Impact of Technological Innovation Capabilities on the Market Value of Firms

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Abstract. In the era of globalisation and with the advent of knowledge economies, organisational innovation has assumed a critical role in enhancing economic performance of firms. Proponents of the Resource Based View of the firm and its more recent extensions such as the Knowledge Based View and Dynamic Capabilities Theory have suggested that generation, diffusion and application of organisational knowledge could be the source of sustained competitive advantage and superior performance of firms. While there is near unanimity in accepting the vital role of innovation in a firm’s performance, consensus on what constitutes organisational innovation and how to measure it has proven to be elusive so far. Most previous research in this area has conceptualised innovation through one or more dimensions of a firm’s innovative capability using R&D of a firm only. The measurement of the construct has thus reflected this narrow conceptualisation with a single measure of R&D expenditure being the most often used proxy. This study utilises a broader definition of organisational innovation capabilities that includes the generation, dissemination and strength of innovative activity in a firm. The unique features of this study is that it uses multiple indicators of a firm’s innovation profile along with lagged measures of market value using fixed effects panel data analysis.

Keywords: Innovation; R&D; firm value; panel data.

1. Innovation and Innovative Capability

Knowledge and the innovative capability of firms driven by technology are considered key factors in firm performance (Isobe et al., 2008; Ma and Liao, 2006; Sher and Yang, 2005; Weikl and Grotz, 1999). Proponents of the Resource Based Theory (RBV) of the firm have supported this view by arguing that innovation, as a source of organisational “knowledge”, could be a critical factor in attaining a sustainable competitive advantage for the firm (Barney, 1991). This view has been crafted into a framework of Dynamic Capabilities (DC) by researchers such as Teece et al. (1997). More recently, the Knowledge Based View (KBV) has emerged as a novel, if not radically new, perspective to examine the nexus between innovation and firm performance (Gopalakrishnan et al., 1999). Chetty and Campbell-Hunt (2003) and Davenport et al. (2003) argued that the technology-driven strategy of firms helps them leverage their strengths toward obtaining international significance. Other interpretations of the important role of innovation in determining a firm’s destiny include innovation as a barrier for entry and exit of competitors (Porter, 1983), as an instrument in increasing the market value of the firm (Toivanen et al., 2002), as a strategic rent-generating asset (Teece et al., 1997) and as a tool for organisational change (Birkinshaw et al., 2002).

While there is near unanimity in accepting the vital role of technology-based innovation in a firm’s performance and profitability, there is very little discussion or agreement on the conceptualisation and measurement of such an innovation and its relationship with different dimensions of corporate performance. We argue that a broader conceptualisation of what constitutes technological innovation and an accurate measurement of factors that are central to various aspects of technological innovation is critical to any extended study of technology and its applications. Thus, the purpose of this research is two-fold.

First, given the paucity of research that captures the multiple manifestations of technological innovation, this study intends to create a technological innovation capability profile of a firm that includes dimensions such as generation, dissemination and strength of a firm’s innovation driven by its technological prowess. Second, it attempts to examine the role of innovation capability in predicting the market value of US-based firms.
2. Literature Review

2.1. Conceptualisation and measurement of innovation

Innovation has been defined as an “internally generated or (externally) purchased device, system, policy, program, process, product or service that is new to the adopting organisation” (Damanpour, 1992). Thompson (1965) defined innovation as the generation of new ideas, processes and products or services. But according to Feeny and Rogers (2003), innovation is the application of new ideas to the products and processes of a firm’s activities, and according to Amabile et al. (1996), it is the successful implementation of creative ideas within an organisation. As can be seen there is a fair amount of debate on what actually constitutes organisational innovation. We argue that a comprehensive definition of innovation should include all the above dimensions.

The RBV (Barney, 1991; Wernerfelt, 1984) has largely driven academic research in this area which proposes that the firm is a collection of capabilities and that organisation’s ability to exploit these capabilities in order to achieve competitive success. This theory also posits that the more valuable and inimitable these capabilities are, the more sustainable its competitive advantage is. The impact of organisational innovation and technology on competitive dynamics of a firm has also been highlighted in the works of Schumpeter (1934), Utterback and Abernathy (1975), Lipman and Rumelt (1982) and Teece (1982), to name a few. Although the idea of exploiting firm capabilities in order to achieve extraordinary results is not entirely new, the resource-based view has been instrumental in shaping the academic and practitioner focus on the “intangible” resources of the firm.

