TOP MANAGEMENT TEAM EXPERIENCES AND INNOVATION: A DUAL TASK AT TECHNOLOGY-BASED ENTREPRENEURIAL FIRMS

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ABSTRACT

Our study examines how top management teams (TMTs) facilitate firm-level innovativeness through the integration of TMT members' resources. We draw from research on TMTs and innovativeness and test our hypotheses with a sample of 151 biotech firms that issued initial public offerings (IPOs) between 1980 and 1995. Our theory predicts that the proportion of TMT members who are founders will have an inverted U-shaped relationship with innovations (captured through patents). Further, our theory predicts that average TMT member company tenure will be negatively associated with innovation, and that average TMT member experiences outside the firm (with competitors or with firms outside the industry) will be positively associated with associated with innovation. Finally, contextual factors such as firm size and firm age moderate the impact of TMT experiences on innovation.

INTRODUCTION

Top management teams have attracted substantial research attention as an important antecedent of organizational outcomes. Researchers drawing upon the upper-echelons' perspective (Hambrick and Mason, 1984) have shown that top managers have significant impacts on a variety of organizational outcomes, such as strategic change (Cho and Hambrick, 2006; Wiersema and Bantel, 1992), firm growth (Kor, 2003; Stam and Elfring, 2008), strategic conformity and persistence (Finkelstein and Hambrick, 1990), and innovation (Bantel and Jackson, 1989; Elenkov *et al.*, 2005; Smith and Tushman, 2005; Wu *et al.*, 2005). These studies share the common theme that the knowledge, experiences, and composition of top management teams (TMTs) are a critical part of organizational resource stocks.

Young, entrepreneurial, technology-based firms provide a context in which top managers' knowledge and experiences influence organizational outcomes in some complex ways. Top managers at post-initial public offering (IPO) entrepreneurial firms face a dual task. The high-growth of these firms requires them to assimilate valuable knowledge and experiences from external sources, and at the same time to develop and solidify unique and non-imitable knowledge and experiences of their own (Boeker and Wiltbank, 2005; Kor, 2003). The TMTs of these firms are where the external and internal knowledge and experiences of managers are brought together, with far-reaching implications. Little research, however, has focused on how TMTs of technology-based

ventures contribute to better performance in the post-IPO period by retaining some internal experiences while also drawing from external experiences.

Our study focuses on the role of TMTs in the innovativeness of technology-based firms that have recently completed IPOs. We examine this issue by integrating the upper-echelons literature and the innovations literature. We focus on the bundle of executive resources represented by the TMT. First, we develop theory to predict how founders impact innovation differently than non-founders. We expect this issue to be important not only because much theory explains how founders differ from non-founders (e.g., Baron *et al.*, 2001), but also because many young, technology-oriented firms have TMTs that include several founders. We propose that founders of technology ventures represent fundamental and unique knowledge specific to their ventures and that the extent to which the post-IPO TMT is composed of founders has an inverted U-shaped (curvilinear) relationship with the venture's innovation performance.

Our theory of executive resources also includes managerial experiences, and where those experiences were garnered. These experiences apply to both founding TMT members and non-founder TMT members. Our theory predicts that TMTs of shorter average tenures, more experiences at competitors (i.e., other firms in the same industry), and more experiences at firms outside the industry are more adaptive and open-minded. Finally, we highlight the impact of the organizational contexts of these ventures and predict that factors such as firm age and firm size moderate the relationship between TMT experiences and post-IPO innovation performance. We test our hypotheses with a

sample of 151 biotechnology firms that undertook IPOs between 1980 and 1995.

We contribute to the research on organizations in two ways. First, our study complements current upper echelons research by considering the implications of different types of executive resources. While most studies of founders consider single individuals as founders (e.g., Haveman and Khaire, 2004; Nelson, 2003) our approach considers founders as more than lone entrepreneurs as the TMTs of our sample firms often have multiple founders present. Further, like a few authors before us (e.g., Castanias and Helfat, 2001; Harris and Helfat, 1997) we consider how the knowledge and experiences executives have gained from previous jobs influence their information processing and decision-making. In addition, in the context of entrepreneurial firms that have recently undertaken an IPO, founders have a different status and capacity to affect organizational outcomes than non-founders. Therefore, we take a fine-grained approach that allows us to better appreciate the complexity within TMTs.

Second, our study contributes to research on entrepreneurship. The knowledge and experiences of top managers constitute important components of the human capital possessed by managers (Wright *et al.*, 2007). Examining the effects of TMT experiences on post-IPO venture performance contributes to understanding about innovation and performance among firms that have demonstrated enough wealth creation potential to successfully implement IPOs. While studies of small, early-stage startups are also important (i.e., Stam and Elfring, 2008) our study emphasizes ventures that have achieved a key milestone and are transitioning to a more complex and permanent form,

i.e., the public corporation. In addition, we highlight the moderating roles of organization contexts, suggesting that the effects of managerial experiences on innovation in post-IPO firms are contingent upon contextual factors like firm age and firm size.

TMTS AND INNOVATIONS AT ENTREPRENEURIAL FIRMS

The development of new ideas, new products, and new processes is essential for gaining competitive advantage in innovation-intensive industries (Drucker, 1985). Innovativeness is a particularly important criterion in evaluating the value and performance of technology-based ventures. In this study, we define innovations as discoveries that lead to patents, and the term innovativeness characterizes the achievement of more numerous or more influential patents. Innovation is not simply determined by technological resources and capabilities within the firm. Rather, successful innovation requires an organizational infrastructure that provides the appropriate resources and motivation to act on emerging opportunities. For example, Leonard-Barton (1992) showed that an effective organizational infrastructure including management systems, organizational routines, and culture, plays a key role in new product development.

Top managers and the resources they embody are critical in the shaping and development of an internal organizational infrastructure that supports successful innovation. Top managers may impact the evolution of organizational infrastructure in the following ways. First, the knowledge and prior experiences of senior executives

affect decisions about internal resource allocations (Burgelman, 1991; Noda and Bower, 1996). Top managers' environmental scanning helps to identify emerging technological trends and market developments, and that knowledge is then applied to decisions about which R&D projects the firm should act upon. Second, once an R&D project is selected, top managers can also affect its implementation or execution. Specifically, top managers can influence how organizational structures, incentive systems, and routines are set up to support the R&D function, as well as its integration with the rest of the company (Hambrick, 1989).

