner and Snow, 2010). These varying customer preferences, in turn, create divergent incentives to innovate on the part of firms catering to these dissimilar segments. While "it has never been questioned that demand factors play an important role in shaping the rate and direction of technological change" (Klepper, 1996: 563), the varying nature of this demand within an industry could also tell us much about the actual innovations pursued by organizations. The current paper thus 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. Furthermore, firms may also face distinct competitive threats within the different segments of their industry. If technological innovation creates innovation gains, competition will generally dissipate those gains (Scherer, 2015). Because the severity of competition can vary greatly between market segments, it is instructive to examine each market 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 market 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 motivation is cost reduction to better serve the needs of price-conscious customers. At first glance, these stylized results would seem little different from those described by technology life cycle scholars (Abernathy and Utterback, 1978), who posit that frequent product innovations at early stages of a new industry eventually lead to a common technological standard – the dominant design – and subsequently give way to innovations of a process-based nature, as firms compete to lower the costs of their now relatively undifferentiated offerings. However, our measure of innovative behavior (degree of technological innovation) captures elements of both product and process novelty, as advances in production generations are pursued by firms intending to push performance standards forward for the industry as a whole, reduce the production costs associated with their particular products, or both. As such, we advance the notion that the product-process dichotomy may not fully describe the innovation incentives – nor capture the nuanced technical development behaviors – of firms seeking to remain competitive in diversified technological settings.

Several contributions are made with this paper. We build upon emerging work on demand heterogeneity over the technology life cycle (Adner and Levinthal, 2001; Adner, 2004) to clarify the distinct incentives for innovation created by customers in different segments of a given industry. The firm-level focus of much demand-side research (Priem, Li, and Carr, 2012) accords well with our examination of the drivers of firm innovation within the various segments of an industry. Our findings provide evidence that such demand heterogeneity is operative not only at different stages of the life cycle as the broad-based technology in question advances, but also at different segments of a (relatively) stable market targeted by firms and populated by users whose requirements of the underlying technology diverge. In a more specific vein, we address the question of whether higher market share encourages or discourages technological innovation. When market share is broken down into a more refined unit of analysis (segment share) we are able to more fully explain and resolve some of the contradictory past findings on firm innovation behavior. Lastly, a growing field of literature has focused on technology defined by product generation, given the increasing number of industries deploying such types of technology, e.g., semiconductor, DRAM, and mobile telecommunications (Banker et al., 2013; Lee et al., 2011; 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 result is a market categorized into multiple discrete segments whose respective offerings cater to the needs of customers with substantially different buying criteria. 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.

MARKET SEGMENT AND SEGMENT SHARE

More advanced technology appeals to demand differently than does less advanced technology (Barnett and McKendrick, 2004). Importantly for our purposes in this study, market segmentation, which proceeds largely on the basis of technology in use (Rogers, 1962; Wedel and Kamakura, 2000), reflects such a variance. An illustrative example of this tendency can be found in the automotive industry, where vehicles powered by 'old technology' gasoline engines attract drivers different from hybrids; customers in the former segment are generally more concerned with performance parameters such as speed and handling while clients in the latter place greater emphasis on fuel efficiency. 'Current technology' hybrid vehicles, in turn, are often less appealing to environmentally-conscious buyers of 'new technology' electric vehicles. Vehicles from all three segments serve the same overall purpose (transportation); however, each employs different technologies to arrive at this end, and each technology is at a different level of maturity. In the following section we outline the demand characteristics pertaining to these types of market segments.

The new technology segment is generally characterized by customers who purchase technology with superior functionalities that surpass those of existing offerings (Moore, 1991). 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 current technology segment consists of customers who tend to be less demanding than their new technology peers in terms of a product's technological performance. The technology in this segment tends to garner more adoptions and often has the highest gross sales of all three segments (Moore, 1991). Current technology customers as a rule are more price sensitive than are users in the new technology segment. Finally, the old technology segment is characterized by a demand profile that is exceedingly sensitive to price (Moore, 1991). Customers in this segment expect little in terms of advanced technological performance, as their requirements are largely met by existing offerings in the marketplace.

THEORETICAL MODEL AND HYPOTHESES

We introduce our theoretical model with three baseline hypotheses explaining and predicting how segment share affects the degree of firm-level technological innovation. Following this description of direct effects, the second set of hypotheses then focuses on how intra-segment competition moderates the effect of segment share on the degree of innovation. Given our supposition that heterogeneous demand across segments may serve to influence the creative activity of organizations, a firm's technical leap seems a particularly germane outcome to examine for the following reasons.

Degree of technological innovation

First, the unique dynamics of customer demand in different market segments presumably make themselves most strongly felt in the ambitiousness with which the firm approaches this segment. Within leading market segments the key criterion for successful new offerings is performance improvement (which customers are willing to pay for), while in lagging segments the primary consideration is cost reduction (that is, delivering a product with similar or slightly improved functionality that can be produced by the organization for a substantially lower cost). In both cases, however, the degree of technological innovation represents a rational response to market – and competitive – pressures: introducing a next-generation product at the high end of the market represents an attempt to make significant performance improvements available to users, while doing so at the low end of the market enables a firm to take advantage of more efficient design and manufacturing capabilities that reduce production costs. Second, the degree of technological innovation as we define it in this paper provides what we believe to be a wholly realistic appraisal of product development activities in many companies. Since pushing forward new innovations entails a significant commitment of time, effort, and financial resources, it stands to reason that organizations would concentrate these resources on a small number of products incorporating the best available firm-level expertise rather than dissipating these assets across several less ambitious modifications.

Segment share

In a manner analogous to market share, segment share is defined for our purposes as the *percentage of sales that a firm has of a given segment's total sales* (Cool and Dierickx, 1993). Since higher share translates to greater market power and, as specified above, the characteristics of demand may vary in important ways across segments (Adner and Levinthal, 2001; Adner, 2004), examining segment share allows us to discern the motivations and influences that face a firm as it attempts to maintain a position of prominence within the new technology, current technology, or old technology categories of its industry.

The new technology segment

Customers in this market segment prefer products that demonstrate high technological performance (Moore, 1991). Hence, firms in this segment find themselves in a race to develop and commercialize offerings consisting of better technology (Barnett and McKendrick, 2004).

These dynamics typically aggregate across firms in the new technology segment, such that a decision to advance its technology by any given firm can trigger a technology race, resulting in multiple advancements by competitors that eventually render the initial advancement ineffective (Costa, Cool, and Dierickx, 2013; Lerner, 1997). As a result, organizations are forced to stretch their innovative efforts forward, seeking to introduce the most technologically advanced products possible in an effort to maintain their lead position over rivals. We posit that a high segment share will prompt a firm to advance more than it would otherwise in order to further distance itself from the competition. If a firm advances only by a small degree, competitors can easily gain ground. Therefore, a technological advancement will more effectively deter competition if the move is of a greater magnitude, thereby creating a technological lead that the competition cannot easily overcome (Mas-Ruiz and Ruiz-Moreno, 2011; Nicholas, 2003).

