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Growth Logics: Market vs. Technological Knowledge and the Direction of Organizational Expansion

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Abstract

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INTRODUCTION

What determines the direction of a firm's growth? Since the publication of *Theory of Firm Growth* by Penrose (1959), the fit between the resources of the firm and requirements of the new market has been found to be an important predictor of new market entry and subsequent performance (e.g., Milgrom and Roberts, 1995; Peteraf, 1993; Wernerfelt, 1984), and substantive efforts have been made to develop a more granular understanding of the resources that underpin a firm's entry into new markets and its competitiveness.[1] For example, Henderson and Cockburn (1994) decompose a firm's R&D capability into component and architectural competence. Helfat and Lieberman (2002) distinguish between specific and general resources as well as core and complementary resources in examining the influence of a firm's pre-entry experience. Such finer-grained examination of a firm's resources and experience has contributed to a better understanding of the heterogeneity in resources and contingencies that determine the success of diversification (Klepper and Simons, 2000; Eggers, 2013).

These studies suggest that firm resources – specifically often knowledge that may be applied to multiple domains – play a key role in understanding the specific direction in which firms diversify over time, but also suggest that different types of resources and knowledge may play different roles in driving diversification. While there are many different types of resources to distinguish between, one of the most common distinctions made in the literature is between core or technological knowledge versus complementary or market-based knowledge (Helfat and Lieberman, 2002). Technological knowledge has been shown to be a key driver both of the decision to diversify (Silverman, 1999) and firm-level performance conditional on diversification (Klepper & Simons, 2000; King & Tucci, 2002; Franco, Sarkar, Agarwal, and Echambadi, 2009).

[1] Consistent with Sosa (2009) and Amit and Schoemaker (1993), we use the terms "competencies" and "capabilities" interchangeably with "resources".

Meanwhile, complementary or market-based resources and knowledge, including the understanding of customer preferences and competitors in the market, has long been recognized as a critical resource (e.g., Teece, 1982), but there has been a surprising lack of empirical research that explicitly linking market knowledge and firm entry and diversification behavior. A few studies have linked decline in existing businesses and entry into related businesses, presumably to capitalize on the redeployment of fungible resources (Anand & Singh, 1997; Wu, 2013). And work on technological discontinuities has shown that valued complementary assets may help incumbent firms to be more adaptive to changing environments (Tripsas, 1997; Sosa, 2009). But these studies offer limited opportunities to compare the effects of technological knowledge with market knowledge, and whether the two affect each other in important ways has also been underexplored.

In this study, we seek to offer a cross-industry theory about why technological and market knowledge will both independently and jointly drive product market entry behavior of organizations that builds on and clarifies existing work on knowledge and diversification (e.g., Silverman, 1999; Sosa, 2009; Helfat and Lieberman, 2002), and suggest that the relative importance of market versus technological knowledge will vary across organizations of different size. To empirically investigate our hypotheses and evaluate the market entry decisions of firms across a wider spectrum of technological and market relatedness, we link CorpTech data that categorizes and catalogues the product portfolio of US high-tech firms to the USPTO patent database, tracking changes in product and patent portfolios of over five thousand high-tech firms across two thousand product markets over the period of 1997-2005.

Our empirical results reveal more complex dynamics underlying a firm’s entry into new product-markets than previously considered. First, contrary to previous findings of a positive relationship at the broader industry level, we find that technological relatedness is negatively related to the likelihood of entry when examined at a more granular level of the product-market. The negative effects are more pronounced for larger companies, suggesting product cannibalization (Figueiredo and Silverman, 2007) as an important contingency that influences product-market entry decisions, and providing dynamic empirical support for suggestions that firms often know much more than they make (Brusoni, Prencipe, and Pavitt, 2001; Kapoor and Adner, 2012). In contrast, we find robust and consistently positive effects of market knowledge across various levels of technological relatedness, demonstrating the importance of market-based knowledge in driving diversification decisions. We also find that while firms of all sizes diversify in directions consistent with the use of market knowledge, the effect is especially pronounced for larger firms. Interestingly, the interaction between technological and market relatedness is insignificant, highlighting the importance of market knowledge as a core, independent resource in driving product-market entry, beyond serving as a complementary asset that enhances the value of technological knowledge. Together, these findings suggest that while technological knowledge may positively drive decisions to diversify the firm's technological portfolio (e.g., Breschi, Lissoni, and Malerba, 2003), its effect on actual product entry is more complicated, and also highlight that firms of different sizes places different weights on different types of knowledge, potentially because technological knowledge is readily acquirable for large firms (Cesaroni, 2004) while the market for market-based knowledge is less fluid.

