TECHNOLOGICAL INNOVATIONS, RESEARCH & DEVELOPMENT, DIVERSIFICATION AND ECONOMIC PERFORMANCE IN HIGH-TECH INDUSTRIES ACROSS COUNTRIES

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ABSTRACT

Technological innovations have become strategic catalysts to maintaining sustainable growth in today's global and competitive business environments. The evolutionary and dynamic innovation perspectives propose a dynamic relationship between diversification strategies and technological capabilities in technology-oriented multinational corporations (TMCs). This study attempts to empirically explore the strategic impacts of corporate diversification on technological innovation. The major findings of this study demonstrate that corporate diversification strategies in markets and products are significantly related to various indices of technological innovation and economic performance in multinational corporations across different country and industry sectors.

INTRODUCTION

Over the past decades, one of the most distinguishing features of the technology-oriented multinational corporations (referred hereafter as TMCs) has been the increased focus on technological innovations and sustained growth in a competitive global market. The globalization of Research and Development (R&D), as one of the major input factors in innovation, has also been one of the several driving forces in building a competitive edge in today's competitive and turbulent economic environment. Globalization has opened market opportunities to companies of diverse national origins, allowing them to offer a multitude of goods, products and services (Porter, 1998; Ravichandran, 2008; Chiang, 2010) to local customers. Global competition coupled with shorter product cycles, growing innovative capabilities, changing customer tastes have shortened product life cycles. TMCs, therefore, can no longer rely solely on economies of scale and scope to build strong global market positions and protect them from their rivals (Cantwell & Vertova, 2004; Ghoshal & Nohria, 1989). Due to intense global market competition and uncertainty, TMCs must continuously innovate to observe sustained growth, otherwise to embrace failure (Artz *et al*., 2010; Chari *et al*., 2008; Huang & Lin, 2006; Teece *et al*., 1997).

Technological innovation is the technical process through which new and/or improved technologies are developed and proliferated through commercialization (Ambuj & Zwaan, 2006). In fact, technological innovation is the main reason for the existence and successful performance of modern enterprises in a competitive global market (Dedrick *et al*., 2003; Kogut, 1990). Innovation allows firms to develop capabilities that give them a competitive advantage over their rivals by introducing unique products, services, and even operational processes that may be hard for competitors to imitate. R&D activities also provide fundamental inputs to TMCs' innovations, leading to patents and ultimately to new products (Anonymous, 1996; Hagedoorn & Cloodt, 2003). It is well recognized that R&D intensity can be referred to as one of the major determinants of a firm's new product introduction (Soderquist & Godener, 2004), patent (Mukherjee & Ray, 2009), market share (Franko, 1989), export (Lee & Habte-Giorgis, 2004), foreign direct investments (Glass & Saggi, 1999; Kogut, 1990), and firm performance (Artz et al., 2010).

Technological innovations have also been known to drive diversification strategies in products and markets as a means of creating wealth for their shareholders. Diversified firms appear to be financially more profitable and are able to achieve a larger market share, domestically and globally. But such realized higher values are more likely to stem from increased innovation efficiency and higher level of R&D activities rather than from more efficient use of assets (Chiang, 2010; Ravichandran, 2008). In today's uncertain market conditions due to intense competition, firms need to develop sustainable capabilities and strategies to help them navigate by diversifying products and markets (Chari *et al*., 2008; Hitt, *et al*., 1997). Whether and how corporate diversification strategies in products and markets, individually or combined, influence today's technological innovations and capabilities, including R&D activities, are still unclear and inconclusive.

Although diversification strategies are motivated by different objectives, they might have differential effects on R&D intensity. If firms differ in their use of product and diversification internationally, then it would be prudent to investigate the interactive effects of these strategies on R&D intensity and their outcomes. Also, in conducting their analyses, researchers have used data primarily available at U.S.-based firms and/or a limited number of countries as well as industry segments. Thus, most studies have failed to establish the generalized effect of technological innovations and R&D capabilities on different dimensions of diversification in products and markets across countries.

Given the important role TMCs play in the international economy, researchers have sought to identify factors that determine their ability to innovate in global markets. Mounting evidences suggest that TMCs' corporate strategies can stimulate their investments with a commitment to maintaining those technological capabilities required for profitable and continuous

innovations (Hitt *et al.*, 1997; Mohnen *et al.*, 2006). Despite the importance of technological capabilities for profitable innovations (Miller, 2006; Patel & Pavitt, 1998), the strategic linkages between diversification and technological innovation as well as capabilities in the global perspectives are not well documented.

Furthermore, most prior research articles have ignored the effects of diversification strategies on the outcomes of R&D intensity including the development of new products and patents which are the sources of a high-tech firm's competitive advantage (Dunning, 1998; Patel & Pavitt, 1997 & 1998; Porter 1998). Prior research also failed to recognize that TMCs differ significantly in their R&D capabilities and technological innovations to diversify markets as well as products (Chiesa, 1996). Some TMCs are also more efficient in managing their own R&D operations and therefore reap greater benefits from their investments. This suggests that diversification strategies may not affect R&D outcomes as much as spending. Consequently, the strategic impact of corporate diversification strategies, in both markets and products, on technological capabilities and innovations, need to be explored in a global context.