Furthermore, if the focal firm in the new technology segment fails to maintain its technological edge, competitors will quickly catch up and eventually take over its position (Levinthal and Purohit, 1989). Given the price premium that characterizes products in the new technology segment, a firm with greater segment share will incur relatively more losses in sales if it fails to maintain its leadership in the segment. Recovering this surrendered position at the top of the market is a tall order, making it all the more incumbent on high segment share firms to maintain a continuously high degree of technological innovation. This concern with potential losses will push a firm to advance its technology to a substantial extent.

The preceding arguments notwithstanding, we acknowledge that lower segment share firms do also innovate. However, their degree of innovation (the number of generations advanced) is expected to be smaller due to learning curve effects, the comparative paucity of resources, and weaker networks of strategic partners. Over time, the cumulative effect of even this small degree of innovation could be substantial; however, the ability to leapfrog multiple generations of a technology on the part of these lower-share organizations at any one point in time would remain small. Following this logic, we advance our first hypothesis:

> Hypothesis 1: The higher the firm's segment share in the new technology segment, the greater the degree of the firm's technological innovation.

The current technology segment

In contrast to the new technology segment described above, demand in the current technology segment typically places less emphasis on the products' technological performance (Park and Podolny, 2000). Additionally, the willingness to pay for performance improvements may be significantly lower in the current technology than in the new technology segment (Christensen, 1997; Geroski, 2000), since purchasing decisions in the former are based more on a practical need that is addressed in a satisfactory manner by existing product offerings. This lower willingness to pay on the part of customers may discourage a firm from advancing because the degree of advancement gives rise to uncertainties and costs (Huisman and Kort, 2004). These uncertainties are rendered more salient for high-share firms operating in the current technology sector when one factors in the influence of powerful customers, who steer the firm in the direction of smaller tweaks to familiar product offerings and thereby divert resources and attention away from potentially important longer-term technologies (Christensen and Bower, 1996).

As a result of the limited potential to realize tangible gains from innovation, the degree of technological innovation on the part of a high segment share firm is likely to be of a lower magnitude than that of a low segment share firm. We do not claim that high share in the current technology segment will create a disincentive to innovate; our reasoning is instead that firms who have already gained a large proportion of the overall sales within this segment will see little incentive to taking large leaps forward with their technologies, given the inherent uncertainty of such initiatives coupled with the inflexible price constraints that they face from customers. This line of logic leads us to predict that:

> Hypothesis 2: The higher the firm's segment share in the current technology segment, the lesser the degree of the firm's technological innovation.

The old technology segment

In many industries, the introduction of a new technological advancement does not completely displace those offerings that preceded it. Sectors such as semiconductors, DRAM, and wireless communication and software are but some of the settings where new generations of technology co-exist with their progenitors (Lee et al., 2011; Lawless and Anderson, 1996; Leiblein and Madsen, 2009). The notion of demand heterogeneity becomes especially salient to both explaining and predicting the consequences of such technical diversity, since studies in this vein explore the varying preferences of different customer segments as these relate to product offerings.

While the new technology segment is oriented primarily towards performance improvements, demand in the old technology segment is driven much more by price considerations. Past research (Henderson, 1995; Klepper, 1997) has found that innovative activity on the part of organizations persists at a high level even in these mature product classes, despite the abiding cost consciousness of users. Taking our cue from these findings, we argue that the price pressure exerted within the old technology segment makes it likely that a high segment share firm will advance its technology to an even greater extent than would be the case for a low share firm. A higher share firm typically has a cost advantage with regard to its lower-share counterparts due to economies of scale for production (Mas-Ruiz and Ruiz-Moreno, 2011; Nicholas, 2003). Such an advantage is more pronounced for the deployment of less advanced production innovation, which is less costly and involves fewer uncertainties than technologies deployed in other market segments. These economies of scale are more easily maintained across generations of a particular underlying technology, since similar production processes can be applied to these different generations. A higher degree of technological innovation is thus rendered more feasible from a cost perspective for high-volume, high-share firms. Also, from the perspective of innovation inputs R&D cost per unit will be lower for a high-share firm compared to a low-share firm advancing by the same degree (Blundell et al., 1999), making the pursuit of more ambitious product development strategies more economically attractive.

Finally, innovation in the old technology segment provides a means for organizations to not only make the best of difficult price-competitive conditions, but to attempt to surmount them completely. Adner and Levinthal (2001: 37) allude to this possibility when they describe innovative activity in a mature technological market as follows: “Unlike the earlier phase, however, where product innovation served to satisfy consumer needs and increase willingness to pay, in this later phase, product innovation serves as way of avoiding direct price-based competition”. Here a higher degree of innovation would seem a rational response on the part of a high segment share firm looking to protect its advantage from would-be rivals bent on undercutting their prices and threatening already thin profit margins. In sum, a firm in the old technology segment can afford to make a greater degree of advancement at a lower cost and will do so to create strategic benefit for itself under trying market circumstances.

Hypothesis 3: The higher the firm's segment share in the old technology segment, the greater the degree of the firm's technological innovation.

If segment share increases the gains from innovation, intra-segment competition will tend to dissipate those same gains if left unchecked. This being said, competition can also act as an impetus towards further creative development by fostering a sense of urgency within the firm and motivating the introduction of next-generation offerings before rivals have the opportunity to do so. Next we develop predictions regarding how segment-level competition of this nature moderates the relationship between segment share and the degree of technological innovation.

Intra-segment competition

As the overall number of firms in competition increases, the risk of new competitive challenges rises – even when the segment share leader dominates the market with a large proportion of overall sales. This challenging environment is made more difficult yet by the fact that the ability to monitor rivals (and thereby control or at least predict strategic activities by other firms in the segment) decreases as competitive intensity rises. Finally, the ability of smaller firms to join together in research consortia or other partnering arrangements focused on technological innovation increases with competitive intensity (Stolpe, 2002), thus posing a credible threat to the position of even large incumbent firms.

While the above reasoning would presumably lead to the prediction that intra-segment competition acts as a general impetus to a higher degree of firm-level technological innovation, the demand heterogeneity lens that we adopt in this paper provides some inkling that this influence may vary across segments. Indeed, in the discussion below we develop hypotheses that claim differential effects of intra-segment competition as a result of the varying customer pressures that predominate in these market sectors.