Our study make several empirical and theoretical contributions to developing a more nuanced understanding of Penrose and the RBV, qualifying Wernelfelt's (1984, p.171) proposition that "resources and products are two sides of the same coin." Specifically, we show that it is important to distinguish technological entry from product-market entry. Concern for cannibalization limits large firms from exploiting technological relatedness in their growth, demonstrating how path-dependency in the product market can lead to divergence between a firm's technology and product market over time (Gambardella and Torrisi, 1998). Theoretically, we highlight the importance of market knowledge as an independent core resource that guides product-market entry decisions of even high-tech firms. Finally, our findings suggest that there is discrepancy in resources that lead to product-market entry (i.e., market knowledge) from resources that enhance post-entry performance (i.e., technological knowledge), highlighting the importance of learning and dynamic capability subsequent to entering the market (Makadok, 2001).

THEORY AND HYPOTHESES

The RBV views firms as bundles of imperfectly imitable resources that combine to produce a set of products (Barney, 1991). A firm may change its bundle of resources over time, but as valuable resources are often specific and difficult to acquire, the direction of a firm's growth is driven by combinations of unused productive services already in hand (Penrose, 1959). As a result, growth and innovation tend to be related or 'adjacent' to existing business, leading to theories of related diversification (Markides and Williamson, 1994; Miller, 2006). The Behavioral Theory of the Firm (Cyert and March, 1963) and evolutionary economics (Nelson and Winter, 1982) also provide consistent predictions – firms are constrained by previous investments and their repertoire of routines, rendering learning and growth a dynamic but local process. Hence, the ability of a firm to create value through recombination quickly dissipates with decreasing relatedness between the resource requirements of the existing and new market.

As a result, growth is path-dependent and firms diversify in a nonrandom manner with purpose and coherence (Teece et al., 1994).

Early empirical tests of RBV looked at industry-level similarities in driving corporate diversification. For example, MacDonald (1985) and Montgomery and Hariharan (1991) find that firms tend to enter industries with similar levels of marketing and capital intensities. Similarly, a number of studies has used proximity within the SIC system to measure the relatedness between two industries as well as the direction of firm's diversification (e.g., Montgomery and Wernerfelt, 1988). However, partly in response to criticisms that these measures reflect similarities in output characteristics rather than inputs, recent research takes an increasingly closer look at both measuring resources and the direction of diversification. Taking a more direct look at resources, Silverman (1999) measures a firm's technological resources in terms of its patent portfolio and finds that firms tend to diversify into industries with a higher share of cross-citation. Sosa (2009) and Nerkar and Roberts (2004) decompose the resources of firm into market and technology related factors to find significant and positive interaction effects.

While these studies demonstrate the importance of taking an increasingly granular look at heterogeneity in resources and studying market entry at the level of product-market, they primarily have focused on specific industries and emphasize post-entry performance over entry decisions. For example, King and Tucci (2002) and Sosa (2009) look at generational shifts in disk-drive and anti-cancer drugs, respectively, in the context of competition between the incumbent and new entrant. Nerkar and Roberts (2004) look at several drug categories within the pharmaceutical industry, but focus exclusively on post-entry performance.

Our three-fold focus in building upon and generalizing these studies is to i) link the two specific types of firm-level resources - technological knowledge and market knowledge - to a new market entry decision, ii) investigate the contingent nature of the these two resources, and iii) do so across a wide spectrum of product and market relatedness.

Technological knowledge. In line with Teece's (1988) definition of a firm's competence as a "set of differentiated *technological skills*, complementary assets, and organizational routines," technological knowledge has been at the center of research on new product-market entry, innovation, and firm growth in the RBV. The accumulating body of research indicates a close relationship between technological experience and technological output (Breschi et al., 2003), the likelihood of introducing new products within existing markets (Katila and Ahuja, 2002), and even the mode of market entry (Helfat and Lieberman, 2002). The study by Breschi, Lissoni, and Malerba (2003), for example, shows that firms typically move into technological spaces (measured through patent data) that are closely proximate to the technological spaces in which they are already active, thus leading to a path dependent growth process. In examining firm growth and diversification, however, it is important to make the distinction between technological entry and product-market entry. Products embed multiple technologies (Pavitt, 1998), and so the role of technological relatedness in technological diversification does not necessarily equate to the role of technological relatedness in product market entry. To address this, Silverman (1999) shows that technological knowledge does predict the entry behavior of organizations, but argues that firm-level measures of technological knowledge (as opposed to industry-level measures) are important, as firms are highly heterogeneous even within the same industry. Building on this existing work, we suggest that a given firm's technological knowledge – and specifically how applicable that knowledge is to any given product market environment – will be positively related to the likelihood of entry into that market.