The influence of TMT knowledge and experiences is likely to be strong in young, entrepreneurial firms. These firms are characterized by relatively simple organization structures and straightforward internal communication channels. Unlike large diversified firms where layers of management separate top managers from active involvement with day to day activities, top managers at entrepreneurial firms are directly involved in resource allocations and implementation processes throughout the firm. Furthermore, as an entrepreneurial firm's management systems and routines evolve, the top managers of these firms may have more latitude of action or managerial discretion than their counterparts in larger, more established firms (Burke and Steensma, 1998; Hambrick and Finkelstein, 1987). These characteristics allow the knowledge and experiences of top managers to penetrate and become integrated into all facets of the operation and performance of the entrepreneurial firm. While upper-echelons theory's original focus was executives and directors of large corporations (Hambrick and Mason, 1984), the

theory's predictions about TMT effects are likely to be even stronger among young and emerging firms without deeply established and institutionalized routines (Finkelstein *et al.*, 2008).

Top managers at entrepreneurial, technology-based firms face a dual task. On the one hand, these firms must assimilate external knowledge and experiences in order to successfully evolve and remain competitive, especially in the post-IPO period (Boeker and Wiltbank, 2005). As entrepreneurial firms often experience high growth, the complexity of managing them can increase rapidly (Kimberly and Bouchikhi, 1995). New managerial skills and capabilities are often essential in responding to such managerial challenges. On the other hand, it is also critical for entrepreneurial firms to develop firm-specific knowledge and capabilities that differentiate them from competitors and allow them to gain and maintain competitive advantage (Kor, 2003). The managerial knowledge and capabilities critical to this objective are often tacit, firm-specific, and embedded in the company's managers (Felin and Hesterly, 2007).

TMTs at entrepreneurial, technology-based firms are an important vehicle for combining and integrating internal and external knowledge. In the following sections, we unpack the broad concept of TMT resources and discuss the implications of these more fine-grained resources on innovativeness in post-IPO technology-based firms. We consider founders on the TMT because they represent in-depth and firm-specific knowledge and capabilities. Beyond founder/non-founder status, we consider how the average TMT tenure within the company, with competitor firms (in the same industry), or

with firms outside the industry, affect post-IPO innovation. It is important to note that we consider these categories of experiences for both founders and non-founders. For example, in our sample, some founders also have outside-industry experience, and many founders have experience with other firms in the industry. Finally, we consider how organizational contextual factors such as firm age and firm size affect the TMT resource – post-IPO innovation relationship.

Different Types of TMT Member Resources

Founders

Founders (i.e., executives who have been with the firm since its inception) are often retained in post-IPO TMTs. Founders are particularly influential because they are the initial architects of the firm's structure and strategy (Nelson, 2003). Founders may influence innovativeness in two ways. First, founders' early decisions establish the initial structure, strategy and culture of the firm (Baron *et al.*, 1999). Founders' influence becomes embodied in the particular structures of the firm and in the premises that guide decision-making (Kets de Vries and Miller, 1986). When founders stay on the post-IPO TMT, they exert a strong influence over the other TMT members (Gimeno *et al.*, 1997). Founders' visions for their firms provide important direction for choosing among potential technological opportunities. Founders also have a lasting influence on the decision-making process because they establish priorities and decision rules early in the firm's life and these tend to persist (Kimberly and Bouchikhi, 1995). In addition, when

founders stay on the TMT, because of their in-depth understanding of firm-specific resources and capabilities, they increase the likelihood that the firm selects and pursues opportunities that are unique to the firm and that fit the firm's resources and capabilities.

Founders also provide an important locus of knowledge for implementing innovations. As founders enact their visions, they mobilize and integrate resources toward productive uses (Holbrook *et al.*, 2000). Founders develop intimate knowledge about where the competencies of the firm lie and what resources outside the firm can be activated and utilized (Stuart and Sorensen, 2005). Founders also develop problem-solving routines that are specific to the strengths and weaknesses of their firms (Katz, 1982). Firm-specific knowledge of this kind is particularly valuable for identifying opportunities, because founders can better identify which opportunities are achievable by the firm (Kor, 2003). For these reasons, when founders are retained in the TMT, their knowledge and experiences are likely to contribute to innovation.

Of course, it is also well-known that founders also carry some liabilities. For example, because founders started the firm and have devoted substantial resources and attention to it, they usually have strong psychological commitments to it (Gimeno et al., 1997). These commitments may bias decision-making when the TMT needs to objectively process information and evaluate alternatives (Certo *et al.*, 2001). For example, founders may choose research programs that match the firm's existing capabilities, and often the founders' own peculiar capabilities, so that they can maintain a central importance to the firm. In addition, founders spend considerable time and

attention developing the firm in the early stages of its life. For this reason, they may not allocate adequate attention to ongoing developments in the technological environment outside the firm. Less attention to external technological development negatively affects the firm's absorptive capacity (Cohen and Levinthal, 1990). Therefore, a TMT that retains too many founders may find that its capacity for innovation is hampered.

H1: The percentage of founders on the TMT will have an inverted U-shaped (curvilinear) relationship with post-IPO innovation.

Within-Firm Tenure

Executive tenure is associated with the learning process in which top managers acquire specific knowledge about the strengths, weaknesses, and problems of the firm (Hambrick and Fukutomi, 1991; Miller and Shamsie, 2001; Wu *et al.*, 2005). Further, we assert that these problems exist whether the executive in question is a founder or not. Executives who have long tenures in the firm may be insulated from current and accurate external information, which at the team-level may limit the TMT's capacity to explore novel opportunities (Katz, 1982). Longer tenured executives tend to be complacent and less likely to take risks (Hambrick and Fukutomi, 1991; Miller and Shamsie, 2001). A negative attitude toward risk-taking can be particularly deleterious for an entrepreneurial firm that operates in a technologically dynamic environment. For example, Wu et al., (2005) concluded that shorter-tenured CEOs are associated with invention in technologically dynamic environments because they tend to be less constrained by prior successes and more open to adaptive changes and initiatives. Longer tenured TMT

members, in contrast, are less likely to be open-minded and supportive of both novel ideas and novel implementation strategies for innovation. Again, even for founders, tenure in the firm will tend to be associated with more close-minded and less innovative perspectives.

H2: The average of TMT members tenure within the focal firm will be negatively related to post-IPO innovation.