The new technology segment

A successful technological advancement will enhance a firm's ability to dominate the competition in the segment, and thus to derive more value from its innovation investment (Blundell et al., 1999). A firm with a high share in the new technology segment will be more willing to invest heavily in R&D because technological leadership, coupled with market dominance, allows it to restrain competition in the segment (Cool and Schendel, 1988). Indeed, as a result of the performance requirements and low price sensitivity of users in this segment, a high share firm can generate more sales from technological innovation because it has the market power to take a bigger share of the demand and recoup its investment more quickly than lower share competitors (Lunn and Martin, 1986). High competition in the new technology segment acts as an accelerator of sorts for innovation on the part of high-share firms, since a rivalrous environment creates added incentive for a market leader to advance its underlying technology as a means to maintain both position and profitability at the leading edge of the industry. Thus, we predict that in the new technology segment, intra-segment competition positively moderates the effect of segment share on the degree of technological innovation.

> Hypothesis 4: Greater competition in the new technology segment strengthens the positive effect of the firm's segment share on the degree of the firm's technological innovation.

The current technology segment

When competition intensifies, sales losses will naturally be greater in volume for firms with high share (Chandy and Tellis, 2000). Since the majority of users buying products based on the current technology generates more sales than do customers in other segments (Moore, 1991), this loss of sales is likely to be particularly significant for current technology. Thus, a firm with a high share of the current technology segment is incentivized to deploy more advanced technology to prevent competition from stealing its sales. As competition grows stronger, the degree of advancement will increase accordingly because technological innovation functions as an effective competitive action (Ferrier, 2001). Also, a firm that advances by a greater degree can better differentiate itself from the competition (Insead and Chatain, 2008), thus creating beneficial distinction for the organization in the minds of customers. A high-share firm in the current technology segment would therefore be well-served by pursuing greater technological advances to fend off competition; we therefore hypothesize that intra-segment competition will positively moderate the effect of segment share on degree of innovation, such that this negative direct relationship (predicted in Hypothesis 2) will be weakened in the presence of greater rivalry. Formally, we have the following:

> Hypothesis 5: Greater competition in the current technology segment weakens the negative effect of the firm's segment share on the degree of the firm's technological innovation.

The old technology segment

As argued above, demand for the old technology segment is typically impacted most strongly by price (Moore, 1991). The higher a firm’s segment share, the more the firm can rely on market power to dominate the competition and, significantly, to compete on its own terms (Ahuja, Lampert, and Tandon, 2008; Cool and Schendel, 1988). When significant levels of competition arise, however, a high-share firm may attempt to tamp down this rivalry by initiating a price war (Majumdar and Venkataraman, 1993). The effect of such price-based competition is particularly pronounced for sales of the old technology where demand is price sensitive. The high-share organization will suffer in such a scenario as the basis of rivalry begins to further accentuate cost, the downward pressure on profit margins increases, and the economic wherewithal to pursue innovation diminishes. Yet even in the alternate scenario where a high-share firm advances its technology to improve its products' technological performance, the competition – supported by price-conscious customers who balk at the notion of paying premium prices for new offerings – may drive down the price of this high-performing technology and decrease the profit realized by the firm from this development. Consequently, the gains of technological innovation will dissipate, and a firm will be discouraged from advancing its technology by too large a margin. Innovation of an exceedingly ambitious technological character would seem to offer little remedy in and of itself for the competitive dynamics that pervade in the old technology segment. Firms in this segment may be forced to continue to offer minimal innovative changes to existing products in an effort to keep pace with rivals, rather than improving technical specifications for customers whose performance requirements have already been substantially met (Adner and Levinthal, 2001).

> Hypothesis 6: Greater competition in the old technology segment weakens the positive effect of the firm's segment share on the degree of the firm's technological innovation.

METHODOLOGY

The flat panel display industry

The flat panel display industry provides a suitable empirical setting within which to examine technological innovation (Eggers, 2014; Linden et al., 1998). Having undergone rapid technological progression since its inception in 1990, this industry gives us an excellent opportunity to observe and examine the pattern of technological innovation over time (Lee et al., 2011; Wang, Yang and Miller, 2015). Importantly for our research questions, there is a useful amount of variability in the degree of innovation among firms in this sector. For example, Samsung usually advances its production technology in a relatively ambitious fashion, moving forward by one or more generations at a time; in contrast, LG typically takes smaller technical steps, advancing by one generation or less. This industry also has the clearly defined market segments necessary to allow us to test our predictions relating technological innovation and change in segment share. In Figure 1, LG and Samsung both show a similar level of total industry market share over time. Hidden within this apparent similarity, however, are quite different dynamics operating at the segment level. LG's segment share of personal computer displays picked up significantly after 2006, while its share of the mobile display segment remained largely unchanged. Meanwhile, Samsung enjoyed a high level of segment share for personal computer displays prior to 2003. The firm began winding down its operations in the mobile display segment as of 2007. This brief example provides some illustrative evidence that disaggregating market share into its constituent segment-level components may reveal interesting differences regarding the ways through which companies compete – and also, potentially, in the approaches to technological innovation undertaken to facilitate these competitive approaches.

[Insert Figure 1 about here]

Generation

Flat panel display manufacturing begins with a large sheet of glass substrate, which is subsequently divided into display panels. The size of the glass substrate corresponds to a specific generation.[1] The generation of glass substrate, in turn, is a commonly accepted indicator of production technology in the flat panel display industry (Lee et al., 2011; Linden et al., 1998). On average, the industry comes out with a new generation of thin film transistor-liquid crystal

[1] Technology generations in the industry do not always proceed in integer fashion (i.e., from Gen 1 to Gen 2 to Gen 3). Although the size of the glass substrate determines the generation, the industry has historically assigned a 'partial generation' indicator to a glass size that falls in between two established integer generations. For example, Gen 3.5 represents a larger glass substrate than Gen 3 but a smaller one than Gen 4. This type of denotation was particularly common during the earlier years of the flat panel display industry.

[2] Due to facility constraints, one glass substrate can only be divided into a varying number of panels of a given size in one single manufacturing process. That is, a panel maker cannot first cut a larger-sized panel out of a glass

display (TFT-LCD) technology every two years. Advancing to higher generations allows a firm to work on glass substrates of a larger size. The larger the glass substrate, the more display panels it can yield per batch and, hence, the better the overall economies of scale for the manufacturing organization. Also, profit margins increase with the size of the panel. For the same specification, the price for one piece of 52” panel is $2,345, compared to $643 for a 32” panel and $97 for a 26-28” panel. Figure 2 illustrates the progression of technology generations in this industry over time. By 2009, the leader in the industry commenced operations in its first Gen 10 plant, while other generations were still in use. The advancement to the latest generation will not automatically retire older generations. As shown in Figure 2, Gen 1 and 2 remain popular generations throughout the observation period, providing some indication of the existence of customer segments with relatively modest performance needs.

[Insert Figure 2 about here]

Figure 3 shows the trend of price and size in the three segments of the flat panel display industry from 1999 through 2006. Because there are multiple display sizes in each segment, and various prices for each size, we take the median value of each measure for each segment in a given year.