> *H1: The probability of product-market entry is a positive function of the relatedness of a firm's existing technological knowledge to that required by the focal product market.*

While close variations of this hypothesis have been tested and supported by a number of previous studies, there are also several studies with contradictory results, suggesting the need for a better understanding of boundary conditions. For example, in the laser printer industry, de Figueiredo and Silverman (2007) find that demand-side incentives to avoid potential cannibalization are sufficient to counteract the supply-side incentive to enter segments that are technologically most proximate. Experience or commitment in one technology can also impede a firm's willingness to enter a market that requires similar but competing technology (Eggers, 2012), especially if it requires disruptive organizational change or displacement of existing technology (Leonard-Barton, 1992; Henderson, 1993). Consistent with such view, some scholars have challenged the assumption that technology is the dominant determinant of new product-market entry. For example, Pavitt (1998) posits that large firms have few difficulties in mastering new technology and emphasizes organizational or integrative knowledge (Helfat and Raubitschek, 2000) as key factor in new driving product introduction. This is consistent with the growing body of literature on markets for technology (Arora, Fosfuri, and Gambardella, 2004) – external technological knowledge is often readily available for organizations. For example, Gambardella and Torrisi (1998) find technological divergence coupled with market convergence for large US and European electronic firms.

Overall, research suggests that firms may often know (in a technological sense) much more than they make, in part to help them work with potential partners (Brusoni, Prencipe, and Pavitt, 2001; Kapoor and Adner, 2012) and in part to help them assimilate new knowledge that may be relevant (Cohen and Levinthal, 1990). Thus, there are potential confounds to the role of technological knowledge in driving product market diversification decisions, and that there could be no resulting relationship between technological relatedness and entry decisions, or that the relationship could even be negative. Given the preponderance of theoretical and empirical evidence suggesting a relationship, we focus on offering the single, positive hypothesis, but wish to suggest the potential for a more complicated relationship.

Market knowledge as an enabler. Similar to Helfat and Lieberman (2002), we define market knowledge as the understanding of the preferences and needs of key stakeholders in the product market, including consumers, competitors, and other relevant stakeholders, such as suppliers and distributors. Compared to technological knowledge, there is limited theoretical and empirical research that examines how market knowledge affects new product-market entry. Most empirical research has operationalized market knowledge as a complementary resource that enables a firm to "derive maximum benefit from its technological achievements" (Nerkar and Roberts, 2004, p.780). Such characterization closely parallels the distinction between resources and capabilities in Amit and Schoemaker (1993), where resources are stocks of available factors owned or controlled by the firm while capabilities are defined as the firm's capacity to deploy resources for desired end results.

There are two primary contexts under which market knowledge has been studied as a complementary resource. The first emphasizes the role of market knowledge in facilitating the match between technological capabilities with market needs. The second characterizes market knowledge as an intermediate good that improves efficiency in recombining existing technology to better address consumer needs. While not mutually exclusive with shared focus on the commercialization of existing technology, the two perspectives yield predictions regarding different stages of product-market entry. The former predicts increased likelihood of entering new markets that share common market knowledge (e.g., same consumer or supplier), triggering the use of technological resources. Consistent with such view, Tripsas (1997) notes that founders of typesetters were also previously users, giving them a better understanding of emerging consumer preferences. Similarly, entrepreneurship literature emphasizes familiarity *with the market* as playing a critical role in recognizing the opportunity to enter the product market (Shane, 2000; Shane and Khurana, 2001). The latter is more concerned with post-entry performance and posits that a high level of market knowledge enhances performance by directing a more efficient combination of existing resources and protects incumbents from new entrants with better technology (Nerkar and Roberts, 2004).[2] Overall, this perspective suggests an interaction between technological and market knowledge – that the effect of market knowledge on entry will be contingent on the possession of relevant technological knowledge.

> *H2: There is a positive interaction between technological and market knowledge in determining the probability of a new product-market entry.*

Market knowledge as a main effect. While most studies, as noted above, have focused on the role of market knowledge as a complement to technological knowledge, many of the foundational studies that have looked theoretically at market knowledge recognize and highlight market knowledge as an independent, core resource that encourages product market entry (e.g., Teece et al., 1994[3]; Helfat and Lieberman, 2002). Many of the studies that have focused on market knowledge as complementary to technological knowledge have investigated competition between incumbents and new entrants (e.g., Sosa, 2009), and have used market knowledge as the unique advantage that sustains the incumbent's position despite disadvantages in technology (Klepper, 1996; Tripsas, 1997). If we step away from linking market knowledge with

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[2] While strictly not a new product-market entry, discussions on the importance of market knowledge in geographical expansion would also fall under the second view. Foreign firms entering US or US firms entering developing markets often lack knowledge of local market – whether it is required customization of products, relationships with distributors or relevant authorities – and have been found pursue partnership with local partners with complementary market knowledge (e.g., Helfat and Lieberman, 2002)

[3] "Two key aspects of the learning environment for new product development are the technologies being employed, and the market into which the new product is to be launched." (Teece et al., 1994, p.17)

incumbency versus entering firms, and instead focus on the idea of market knowledge as an independent driver of product-level diversification, it seems quite plausible that market knowledge – existing relationships with customers, distribution and marketing assets, etc. – would play a key role. To the extent that, as Helfat and Eisenhardt (2004: p. 1219) state, "benefits from economies of scope can also be formulated in terms of demand-side benefits related to outputs" as opposed only to costs and supply-side benefits, we should expect diversification to potentially be built around the reuse and fungibility of marketing knowledge. This may be especially true given the ambiguity raised earlier about the role of technological knowledge, as firms may invest research dollars in technological knowledge without a clear plan to offer products in that space. As a result, we hypothesize that market knowledge will have its own, independent effect from technological knowledge on the direction of diversification.