RESEARCH QUESTIONS

This study empirically explores the strategic impact of diversification activities on technological capabilities created by innovation and R&D intensity for TMCs that operate globally. More specifically, this study is primarily designed to focus on three major indicators of a firm's technological innovation capabilities. The first is R&D intensity, which is a key source of technological innovation capabilities and how they are crucial for creating the knowledge flow necessary for product and process innovations (Hagedoorn & Cloodt, 2003). The dynamic capability and evolutionary perspectives propose that R&D investments are crucial to creating the knowledge—a key intangible resource that TMCs can employ in their business operations. The second is the number of patents a firm hold, which is a key measure of innovative capacity of a firm as well as an important source of competitive advantage in global markets (Patel & Pavitt, 1991, 1997; Hagedoorn & Cloodt, 2003), and knowledge stocks (DeCaloris & Deeds, 1999). Patents indicate a firm's success in discovery and innovation (Griliches, 1988; Hagedoorn & Cloodt, 2003) and represent a reliable proxy of a firm's progress in developing strong technological capabilities (Narin, Noma & Perry 1993; Patel & Pavitt, 1998). Third, a new measure of innovation according to *Business Week*, called technological strength is a composite of the number of product patents and their citations reflecting on the quality of innovation.

In addition to the functional linkages between R&D and diversification at the subsidiary level (Almeida & Phene, 2004; Frost, 2001; Feinberg & Gupta, 2004), this study further examines the individual and interactive effects of international and product diversification strategies on TMCs' future innovations (Ahuja & Katila, 2004; Frost, 2001; Hitt *et al.*, 1994; Hitt *et al.*, 1997). Given the importance of innovation for global success (Patel & Pavitt, 1997; Artz *et al.*, 2010), the effect of these strategies on TMCs' innovation requires rigorous empirical investigations. Since international diversification brings new and perhaps different knowledge into the firm's innovation process and enhances its ability to generate patents and, therefore, develop new products, researchers need to document these effects.

Theoretical Foundation of the Study

TMCs usually start their international operations by marketing products that have been developed in their R&D units and have been successful in their domestic market. Their successful performance is predicated on continuous and successful innovation strategies. TMCs compete by exploiting a combination of firm specific advantages which include ownership of intangible assets, location-specific advantages, and internalized transactions to achieve control over their foreign investments (Dunning, 1988). Intangible assets, such as technological capabilities, can give high-tech corporations competitive advantages over their rivals (Dunning, 1998; Shan & Song, 1997). TMCs can sustain these advantages only if they have technological capabilities that are rare, inimitable, and not substitutable (Barney, 1991). International market diversification (IMD) and product diversification (PD) can foster the accumulation of technological capabilities by exposing TMCs to different domestic and international business environments (Barkema & Vermeulen, 1998). It is also empirically demonstrated that the impact of technology innovation is greater for firms with higher levels of diversification than for those with lesser diversification (Chari *et al.*, 2008; Shin, 2006).

International Market Diversification (IMD) and Technological Innovation & Capabilities

Several studies have demonstrated the growing internationalization of R&D activities in TMCs. In the Global Benchmark Survey of the strategic management of technology of the largest TMCs, Gerybadze (2004) reported six industries that are highly characterized by high foreign R&D. Multinational enterprises use IMD to achieve a variety of objectives, including the ability enhance their shareholders' wealth (Markides & Ittner, 1997). The organizational learning perspective (Huber, 1991) suggests that IMD can also enable TMCs to acquire new technological skills to augment their in-house R&D and other innovative capabilities (Chiesa, 1996; Kotabe, 1990). The organizational learning perspective also highlights the importance of the TMCs' increased exposure and access to diverse knowledge and skills as IMD increases (Barkema & Vermeulen, 1998; Hitt *et al.*, 1997). The diversity of markets and business environments can enhance the firms' learning capabilities, and future innovations (Stata, 1989). Thus, international diversification induces organizational learning of new technology by broadening the TMCs' geographic scope, giving them an opportunity to recoup their R&D investments and make a profit (Korbin, 1991). These skills can improve the TMCs' capacity to innovate,

thereby, increasing their future market values and enriching their shareholders wealth.

However, the TMCs' ability to protect their markets depends largely on their success to create new products and services that meet local needs. Technology oriented firms, therefore, must successively generate radical innovations (Kogut, 1990). However, such radical innovation is costly (Mansfield, 1988). International market diversification (IMD) stabilizes profits (Caves, 1982), creating slack resources needed for costly and radical innovations that improve firm responsiveness to local customers through product customization and original product developments (Kotabe, 1990). As production becomes more global, the need for appropriate knowledge derived from patents also increases. The internationalization of production leads to the internationalization of knowledge, which in turn, leads to true global integration in TMCs.

With the growing dispersion of technological knowledge, innovations frequently result from the interaction and cooperation of multiple organizations around the globe (Arora & Gambardella, 1990; Porter, 1998). These organizations usually have different resources and specialized knowledge bases. Technological knowledge is usually tacit in nature (Nonaka & Takeuchi, 1995) and therefore cannot be easily duplicated, transferred or efficiently separated from its context (Szulanski, 1996). Given that modern technologies are complex and characterized by complementarities (Chiesa, 1996; Rosenberg, 1976), a high-tech firm's success in one innovation requires gaining access to other innovations and technologies developed elsewhere (Ferne, 1998). IMD takes TMCs closer to the centers of innovation located outside their domestic markets, thus promoting greater learning of new technological skills (Tihanyi *et al.*, 2005). TMCs use subsidiaries with world mandates or "specialized contributor" subsidiaries to obtain new technological knowledge from foreign markets.

Technological performance is the accomplishment of firms with regard to the combination of their R&D input (R&D expenditures) and R&D output (patents) (Hagedoorn & Cloodt, 2003). DeCarolis and Deeds (1999) relate a firm's knowledge measured in terms of stocks and flows— stocks by the number of patents *and flows* in terms of R&D investments. Various studies have shown a strong correlation between R&D intensity and patents (Ahuja & Katila, 2004; Hagedoorn & Duyters, 2002). Kogut and Zander (1993) stated that entry or expansion into foreign markets alters the global knowledge of that firm. The entry increases the chances of the proliferation of diverse types of technological knowledge and capabilities.