Tenure with Rival Firms

Novel knowledge and experiences may be absorbed into the firm's decision-making processes when executives have experiences with other firms and other industries (Bailey and Helfat, 2001). Career experiences elsewhere may broaden the scope of knowledge and capabilities available to the TMT in the decision-making process. Executives with work experiences (employment) outside the focal firm but inside the industry are more likely to raise novel perspectives about developments in technology, competition, and other industry conditions, or to accept those perspectives when presented by others. Executives with career experiences outside the focal firm are likely to be less committed to the status quo (Finkelstein and Hambrick, 1996). Such executives may direct the attention of the TMT to new trends that are not obvious to those whose experiences are limited to a single firm. They may also provide new insights about which R&D projects should receive higher priority. The combination of novel knowledge and breadth of experiences may improve the TMT's capacity to direct and implement innovation (Rosenkopf and Nerkar, 2001).

Executives who have worked at rival firms may combine their industry-specific experiences with other insights from executives who have spent their executive or managerial careers at only the focal firm (Kor, 2003). Executives with experiences at rival firms may draw upon the knowledge, training and experiences at those firms, where the understanding of how to gain competitive advantage in the industry may be different but very relevant. Experiences at established competitors may also benefit in the development of a sophisticated organizational infrastructure to support innovative activities (Baron et al., 1999). Such knowledge may be particularly valuable to post-IPO entrepreneurial firms where organizational infrastructure is still rapidly developing (Flamholtz and Randle, 2000). Therefore, executive tenure with rival firms in the industry is likely to facilitate innovation. These effects apply to both executives who are founders as well as those who joined the firm after its founding.

H3: The average of TMT members' tenure with rival firms will be positively related to post-IPO innovation.

Tenure outside the Industry

Executives who have work experience from outside the industry have been exposed to different logics and business models. Knowledge and experiences gained from other industries may enable the executive to spot new and valuable opportunities. Knowledge gained from outside the industry may also bring radically new ideas about how to implement innovation. Executives from other industries may introduce different approaches to establishing internal structures and processes for screening and selecting

R&D projects. For these reasons, TMT member' longer average work experiences in other industries may improve the TMT's capacity to identify innovative opportunities and follow through on them. Again, these effects apply to founders and non-founders alike.

H4: The average of TMT members' tenure outside the focal industry will be positively related to innovation.

Organizational Context as a Moderator

Organizational context may moderate the impact of executive and TMT resources in important ways. Organizational scholars have found that the influence of executives on organizational outcomes differs according to contextual factors, such as firm age and firm size (Hatton and Raymond, 1994; Ling *et al.*, 2007; Miller and Droge, 1986). Smaller and younger organizations tend to have less developed management systems and organizational routines, which in turn afford more managerial discretion and influence to the TMT (Finkelstein and Hambrick, 1990). Smaller and younger organizations lack firm-specific knowledge and capabilities because the development of these takes time and follows path-dependent processes (Barney, 1991). Smaller and younger organizations are more amenable to new insights and knowledge imported from other firms and industries. Novel knowledge and insights may also be particularly beneficial to the development of decision-making routines, communication channels, and R&D implementation in smaller and younger firms.

By contrast, older and larger firms are less open to novel knowledge and insights. Older and larger firms tend to have more inertia in systems and structures (Hannan and

Freeman, 1984). They may have developed firm-specific routines and knowledge about how to identify technological opportunities, how to implement innovative ideas, and how to commercialize new products. In older and larger firms, novel knowledge and capabilities are more difficult to assimilate into the already established routines and organizational infrastructure. Executives hired from outside have to spend time proving themselves, building their legitimacy and convincing others in the firm of the relevance of their "outsider's knowledge" to the firm's existing systems. Their ability to contribute effectively to the firm's systems and procedures is limited until they are fully integrated into their new TMTs and firms, and that takes longer in older and larger firms where novel knowledge is less likely to be appreciated and may actually be thought of as interfering with established routines (Miller and Friesen, 1984). Therefore, we expect that novel knowledge and experiences among TMT members can better contribute to innovation in younger and smaller firms and will have less impact on older and larger firms.

H5: Firm age and size will negatively moderate the effects of average TMT tenure with rival firms on innovation.

H6: Firm age and size will negatively moderate the effects of average TMT outside-industry tenure on innovation.

DATA AND METHODS

Sample

We focused on the biotechnology industry because it is very dynamic and driven by patentable innovations. Our sample consists of publicly-traded biotechnology

companies that had recently experienced IPOs. These biotech firms are often less than five years old when they issue IPOs, which ensures that the firms, although established, are still high-growth and entrepreneurial in orientation.

We used TMT demographic information for constructing independent variables. We collected demographic information about the TMT from IPO prospectuses. The TMT is defined as corporate officers, including the chief executive officer, chief operating officer, and vice presidents (Finkelstein and Hambrick, 1996). We started from a list of 317 biotechnology companies that went public between 1980 and 1997. From the database of IPO prospectuses in Thomson Research, we collected 231 prospectuses of these listed biotech companies. The sample was reduced to 180 companies since 51 out of the 231 companies did not have any patents prior to their IPOs. After deleting observations with missing values, we tested our hypotheses on a sample of 151 public biotechnology firms. Our study covers the first three post-IPO years.[1] All of our key independent variables are captured at the time of the IPO, while our dependent variables are all gathered in the post-IPO period only.[2] Unless otherwise noted, all independent variables refer to patents issued in the first three years following the IPO.

We used patent data to construct our dependent variables because patents are tangible manifestations of innovation. The issuance of a patent indicates that the

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[1] We focus on patent applications filed in the first three post-IPO years, but to characterize the innovativeness of those patents, we examine citations in the four years following each patent's application.

[2] As we explain later, some control variables are captured in the post-IPO period.

knowledge behind it (1) is novel and not anticipated by current knowledge; (2) can potentially provide economic benefits to society; and (3) is non-obvious. Therefore, patents provide useful information about the innovativeness of the firms that developed the knowledge behind them. In the biotechnology industry, patents are particularly important because they confer property rights and signal firm-level technological capabilities (Wu et al., 2005). All of our patent data were gathered from the United States Patent and Trademark Office (USPTO) and the National Bureau of Economic Research (NBER) (Hall *et al.*, 2005).

Dependent Variables

Our study incorporates two dependent variables designed to capture related and complementary aspects of innovation performance. The measures are citation-weighted counts of patents, and counts of "breakthrough" or highly cited patents.