H3: The probability of product-market entry is a positive function of the relatedness of a firm's existing market knowledge to that required by the focal product market.

Size, market knowledge, and technical knowledge. Previous research suggests there are important potential contingencies that influence the relative importance of market and technological relatedness in driving market entry. For example, in their survey of European high and low technology sector companies, Grimpe and Sofka (2009) find that firms in the low-technology sector place focus on market knowledge over technological knowledge, suggesting the degree of technological requirements in the market as an important contingency variable. In this study, we focus on firm size as a potentially critical contingency that can influence the relative importance between the two resources.

Pavitt (1998) posits that large firms in advanced countries will have few difficulties in mastering new technology, suggesting firm size as an important proxy that reduces constraint to the existing bundle of resources. For example, larger firms can acquire or partner with smaller firms with requisite technological knowledge, as in the case of Wal-Mart's entry into the online market. While Wal-Mart possessed a deep understanding of suppliers and consumers, it lacked requisite technology and know-how to build and maintain a large-scale online interface to reach online consumers. Wal-Mart entered the market after partnering with Accel Partners, a venture capital firm specializing in on-line business (Helfat and Lieberman, 2002). Google's acquisition of YouTube in 2006 and Microsoft's purchase of Motorola provide other illustrative examples. The general sense is that markets for technology make the acquisition of technology knowledge easier for firms that have the resources and capabilities to use those markets, typically larger organizations. Meanwhile, market knowledge based on customer relationships and an understanding of their needs and wants may be more difficult to acquire externally. Thus, we expect that market knowledge will play a larger role in the entry decision making process for large firms than for small firms.

H4A: Market knowledge plays a more important role in determining the probability of new product introduction for large firms compared with small firms.

It is important to note that entry into a product-market with low or high technological relatedness is likely to require different approaches and degrees of investment. As illustrated in the previous case of Wal-Mart, entry into a product-market with high market knowledge but low technological knowledge is likely to require significant R&D or a partnership, whereas entry into markets with a high level of technological knowledge leverages existing technological capability with limited need for investment in developing the required technology. As small firms are more constrained in terms of available financial, managerial and even network resources (Lee, 2007), we expect that technological knowledge will play a more significant role for smaller firms.

H4B: Technological knowledge plays a more important role than market knowledge in determining the probability of new product introduction for small firms.

DATA AND EMPIRICAL APPROACH

To evaluate our theory about the relevance of technological and market knowledge for product market entry, we rely on two primary data sources – the CorpTech database and the NBER's USPTO patent database. The time period of the sample runs from 1997 to 2005, with the first three years used only to construct the lagged measures used in the analysis (as described below). We draw our information on product markets and market knowledge (as well as a series of other control variables) from the CorpTech Directory of Technology Companies, which provides a listing of products for about 50,000 high-tech firms in the United States across a wide variety of industries. Additional information includes geographical location, sales, founding year, ownership structure, and the names of key executives as well as the primary SIC code associated with the company and specific CorpTech product categories for each product. More than half the companies covered are not publicly traded. Due to the availability of detailed data and the coverage of small, private firms, CorpTech has been used by several previous studies related to new product introduction and behaviors of small high-tech firms, such as effects of network resources on product entry (Lee, 2007), entrepreneur boundary crossing (Dokko and Wu, 2007), and optimal timing of organizational consolidation (Puranam et al., 2006) and IPO (Stuart et al., 1999).

CorpTech classifies products into three levels of hierarchy – 17 sectors, 255 industries, and 3,000 product segments. Sectors include software, medical devices, manufacturing equipment, and computer products. At the most granular level, the set of product segments in marketing software includes different codes for sales reporting software, direct marketing software, sales force automation software, and market planning software (among others). Thus, the product segments are much more fine-grained than "industries" in the classical sense, and provide a much more detailed opportunity to observe both entry behavior and the role of market-based knowledge (as described below). In addition, similar to SIC, its classification reflects output characteristics rather than input characteristics as it primarily serves as the directory for a sales force. While such feature makes it an inappropriate source of data for a direct test of RBV (Silverman, 1999), it is suitable for measuring market relatedness, especially in terms of consumers and competitors.