[Insert Figure 3 about here]

The segment data presented in these charts support the relevance of adopting a demand heterogeneity lens within this industry. The new technology segment is the only segment that shows growth in display size, indicating the abiding importance placed by customers on technical advancements at the higher end of the market. The largest display has grown from 30” in 1999 to 52” in 2006. These displays also command a higher price point when compared with other segments. To this end, from 2001 to 2004 we observe a simultaneous increase in size and price. The price later declines because of industry over supply to this segment.

In contrast, the current technology segment has a more stable growth in terms of display size. The largest display size on offer changed very little over the years, from 19” in 1999 to 22” in 2006. The 15” display remains the most popular size since in this segment the products are targeted specifically for desktop monitors and laptops. Supporting the notion that customers in this segment are less concerned with technical advancements per se, we observe a significant drop in price for existing display sizes over the years. This price decline reflects the maturity of technology used in producing display panels in this size range, and also arises as a result of the price competition in the PC industry. For example, a laptop that sold for $2,000 in 1998 was priced at $700 or less in 2007. The downward trend in price is even more significant for desktop PC end-products.

Finally, the old technology segment shows nearly no change in size and in price over the period for which we have data. Demand for the old technology is highly diversified, and as such the price fluctuates very little despite the relative lack of sophistication of the underlying display technology. If the demand for cellphone ebbs, for example, panel makers can sell the old technology to GPS or to digital frame manufacturers. The overall extent of technological dynamism in this sector – as well as the prices for which the related products are sold – is therefore quite low, in stark distinction to the other segments of this market.

Market segment

Flat panel displays have evolved from their initial market basis as substitutes for cathode ray tube TV sets to a wide range of current applications, including outdoor displays and instrument panels, with varying glass substrate sizes. The diversity of its applicability in different end-use industries has been noted by previous management studies (e.g., Eggers, 2014; Hu, 2012).

As noted above, the manufacturing process for flat panel displays entails dividing a glass substrate into panels; these panels are then sold to downstream firms for assembly into final products. The size of the display panels largely determines the end application for which the panel is best suited (Hu, 2012). In this regard, the industry as a whole is divided into three segments based on the associated final product application: 1) panels produced in large sizes, typically for televisions and outdoor displays, use new technology; 2) panels produced in medium size, typically for personal computers, laptops and large display devices, use current technology; and 3) panels produced in small size, for use in mobile devices and instrument displays, employ old technology. The large-size segment typically deploys the higher generations available for production. Prior to 2010, makers of TV panels were under constant pressure to catch up with the latest generations of technology being deployed because older generations could not furnish the increasingly large panels needed to satisfy market demand (at least not cost effectively). In contrast, lower generations are mostly employed in the production of medium-size displays. Demand in this segment is more mature and stable. The key to surviving competition in this market segment is to achieve better economies of scale, be more price competitive (Nikkei Microdevices, 2005) and provide more technologically sophisticated products (e.g., better picture quality) with the same size of panel (Hoetker, 2005). Finally, the lowest generations of technology, e.g., Gen 1, are most often deployed to produce displays for the small-size segment. Prices of small displays are the main concern for downstream firms that purchase these inputs for their products (Nikkei Microdevices, 2005).

Generation and market segment

When a manufacturer decides to build a plant of a certain generation, it has already decided on the size of panel it intends to produce, and hence the market segment in which it will compete. For instance, a Gen 6 (or higher) plant is required to produce a 60” panel. In addition to these physical considerations, overall cost is a key factor for manufacturers. First, the higher the generation, the higher the overhead and depreciation cost. Building a Gen 7 plant costs US$2 billion; for Gen 10, the figure is US$3.5 billion. The cost of building a plant accounts for about one-third the total cost of manufacturing. Makers will thus designate higher generations for production of larger, more profitable panels. Second, it is more cost effective to produce panels of a given size using only certain generations. Due to the geometry associated with the cutting of glass substrate, each generation will end up having several corresponding panel sizes that maximize the total utilization area.[2] [3]

Data

Data used to test our hypotheses are gathered from annual reports on the flat panel industry published by research institutes in Japan and Taiwan. The main data source is Flat Panel Display Applications: Trend and Forecast, published by Fuji Chimera in Japan from 1998 through 2011. This series of reports covers plant-level manufacturing data and firm-level product sales data. A complementary data source is The Dynamics of Flat Panel Display Industry,

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[2] Due to facility constraints, one glass substrate can only be divided into a varying number of panels of a given size in one single manufacturing process. That is, a panel maker cannot first cut a larger-sized panel out of a glass substrate and then divide the remaining area into smaller panels.

[3] The goal of dividing glass substrate into panels is to minimize the waste area. For example, a substrate size of 1500 x 1850 mm^2 (Gen 6) yields six 39” panels with an area utilization rate of 97%. However, if the firm wishes to instead produce for a more technologically discerning customer segment, such a decision necessitates the creation of larger panels; in this case, the Gen 6 plant utilization rate decreases to 64% if the glass substrate is divided into 55” panels, yielding two panels. In contrast, the glass substrate of 2200 x 2500 mm^2 that characterizes Gen 8.5 can yield six pieces of 55” panel, with an area utilization rate of 96%. A firm will therefore advance to a higher generation if it intends to produce larger-sized panels in a cost-effective manner.

published by the Photonics Industry and Technology Development Association in Taiwan from 1991 through 2010. Both publications present similar content covering all panel makers globally, with the latter providing more detailed information on Taiwanese and Chinese panel makers in particular.

The majority of firms in this industry produce flat panel displays using the TFT-LCD technology described briefly above. An alternative technology is based on organic light emitting diodes (OLED). Each firm could potentially compete in one or both technological trajectories. Because the segment sales data from Fuji Chimera reports are limited to larger panel makers, the final sample size is comprised of 367 observations from TFT-LCD and 45 from OLED, totaling 412 firm-year observations with full data sets for all measures. Although TFT-LCD and OLED are different technologies, the patterns of segment demand in each are sufficiently similar to justify including both within our final sample. Ninety-five (95) percent of the firms in our sample are 'pure-play' manufacturers of either TFT-LCD or OLED. Only three firms – Samsung, Sony, and Toshiba – concurrently supply panels based on both technologies.[4]

Dependent variable

Of the various possible measures of the innovativeness of an organization, our assessment of firm-level technological innovation views the ability of a company to take a sizable technical leap forward with its product offerings as the defining consideration. Specifically, we characterize the degree of technological innovation as the number of production generations advanced by a given firm with its most recent new product introduction. Viewed in this way, it is the absolute magnitude of generational change embedded in a newly released

[4] As a robustness check, we also ran our models on a scaled-down dataset that included only TFT-LCD observations. Estimates from those regressions are consistent with those reported here for our hypothesis-testing models.

offering, rather than the mere frequency of such new releases per se, that defines a high degree of innovation.