Citation-weighted patents — We measured the total number of patents, weighted by their external citations.[3] Patent applications build on previous knowledge, so they typically cite previous patents to clarify how and where knowledge is extended. The extent to which an existing patent is cited by subsequent patent applications provides an indicator of the patent's impact. Citation-weighted patent counts are superior to simple (unweighted) patent counts because they better capture overall innovation impact (Hall et al., 2005; Sampson, 2005; Trajtenberg, 1990). To derive the weights, we first identified all patents awarded to the firm in the first three years following the IPO. We then

[3] This measure is equivalent to the total citations on the patents.

followed each patent for the four years after its application, counting the total number of citations that the patent garnered (omitting self-citations). The four-year limit helps us avoid truncation issues associated with citation data (Hall *et al.*, 2005; Phene *et al.*, 2006). We limited the window of citations to four years since application because Jaffe, Tratjenberg and Henderson (1993) concluded that citations typically peak within a few years after application. We excluded self-citations to better capture the technological importance of each patent to the technical field (Miller *et al.*, 2007).

Breakthrough patents — The second dependent variable is the number of highly cited patents awarded to firms in our sample. Prior research suggests that the most highly cited patents also tend to be the most valuable (Ahuja and Lampert, 2001; Phene *et al.*, 2006; Trajtenberg, 1990). We sorted the patents in our sample by the number of citations each received within the first four years after the application was filed. We then identified the top two percent of our sample (those with the most citations) as breakthrough patents. Trajtenberg (1990) concluded that there is no ideal cut-off point for identifying breakthrough patents because the distribution of citations is highly skewed. In our sample, we analyzed the top 1, 2, and 5 percent of the patents based on number of citations. The analysis suggests that the top 1 percent of our sample's patents averaged 22 citations, the top 2 percent 18 citations, and the top 5 percent 13 citations. In accordance with prior studies, we defined the top two percent (those with 18 or more citations) as breakthrough patents (Ahuja and Lampert, 2001; Phene *et al.*, 2006). We then summed the number of each firm's patents awarded in the first three post-IPO years

that were identified as breakthrough patents.

Independent Variables

TMT percent founders — This variable captures the percentage of the TMT members who were founders at the time of the IPO. Founders are those executives who have been involved in the venture since its inception and whose names are identified as founders in the IPO prospectus (Kor, 2003).

TMT average company tenure — This measure captures the average number of years that TMT members had worked for the focal company at the time of the IPO.

TMT average rival firm tenure — This variable captures the average number of years that TMT members had worked for rivals, i.e., in other biotechnology or pharmaceutical firms, at the time of the IPO.

TMT average outside-industry tenure — This variable captures the average number of years that TMT members had worked in industries other than biotechnology and pharmaceuticals at the time of the IPO.

Moderating Variables

N of Employees— This variable controls for firm size. Because most biotech firms have zero or modest sales by the time of their IPOs, the number of employees provides a better measure of firm size than sales or assets. We log-transformed the measure to control for outliers.

Firm age— This variable represents the number of years between a firm's

founding and its IPO.

Control Variables

TMT average age — We controlled for average age of TMT members at the time of the IPO because research has shown that a younger TMT is more receptive to new information and insights and firms with younger TMTs tend to be more innovative (Bantel and Jackson, 1989).

TMT size — The count of individuals on the TMT at the time of the IPO. Research suggests that larger TMTs have at least some capacity to provide wider sets of knowledge and experiences in decision-making (Eisenhardt and Schoonhoven, 1990).

TMT functional diversity — We used Blau's index to account for heterogeneity in the functional backgrounds of TMT members at the time of the IPO (Bantel and Jackson, 1989). Teams with more diverse functional backgrounds have the capacity to be more innovative (Cannella *et al.*, 2008).

TMT % doctorates — the percentage of top managers who possess advanced degrees such as PhDs and MDs at the time of the IPO. We controlled for this variable because advanced degrees among TMT members suggest specialized knowledge that may be relevant for innovation.

TMT previous jobs — We measured the average number of companies that TMT members had previously worked for at the time of the IPO. Research has shown that top managers with broader job experiences also tend to have stronger social networks

(Eisenhardt and Schoonhoven, 1990), which may affect innovation.

R&D intensity — We used this variable to control for the intensity of R&D efforts. We measured this variable by dividing R&D expenses by the value of total assets (Wu et al., 2005). This measure represents the average R&D intensity in the first three IPO years.

Prior research has indicated that the "backward" search process, i.e., the innovation search strategy in which knowledge is sourced and recombined into patented innovations, can affect the "forward" citations the patented innovation subsequently receives (Ahuja and Lampert, 2001; Argyres and Silverman, 2004; Hall *et al.*, 2001). We created three variables to control for the effects of innovation search strategies. These are firm originality, firm pioneering technologies, and average citation age.

Firm originality — Originality gauges the novelty of the technological combination used to create the firm's post-IPO patents (Argyres and Silverman, 2004; Hall *et al.*, 2001), and is calculated as follows:

$$\text{Firm originality} = 1 - \sum_{j}^{n_i} s_{ij}^{\,2}$$

Where s_{ij} denotes the proportion of citations made by patent i that belong to class j, out of n_i technological classes assigned to patents by the USPTO. When the citations are more concentrated in a few technological classes, originality is lower and when the citations are more dispersed in more technological classes, originality is higher.

Firm Pioneering Technologies — This measure is the number of a firm's post-IPO patents that cite no prior art (Ahuja and Lampert, 2001). Prior research suggests that

innovations listing no prior technological lineage (i.e., no citations) represent pioneering explorations, are likely to represent a high degree of creativity, and tend to represent exploration at technical boundaries.

Firm average citation age — This measure captures the average age of the patents cited by the focal firm's post-IPO patent applications. We used this variable to control for the degree to which a firm experiments with emerging technologies. Prior research indicates that firms focused on emerging technologies (i.e., those that cite newer patents) tend to create more highly cited patents (Ahuja and Lampert, 2001).

Statistical Technique

Because the dependent variables are both non-negative, count variables, we use negative binomial regression as our analytical methodology, following a number of earlier studies (Ahuja and Lampert, 2001; Rosenkopf and Nerkar, 2001; Sampson, 2005; Sorensen and Stuart, 2000). Negative binomial regression is appropriate for non-negative integers and reduces the effects of variance overdispersion. We also included year dummies, though not reported here, to account for temporal variations across the different IPO years in our sample. None of the year controls were significant.