Dependent variable and data structure. We organize our data in a firm-category-year panel, with one observation for each firm-year in each product category in which they had not been active in the previous three years (to measure entry behavior). Our dependent variable PRODUCT ENTRY is a binary variable based on the finest degree of characterization in the CorpTech data – the 3,000+ product segments – and is set to 1 if there is a listing in a new product segment for the firm in a given year, and 0 otherwise. Thus, we have many observations per firm-year across the more than 3,000 different product categories. To be useful for our study, our data need to be able to discern three things – the entry behavior of organizations in different product categories, the technological relatedness between the firm's existing knowledge stock and any potential product category into which they could enter, and the market relatedness between the firm's existing market knowledge stock and any potential product category into which they could enter. The final sample is limited specifically by our ability to reliably ascertain the relevant technology for any given product category, so we begin by discussing this process.

Technological relatedness. Assessing the relatedness of a firm's existing knowledge to any given product category requires an understanding of the technologies relevant to the category. To construct the technology requirements for each product category, we identify all firms in each product category. The USPTO classifies patents into 421 technology classes, and all U.S. patents are classified at least by one class code (data from the most recent NBER patent data file (Hall et al., 2001)). We obtain the technology requirement matrix *R* of product categories by technological classes. The element R_{ij} is set equal to 1 if more than 10% of firms in the category *i* has more than one patent of patent class *j* and R_{ij} is 0 otherwise. We limit our sample to categories with at least ten incumbent firms, so the criteria means that at least two firms previously active in the category (during the previous three years) have patented during that window in the same technological class. Such an assessment allows us to identify more than one technological class that may be relevant for a given product category, and indeed we see that the average category had at approximately six technological classes associated with it.

To measure the relatedness between the firm's technical knowledge portfolio and these category-level technological requirements, we follow the method of Jaffe (1986, 1989) and Brechi et al. (2003) and construct technological relatedness among technological classes by using the main class code of each patent. We assume that if there is a citation between patents of class A and B, there is a link between two classes. By applying this count of patent citations to all possible pairs of classification code, we obtain a square (421 x 421) symmetrical matrix of technology-relatedness among technology classes (*L*), whose element L_{ij} denotes the number of patent citations between class *i* and *j*. This matrix *L* is used to derive a measure of technology relatedness among technology classes. We use the cosine index, S_{ij}, which measures the angular separation between the vectors representing the citations between technology class *i* and *j*:

$$S_{ij} = \frac{\sum_{k=1}^{421} L_{ik} L_{jk}}{\sqrt{\sum_{k=1}^{421} L_{ik}^2}\sqrt{\sum_{k=1}^{421} L_{jk}^2}}$$

S_{ij} is the greater the more the two classes *i* and *j* are more related.

Then, we calculate the technological relatedness (TR_{ij}) of between firm i and product category j. There are multiple technology requirements for a product category j. If firm i has a patent from any required technology class of product j, TR_{ij} is 1. If TR_{ij} is not 1, we find the best alternative technology class of firm i, which has the highest relatedness (S_{ij}) among the possible pairs of patent portfolio of firm i (P_i) and technology requirements of product category j (R_j):

$$TR_{ij} = \max_{f \in F_i, r \in R_j} (S_{ij})$$

Figure 1 shows the distribution of technological relatedness between firm and product category (TR_{ij}). When TR_{ij} is equal to 1, the firm has direct technological experience in one or more technological classes required by the product category, and as the measure declines the firm's most proximate technological knowledge is increasingly distant. When TR_{ij} is smaller than 1, the frequency of TR_{ij} decreases, as the TR_{ij} increases. The frequency of 1 is higher than those of other high TR_{ij} values – there are quite a few firms with the potential to enter into product categories in which their knowledge would be directly relevant, but very few firms with closely proximate knowledge.

Figure 1 here

Market knowledge relatedness. We construct our measure of market relatedness between the firm's existing product categories and any focal new category directly from the CorpTech data. Analogous to previous research using the SIC system, we use proximity within CorpTech product classification as a proxy for market relatedness. Corresponding to the three-level hierarchy that consists of sector, industry and product, market relatedness is set to 2 for product-market entry within an industry of a firm's existing product portfolio, 1 if the entry is within the same sector but different product segment, and zero if across different sectors. We feel that this measure of relatedness is specifically applicable to market knowledge for two reasons. First, the CorpTech data were designed to be used in sales efforts. The goal was to allow vendors to understand which closely related product categories their potential customers were engaged in, and the data surveys were designed to collect the point of contact for potential vendors within the organization, thus facilitating the sales process. For example, as noted earlier categories such as sales reporting software, direct marketing software, sales force automation software, and market planning software are all in separate product categories, but all grouped together in the same industry code. These are all sales and marketing-related software products that in theory would sell to the same customer group within any potential client (e.g., the marketing department within a firm), despite the differences in underlying technology (e.g., some are contact database programs, while others are financial reporting programs). Thus, we feel that the CorpTech data – based on the intended purpose of the database – capture market relatedness. Second, by controlling for technological relatedness, we are already eliminating the role of technology in affecting relatedness for our market measure. While "market knowledge" may be seen as too specific of a term, the measure (controlling for technological relatedness) captures something distinct that is likely related to product market knowledge.