In sum, internationally diversified technology oriented corporations can gain access to many resources and inputs that can spur innovation (Chari et al., 2008; Kotabe, 1990; Tihanyi *et al*., 2005). As IMD rises, the TMCs are likely to engage in more innovations by spending more on R&D, a process that can generate more patents (Mansfield, 1989; Scherer, 1984). The knowledge gained through IMD can also promote the TMCs' learning of new skills and the acquisition of insights about best practices in managing and using modern technologies. This process can strengthen a TMC's overall technological capabilities. These observations suggest the following hypotheses:

H1: International diversification (IMD) is statistically significant and positively related to the TMCs' Technological Innovation and Capabilities.

H1a: IMD is positively related to R&D activity.

H1b: IMD is positively related to Number of Patents.

H1c: IMD is positively related to the Technology Strength.

Product Diversification (PD) and Technological Innovation & Capabilities

Some prior empirical research suggests that PD can negatively affect a firm's innovation, as measured by R&D intensity (Hitt *et al.*, 1997). Several studies have shown that small to moderate amounts of PD can reduce R&D intensity, a factor that would lower a firms' technological capabilities. Changes in the TMCs' organizational culture and structure appear to detrimentally underlie the effect of PD on the intensity of R&D spending. The widespread use of financial controls can induce risk aversion and reduce innovation (Hoskisson & Hitt, 1988; Baysinger & Hoskisson, 1989; Hitt *et al*., 1996). As PD increases, a management's ability to process information about the TMCs' diverse products, markets and customers is also challenged, increasing the use of financial controls. As PD increases, the financial controls prevail, R&D investments decline (Hitt *et al*., 1994), promoting a focus on incremental innovations that do not generate patents.

Given that PD is often achieved through acquisitions that are financed by debt (Hitt, Hoskisson, Ireland & Harrison, 1991), some high-tech firms may reduce their discretionary expenditures such as investments in R&D. Increased debt often limits a manager's discretion by reducing the slack resources needed for innovation (Hansen & Hill, 1991; Hoskisson & Hitt, 1994; Litchenberg, 1994). Consistent with these arguments, some studies have found a negative relationship between PD and R&D intensity in U.S. (Hoskisson & Hitt 1988; Baysinger & Hoskisson, 1989; Hitt *et al*., 1997) and Japanese companies (Doi, 1985). As PD rises, some TMCs also adopt M-form organizational structures (Hoskisson & Hitt 1994) that reduce inter-unit communication and the transfer of knowledge (Hamel & Prahalad, 1994). Furthermore, as PD increases, the TMCs might spread themselves too thin and lose sight of the sources of their marketing and technological advantages.

The organizational learning perspective suggests that companies that pursue PD can build strong technological capabilities by spending heavily on R&D, obtaining more patents, and quickly developing new technologies. This continues until a peak is reached by the TMC and then the performance begins to decline. As PD continues, however, inter-unit communications become difficult, time consuming, and costly. Turf wars

among the units may ensue, depriving the firm of technological synergies. Coordination and communication problems become so severe that gains in technological capabilities begin to decline. These declines are further exacerbated by a lack of support for other innovation activities as financials dominate strategic controls. Thus, a curvilinear relationship resembling an inverted U-shaped curve is expected between PD and technological capabilities.

It has been demonstrated that European and U.S. executives recognized PD as a strategy to build strong technological capabilities and they also noted the importance of PD in developing these capabilities (Kerin *et al.*, 1990). In general, multinational enterprises with a high PD can enjoy economies of scale and scope, thereby increasing their returns from their innovations while spreading the risk (Teece, 1981; Teece *et al*., 1997). TMCs with high PD will have an incentive to maintain strong R&D programs that support their business objectives. Thus, diversified TMCs can benefit from having efficient R&D programs which support their diverse operations while reducing their risks of failure. This can encourage investments in R&D, improve the firm's ability to build stronger technological capabilities, and generate a higher number of patents (Artz *et al*., 2010; Griliches, 1998; Scherer, 1989). A higher PD will be positively associated with the outcomes of TMCs' innovation process.

Product diversification (PD) also strengthens the TMCs' technological position. As the TMCs expands their product lines to achieve higher PD, their pool of knowledge expands. Knowledge can be leveraged to build stronger market position. One way to do this is to embed the technology into the TMC's products, making them difficult for the competition to imitate (Porter, 1985 & 1990). Alternatively, TMCs can use their technology to upgrade their products making them current and easier for customers to use (Day, 1994). These actions allow the TMCs to capture and retain high market share and achieve profitability. PD is an important means for acquiring distributed technological competencies (Argyres, 1996; Chari *et al.*, 2008; Wolf, 1977) that can spur learning and knowledge creation.

Contrary to our conventional and traditional notions of significant effect of PD on technology innovation, some innovations are likely to be incremental in nature. Even when unsure about the full implications of their discoveries, firms may patent them in order to stake their claims to certain technologies, put a roadblock to a rival's entry, or exercise an option at some point in the future. Firms may also swap patents to gain access to other companies' innovations (Mowery and Teece, 1993; Mowery *et al*., 1996), which can strengthen the TMCs' ability to develop new products, obtain more patents, and strengthen their own technological base.

In sum, a high PD can intensify the high-tech firm's R&D spending, increases the number of its new patents, and improve its technological capabilities. Indeed, past studies (Link & Long, 1981; McEachern & Romeo, 1978) have reported a positive association between PD and R&D intensity. High R&D intensity yields new products (Galan & Sanchez, 2006) and patents (Griliches, 1984). Other studies (Artz *et al*., 2010; Baysinger & Hoskisson, 1989; Chari, 2008; Lunn, 1987; Shin, 2006) have also found a positive association between PD and technology innovation activities including the number of patents. Thus, our discussion uggests the following hypotheses:

H2: Product diversification (PD) is statistically significant and positively (but curvilinearly) related to the TMCs' Technological Innovation and Capabilities.