This focus on the intangible resources has also given rise to a “knowledge-based view” of the firm (Grant, 1996). This view provides a new perspective on not just the performance of the firm but its very existence — for the creation, and application of knowledge (Demsetz, 1991; Grant, 1996). Thus, researchers in this area have viewed the innovation of a firm as a manifestation of firm-specific knowledge that is created and/or transferred in order to attain a competitive advantage and earn above average returns.

Thus, it is clear that although previous research in this area has conceptualised innovation of a firm through multiple dimensions of a firm’s innovative capability, the measurement of organisational innovation has not reflected this. Most empirical studies have relied upon a single indicator such as R&D expenditure of a firm or number of patents only (Archibugi and Pianta, 1996). These measures, although useful indicators of a firm’s innovation-driven output, are not an accurate reflection of its innovative capability. Moreover, patent counts do not reflect small and medium-sized enterprises adequately since many small firms do not patent their innovations for various reasons (Romijn and Albaladejo, 2002). A few researchers have attempted a composite index of innovation based on a factor analysis of several innovation variables (Hollenstein, 1996). This index included “input-oriented”, “output-oriented” and “market-oriented” measures of innovation. Romijn and Albaladejo (2002) constructed an innovation index based on a survey of the “extent” and “significance” of a firm’s innovative outputs (p. 1057). They found that the index was able to predict a firm’s export orientation more than the single item measures such as patent counts.

2.2. Performance implications of innovation

Most studies linking innovation to firm performance can be categorised as those that use

(a) “Type” of innovation, such as administrative, technological, product or process-based, and
(b) “Extent” of innovation in an organisation, such as radical vs gradual innovation, extent of investment in R&D to generate innovative activity.

Damanpour et al. (1989) found a positive relationship between adoption of administrative and technical innovations over time and organisational performance. Ettlie (1983) and Kimberly and Evanisko (1980) are among other studies in this regard. Yamin et al. (2003) computed what they called an “innovation index” of a firm using administrative, technical and product innovation dimensions. While the idea of incorporating multiple dimensions is certainly meritorious, the study fails to incorporate the diffusion and management dimensions of innovation.

Feeny and Rogers (2003) studied the impact of innovation on firm performance using a sample of large Australian firms. Toivanen et al. (2002) studied the impact of firm innovation, as measured by its R&D spending, on the market value of the firm. They found that R&D positively impacts market value of a firm.

A few studies have focused on the impact of firm innovation or innovative capabilities on international performance of firms. The empirical studies on European firms by Roper and Love (2002), and on Chinese firms by Guan and Ma (2003) are a few examples. The latter study used a variety of innovative capability dimensions spanning the functional domain of firms such as R&D, marketing, resource allocation and strategic planning to predict the export behavior of a firm. They found evidence
to support their claim that a collection of innovation dimensions including R&D promotes the international competitiveness of the firm.

Based on the previous research as discussed above and summarised in Table 1, the following conclusions can be drawn:

1. Innovative capabilities of firms are important predictors of firm performance.
2. Most studies use a narrow definition of innovation while it remains a multidimensional construct.
3. Very few studies have examined the impact of innovation on market value of firms (almost none involving US firms).
4. Very few studies used panel data methodology. Most of previous studies either used OLS or pooled OLS.

This paper addresses the above issues using a sample of 64 firms over a nine-year period by examining the relationship between a variety of innovation dimensions including generation, dissemination and strength of innovation that constitutes a firm’s “innovation capability profile”, and market value of firms.

We define innovation generation as the capacity of a firm to generate knowledge through investments in R&D, filing of patents, trademarks and copyrights and so on. We measure this by the number of patents filed by a firm with the United States Patent and Trademark Office (USPTO) in a given year.

We define innovation dissemination as the capacity of a firm to disseminate the knowledge it has generated for other applications or to generate further knowledge for the firm. A firm’s capacity for knowledge dissemination can also be reflected in the way its patents are cited by other firms in the industry. Therefore we operationalise this by using an index that measures the impact and citation frequency of a firm’s patents and resultant knowledge.

Finally, we argue that a firm’s innovative capability lies not just in the number of patents it generates but also in the quality of such patents. By quality, we mean the strength of a firm’s knowledge which can be measured by the quality-weighted portfolio size.

Please refer to Table 2 for specific operationalisation of each of the above.

The following hypotheses will be empirically verified:

(H1) A firm’s capacity for innovation generation is positively associated with its market value.
(H2) A firm’s capacity for innovation dissemination is positively related to its market value.
(H3) A firm’s strength of innovation is positively related to its market value.