RESULTS

Table 1 presents descriptive statistics for our variables and Table 2 provides the correlations. Tables 3A and 3B provide the negative binomial regression results for citation-weighted patents and breakthrough patents respectively. We examined variance

inflation factors for all independent variables and none was higher than four, which suggests multicollinearity is not an issue (Greene, 2000). In total, we report eight models. The first four appear in Table 3A (with citation-weighted patents as the dependent variable) and the second four appear in Table 3B (with breakthrough patents as the dependent variable). For both Tables, Models 1 include control variables and the main effects of key independent variables. Models 2 include control variables, main effects, and interactions with firm age. Models 3 include control variables, main effects and interactions with firm size. Finally, Models 4 presents fully-specified equations, including all controls, main effects, and interactions. The model chi-squares indicate that all reported models explain significant variance in firm innovativeness.

Insert Tables 1, 2, 3A and 3B About Here

Hypothesis 1 predicted that the percentage of founders in the TMT would have an inverted U-shaped relationship with innovativeness. The evidence for both dependent variables supports this hypothesis. When citation-weighted patents is the dependent variable (Table 3A), the coefficient for TMT percent founders is 2.82 ($p<.001$) in Model 4, and the corresponding coefficient for breakthrough patents (Table 3B) is 4.67 ($p<.01$). Further, from the same models, the coefficients for TMT percent founders squared are negative and significant ($b=-4.78$; $p<.05$, and $b=9.98$; $p<.05$, respectively). Therefore, Hypothesis 1 is strongly supported. We used Model 4 in Table 3B (for breakthrough patents) to graphically estimate an optimal level of founders on the TMT. The graph,

displayed as Figure 1, indicates that the benefits of TMT percent founders peak at about 23%, after which the effects of having more founders on the TMT begins to decrease.

Insert Figure 1 About Here

Hypothesis 2 predicted that TMT average company tenure would be negatively associated with innovativeness. Evidence from Tables 3A and 3B consistently supports this prediction, indicating that shorter average TMT tenure in the firm allows the TMT to be adaptive and open-minded toward innovative ideas and practices. For example, TMT average company tenure is negative and significant in Model 4 of Table 3A – for citation weighted patents ($b=-.36$; $p<.001$), and Model 4 of Table 3B – for breakthrough patents ($b=-.62$; $p<.01$). This evidence strongly supports Hypothesis 2.

Hypothesis 3 predicted that average TMT experiences at rival companies (TMT average rival firm tenure) would be positively associated with innovation. Evidence from Model 4 in both Table 3A ($b=.12$; $p<.01$) and Table 3B ($b=.22$; $p<.01$) is supportive. This evidence strongly supports Hypothesis 3.

Hypothesis 4 predicted that average TMT member experiences in other industries would be positively related with innovation. The evidence in support of this prediction is weak. While the coefficients for TMT average outside-industry tenure are positive and weakly significant in Models 1 and 3 of Table 3B ($b=.22$; $p<.10$, and $b=.26$; $p<.10$), no other coefficients are significant. This evidence is quite weak, and none of the coefficients for the models with citation-weighted patents, though positive as predicted,

are significant. Therefore, Hypothesis 4 receives very weak support from the analyses reported in Tables 3A and 3B.

Hypothesis 5 predicted that firm age and size would negatively moderate the effects of TMT members' rival firm tenure on innovativeness. The evidence from Tables 3A and 3B consistently support the age prediction, as the coefficients for the interactions between firm age and TMT average rival firm tenure are negative and significant in Model 2 of Table 3A ($b=-.02$; $p<.05$) and Model 2 of Table 3B ($b=-.06$; $p<.05$). Both effects are also weakly significant ($p<.10$) in the fully specified models (Models 4). The evidence from Table 3A and 3B also provides partial support for the size prediction. For citation-weighted patents as the dependent variable (Table 3A) the evidence is weakly supportive in Model 3 ($b=-.07$; $p<.10$), but not supportive in the fully specified Model 4 ($b=-.03$; ns). With breakthrough patents (Table 3B) the evidence is similar, with weak support evident in Model 3 ($b=-.14$; $p<.10$) but insignificant in the fully specified Model 4 ($b=-.04$; ns). Overall Hypothesis 5 is supported with respect to the age prediction, and weakly supported for the size prediction.

Hypothesis 6 predicted that firm age and size would negatively moderate the effects of outside-industry tenure on innovativeness. The age prediction is supported in Models 2 and 4 of Table 3B (with breakthrough patents as the dependent variable ($b=-.11$; $p<.05$, and $b=-.15$; $p<.05$, respectively), but not for citation-weighted patents (Table 3A). The age prediction was not supported for either dependent variable. None of the interactions between firm size and TMT average outside-industry tenure are significant

except for Model 4 of Table 3A, where the coefficient is significant but positive, not negative ($b=.19$; $p<.05$). Therefore, Hypothesis 6 is partially supported for age and not supported for size.

Two figures are presented below to graphically represent selected interaction effects, and both are plotted using Model 4 of Table 3B. Figure 2 demonstrates the interaction effects of firm age on the relationship between competitor experiences and breakthrough patents. While more competitor experiences increase breakthrough patents in younger firms, the effects are reversed in older firms. Figure 3 shows how firm age moderates the relationship between other industry experiences and breakthrough patents. The figure shows that other industry experiences increase innovativeness when firms are younger, but this relationship is reversed for older firms and other industry experiences decrease innovativeness in older firms.

Insert Figures 2 and 3 About Here

DISCUSSION

Our study developed theory suggesting that top managers are faced with a dual task in contributing to a young, entrepreneurial firm's innovation performance. On the one hand, managers in such firms need to absorb knowledge and experiences from external sources. On the other hand, these managers also need to solidify and develop firm-specific and unique knowledge and capabilities. We predicted that the composition of the TMT and the members' knowledge and experiences would be critical to solving

these complex tasks in entrepreneurial firms. Consistent with this perspective, we separated the bundle of top managers' knowledge and experiences into different categories and predicted that experiences from different sources would affect innovation performance differently. We tested our hypotheses with a sample of 151 firms in the biotechnology industry that recently experienced an IPO. The results, in support of our predictions, indicate that founder percentage on the TMT has an inverted-U shaped (curvilinear) relationship with firm-level innovativeness. TMTs with shorter current average company tenure are associated with higher innovativeness, as are TMTs with more experiences at rival firms. Further, our evidence showed that firm age moderates the effects of TMT experiences at rival firms on innovativeness. We concluded that firm age moderates the effects of outside industry experiences on breakthrough patents. Finally, our analyses supported the notion that firm size moderates the effects of TMT average tenure with rival firms on innovativeness.