H2a: PD is positively (but curvilinearly) related to future R&D Intensity.

H2b: PD is positively (but curvilinearly) related to the number of patents.

H2c: PD is positively (but curvilinearly) related to technological strength.

The Interactive Effects of IMD and PD on Technological Innovation and Capabilities

International and product diversification may also interact to determine a TMC's innovations (Hitt *et al*., 1994, 1997). Though several studies have explored the interaction of international and product diversification on financial performance (Grant *et al*., 1988; Hall & Lee, 2010; Sambharya, 1995; Tallman & Li, 1996), the effect of this interaction on a TMC's R&D intensity and patents has received scant attention (Hitt *et al*., 1997). Using the evolutionary theory and the dynamic capability perspective, it becomes clear that TMCs can use the expertise gained from market and product knowledge to enhance and develop their technical capabilities.

As afore-proposed, international market diversification (IMD) contributes to TMCs innovative capabilities by increasing their exposure of TMCs to technological knowledge bases worldwide by absorbing capacity, investing in lead markets, and learning from local spillovers. Product diversification can also enhance innovation capabilities by taking advantage of inter-temporal and intra-temporal economies of scope by redeploying their resources among businesses over time and share those resources contemporaneously (Helfat & Eisenhardt, 2004). Thus TMCs expand their reach through both types of diversification.

However, PD may depress the predicted positive effect of IMD on the outcomes of TMCs' innovation efforts. As PD rises, TMCs will use their financial resources to support the operations of their increased product diversification portfolio, hoping to cultivate the technological skills that already exist within their operations. Business operations derived by an increased PD can reduce R&D spending (Hitt *et al*., 1997). Lower R&D spending can reduce the availability of talented researchers for future innovation which can slow down the development of new technology. Thus, as PD increases, new layers of management are installed (Hoskisson & Hitt, 1995), further slowing down the speed of technology development. These observations are consistent with past studies in which PD will negatively moderate the effect of ID on innovation (Hitt *et al.*, 1994).

Previous research has also shown that the interaction of IMD and PD leads to an increase in the

variance explained in firm performance (Tallman & Li, 1996). Those TMCs that achieve the optimal combination of IMD and PD are usually successful (Hall & Lee, 2010; Sambharya, 1995). Similarly, TMCs that can handle the complexities of both IMD and PD simultaneously will get the maximum benefits from their innovation activities. TMCs also can gain from spillovers from PD by increasing innovations. Given the globalization of R&D activities, the interaction of international and product diversification should improve both the TMCs' innovation base in terms of R&D spending and patents. These observations lead to the following hypotheses:

H3: The interaction of IMD and PD is statistically significant and positively related to the TMCs' Technological Innovation and Capabilities

H3a: The interaction of IMD and PD is positively related to R&D intensity.

H3b: The interaction of IMD and PD is positively related to number of patents.

H3c: The interaction of IMD and PD is positively related to technology strength.

Empirical Design and Methodology

Selected Samples and Data Collection

The sample of this study was initially taken from *The Directory of Multinationals* which profiled 458 of the World's largest industrial corporations, with sales of over $ 1 billion (U.S. dollars) with significant international operations. However, initially finance related firms (SIC 6000-6999) and service oriented firms, excluding tech service related firms (SIC 7370-7376), were eliminated to maximize the generalizability and reliability of the study. The initial sample was additionally confirmed through the Patent Scoreboard by *the U.S. Patent and Trademark Office* and Patent Scorecards by *MIT Technology Review*. A total of 197 leading firms in the U.S.A., Japan and European countries (EEC) were selected for the purposes of the present study (see Table 1). All other data for the variables including R&D expenditures were taken from *Compact-D Word Scope* and *Research Insights* for the period 2000 through 2004. Because the sample is a quasi panel dataset and had missing values for some firms and years, we used the five-year aggregated averages of all the variables tested in this study for the period through 2000 through 2004. A five-year period was chosen in an attempt to avoid any issues that may be associated with a one-year fluctuation. Aggregated averages were used to help minimize the effects of any outliers or idiosyncratic variations; thereby, providing a more accurate assessment of the effects of the variables being studied (Hall & Lee, 2010).

Insert Table 1 about here

Description and Measurement of Variables

Technology (Dependent) Variables. The dependent variables were measured as follows:

R&D Intensity was measured as the firm's allocations to this activity (i.e., R&D expenditures) as a percent of its annual sales and it was used as one of proxies for innovation (Hitt *et al.*, 1997). The barometer to gauge the firm's technological and innovative capability is the extent to which the firm concentrates and invests in research and development. The R&D intensity ratio is commonly and widely used in studies of innovation (Baysinger & Hoskisson, 1989; Hall & Lee, 2010; Hitt *et al.*, 1997).

Number of Patents were measured by the number of patents granted to firms by the U.S. Patent & Trademark Office. This number excluded design and other special case patents. Though incomplete, the number of patents obtained in the U.S. is a valid proxy for a firm's overall patenting activities (e.g., Patel & Pavitt, 1991, 1998). The attractiveness of the U.S. market encourages the patent process for inventions that are of significant commercial importance (Zander, 1997). Narin and his colleagues (1987) also provide extensive evidence on the validity of this measure.