3. Research Methodology

3.1. Sample

An original cross-sectional national sample of 200 multinational firms from four sectors (biotechnology, chemicals, electronics and semiconductor) was selected for the study. The sample period is 1992–2000. The sample was randomly drawn from a list of manufacturing firms from the CHI Research™ (CHI) database containing patent information. These firms were then matched with the Compustat—Research Insight database that contained market value data. After eliminating firms with incomplete data on market value and other innovation related information, a total of 64 firms remained in the sample.

3.2. Data and variables

Data for dependent variable (market value) were obtained from the Research Insight® database. Data for the independent variables of Innovation capability profile were obtained from the patent database called TECH—LINE®, maintained by CHI. The use of patents and patent citations to measure innovation and knowledge of a firm has precedent in the studies by Narin et al. (1987), Jaffe et al. (2000) and Fung and Chow (2002). Table 2 explains the variables and their operationalisation.

3.3. Empirical model

In the econometrics literature, cross-sectional time-series models are called panel data. Panel data facilitates regression analysis in terms of spatial and temporal dimensions. The spatial dimension relates to a group of cross-sectional data (in our case the individual firms). On the other hand, the temporal dimension refers to periodic observations of a set of variables over a particular time period. In this study, time series of the observations are at individual firm level rather than aggregate level. In a pooled observation situation, estimating the OLS would yield a biased estimate.

For the panel data analysis, the data set consists of $i = 1, \ldots, N$ cross-sections (number of firms), and several points of time series for each firm $t = 1, \ldots, T(i)$, or a cross-section of $N$ time series each of length $T(i)$. To break down the effect of R&D together with innovation generation, innovation dissemination and innovation strength, the following linear models are estimated:

(i) Ordinary Least Squares (OLS).

$$FV_{it} = \lambda_i + \beta'G_{it} + \alpha'D_{it} + \gamma'S_{it} + \phi'X_{it} + \mu_{it} \quad (1)$$

where $FV_{it}$ is the firm value in firm $i = 1, \ldots, N$, year $t = 1, \ldots, T(i)$. 

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<table>
<thead>
<tr>
<th>Study</th>
<th>Conceptualisation of innovation</th>
<th>Measurement</th>
<th>Criterion variable</th>
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<tbody>
<tr>
<td>Morone and Testa (2008)</td>
<td>Process innovation</td>
<td>Turnover growth of 2600 Italian SMEs</td>
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<td>Product innovation</td>
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<td>Marketing innovation</td>
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<td>Isobe et al. (2008)</td>
<td>Technological capabilities</td>
<td>Refinement capabilities</td>
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<td>Reconfiguration capabilities</td>
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<td>Ma and Liao (2006)</td>
<td>Innovative capability</td>
<td>(1) Technological capability</td>
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<td>(2) Managerial capability</td>
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<td>(3) Resource exploiting capability</td>
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<td>Flor and Oltra (2005)</td>
<td>Technological innovation in their export performance</td>
<td>Investment in internal non-R&amp;D innovations (engineering</td>
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<td>design and pre-production), investment in R&amp;D, investment in</td>
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<td>external acquisition of technology</td>
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<td>Hult et al. (2004)</td>
<td>Capacity of firms to introduce new product, process or idea in the</td>
<td>Number of new ideas recognized and adapted in the organisation</td>
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<td>(2) Profitability</td>
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<td>(3) Sales growth and</td>
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<td>(4) Market share growth</td>
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<td>Ozcelik and Taymaz (2004)</td>
<td>Technological capabilities to enhance product and process</td>
<td>Rate of product and process innovations in firms (based on</td>
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<td>survey)</td>
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<td>Hsueh and Tu (2004)</td>
<td>Entrepreneurial spirit</td>
<td>Factor analysis leading to</td>
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<td>(1) innovative atmosphere</td>
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<td>(2) ability to innovate</td>
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<td>Acs et al. (2002)</td>
<td>Knowledge generated in firm including product, process and</td>
<td>(1) Number of patents granted</td>
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<td>“disruptive” types</td>
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<td>(2) Employment in R&amp;D laboratories</td>
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<td>(3) University R&amp;D expenses</td>
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<td>(4) Private sector R&amp;D expenses</td>
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<td>Romijn and Albaladejo (2002)</td>
<td>Degree of novelty in product introductions</td>
<td>Product innovation index (5 item scale based on survey)</td>
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<td>Export orientation of firm</td>
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<td>Study</td>
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<td>Soutaris (2002)</td>
<td>Portfolio of a firm's competence</td>
<td>Rate of technological innovation</td>
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<td>(1) Technological competencies</td>
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<td>(2) Human resource competencies</td>
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<td>(3) Organisational competencies</td>
<td>(4) Market Competitance</td>
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<td>(5) Market Competitance</td>
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<td>(6) R&amp;D expenditure</td>
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<td>(7) Number of patents</td>
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<td>Yamin et al. (1999)</td>
<td>Aggregate indicator consisting of product, process, and personnel</td>
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<td>Hollenstein (1996)</td>
<td>Complex activity permeating all stages of a firm’s value chain</td>
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<td>Leonard-Barton (1992)</td>
<td>Core competencies of a firm based on:</td>
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<td>(1) Core competency: People's skills and knowledge</td>
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<td>(2) Core competency: People's skills and knowledge</td>
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<td></td>
<td>Firm performance</td>
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<td>New product development</td>
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<td>N/A</td>
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G