Control Variables. As a proxy for available resources that may affect the likelihood of new market entry and adoption of new technology and to measure firm size in a way that allows us to test our H4a and H4b, we include the logged value of sales (Singh, 1986; Agarwal and Audretsch, 2001) and the lagged number of product categories in which the firm was active in the previous year. We also include a control for the competitive intensity of the market by including the number of firms in the product category and its square term. In addition, we include year fixed effects to control for the overall rate of entry based on macroeconomic conditions, and we include dummies at the level of the 17 sectors in the CorpTech data.

Overall sample and descriptive statistics. While CorpTech and the NBER patent database cover many more firms than we use in our sample, our exclusion process is based solely on measurement. On the firm size, we exclude any firms with no patents in the previous three years, as without this measure we could not ascertain the firm's existing technological knowledge portfolio. On the category side, we exclude any categories with no entry between 1997 and 2005 (the period of the study), with no firms with any patents, and to which we are not able to assign any single technological class (through the process noted above, meaning there were not multiple firms with patenting in the same technological class in the data). As a result, our final sample has 5,235,021 firm-product-year observations across the six years of the study. These data, and the number of entries, are shown in Table 1.

Insert Table 1 about here

Methods and Summary Statistics. Since the dependent variable, product entry, is a binary outcome, we employ a logistic model. As mentioned earlier, we use year and product sector fixed effects. Future iterations of our analysis will also employ firm fixed effects. Descriptive statistics are summarized in Table 2. Between Tables 1 and 2, we can see that there are approximately 1,451 entries compared with over five million observations, making for a relatively small entry rate. We can see from the correlation table that the correlations are all very small, minimizing any concerns about multicollinearity. In addition, we find interestingly that the correlation between technology relatedness and product relatedness is only 0.002, suggesting that the two measures clearly are capturing different aspects of relatedness, which increases our confidence in our measurement and approach.

Insert Table 2 here

RESULTS

Table 3 reports the results of testing our hypotheses based on a panel logit model. Model (1) in Table 3 includes control variables, all of which are significant. Firm size – both measured as sales and as the number of product categories in which the firm is active – is positively related to entry into any given product category, suggesting that larger firms enter more categories in any given year than smaller firms. The measure of competitive density in the product category demonstrates an inverted U-shape, as the main effect is positive while the squared term is negative. Thus, firms appear to be most likely to enter into product categories with a moderate level of competitors, which is consistent with firm survival outcomes in density dependence theory (Hannan & Freeman, 1977). In all, the control variables behave as expected.

Insert Table 3 here

Models 2 to 4 report the results from running different variations of market and technological knowledge. In Model 2, the effect of technological relatedness is actually *negative* and significant ($p < 0.01$), suggesting that more proximate locations are less likely to result in product category entry than more distant locations. In Model 4, we include the squared term of technological relatedness, and while the squared term is only weakly significant (especially given the large sample size) the suggestion is a slight U-shape, with the minimum value around

0.75. Thus, for most of the range of our measure of technological relatedness, it is negatively related with entry probability, but there is a small increase at the end. Further analysis (not included here for the sake of brevity) confirms this relationship – the probability of entry is highest for the lowest values of technological relatedness, very low for the highest values of technological relatedness (where the firm already possesses direct experience in one or more technological classes relevant for the product category), and is the lowest at moderate levels of relatedness, where the firm does not have direct experience in the technological class but has experience in closely related classes. This finding clearly runs counter to H1, which suggested that entry would be higher for more proximate technological spaces, and the fact that entry probability is the lowest for nearby – but not identical – technological experience is suggestive of the idea that technological substitution and competition may limit firm desire to enter into some product market spaces.

Hypothesis 2 suggested that market relatedness would only matter in the context of high levels of technological relatedness, building off a theory of complementary assets. This is tested with the interaction term in Model 5, which is not significant. Additional analysis indicated that there was no range of the data (i.e., limited subset of market or technological relatedness) where the interaction term was significant – the effects of market (discussed below) and technological relatedness appear to be independent from one another. This clearly does not support H2.

In contrast, our measure of market relatedness is consistently positive across all settings ($p < 0.001$). This is true for the main effect (Model 2), as well as when we split relatedness into three categories in Model 3 – firms with experience in the same industry but not the same product category (Product Relatedness 2) show the highest propensity to enter, those with experience in the same sector but not the same industry (Product Relatedness 1) show a more modest propensity to enter, and those without experience in the same sector (the omitted category) are the least likely to enter. In general, these results are strongly consistent with H3, and provides some initial evidence both that market relatedness is exceptionally important to firm entry decision making, and that its effect appears independent from – as opposed to complementary to – technological knowledge.