Technological strengths (as one of the aggregate ratings to indicate the overall quality of a company's patent portfolio: *MIT Technology Review*) were measured by the firm's number of patents awarded to the company times the Current-Impact Index (CII). The current impact index (CII) measures how significant a patent is and how often a company's patents from the previous five years are cited in the current year's batch (e.g., A value of 1 represents the average citation frequency, so for an example, a value of 1.2 indicates this company's patents are cited 20% more than average). These citations indicate the technological, scientific or marketing importance of a given patent. Thus, this measure adjusts for some of the weaknesses associated with using total patent counts. Data for the later time period 2000-2004 was bought from the CHI research firm. Patent citations have been widely used in the innovation and R&D literature (Ahuja & Katila, 2004; Hagedoorn & Cloodt, 2003; Jaffe & Lerner, 2001; Markmanm et al., 2004). Narin, Noma and Perry (1987) also provided extensive evidence on the validity of these measures.

Corporate Diversification Variables. Both product and market diversification were computed using an entropy measure with data obtained from the *Directory of Multinational* and *Compustat* (Chari *et al.*, 2008; Palepu, 1985). The entropy measure is widely used in corporate strategy literature and it also provides more comparative application to corporate diversification (Jacquemin & Berry, 1979). Specifically, they were measured as follows:

Product Diversification (PD) was measured using an entropy measure (Jacquemin & Berry, 1979; Hall & Lee, 2008; Palepu, 1985). This measure, which has been used in prior research (Chari *et al*., 2008; Hitt *et al.*, 1997), was calculated as follows: PD= $\sum$ (1/P*i*)]. P*i* was the sales reported by a given business segment *i*. Ln (1/Pi) was the natural logarithm of a given segment's sales and was the weight given to that segment. Prior research found that this measure had good construct validity compared to other measures (Hitt *et al.*, 1996).

Market Diversification (IMD) was also measured using an entropy index (Hall & Lee, 2008; Hirsch & Lev, 1971; Miller & Pras, 1980; Hitt *et al.*, 1997) and was calculated using the formula: $ID=\sum [P_i \times \ln (1/P_i)]$. P_i was the sales reported by a given market region *i*. Ln $(1/P_i)$ was the natural logarithm of that region's sales and was the weight assigned for that region.

Strategic Control Variables including Performance Measures. Several other strategic factors in business and operations including two performance measures with respect to accounting-based and market-based performance measures were also employed as controls in the relationship between technological capabilities and corporate diversification. These control variables are measured as follows:

Firm size was measured by the natural log of the company's total assets, as performed in the past research (Chari *et al*., 2008; Hitt *et al*., 1996). Firm size affects a firm's innovation (Chaney & Devinney, 1992) and diversification position (Grant *et al*., 1988; Tallman & Li, 1996)), in both product and market diversification (Hall & Lee, 2008 & 2010).

Performance was measured by the firm's return on assets (OPROA) and Tobin's q. OPROA was measured by earnings before income taxes (EBIT) divided by the firm's total assets (Hall & Lee, 2010; Hitt et al., 1997; Sambharya, 1995). To minimize the impact of accounting variations on accounting based performance across countries this study used earnings before interest and taxes (EBIT) rather than net income after tax which is commonly employed in most global business studies (Lee & Hall, 2009). Tobin's q, a widely used measure of market performance which reflects investors' expectations of a firm's future oriented performance (Chung & Pruitt, 1994; Finkelstein & Boyd, 1998; Lee & Hall, 2009; Teece & Rumelt, 1994), was calculated by dividing the market value of the TMC's equity plus the liquidation value of its preferred stock plus the value of its total debt divided by total assets. Tobin's q was expected to positively influence the firm's support for future R&D (Chaney & Devinney, 1992).

Other Strategic Control Variables: In addition to firm size and performance measures, five additional control variables were introduced to capture cost leadership and diversification strategy differentiation. The selected control variables are commonly used in most business studies because of their significant influences on the linkage between technology and diversification. The control variables incorporate in this study are: (1) *Debt leverage* (= long-term debt / total debt plus shareholders' equity), (2) C*apital intensity* (= plant & equipment/total assets), (3) *Operating cost efficiency* (= cost of goods sold /sales), (4) *Inventory turnover* (= cost of goods sold/average inventory), and (5) *Average collection period* (=accounts receivable/credit sales x 365 days).

Country effect was captured using dummy codes. To do this, companies in the sample were assigned to one of three groups based on the country where their headquarters were located: such as the United States, Japan, and European countries (EC). We controlled for country effects because most leading multinational corporations, particularly TMCs., could derive major advantages from establishing their headquarters in a given location (Cantwell, 1998). Countries differ in their innovation (Kotabe, 1990), technological resources (Anand & Kogut, 1997; Nelson, 1993), R&D spending (Porter, 1990), and in the types of innovations developed (Kotabe, 1990).

Empirical Model and Statistical Methods. To investigate the impact of technological capabilities on corporate diversification in the leading high-tech oriented global firms across countries in the U.S., Japan, and European countries (EC), a series of hierarchical regression analysis models were employed. Hierarchical regression analysis is ubiquitous in the business and economic research fields. As presented below, only three strategic factors including firm size, performance measures (OPROA and Tobin's Q), and country dummy variable was entered in the first regression model to explore the impact of technology on different size of firms across countries. All other control variables were added to the model 2 to examine the focus of technology factors on traditional business and operations strategies. In order to provide more exploratory implication to linkages between implicit technological capabilities and diversification strategies, two major corporate diversification strategies were, individually and jointly, used in the models 3 and 4. By eliminating the effects of the control variables in the initial steps, it was possible to more accurately assess the true impact of technology efforts on corporate diversification and diverse firm performance. Empirical models are specified below:

Technology Efforts (R&D Intensity, No. of Patents, Technology Strength) =

Model 1: country dummy, firm size, Performance (OPROA, Tobin's Q)

Model 2: country dummy, firm size, performance, business & operations strategy factors (leverage ratio, operating cost efficiency, capital intensity, inventory turnover, average collection period)

Model 3: country dummy, firm size, performance, business & operations strategy factor, market diversification, and product Diversification

Model 4: country dummy, firm size, performance, business & operations strategy factor, market diversification, product Diversification, and Joint factor of market-and product-diversification.