Our evidence regarding founders' on the TMT supports the argument that founders initiate the identification and exploitation of opportunities at entrepreneurial firms, and that they represent an important locus of unique and firm-specific knowledge. Founders' presence on TMTs offers an important avenue for activating and utilizing some path-dependent, socially complex, and causally ambiguous knowledge and capabilities within the firm. Such firm-specific knowledge and experiences contribute to the decision-making processes within the TMT regarding the appropriate matching of internal technological capabilities and external opportunities. Founders' experiential

knowledge also contributes to the successful implementation of innovative projects, because founders have unique knowledge of the firm's employees, culture, and communication styles.

At the same time, however, our study also suggests that too many founders on the TMT may decrease innovativeness. A TMT composed of too many founders may be too committed to existing products and technologies, and less open to emerging opportunities and environmental changes. Too many founders on the TMT may cause the team to be rigid in its decision making and less open to novel ideas and approaches. Founders of entrepreneurial firms may often lack the kinds of knowledge and experiences that are necessary at more mature and complex organizations (Wasserman, 2003). The entrepreneurial firm may appreciate the firm-specific knowledge offered by founders, but need to balance this resource against possible liabilities associated with too much reliance on them.

While our study demonstrates the importance of founders' firm-specific knowledge, it also shows that TMT members' novel knowledge and experiences contribute to innovativeness. Consistent with upper echelons theory (Finkelstein *et al.*, Forthcoming; Hambrick and Mason, 1984), our evidence shows that TMTs with shorter average company tenure and more experiences at rival firms tend to be more effective innovators. Since top managers participate in decision-making and implementation of fundamental strategies, novel insights from rival firms allow the TMT to borrow relevant ideas and convert them into innovations. TMTs of shorter average company tenure tend

to weaken commitment to the status quo, and allow the TMT to be adaptive in exploring new possibilities. Our study extends upper echelons theory by highlighting the balance between firm-specific experiences and outside-firm experiences in the setting of entrepreneurial firms. Because TMTs of entrepreneurial firms have the dual task of further developing firm-specific knowledge as well as absorbing external, novel insights, the composition of the TMT is critical concern.

Our study further extends upper echelons theory by considering firm-level contextual factors as important contingencies for entrepreneurial firms. While for young firms, novel knowledge and experiences help to develop innovation pipelines and decision rules, these effects are much weaker at relatively older and more mature firms. Although novel knowledge from rivals and shorter company tenures can enlighten decision-making, the absorption of novel ideas and knowledge appears to be more difficult at more mature firms. Relatively older entrepreneurial firms may have already developed management systems to support their innovation pipelines. In that setting, novel ideas and approaches may be at odds with existing beliefs and norms. TMT members with fresh ideas may have to demonstrate the relevance and legitimacy of those ideas before their knowledge and experiences can contribute effectively to innovation. While recent research has examined how external contextual factors such as technological dynamism moderate the relationship between upper echelons and innovativeness (Wu et al., 2005), our study contributes to this larger theory by showing that internal contextual factors such as firm age and firm size are also important in

entrepreneurial firms.

Our study has limitations that suggest directions for future research. First, there are concerns about generalizability because we used a single industry setting. Our focus on the biotech industry has both benefits and liabilities. The benefits of choosing this particular industry lie in the fact that there is widespread and active innovation in the industry, making it a good one for testing our hypotheses. However, the single-industry design also has liabilities. The generalizability of our results may be limited by some idiosyncrasies of the biotech industry. Specifically, our conclusions about outside-industry tenure may not hold in other industries. For example, the semiconductor industry is closely linked with both the computer industry and the chemical industry. Knowledge and experiences developed from these relatively related industries may yield conclusions that differ markedly from ours.

A second limitation of our study is that we hypothesized firm age and firm size as contextual factors, but our sample is comprised of relatively young and small firms. Certainly, our sample does not represent the universe of firms, but it is also unclear where the boundaries of generalizability might be regarding these two contextual factors. We hope future researchers can begin to explore these boundaries, as our study of relatively young and small firms leaves us unable to comment on boundary conditions.

CONCLUSION

We hypothesized and found a curvilinear relationship between founder percentage

on the TMT and the innovativeness of technology-based entrepreneurial firms. We also found that firm-level innovativeness benefits from a TMT with shorter company tenure and more rival company experience. In addition, we added organizational contextual factors and were able to show that firm age moderates the effects of rival firm experiences and other industry experiences on innovativeness. Novel knowledge and experiences acquired from rivals and other industries tends to improve innovativeness more among younger firms.

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TABLE 1: SUMMARY STATISTICS

	Mean	Std Dev	Min	Max
Citation-weighted patents	11.04	14.18	0.00	57.00
Breakthrough patents	0.39	1.42	0.00	15.00
TMT % founders	0.19	0.26	0.00	1.00
TMT % founders squared	0.06	0.12	0.00	1.00
TMT avg company tenure	2.71	1.71	0.00	9.50
TMT avg tenure with rival firms	6.06	3.93	0.00	16.50
TMT avg outside-industry tenure	1.87	2.22	0.00	10.67
TMT average age	43.87	4.35	31.33	62.50
TMT size	4.46	2.03	1.00	14.00
TMT functional diversity	0.57	0.18	0.00	0.80
TMT % doctorates	0.4	0.29	0.00	1.00
TMT avg number of previous jobs	1.81	0.73	0.00	6.00
Firm age	4.75	3.02	0.00	17.00
Firm N of employees	3.66	1.05	0.00	6.18
Firm R&D intensity	0.43	0.97	0.01	9.41
Firm NBER originality	0.66	0.22	0.00	0.98
Firm pioneering technologies	1.82	7.81	0.00	94.00
Firm average citation age	7.63	2.71	0.00	16.48