We test our additional hypotheses (H4a and H4b) about the moderating effect of firm size with the split sample results in Table 4. The table effectively shows the results of Model 2 in Table 3 across subsamples segmented into quartiles by firm sales. Hypothesis 4a suggested that market relatedness would matter more for large firms than for small firms. As seen when comparing the first and fourth quartiles (and supported by additional analysis with interaction terms), the impact of market relatedness declines for smaller firms. This supports H4a. Hypothesis 4b said that technological relatedness would matter more for small firms than for large. Given the negative sign on technological relatedness, we expect that the coefficient would become "less negative" for smaller firms. Again, the results provide at least some support for this hypothesis, as the effect of technological relatedness is significant only for the largest quartile of firms, but the coefficient does not shift much between the first and the fourth quartile. Instead, the significance drops primarily because the standard errors increase as firm size decreases, suggesting that there is much more variation in the behavior of smaller firms than large. In all, this provides modest support for H4b, and suggests that large firms seem to focus on exploiting their existing market-based knowledge and avoiding cannibalization from technologically-based expansion.

Insert Table 4 here

DISCUSSION

In this study we investigated how the relatedness of two different aspects of knowledge – market and technological – to available opportunities influenced the direction of organizational growth and diversification. We built our theory based on the potential usefulness of technological and market knowledge in proximate product categories, while recognizing both that technological knowledge may be accumulated for more reasons that simply product market entry and that market knowledge may contribute to entry only through technological knowledge (as a complementor) or directly. Our cross industry results using data from CorpTech and patent data showed a surprising negative relationship between technological proximity and entry behavior, suggesting that firms that were the most distant technologically were actually the most likely to enter. Market knowledge behaved more as expected, dramatically increasing the likelihood of entry as market knowledge was more proximate, but interestingly the effect was not contingent upon technological knowledge. This finding reinforces the suggestion that markets for technology externally may make technological knowledge as a driver of diversification somewhat irrelevant. Finally, our results showed that market knowledge became a more significant driver of entry behavior for larger firms (again consistent with large firm access to technology), while technological knowledge was more important (or at least less negative in its effect) for smaller firms.

Clearly, the most interesting finding is the negative effect of technological knowledge. We rationalize our counter-intuitive finding on two grounds. First, our findings do not reject the significance of technological relatedness in post-entry performance, but point to different resource dynamics that differentiate product entry from post-entry performance and the importance of examining the two phases of a firm's growth separately. Moreover, we find the negative effects of technological relatedness to be significant only for large firms. Such finding is consistent with previous empirical research that documents the risk of cannibalization for large firms (de Figueiredo and Silverman, 2007), positive correlation between organizational size and rigidity (Chen and Hambrick, 1995), and reduced technological constraint for larger firms (Pavitt, 1998). It also raises concern for potential upward bias in previous empirical studies that examine the post-entry performance effects of technological relatedness. As Figueiredo and Silverman (2007) points out, entry into a technologically proximate market is justified only if the value of the technology is sufficient to compensate for potential loss from cannibalization. Without accounting for cannibalization and other spill-over effects on the rest of the product portfolio, the net effect of technological knowledge on firm performance remains tentative.

We also contribute to more precise characterization of market knowledge. We demonstrate that market knowledge is a core resource that drives product-market entry, independent of related technological knowledge, corresponding to findings of Nerkar and Roberts (2009) on post-entry performance. The partnership of Wal-Mart with Accel Partners in entering the on-line market also provides a case of market knowledge guiding the direction of technological knowledge development. The possibility of market knowledge serving as an antecedent of technological knowledge represents an interesting area for future research that has received little attention.

This study builds on recent developments in research based on the RBV that take a closer look at heterogeneity in resources and the direction of a firm's growth. By decomposing the resources of firms into market and technological knowledge and looking at their effects across a wide range product categories and resource relatedness, we make several contributions beyond testing for the significance of individual resources in driving a firm's product-market entry. First, we show that it is important to distinguish between technological entry from market entry at a more detailed product-market level to verify the findings of Brusoni et al. (2004). We also find that product-market entry is driven by resources and dynamics that differ from those that influence post-entry performance, and firms are willing to enter a product-market without necessarily developing the required technological resources beforehand.

While making significant contributions, we also recognize that this study raises as many questions as it answers, especially around the different factors that limit the significance of technological relatedness. We hope that our investigation will help spur more research that investigates the importance of market knowledge and a broader set of contingencies that influence the relative importance of a firm's resources.