Empirical Analysis and Discussion

Descriptive Statistics and Correlation Analysis

The means and standard deviations for technology variables, including diversification strategy, performance measures and all other control variables across countries are displayed in Table 2. Japanese firms show a higher mean than that of other countries for most

technology indicators with respect to R&D intensity, number of patents, and technology strength. This indicates that Japanese firms are superior to those of other countries. Therefore, firms in Japan are more likely to reinforce the technology capabilities with a higher emphasis on R&D expenditures to expand and maintain competitive edge in the global market. The technological diversification strategy through R&D efforts in Japan has been traditionally intensified by the governmental R&D policies in which competing firms share researchers and costs and the government provides funds and tax benefits (Komada, 1986). With respect to corporate diversification strategy, Japanese firms are more likely to be less diversified in product while they are more diversified in the market. This finding tends to confirm that geographic expansions appeared to be a more effective strategy for improving the performance in Japanese firms (Delios & Beamish, 1999). The firms in the European countries show more diversified strategies than those in the other two countries. But the U.S. firms seem to outperform in both accounting- and market-based performance, during the time period of the study compared to those in other countries. In addition, the U.S. firms appear to be more diversified in product than those of other countries.

Insert Table 2 about here

Table 3 presents the inter-correlations for all the variables used in the study. To avoid multicollinearity problems that are most likely to skew the correct interpretation of multiple regression models with interaction effects, we centered the diversification strategy and also separated possible potential factors (i.e., squared value of product diversification and interaction factor of product-and market-diversification)(Aiken & West, 1991; Hair *et al*., 2010). Then, we found that the problem of multicollinearity does not appear to exist since the Variance Inflation Factors (VIFs) were well below the threshold value of 10, i.e., none of our VI.Fs were above 3.19 (Hair *et al.*, 2010).

As presented in Table 3, most technology factors are positively and significantly correlated with corporate strategy factors at 0.01 level (except for product diversification; $p<0.05$). They are also positively correlated with performance measures, but significantly correlated with Tobin's Q only ($p <0.01$). These results also support that technological competence through R&D intensity can be significantly related to IMD (Dedrick *et al*., 2003; Hitt *et al.*, 1997; Tihanyi *et al*., 2009). That is, technological strength can be used to achieve more efficient coordination by reducing the costs of coordinating business resources across multiple products and markets (Shin, 2006). With respect to the impact of corporate strategies on firm performance, only market diversification appears to be positively and significantly correlated with most dimensions of performance measures ($p <0.01$) across countries being studied. Although diversified firms can be more profitable and maintain competitive edge in the global market, product diversification may not contribute to the firm's performance. Rather, the effect of diversification on financial performance and firm value is likely to be more significant when their strategic scope and direction is oriented by a greater level of related diversification (Chari *et al*., 2008; Shin, 2006). As expected, firm size is uniformly significant ($p <0.01$) and positively correlated with a majority of technology factors and diversification strategies regardless of different dimensions and scopes.

In summary, the strategic impact of corporate diversification strategies on products and markets, performance, and other business and operations strategic factor does not seem to be uniformly correlated among variables utilized in this study. However, both market and product diversification are positively and significantly correlated with a majority of technology factors with respect to R&D intensity, number of patents, and technology strength. All technology factors and diversification are positively and significantly correlated with market-based performance (e.g., Tobin's Q), while only technology strength is significant in accounting-based performance (e.g., OPROA). The firm size is uniformly and positively correlated with a majority of technology factors and diversification strategies in generating a higher performance. Other variables, such as capital intensity, leverage, operating cost efficiency, inventory turnover, and average collection period do not show correlations with technology capability.

Results of Hierarchical Regression Analysis.

Using hierarchical multiple regression analysis, the empirical models shown were estimated separately with three different technology factors. Furthermore, this analysis was used to examine the significant effect of corporate diversification strategy in product and market. Other selected strategic factors on various dimensions of technological capabilities were also explored. As presented in Tables 4, 5 & 6, the hierarchical regression analysis was used to empirically explore the nature of the relative significance of corporate diversification on a firm's various aspects of technological competences, after controlling all moderating variables in a separate and simultaneous steps of the model. All regression models were highly significant ($p < .001$), indicating that the multiple regression models were useful in exploring the major determinants of technological competence across different countries. The results show that the study's statistical control variables together contributed a significant portion of the variation in the R^2 (from 0.2543 to 0.4371). Therefore, the results provide more confidence in arguing that even when other strategic factors are held constant, corporate diversification and two dimensions of performance measures are likely to be conducive to facilitating the firm's technological capabilities in the leading high-tech firms across countries. As expected, the effect of the number of patents and technology strength of measuring the overall quality of a company's patent portfolio appeared to be confined to R&D intensity. More importantly, market-based performance is more likely to significantly affect technological competence and, to a greater extent, market diversification. As previously examined, firm size was significantly associated with the TMCs' technological capabilities in the global market .