A focal firm i's degree of technological innovation is measured as Gen_{it+1}-Gen_{it}, in a given year.[5] The higher the generation to which a firm advances, the more technological difficulties it will encounter. Major technical hurdles include the following: the filling of liquid crystal between sheets of glass becomes more difficult as these sheets increase in size; larger glass is heavier and more likely to bend during transit between work stations; larger glass is also more likely to be contaminated with dirt and particles, which render the finished product defective; and larger glass is more likely to have an uneven surface, making it more difficult on which to print electric circuits. Additionally, the equipment required to manufacture each generation is highly specific. Thus, the decision to manufacture a new-to-the-firm generation marks a specific decision point that requires development or acquisition of a new set of technological capabilities and substantial investment in equipment for the new fabrication line ("fab"). Hence, the higher the generation a firm deploys relative to its current generation, the more it advances its technology.

Independent variables

We follow Cool and Dierckx (1993) in operationalizing our segment share measure. Segment share is defined as the ratio of the sales of firm i in segment j to segment j's overall sales in year t. That is:

$$segment\ share_{ijt} = \frac{sales_{ijt}}{\sum_{i=1}^{I} sales_{ijt}}$$

[5] In our sample there are two observations representing downward steps from (rather that the more common upward progression toward) a higher generation. Mitsubishi downgraded from Gen 3 to Gen 2 in 1997, and Quanta from Gen 4 in 2001 to Gen 3.5 in 2002. Quanta subsequently upgraded to Gen 5 in 2003; as a result of this upgrading, Gen 4 was not in service during 2002, and Gen 5 came online in 2004. We re-tested our hypotheses excluding these two observations and receive consistent and significant estimations.

where i=1, 2, ... , I represents the total number of firms selling in segment j, which includes new, current and old technology.

Intra-segment competition is measured as the number of firms in each market segment in a given year (Lerner, 1997). Firm count is a common proxy for competitive intensity (Jayachandran, Gimeno, and Varadarajan, 1999). The variable segment competition is created for each market segment.

Control variables

To account for additional factors that could potentially affect technological innovation decisions, a number of control variables are added to our models. Technological capabilities typically determine the technology that a firm can deploy (de Figueiredo and Teece, 1996), with the result that superior technological capabilities are conducive to innovation. To control for this, our models include patent stock, measured as the number of newly granted patents (in thousands) that a firm receives in International Patent Classification sections F21V, G02F, G09G, G09F, H01J, H01L, H04N, H05B and H05H in a given year (Spencer, 2003). The model also controls for an alternative measure of technological capabilities, a firm's highest generation of plant(s) currently in operation in a given year. Larger firms possess more resources than their smaller brethren, allowing them to operate on a greater scale. Our models therefore also control for such firm size effect by incorporating a variable for a firm's annual production value, in billion Japanese Yen. Firm age represents the number of years since the firm established its first plant in the industry. Firms may gain experience and absorptive capacity as they operate in the industry (Nelson and Winter, 1982). We include the squared term to control for a potential nonlinear effect of firm age (Agarwal et al., 2004). Strength of market demand correlates with a firm's motivation to pursue technological innovation. Industry growth, the annual percentage growth of the industry's total production value, is included to control for the industry's demand effect. Finally, since our data set includes firms from Japan, Taiwan, Korea, China, and the rest of the world, Nationality dummy is included to control for potential country-level effects.

Model

The data set in use is an unbalanced panel ranging from 1995 to 2011. To account for autocorrelation and heteroskedasticity[6], we therefore fitted panel-data linear models using feasible generalized least squares (FGLS), which allows for estimation in the presence of AR(1) autocorrelation within panels and cross-sectional correlation and heteroskedasticity across panels (Afuah, 2001). FGLS is generalized least squares for panel data, assuming some structure for the distribution of $e(i,t)$ without requiring the user to directly specify fixed or random effects. Compared with other linear regression models, FGLS estimates are more efficient and hence preferred (Wiggins, 1999).[7]

Our model simulates the decision-making process undertaken by firms in the flat panel display industry. Market segments represent a decomposition of the overall market, and by including all market segments in the model, we control for all possible demand influences on the firm. It is appropriate in this case to study technological innovation and segment share without simultaneously isolating other market segments because panel makers are generally present in more than one of these segments at the same time. Moreover, advancing to higher generations

[6] We first run autocorrelation and heteroskedasticity tests on the data. The result of a Breusch-Pagan/Cook-Weisberg test for heteroskedasticity is λ_1^2=94.46 (p-value=0.00), indicating the rejection of the null hypothesis of constant variance. The result of a Wooldridge test for autocorrelation in panel data is F(1, 41)=110.89 (p-value=0.00), rejecting the null hypothesis of no first-order autocorrelation.

[7] Our final sample size is limited to larger firms with market segment data. We use a two-stage model to alleviate endogeneity concerns due to sample selection bias (Boulding and Christen, 2008). The first stage model includes the full data set, and the second stage model includes only observations with market segment data. The significance of the coefficient of the Inverse Mills ratio indicates if there is selection bias in the data. This ratio is not significant in our second-stage model, thereby assuaging the concern of selection bias.

can be part of a sequence of moves. Prior to advancement, a firm concurrently serving multiple market segments may rely on only one generation for all its production. After advancement, it can assign the new generation for the production of more sophisticated new and current technologies; the old generation can correspondingly be re-directed towards production for old technologies. As discussed above, this approach results in a better utilization rate and less waste in panel production – and is therefore more likely to mirror the actual decision-making undertaken by a flat panel display maker. We set up our models to accurately incorporate the dynamics of such decisions across market segments, and to link these aggregated dynamics to technological innovation.

RESULTS AND DISCUSSION

Table 1 summarizes the descriptive statistics and correlations for the variables in our dataset. The mean variance inflation factor (VIF) is 2.71 and the highest VIF is 5.47 for production value; all values are below the customary threshold at which multicollinearity is held to become problematic. In addition to verifying VIF, we perform collinearity diagnostics in an attempt to further assuage the concern of multicollinearity (Echambadi and Hess, 2007). As a general rule, condition indices of 30 to 100 indicate moderate to strong collinearities. In contrast, condition indices for the variables included in our models are all below six. Based on these diagnostic tests, we conclude that multicollinearity does not introduce bias into the model's estimates.

[Insert Table 1 about here]

Table 2 shows the results of our hypothesis tests. Model 1 includes our control variables only. Models 2-4 report on the estimates of the three hypothesized direct effects separately, while

Model 5 produces estimates of all direct effects on the degree of technological innovation simultaneously. We use Models 2-5 to verify Hypotheses 1-3. Models 6-8 test the moderating effects predicted by Hypotheses 4-6.