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Table 1: Descriptive statistics of sample

Year	Entry Year	Total Firms	Sample Firms	Total Categories	Sample Categories	No. of Entries	No. of Observations
1997 – 1999	2000	41,339	3,840	2,063	221	193	669,263
1998 – 2000	2001	40,412	4,243	2,084	220	161	729,306
1999 – 2001	2002	43,274	4,620	2,190	266	258	965,177
2000 – 2002	2003	45,151	4,936	2,172	318	321	1,164,994
2001 – 2003	2004	52,264	5,141	2,115	318	306	1,191,805
2002 – 2004	2005	58,118	5,244	2,104	289	212	1,046,656

Table 2: Correlations and Summary Statistics of Variables

	1	2	3	4	5	6
1. (DV) Product Entry	1					
2. Technology Relatedness	-0.001	1				
3. Product Relatedness	0.018	0.002	1			
4. (Firm) *log* (Sales)	0.005	0.032	0.014	1		
5. (Firm) No. of Products	0.015	0.017	0.114	0.110	1	
6. (Product) No. of Firms in Category	0.005	-0.099	-0.012	0.001	0.031	1
Average	0.0003	0.22	0.14	19.4	17.69	18.77
SD	0.016	0.30	0.40	3.32	18.35	10.26
Min	0	0	0	0	1	10
Max	1	1	2	28.5	288	100

Table 3: Logistic Regression Results on Product Entry Decision

	Dependent Variable:				
	Product Entry				
	Model 1	Model 2	Model 3	Model 4	Model 5
Tech. Relatedness		−0.329**	−0.329**	−0.995**	−0.398**
		(0.101)	(0.101)	(0.381)	(0.132)
Tech. Relatedness (sq)				0.707+	
				(0.388)	
Product Relatedness		1.237***		1.237***	1.218***
		(0.037)		(0.037)	(0.044)
Product Relatedness 1			1.270***		
			(0.068)		
Product Relatedness 2			2.463***		
			(0.078)		
Tech. Rel. × Product. Rel.					0.105
					(0.126)
log (Sales)	0.047***	0.052***	0.052***	0.052***	0.052***
	(0.010)	(0.011)	(0.011)	(0.011)	(0.011)
No. of Products	0.018***	0.014***	0.014***	0.014***	0.014***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
No. of Firms in Category	0.042***	0.041***	0.041***	0.041***	0.041***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
No. of Firms in Category (sq)	-0.0002***	-0.0002***	-0.0002***	-0.0002***	-0.0002***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Constant	-9.870***	-10.322***	-10.330***	-10.267***	-10.311***
	(0.255)	(0.265)	(0.265)	(0.266)	(0.265)
Year Fixed Effect	*included*	*included*	*included*	*included*	*included*
Product Fixed Effect (Main code level)	*included*	*included*	*included*	*included*	*included*
Observations	5,235,021	5,235,021	5,235,021	5,235,021	5,235,021
Log Likelihood	−11,909.22	−11,481.36	−11,481.19	−11,479.68	−11,481.02
Akaike Inf. Crit.	23,870.440	23,018.720	23,020.380	23,017.360	23,020.030
Note:			+p<0.1; *p<0.05; **p<0.01; ***p<0.001		

Table 4: Regression Results for Subsamples by Firm Size

	Dependent Variable:			
	Product Entry			
	1st Quartile Very Large	2nd Quartile Large	3rd Quartile Small	4th Quartile Very Small
Tech. Relatedness	−0.421**	−0.093	−0.382	−0.345
	(0.154)	(0.202)	(0.263)	(0.246)
Product Relatedness 1	1.349***	1.467***	1.246***	0.804***
	(0.104)	(0.146)	(0.168)	(0.160)
Product Relatedness 2	2.435***	3.004***	2.361***	1.678***
	(0.121)	(0.152)	(0.204)	(0.214)
log (Sales)	0.042	0.072	-0.312+	-0.012
	(0.029)	(0.127)	(0.170)	(0.015)
No. of Products	0.012***	0.021***	0.023***	0.031***
	(0.001)	(0.003)	(0.004)	(0.005)
No. of Firms in Category	0.036***	0.043**	0.036*	0.060***
	(0.010)	(0.013)	(0.014)	(0.016)
No. of Firms in Category (sq)	-0.0002	-0.0002	-0.0001	-0.0005*
	(0.0001)	(0.0002)	(0.0002)	(0.0002)
Constant	-9.544***	-11.056***	-3.867***	-9.952***
	(0.702)	(2.584)	(3.193)	(0.470)
Year Fixed Effect	*included*	*included*	*included*	*included*
Product Fixed Effect (Main code level)	*included*	*included*	*included*	*included*
Observations	1,285,876	1,291,076	1,283,087	1,374,982
Log Likelihood	−4,411.459	−2,507.544	−1,994.526	−2,433.300
Akaike Inf. Crit.	8,880.917	5,073.087	4,047.052	4,924.599

Note: +p<0.1; *p<0.05; **p<0.01; ***p<0.001

Figure 1. Histogram of Technological Relatedness between Firms and Product Category