Insert Tables 4, 5 and 6 about here

The Effect of Diversification Strategy on R&D Intensity. Table 4 presents the results for the effects of diversification on R&D intensity (H1a, H2a, H3a). Results for models 2 and 3 indicate that both PD and IMD significantly influence R&D intensity at least at the 0.01 level, thereby supporting H1a, H2a. Although the effects of IMD and PD are different in their signs, diversification significantly influences R&D investment (Baysinger & Hoskisson, 1989; Galan & Sanchez, 2006) in leading TMCs across countries. But the findings of this study seem to be in contrast to other studies (Doi, 1980; Lopez-Sanchez *et al*., 2006) demonstrating that there is no evidence of relationship between R&D and diversification. Next, PD has an inverted relationship with R&D intensity, thus supporting hypothesis H3a. The interaction of IMD and PD is also significant at 0.05level. Firms are more likely to diversify both product and market jointly, where their technological resources, through R&D investment, have a broader application (Silverman, 1999). The results also appear to support the notion that technological capabilities through R&D intensity is facilitated by market diversification. Both IMD and PD are significantly related to R&D intensity linearly and in the form of an inverted U shape, as predicted in H1a and H1b, respectively. Although the result of our study for the effect of the interaction of IMD and PD on R&D intensity is inconsistent with previous studies (Hitt, *et al.*, 1994 & 1997), the interactive effects of ID and PD are significant and add to the total variance explained by less than five percent ($p<0.05$).

The Effect of Diversification Strategy on Number of Patents. Table 5 presents the results of regression analyses for the number of patents. An additional control variable (past R&D spending) was added to the other control variables used in the case of R&D intensity. The results show a strong support for both hypotheses H1b, H2b, and H3b. About 3.8 percent increases in the amount of variance explained as independent variables are added to models 3 and 4, respectively. The results from patenting (H1b, H2b, and H3b) are also consistent with the previous finding that IMD provides major and significant opportunities for innovation by exposing firms to different systems of innovation (Kogut, 1990) and centers of excellence around the world (Porter, 1998). IMD also enhances learning from the firm's global partners and customers (Hitt *et al*., 1994; Hitt *et al*., 1997). Of course, given that IMD is conducive to higher R&D spending, it can further increase the firm's patents. Consequently, internationally diversified firms are likely to innovate with greater frequency than less diversified firms, a process that generates more patents.

Contrary to our expectations, the effect of product diversification on the firm's patenting process does not appear to be clear (Scherer & Ross, 1992). As reported in Table 5, there is an inverted U-shaped relationship between PD and the number of patents. This result supports H2b (Hitt *et al.*, 1994). They also highlight the concern that as PD continues to increase until a threshold is reached and then the number of patents declines. The reason may be that the information about the firm's innovation activities is communicated to the top management, or it becomes increasingly difficult for executives to focus on turning the learning gained from PD into patents. Although IMD, PD and the interaction of IMD and PD are significant at 0.05 level, PD^2 is not statistically significant. Thus, hypothesis H2b was not supported. Specifically, the relationship between PD and the number of patents is linearly associated as predicted.

The Effect of Diversification Strategy on Technology Strengths. Table 6 presents the regression results for technological strengths which indicate overall quality of patents. Models 3 and 4 indicate that our proposed hypotheses (H1c and H3c) were partially supported, while hypothesis 2c (for PD) was not supported. Though IMD is significantly related to the firm's future technological intensity, the relationship between IMD and technological strength is linear but not an inverted U-shape as the hypothesis predicted. Furthermore, though the interaction of IMD and PD is highly significant ($p<0.001$), it does not significantly add to the variance explained. Results of regressing differences in technological strength on the differences in the control variables, IMD, PD, PD^2, and the interaction of PD and IMD are shown in models 3 and 4. These results indicate that hypothesis 1c and 3c are supported. The interaction of IMD and PD is significant; it also improves the variance explained about three percent, from 0.3229 to 0.4058 ($p<0.001$). Overall, the proposed hypothesis (H1c) for variations in technological strengths have a significant effect on IMD ($p<0.001$) but not on PD. In all three cases, the interactions of IMD*PD are significant at the 0.001 level; it also improves the variance explained by a modest two to four percent ($p<0.001$).

Effects of Performance and other Strategic Factors on Technological Capabilities. As explored through hierarchical regression analysis, the firm performance and other strategic business and operations factors also significantly affect the firm's technological capabilities. First, firm size is uniformly and significantly associated with most technological innovation. In fact, technology innovation is more productive in large firms as a result of complementarities between R&D efforts and other functional activities, such as marketing and operations (Cohen, 1995). Also financial advantages due to cost spreading are shown in Cohen (1990) and Cohen & Klepper (1996). In a recent study, Artz *et al.* (2010) also empirically demonstrated that the firm size was significantly and positively related to both patents and R&D spending. Second, a majority of past studies support the significant effect of a firm's performance on technology development as well as the significance of the use of technology to improve performance (Artz *et al.*, 2010; Chari *et al.*, 2008; Lopez-Sanchez *et al.*, 2006). Consistent with earlier studies, our study also appears to prove the competitive advantages of firm performance to

increase technological capabilities and strengths. But the performance impact of technology strength is significant in a market-based performance, particularly with respect to Tobin's Q only (Miller, 2006). As expected, a firm's R&D intensity is a good predictor of its patenting disposition and overall quality of patenting at least at the 0.01 level. It is supported that TMCs are using patents as strategic tools to take advantages over their competitors in a rapidly changing market. One possible justification of this phenomenon is that R&D intensity and quantity of patents can be used as a safeguard to create incentives for technological competencies and a defensive maneuver to protect strategic position in conjunction with other firm specific resources (Artz *et al.*, 2010).

Country Differences on Technological Capabilities. The effect of country differences on TMCs' technological capabilities are not uniform and are mixed in terms of various aspects of technology strength. Marginal values of all technological innovations and capabilities in the U.S. firms are most likely to be higher than that of the European countries ($p<0.05$). Such significant differences in technological strengths between Japanese firms and European firms appear to exist in terms of R&D intensity only. Thus, the effect of selected strategic variables including corporate diversification on the TMCs' technological competences is not significantly different between Japan and European countries (EC).