[Insert Table 2 about here]

Degree of technological innovation

Hypothesis 1 receives statistical support. The coefficient for segment share, new is positive and significant in Models 2 and 5 (Model 5: $\beta=1.243$, $p\text{-value}<0.05$). Our results indicate that a ten percent increase in firm share in the new technology segment will increase the degree of technological innovation by 0.12 generations on average. A firm with a high share in the new technology segment is impelled forward from an innovation perspective by the abiding technical requirements of its sophisticated customers. Such a leading organization is also able to fund the investment required to make such a move because the revenue it draws from the high price point segment is significant enough to cover it. The higher the segment share, the greater the R&D budget that is allocated towards funding the advancement in technology (Blundell et al., 1999).

Hypothesis 2 receives modest support when considered across Models 3 and 5. Despite non-significance in Model 3, the coefficient of segment share, current is negative and marginally significant in our full Model 5 ($\beta=-0.399$, $p\text{-value}<0.1$). We use Model 5 to verify the hypothesis because it includes all segment shares (old, current, and new) for a firm and is hence more comprehensive in reflecting the firm’s overall conditions. Results indicate that a ten percent increase in segment share in the current technology will reduce the degree of technological innovation by 0.04 generations. The findings lend credence to our claim that the price consciousness and overall technical satiety of customers in this segment create a disincentive for leading firms to innovate by large technological leaps. Such ambitious moves may not pay off in a satisfactory way for market leaders, given the difficulty of capturing the value created by these new product offerings.

Hypothesis 3 is also supported by our results. The coefficient of segment share, old is positive and significant in both Models 4 and 5 (Model 5: $\beta=0.493$, p-value<0.01). Here we observe that a ten percent increase in segment share in the old technology will increase the degree of technological innovation by 0.05 generations. Even with a strong presence in the old technology segment, a leading firm is more likely than its lower-share counterparts to innovate in such a fashion as to advance by greater technological steps.

The comparison of results between the current technology segment and the old technology segment is of particular interest here. As we argued in our hypothesis development section, and as was borne out by our empirical models, high share in the current technology segment acts as a relative deterrent to the degree of technological innovation pursued; in contrast, high share in the old technology segment augments this degree of innovation. We believe that the notion of demand heterogeneity again sheds light on this puzzling trend. In the current technology segment, leading firms are beset by specific customer pressures that serve to diminish the realized returns from generational jumps in technology. The needs of buyers in the current technology segment are generally well met by existing product offerings (Christensen, 1997; Geroski, 2000), and what innovation is seen as necessary tends to focus on small refinements to these current goods (Christensen and Bower, 1996). These dynamics may also be present to a lesser extent in the old technology segment; however, here customer requirements revolve largely around price considerations. Leading firms in the old technology segment are motivated to move forward in a more ambitious way with their production generations since doing so enables them to address these price issues by competing in the market with a more efficient advanced technology, or to potentially move up to higher segments of the industry where these challenging pricing obstacles can be avoided entirely. In circumstances of low competition, high-share firms can act largely of their own volition. However, as we show below, competitive effects become an important consideration for the innovative activities pursued by firms in these different segments.

Turning next to our posited interaction effects, Hypotheses 4-6 test how intra-segment competition moderates the effect of segment share on the degree of technological innovation. Competition intensity above the median is considered high competition, otherwise it is low. Hypothesis 4 receives statistical support. The coefficient of segment share * competition, new is positive and significant (Model 6: β=0.166, p-value<0.01), indicating that intra-segment competition of the new technology strengthens the effect of segment share on the degree of technological innovation.[8] The estimation suggests that for the same level of segment share, a firm facing high competition shows a greater degree of technological innovation than does a firm facing low competition. This finding lends support to the argument that intensifying competition accelerates the pace of the technology race, driving firms to innovate more (Khanna, 1995). This seems to be especially the case in the new technology segment, where customer demands for continued increases in performance coupled with a large number of rivals create substantial incentives to innovate ambitiously on the part of a focal firm.

[8] The coefficient of segment share, new turns negative in Model 6, but is statistically insignificant. Even though the interpretation of the interaction term does not involve the main effect, this reversed sign could suggest multicollinearity. To address this concern, we test Hypothesis 4 with ridge regression which corrects the inflated standard errors resulting from multicollinearity (Mason and Perreault, 1991). In the ridge regression, the coefficient of segment share, new is -0.46 (p-value=0.155), and the interaction term testing the hypothesized effect remains statistical significant. The estimates are consistent with Model 6, assuaging the concern of multicollinearity. Thus, we conclude that the estimates in Model 6 are not biased.

Hypothesis 5 is also supported in our analyses. The coefficient of segment share * competition, current is positive and significant (Model 7: $\beta=0.159$, $p\text{-value}<0.01$), indicating that intra-segment competition of the current technology weakens the negative effect of the segment share on the degree of technological innovation. That is, for the same segment share in the current technology, a firm experiencing high competition will show a greater degree of technological innovation than one experiencing low competition. In the flat panel display industry, the current technology segment is the one that needs to strike the balance between product price and technological performance. In general, a firm active in the current technology segment is conservative in its degree of technological innovation, as predicted by Hypothesis 2. However, the intensity of competition compels even the segment leaders to make a stronger push towards new production generations than would otherwise be the case. Strong competition provides incentives for a firm to advance its technology in an attempt to produce products with more sophisticated technology and thereby protect its competitive position.

Finally, Hypothesis 6 receives statistical support. The coefficient of segment share * competition, old is negative and significant (Model 8: $\beta=-0.0224$, $p\text{-value}<0.01$), indicating that intra-segment competition of the old technology weakens the positive effect of the segment share on the degree of technological innovation. The model estimation shows that for the same level of segment share, a firm facing high competition evinces a lower degree of technological innovation than does one facing low competition. Although leading firms in the old technology segment are apt to innovate in a more ambitious manner, this dynamic is attenuated under conditions of high rivalry. Considering the fact that customers in this segment are exceedingly price conscious, high segment share firms may conclude that the benefits of moving forward with large jumps in generational technology are outweighed by the drawbacks of attempting to capitalize on this innovation in a context of strong competitive pressure.

CONCLUSION

Beginning from the premise of demand heterogeneity across intra-industry market segments, this paper uses segment share as a unit of analysis to attempt to resolve the conflicting predictions regarding the effect of market share on a firm's innovation performance. The current study complements the mainstream view in the innovation literature that competition drives more innovation (Adner and Zemsky, 2003; Khanna, 1995; Lerner, 1997). We are able to better discern the other external factors that drive and deter innovation when market share is broken down into a more refined (segment-level) measure.