TABLE 2

CORRELATIONS

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Citation-weighted patents																	
2	Breakthrough patents	.43																
3	TMT % founders	-.02	.09															
4	TMT % founders squared	-.13	-.01	.76														
5	TMT avg company tenure	.02	-.05	-.02	-.06													
6	TMT avg tenure with rival firms	.03	-.05	-.10	.00	-.04												
7	TMT avg outside-industry tenure	.03	.27	-.06	-.05	-.07	-.39											
8	TMT average age	-.07	-.09	-.06	.10	.12	.40	-.15										
9	TMT size	.25	.07	-.16	-.23	.20	-.01	-.01	.10									
0	TMT functional diversity	.21	.07	-.04	-.18	.15	-.05	.06	-.04	.44								
1	TMT % doctorates	.11	-.05	.06	.07	-.10	.07	-.27	.13	.12	.25							
2	TMT avg number of previous jobs	-.15	.00	-.08	-.06	-.27	.26	.09	.03	-.12	-.26	-.18						
3	Firm age	.16	-.09	-.23	-.20	.69	.01	-.11	.14	.30	.24	.01	-.22					
4	Firm N of employees	.30	.08	-.17	-.26	.41	.00	-.07	-.07	.61	.45	.15	-.29	.43				
5	Firm R&D intensity	-.11	.00	.11	.12	.03	-.08	.23	.02	-.16	-.04	-.07	.07	.00	-.14			
6	Firm NBER originality	.02	.08	.10	.01	.13	-.12	.18	-.06	.00	.06	-.04	-.12	.04	.07	.09		
7	Firm patent novelty	-.01	-.03	.04	-.03	-.13	-.09	-.09	-.09	-.03	.03	.03	-.02	-.11	-.09	-.04	-.22	
8	Firm average cited patent age	-.04	.01	.02	-.04	.20	.02	.14	.05	-.08	.03	.00	-.04	.14	-.06	.12	.43	-.16

N=151. Two-tailed test; correlations with an absolute value greater than 0.16 are significant at $p \leq 0.05$ or smaller.

TABLE 3A
NEGATIVE BINOMIAL REGRESSION OF CITATION-WEIGHTED PATENTS

Variables	Citation-Weighted Patents			
	Model 1	**Model 2**	**Model 3**	**Model 4**
TMT % founders	2.94***	2.87***	2.89***	2.82***
	(0.83)	(0.82)	(0.81)	(0.79)
TMT % founders squared	-4.65*	-4.32*	-4.80*	-4.78*
	(1.92)	(1.92)	(1.92)	(1.88)
TMT avg company tenure	-0.28**	-0.32**	-0.31**	-0.36***
	(0.10)	(0.11)	(0.10)	(0.11)
TMT avg tenure with rival firms	0.13**	0.13***	0.11**	0.12**
	(0.04)	(0.04)	(0.04)	(0.04)
TMT avg outside-industry tenure	0.10	0.10	0.12	0.07
	(0.08)	(0.07)	(0.07)	(0.08)
Firm age X TMT tenure with rivals		-0.02*		-0.02†
		(0.01)		(0.01)
Firm age X TMT outside-ind ten		-0.03		-0.05
		(0.03)		(0.03)
Firm Size X TMT tenure with rivals			-0.07†	-0.03
			(0.04)	(0.04)
Firm Size X TMT outside-ind ten			0.12	0.19*
			(0.08)	(0.09)
Firm age	0.15**	0.14*	0.16**	0.14*
	(0.05)	(0.05)	(0.05)	(0.06)
Firm size	0.31†	0.30†	0.30†	0.33†
	(0.18)	(0.18)	(0.18)	(0.17)
Average age	-0.07*	-0.08*	-0.08*	-0.09*
	(0.03)	(0.03)	(0.03)	(0.03)
TMT size	0.05	0.06	0.04	0.05

	(0.07)	(0.07)	(0.07)	(0.07)
Functional diversity	0.91	0.76	1.01	0.82
	(0.90)	(0.91)	(0.91)	(0.90)
TMT % doctorates	-0.36	-0.19	-0.27	-0.28
	(0.50)	(0.52)	(0.48)	(0.47)
TMT avg number of prev jobs	-0.38†	-0.35†	-0.35	-0.30
	(0.21)	(0.21)	(0.21)	(0.21)
Firm R&D intensity	0.004	0.01	0.04	0.04
	0.16	(0.16)	(0.17)	(0.18)
Firm NBER originality	-0.41	-0.56	-0.11	-0.32
	(0.67)	(0.65)	(0.63)	(0.62)
Firm pioneering technologies	-0.003	-0.002	0.0001	0.002
	(0.02)	(0.02)	(0.02)	(0.02)
Firm average citation age	0.01	0.03	-0.01	0.01
	(0.06)	(0.06)	(0.05)	(0.05)
Constant	2.59	2.96†	2.78	3.23†
	(1.74)	(1.71)	(1.73)	(1.69)
LR Chi^2	67.34***	70.82***	75.75***	79.55***
ΔChi^2		3.48	8.41*	8.73*
Number of Observations	151	151	151	151

†p≤0.10, *p≤0.05, **p≤0.01, ***p≤0.001, using a two-tailed test with standard errors in parentheses.

TABLE 3B
NEGATIVE BINOMIAL REGRESSION OF BREAKTHROUGH PATENTS

Variables	Breakthrough Patents			
	Model 1	**Model 2**	**Model 3**	**Model 4**
TMT % founders	5.05**	5.22**	5.15**	4.67**
	(1.81)	(1.77)	(1.68)	(1.57)
TMT % founders squared	-8.52†	-8.27†	-9.91*	-9.98*
	(4.97)	(4.94)	(4.52)	(4.36)
TMT avg company tenure	-0.44†	-0.56*	-0.63*	-0.62**
	(0.24)	(0.23)	(0.28)	(0.24)
TMT avg tenure with rival firms	0.24**	0.30**	0.26**	0.22**
	(0.09)	(0.09)	(0.09)	(0.08)
TMT avg outside-industry tenure	0.22†	0.22	0.26†	-0.001
	(0.12)	(0.14)	(0.15)	(0.18)
Firm age X TMT tenure with rivals		-0.06*		-0.05†
		(0.03)		(0.03)
Firm age X TMT outside-ind ten		-0.11*		-0.15*
		(0.05)		(0.06)
Firm Size X TMT tenure with rivals			-0.14†	-0.04
			(0.08)	(0.09)
Firm Size X TMT outside-ind ten			0.04	0.42
			(0.22)	(0.27)
Firm age	0.21	0.32*	0.25†	0.33*
	(0.15)	(0.15)	(0.15)	(0.13)
Firm size	0.61	0.60	0.63†	0.55
	(0.37)	(0.37)	(0.37)	(0.34)
Average age	-0.05	-0.08	-0.07	-0.08
	(0.08)	(0.08)	(0.07)	(0.07)