it

is the vector of generation of innovation variables.

D


it

is the vector of dissemination of innovation variables.

S


it

is the vector of strength of innovation variables.

X


it

is the R&D expenditure.

/C21

i

is the overall constant term, which is the same for all firms.

/C22

it

is independently and identically distributed among firms and years.

(ii) Fixed Effects.

FV

i

¼

/C17

1

/C14

1

i

þ/C17

2

/C14

2

i

þ/C1/C1/C1þ

/C12

0

G

i

þ/C11

0

D

i

þ/C13

0

S

i

þ/C30

0

X

i

þ/C22

i

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2

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FV

i

is the firm value in firm

i

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1

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N

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. Equation (2) does not include a general intercept to avoid perfect collinearity with the set of

N

indicators

/jit

. For the obvious reasons, Eq. 2 is often called the LSDV (Least Squares with Dummy Variables) model.

4. Empirical Results

Table 3 reports the descriptive statistics. The time series observations for all the cross-section units can be pooled and the regression coefficients can be estimated by OLS. As a matter of fact, prior research in the literature (refer to Sec. 2) used both OLS as well as pooled OLS regression. However, using OLS to estimate the coefficients has two drawbacks. First, errors in the model may be autocorrelated. The second drawback is that the variance of the error term may not be constant over time. To overcome the second drawback, White’s robust heteroscedasticity corrected covariance matrix was used in the fixed-effects model. To examine whether the fixed-effects (FE) model is superior to the pooled OLS, we tested the joint significance of the dummies by performing an F-test.

\[ H_0 : \eta_1 + \eta_2 \cdots + \eta_n = 0 \]

There are

N

/jit

indicators, one for each unit in the analysis. Equation (2) does not include a general intercept to avoid perfect collinearity with the set of

N

indicators

/jit

. For the obvious reasons, Eq. 2 is often called the LSDV (Least Squares with Dummy Variables) model.
Under the null hypothesis, the model becomes the pooled regression, i.e., $Y_{it} = \lambda_i + \beta'X_{it} + u_{it}$.

Under the null hypothesis,

$$F = \frac{(SSR_{\text{pooled}} - SSR_{\text{fixed effects}})/(n - 1)}{SSR_{\text{fixed effects}}/(nT - n - k)} \sim F_{n-1, n(T-1)-k}$$

In Tables 4, 5 and 6 we present the model selection test ($F$-stat). In all the three cases, the $F$-statistics are significant indicating that the fixed-effects model is preferred to pooled OLS. Thus, our discussion will be focusing on the fixed-effects model.

In Table 4, regression results of the R&D for 64 firms are reported. Parameter estimates of R&D were strongly positive and significant in the one-year lag and three-year lag. This confirmed our expectation that R&D spending positively impacts the firm value immediately as well as over time. To further investigate the impact on various components of R&D on the firm value, we regressed various other independent variables. In the fixed-effects model, the number of patents (PAT), a proxy for innovation generation, was positive but not significant in the one-year lag. However, PAT was highly positive and significant when we tested with a three-year lag. This indicates that patent applications impact the market value of firm with a time-lag. This is reasonable when one considers the corporate reality that investments in firm innovation and knowledge involve a lead time before the payback occurs.

In terms of innovation dissemination, the fixed-effects model in Table 5 provides some interesting results too. Current Impact Index (CII), which indicates the impact and citation frequency of a firm’s patents, is negative and insignificant in the one-year lag. However, with a three-year lag the coefficient becomes highly positive and significant. Table 6 provides regression results for technology strength (TECH), a proxy for innovation strength. It appears that for the fixed effects model, TECH is positive but insignificant in the one-year lag. In the three-year lag TECH becomes positively significant at the 1% level.