This disaggregation is undertaken and, we believe, justified when one considers the nature of market dynamics through the prism of demand heterogeneity (Adner and Levinthal, 2001). The demand-side view posits that the degree of technological innovation that a firm carries out depends on how distinct market segments make use of existing offerings and evaluate potential product changes. A leading firm may only need to advance in small steps to continue to fruitfully address the needs of customers that are already technologically satisfied. In contrast, the pursuit of new technologies may need to be more ambitious in nature when a high segment share firm seeks to maintain its competitive position with regards to sophisticated, non-satiated customers with a correspondingly high willingness to pay (Adner, 2004). While anecdotal evidence of these dynamics has been found in the microprocessor industry and the U.S. automobile sector, our study applies this view in the context of the decision to deploy new technologies in the form of production generations, and finds results consistent with the overall theory. Our findings also extend the work of Adner and Snow (2010), which questions whether firms should engage in technological racing. We offer empirical support to these authors' argument that the decision to maintain relevance in the market depends on the attributes and performance that the new technology addresses.

Our research also contributes to the technology management literature. A perennial question posed by work in this domain is whether a firm should deploy a technology more advanced than its current one (Appleyard et al., 2008; Christensen, 1997; de Figueiredo and Teece, 1996). Following Pacheco-de-Almeida and Zemsky's thesis (2007) on timing of resource deployment, the current study defines some key conditions under which a firm should deploy a newer, more advanced technology (and by how much). We also complement previous work that focuses on the potential organizational gains from technology deployment (Fuentelsaz, Gómez, and Palomas, 2012; Gilbert, 2006). These gains depend largely on the intensity of competition; our research sheds light on the interplay between the character of the next technology to be deployed by an organization and that firm's control over its competition.

We also offer some useful implications for managerial practice. Insights derived from our findings should enhance a manager's ability to predict which firm is more likely to move forward with a given technological innovation, in which segment it is more likely to act, and how much of a technological leap forward its initiative will take. This finding is in line with some anecdotal managerial insights we gained from interviews with industry insiders. Before deciding to which generation to advance, industry practice in the flat panel display sector is to first look at what close competitors are about to do – that is, to assess to which generation their competitors plan to advance. We believe that the results of our study will enable managers to better define which competitors should be given their attention, and to predict their moves more accurately.

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Table 1 Summary statistics and correlation

		Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12
1	Technological innovation	0.19	0.48	-1	2.5	1											
2	Segment share, new	0.02	0.07	0	0.68	0.21	1										
3	Segment share, current	0.04	0.09	0	1	0.10	0.51	1									
4	Segment share, old	0.06	0.11	0	0.91	0.10	0.16	0.18	1								
5	Segment competition, new	5.47	8.82	0	27	0.08	0.32	0.18	0.01	1							
6	Segment competition, current	7.9	8.94	0	27	0.08	0.23	0.28	0.04	0.82	1						
7	Segment competition, old	11.37	11.78	0	43	0.01	0.08	0.10	0.33	0.46	0.52	1					
8	Patent stock	0.18	0.28	0	1.57	0.07	0.12	0.32	0.08	0.14	0.24	0.09	1				
9	Generation	2.99	2.02	1	11	0.10	0.65	0.54	0.25	0.49	0.47	0.17	0.22	1			
10	Production value	1.93	3.84	0	20.22	0.15	0.77	0.61	0.19	0.33	0.26	0.07	0.18	0.83	1		
11	Firm age	6.42	4.2	0	17	0.02	0.39	0.23	0.26	0.40	0.27	0.22	0.15	0.55	0.52	1	
12	Industry growth	23.487	31.972	0.43	349.63	-0.01	-0.06	-0.09	0.10	-0.10	-0.19	0.11	-0.04	-0.15	-0.12	-0.11	1

Table 2 Feasible generalized least squares regression; Dependent variable is degree of technological innovation

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
	Control	H1	H2	H3	H1-3	H4	H5	H6
Segment share, new		1.366** (0.526)			1.243* (0.498)	-1.532 (1.115)	1.116* (0.496)	1.210* (0.502)
Segment share, current			-0.224 (0.235)		-0.399^{+} (0.233)	-0.332 (0.222)	-2.557** (0.866)	-0.382 (0.235)
Segment share, old				0.422* (0.168)	0.493** (0.172)	0.538** (0.165)	0.554*** (0.165)	0.947*** (0.192)
Segment share* competition, new						0.166** (0.0597)		
Segment share* competition, current							0.159** (0.0598)	
Segment share* competition, old								-0.0224** (0.00724)
Segment competition, new	0.0002 (0.00)	-0.001 (0.00)	-0.001 (0.00)	0.003 (0.00)	0.0001 (0.00)	-0.001 (0.00)	-0.001 (0.00)	0.0004 (0.00)
Segment competition, current	0.002 (0.00)	0.002 (0.00)	0.002 (0.00)	0.002 (0.00)	0.005 (0.00)	0.005^{+} (0.00)	0.005* (0.00)	0.0003 (0.00)
Segment competition, old	-0.001 (0.00)	-0.0003 (0.00)	-0.001 (0.00)	-0.004*** (0.00)	-0.005*** (0.00)	-0.004*** (0.00)	-0.005*** (0.00)	0.00004 (0.00)
Patent stock	0.034 (0.05)	0.035 (0.04)	0.047 (0.05)	0.056* (0.03)	0.079* (0.04)	0.070* (0.04)	0.034 (0.04)	0.062 (0.06)
Generation	-0.022 (0.02)	-0.048** (0.02)	-0.022 (0.02)	-0.042* (0.02)	-0.052** (0.02)	-0.040* (0.02)	-0.050** (0.02)	-0.045* (0.02)
Production value	0.012^{+} (0.01)	0.005 (0.01)	0.017* (0.01)	0.020* (0.01)	0.012 (0.01)	0.017^{+} (0.01)	0.018^{+} (0.01)	0.011 (0.01)
Firm age	0.005 (0.00)	0.003 (0.00)	0.006* (0.00)	0.007^{+} (0.00)	0.003 (0.00)	0.001 (0.00)	0.0004 (0.00)	0.002 (0.00)
Firm age, square	-0.0004 (0.00)	-0.0003 (0.00)	-0.0006^{+} (0.00)	-0.0008* (0.00)	-0.0005 (0.00)	-0.0002 (0.00)	-0.0001 (0.00)	-0.0006 (0.00)
Industry growth	0.000002 (0.00)	- 0.000003 (0.00)	- 0.000002 (0.00)	-0.00001 (0.00)	-0.00001 (0.00)	-0.00002 (0.00)	0.000002 (0.00)	-0.00003 (0.00)
Nationality	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.	Incl.
Constant	0.318 (0.20)	0.413* (0.20)	0.327 (0.18)	0.355 (0.19)	0.440* (0.20)	0.439*** (0.09)	0.301 (0.16)	0.334 (0.19)
Observations	412	412	412	412	412	412	412	412
Wald λ^2	37.03	42.22	40.63	145.79	123.29	143.79	106.60	138.05
Probability>λ^2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Standard errors in parentheses
$^{+}$ $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.00$