Major Findings and Conclusions

Technological innovations and capabilities are the core of the firm's ability to innovate and compete in today's global markets. Research suggests that the product and international diversification strategies (PD and IMD) in TMCs can profoundly affect their future technological capabilities, particularly in high-tech industries. Most prior studies, however, have been limited by their use of U.S. databases and/or an industry segment. Examining only R&D spending as a surrogate for technological capabilities and employing short time spans in investigating the link between the TMCs' diversification and their technological capabilities are scant. The present study highlights the link between the globalization of technology and globalization of firms. One of the most crucial sources of competitive advantage for high-tech firms is their strong technological capabilities that determine their speed, responsiveness to customers' needs and demands for innovation. This study joins a growing body of empirical research that shows product and international diversification of TMCs can significantly influence their future technological capabilities, albeit, differently.

The First noteworthy finding of our study suggested that IMD is positively associated with the firm's future technological capabilities. The findings of this study are consistent with the theory (Kobrin, 1991; Hitt *et al.*, 1994) and prior empirical findings (Hitt *et al.*, 1997; Kotabe, 1990). It appears that IMD gives high-tech firms the incentive to invest heavily in R&D activities to build strong technological capabilities to serve diverse needs of different foreign markets. The results for the positive and significant effects of IMD on the TMCs' technological capabilities also suggest that diversified firms have the resources needed to maintain strong R&D activities which allow them to develop the technological capabilities required to develop new products and goods as well as customize their offerings for different markets. Our findings support the past assertions that competition in TMCs is knowledge-based, and R&D activities are among the most important sources for creating this knowledge (Leonard-Barton, 1995). In summary, the results show that IMD is associated with greater R&D investments, more patent development, and stronger technological capabilities. These results are consistent with the recent discussion in the literature of the powerful role of a firm's network (Ghoshal & Nohria, 1989) in developing technological capabilities (Cantwell, 1995; Nobel & Birkinshaw, 1998; Zander, 1997).

As expected, the results for product diversification (PD) are not as uniform or as strong as those for market diversification (IMD). Our analyses reveal an inverted U-shaped relationship between the level of PD in TMCs and future R&D spending. This finding indicates that as TMCs become more diversified, their R&D investments increase until a threshold is reached, and then R&D investments begin to decline. The initial increases are consistent with the predictions of the learning perspective (Huber 1991), while the declines appear to support the strategic control perspective (Hitt *et al.*, 1997; Hoskisson & Hitt, 1996). Thus, the findings of our study reveal an inverted U-shaped relationship between increases in PD and increases in future R&D investments intensity. Overall, a higher PD is related to stronger technological skills. The relationships between PD and changes in PD as well as technological strengths are also positive and linear, contrary to speculations in the literature (Hitt *et al.*, 1994). Even though the results did not fully support the predicted relationship, they still help to clarify the effect of the TMCs' global PD activities. The failure to capitalize on technological synergies in developing new technologies is a serious problem in TMCs that sometimes fail to integrate the technological learning that occurs within their diverse operations. It suggests that as PD increases through significant amount of patenting, information processing for competitive edge becomes difficult and technological accumulation in technology oriented firms starts to decline.

Finally, one of the major findings in this study also indicates that IMD and PD have positive effects on the firm's future technological capabilities. This is evidenced by consistently positive and significant relationships between the ID*PD interaction terms and future R&D intensity, patents, and technology strengths. Indeed, most interactions are highly significant and positive, though the magnitude of the effect varies depending on the particular measures used for the dependent variables. As noted earlier, IMD gives product-diversified high-tech firms the incentive and resources to strongly support future R&D efforts. IMD also gives firms an opportunity to gain new knowledge that improves their ability to innovate to increase their patent potential and build stronger technological capabilities. The task of top management in high-tech

firms is to balance and optimize the degree to which they are diversified (i.e., in both IMD and PD) and to gain the maximum benefits both in terms of technological capabilities and financial performance.

Limitations and Implications of the Study

The above results should be interpreted with the study's limitations in mind. Although this study attempts to explore the strategic impact of corporate diversification on the firm's technological capabilities and competencies across countries, the results may have some limitations in regard to different industry and country characteristics. Furthermore, this study did not capture the dynamic interplay between a firm's diversification activities and technological capabilities. Another limitation of the study is its reliance on data from three major world clusters in examining the diversification-technological capability relationship. While these three clusters are the most important worldwide centers for innovations as noted earlier, other centers of technological innovation also exist (Porter, 1998). Finally, because the TMCs examined in this research are among the most powerful in the high-tech industries and markets, the results may not apply to smaller firms, regardless of their country of origin and industry characteristics.

Although there are limited relevant literatures to support and/or justify the foundation and findings of this study, this study explores the impact of corporate diversification and performance on a firm's technological capabilities and should warrant more attention in the future. One of the key findings of this study is that international market diversification can significantly influence a firm's future technological capabilities, whether measured by R&D intensity, or overall patent application as a proxy measure of technological strengths. The results also suggest several avenues for future research in this area. Considering some limitations described above, more studies would help to further explore the relationships between diversification and technology that might exist across different industries and countries. The strategic motives to expand market may differ by industries (Hall & Lee, 2010; Hennart & Parks, 1993). Furthermore, the effects of market diversification on technological capabilities are expected to be significantly different with respect to the different scope and patterns of industry such as growing vs. declining and high-tech vs. low-tech industries. Researchers would benefit from examining the effect of industry variables on market diversification and technology relationships across countries. The understanding of the linkage between corporate diversification and technological capabilities will not only engage us with efficient and effective strategic planning but it will also help a firm to gain a competitive advantage. As a matter of fact, this study has opened the door for additional research efforts to generalize the relationship between technology and diversification in the leading high-tech industries worldwide.