Again, these findings support our notion that investments in technology require time to pay back. Research evidence exists to show that CII positively impacts firm performance which is reflected in long-term appreciation in firm value (Wolff, 1998; Breitzman and Thomas, 2002).

### 5. Conclusion

This study attempted to examine factors that determine the technological innovation profile of a firm. By using data that originated from firm level patenting activities, we were able to create such a profile consisting of generation, dissemination and strength of a firm’s innovation.

<table>
<thead>
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<th>Table 4. Regression results of R&amp;D.</th>
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<td><strong>Variable</strong></td>
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<td>Constant</td>
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<td>R&amp;D</td>
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<td>Adj. $R^2$</td>
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<td>$F$-Statistic</td>
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<td>Model selection test ($F$-stat)</td>
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*Note:* $^{***}$, $^{**}$, $^{*}$ denote significance at 1%, 5%, and 10%, respectively.

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<th>Table 5. Regression results of R&amp;D, patent and citation impact index.</th>
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<td><strong>Variable</strong></td>
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<td>Adj. $R^2$</td>
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<td>$F$-Statistic</td>
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*Note:* $^{***}$, $^{**}$, $^{*}$ denote significance at 1%, 5%, and 10%, respectively.
We also aimed to predict the market value of a firm using these dimensions of technological innovation using a panel data methodology. Our findings support the resource-based view of the firm (Barney, 1991) and the dynamic capabilities framework (Teece et al., 1997) and indicated that a relationship exists between innovation capabilities of a firm and its market value in the long run. While the OLS results seem to ignore the time factor, our fixed-effects model shows that a lagged relationship exists between innovation and market value. We believe that our study supports the notion that firms’ investments in R&D take time to deliver returns. The results also show that stock market reaction for firm R&D strategy is long-term oriented.

Though this study did not provide comprehensively conclusive results, we believe that it provides some useful insights into the relationship between technological capabilities of a firm and its market value. The predictor variables innovation generation, dissemination and strength were significant predictors of the firm value with a three-year lag. Thus, we find support for Hypotheses 1, 2 and 3 with a time-lag of three years. Another explanation for the lagged effect on firm valuation is the fact that many US firms are filling for patents a great deal more than in previous years, and many of those patents almost encircle the actually “important” patents, thus their contribution to the true body of knowledge and eventually firm value may be effective only after a few years.

The limitations of the study are apparent. First, we only examined US firms, and an international comparison could provide vastly different results. Second, due to missing data, our sample size and time frame were somewhat limited. While we were moderately successful in identifying a pattern, we realise that additional data along with some new dimensions of a firm’s technological strength such as “management” of a firm’s innovation profile could possibly shed better light on this issue. Finally, many firms rely less on patenting and more on secrecy to protect their innovations, and those types of innovations could not be captured with our current means of analysis (McMillan et al., 2000).

References


Table 6. Regression results of R&D and Tech.

<table>
<thead>
<tr>
<th>Variable</th>
<th>1-year lag OLS</th>
<th>1-year lag Fixed effects</th>
<th>3-year lag OLS</th>
<th>3-year lag Fixed effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-1989.64***</td>
<td>-1989.64***</td>
<td>-560.26</td>
<td>-560.26</td>
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<tr>
<td>R&amp;D</td>
<td>37.95***</td>
<td>42.334***</td>
<td>41.37***</td>
<td>10.81</td>
</tr>
<tr>
<td>TECH</td>
<td>7.84***</td>
<td>11.900</td>
<td>8.68***</td>
<td>7.03***</td>
</tr>
<tr>
<td>Adj. $R^2$</td>
<td>0.744</td>
<td>0.837</td>
<td>0.607</td>
<td>0.6405</td>
</tr>
<tr>
<td>F-Statistic</td>
<td>797.97***</td>
<td>45.03***</td>
<td>427.60***</td>
<td>47.68***</td>
</tr>
<tr>
<td>Model selection test ($F$-stat)</td>
<td>14.12***</td>
<td>44.30***</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: ***, **, * denote significance at 1%, 5%, and 10%, respectively.


Madan Annavarjula graduated with a PhD in International Business from Temple University, Philadelphia, in 1998. He currently teaches International Business and Business Policy courses at Bryant University. He is also the coordinator of the Bachelor of Science in International Business Program at Bryant. His current research interests include international trade in services and technology strategies of multinational corporations. His research has been published in refereed journals including *International Journal of Public Administration, Public Administration Quarterly, Journal of Global Business, American Business Review, Journal of Transnational Management Development*, and *International Journal of Organizational Analysis*.


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