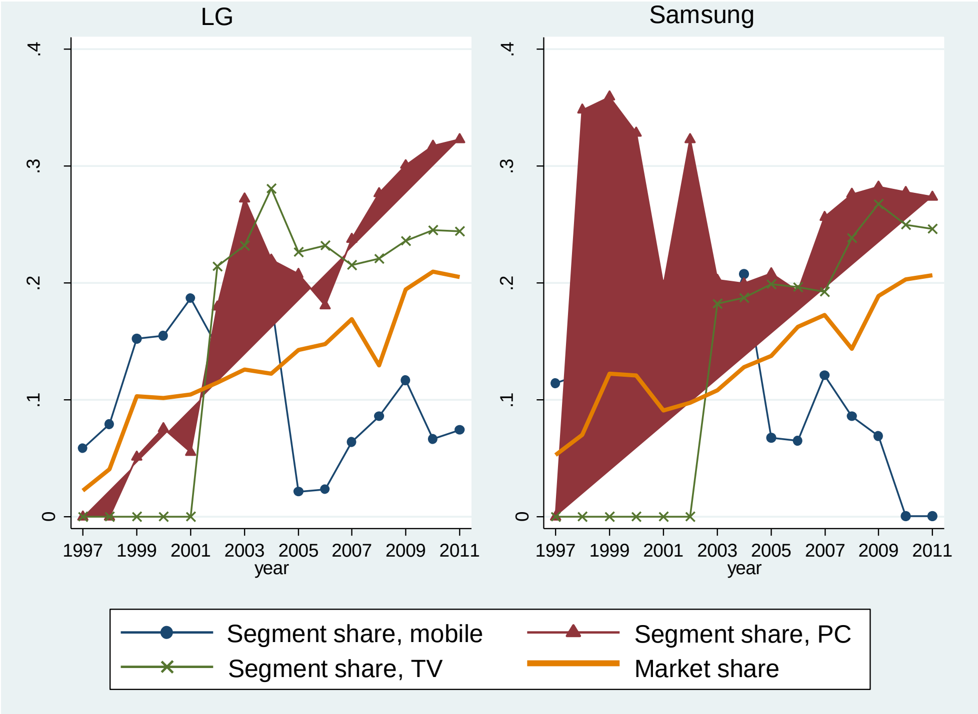

Figure 1 Market share breakdown: Segment share

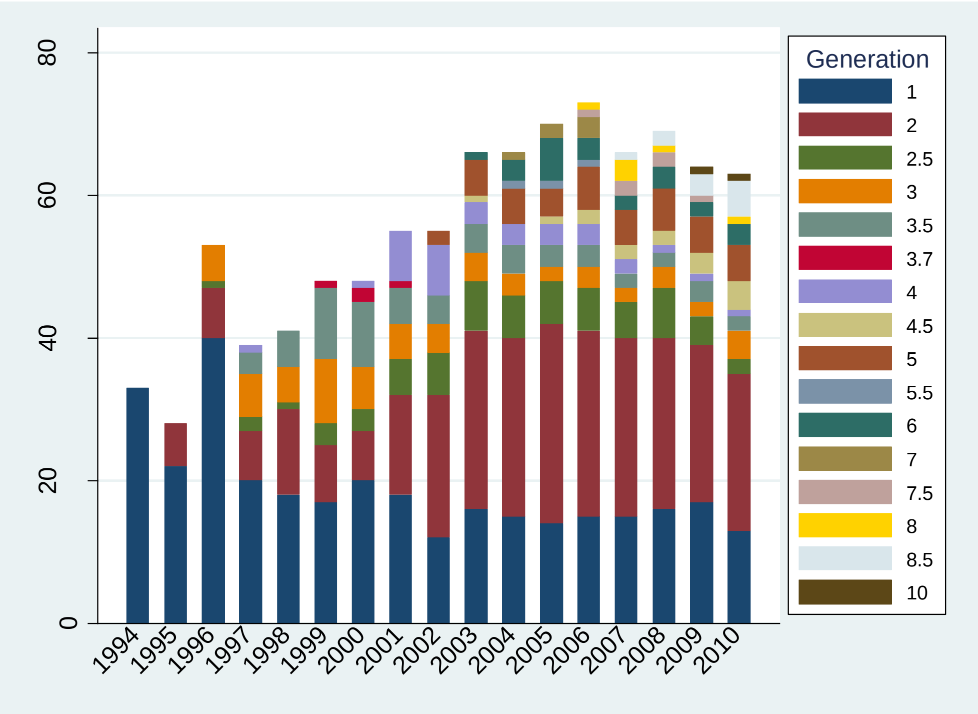

Figure 2 Generation distribution over year

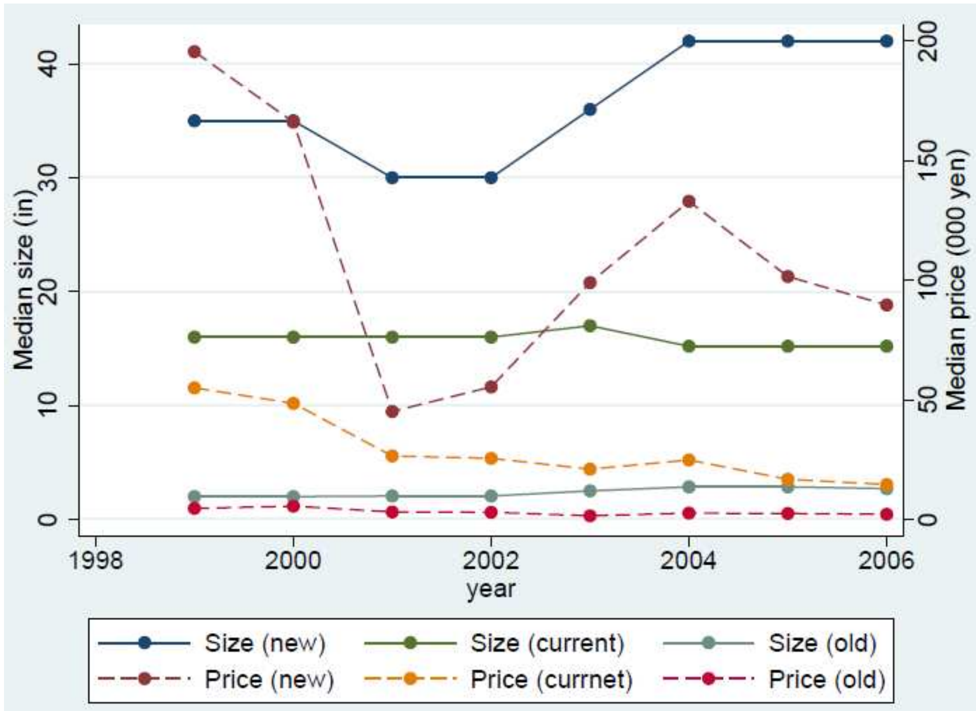

Figure 3 Trend in display size (performance) and price in the new, current, and old technology segments