TMT size	0.41*	-0.40*	-0.48*	-0.49**
	(0.21)	(0.19)	(0.20)	(0.19)
Functional diversity	2.32	1.79	3.96*	2.70
	(1.76)	(1.64)	(1.84)	(1.82)
TMT % doctorates	-1.15	-1.25	-1.32†	-1.54*
	(0.90)	(0.88)	(0.79)	(0.70)
TMT avg number of prev jobs	-0.58	-0.52	-0.61	-0.43
	(0.47)	(0.45)	(0.46)	(0.41)
Firm R&D intensity	-0.16	-0.42	-0.07	-0.48
	(0.64)	(0.70)	(0.07)	(0.58)
Firm NBER originality	1.31	0.87	1.59	0.96
	(1.48)	(1.43)	(1.31)	(0.11)
Firm pioneering technologies	-0.06	-0.12	-0.06	-0.11
	(0.13)	(0.13)	(0.12)	(0.11)
Firm average citation age	-0.10	-0.12	-0.11	-0.02
	(0.13)	(0.13)	(0.11)	(0.11)
Constant	0.74	0.44	-0.55	1.64
	(3.22)	(3.18)	(3.54)	(3.08)
LR Chi^2	60.27**	66.82***	68.13***	76.78***
ΔChi^2		6.55*	7.86*	9.96**
Number of Observations	151	151	151	151

†p≤0.10, *p≤0.05, **p≤0.01, ***p≤0.001, using a two-tailed test with standard errors in parentheses.

FIGURE 1

RELATIONSHIP BETWEEN FOUNDER PERCENTAGE AND BREAKTHROUGH PATENTS

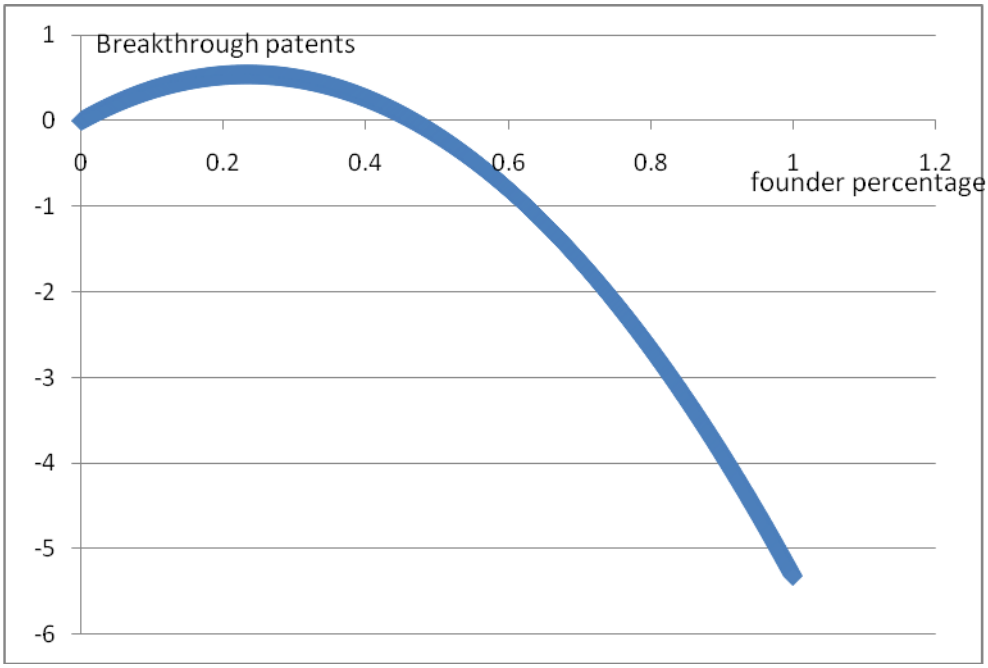

FIGURE 2

INTERACTION BETWEEN FIRM AGE AND TMT AVERAGE COMPETITOR TENURE ON BREAKTHROUGH PATENTS

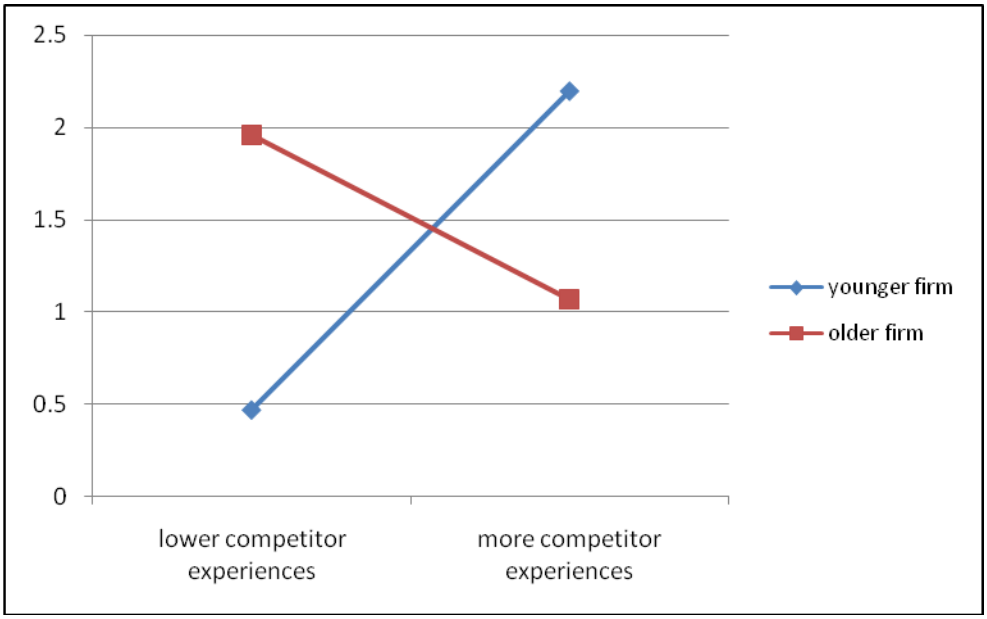

FIGURE 3

INTERACTION BETWEEN FIRM AGE AND TMT AVERAGE OUTSIDE-INDUSTRY EXPERIENCES AND ON BREAKTHROUGH PATENTS