IT Patent and Firm Value in IT Industry: The Role of Innovation Orientation and Environmental Uncertainty

1. Introduction

Innovation is an important means to achieve competitive advantage. In order to protect the resulting innovations and prevent other firms from using them, firms invest resources in obtaining patents for their innovations.[1] In fact, patents are one of the strongest form of firms' intellectual property (Teece 1998). Patents grant legal authority to the inventor to prohibit others from making or selling the patented invention for a fixed period of time. A firm's stock of patents can be a significant strategic asset as it provides opportunities to license or to exclude others from using a wide variety of patented products, processes, technologies and other features.

While prior research has examined the value of patents mostly at the economy level (i.e., across various industries), the value of patent may differ across industries (Hall et al. 2005). Not only do the industries vary in terms of the average number of patents generated by each dollar of R&D investment (Scherer 1983), but they also differ significantly in terms of their ability to appropriate the returns from their R&D investments (Levin et al. 1987). Of particular interest is the IT industry, which is characterized by fierce competition and fast technological changes. Until recently, firms in IT industries had not been able to freely patent innovations, especially in the software domain. A few landmark decisions of the U.S. court in late 1990s and the release of new guidelines of the U.S. Patent & Trademark Office (USPTO) in 1996, have nullified earlier restrictions, which, in turn, has led to a deluge of software patents. Recent high profile patent lawsuits (for instance, Apple vs. Samsung) as well as strategic deals to acquire patents (for

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[1] The number of patent applications filed and granted has been increasing over time (Source: http://www.uspto.gov/web/offices/ac/ido/oeip/taf/us_stat.htm).

instance, Google acquiring Motorola Mobility for $12.5 billion and Microsoft spending $1.1 billion for licensing patents from AOL) highlight the importance of patents in IT industry (Duhigg and Lohr 2012; Ovide and Letzing 2012).

IT innovations that can generate revenue have been recognized as an important factor in IT management over the past several years (Luftman and Derksen 2012). Recently, IT innovations are believed to have played an important role in enabling firms to safely and efficiently overcome the adverse impact of the recession (Nash 2011). To ensure a continuous stream of high quality innovations that are necessary for sustainable competitive advantage, IT firms invest a significant amount of resources in R&D activities.[2] However, given IT innovations can be easily reverse engineered and imitated, IT firms patent their innovations to ensure that their innovations are not imitated or substituted by competitors (Weiss 2011). These IT patents allow a firm to recover its R&D expenses by commercializing or licensing its patented innovation and obtain temporary monopoly rents.

Despite the growing importance of IT patent and the call for research on the impact of IT patent on competitive advantage (Mykytyn et al. 2002), relatively little research efforts have been made to examine whether IT patents actually impacts firm performance; therefore, the financial returns from investments in IT patents remain unclear. More importantly, we have a limited understanding of *how* IT patents impacts firm performance. In this paper, we focus on IT industry, which has become patent-intensive due to the rapid advances in technology and the fierce competition among firms, to investigate the impacts of IT patents on firm value. Drawing on the resource-based view (Barney 1991; Wade and Hulland 2004), we conceptualize IT patent

[2] The R&D expense in US IT industry reached U.S. $117.4 billion in 2012. On average, US IT firms spend about 8.3 percent of their revenue on R&D, and the R&D spending has increased with an 11.7 percent compound annual growth rate since 2005 (Source: Authors' calculations based on the data from Compustat).

as a key resource in IT industry for gaining competitive advantage. Specifically, based on a large panel dataset consisting of 1,384 firms in US IT industries, we examine the relationship between IT patent and firms' market performance, while also considering the moderating effect of innovation orientation of a firms' patent portfolio – i.e., exploitative vs. explorative (March 1991). Moreover, we examine how environmental uncertainty (complexity and dynamism, Dess and Beard 1984; Keats and Hitt 1988) influences the relationship between firms' IT patents, innovation orientation, and performance.

2. Related Literature

2.1. Innovation and Value of a Patent Portfolio

Given the large investments in building a patent portfolio and uncertainty regarding the ability to benefit from the patented innovations, prior research has examined the value of patents to a focal firm. A number of studies have employed market valuation approach to assess the value of a firm's patents (Connolly and Hirschey 1988; Hall et al. 2005). To the extent that the patent portfolio of a firm influences the expected future profits of the firm, the value of the patent stock should be reflected in the observed market value of the firm. For the most part, these studies have found that the patent portfolio of a firm is positively associated with firms' performance and market value (Ernst 2001; Hall et al. 2005).

A few studies have examined the value of patents in IT industry. Using the patents and citation data for 1963-1995 period, Hall et al. (2005) find that impact of citations/patent on market value is small and lower in the computers and communications industry, compared to almost all other sectors in their sample. The authors suggest that since computers and communication industry deals with complex product where any particular product may rely on various technologies embodied in different patents held by different firms, it is more important to have a larger patent portfolio (that can be used to negotiate cross-licensing agreements) rather than having few patents with high individual quality. In a recent study, Hall and MacGarvie (2010) analyze the value of software patents granted between 1975 and 2002. They find that the market value of software patents was similar to other patents in period prior to 1995 but has increased vis-à-vis other patents after the change in patentability of software innovations around 1995. We extend these studies by refining our theorization of IT patents and empirically testing the moderating mechanisms that influence the market value of IT patents in IT industry.

2.2. IT Patent as a Key Resource in IT Industry

The resource-based view (RBV) emphasizes the role of heterogeneous firm resources in gaining competitive advantage (Barney 1991; Wernerfelt 1984). To confer a sustainable competitive advantage, a resource needs to be valuable, rare, imperfectly imitable, and difficult to substitute for (Barney 1991). While IS scholars have applied RBV to identify key IT resources that can lead to superior performance (see for a review, Wade and Hulland 2004), they have focused on IT human resources (especially managerial skills possessed by IT workers) and have not paid much attention to IT patent as a potential key IT resource.

Firms patent IT innovations to build competitive advantage around their IT-dependent strategic initiatives such as business processing reengineering, ERP-enabled business integration, and electronic supply chain management initiatives (Piccoli and Ives 2005). Such IT-dependent strategic initiatives can provide competitive advantage and sustainability of that advantage by creating barriers that reduce profit erosion. Thus, firms patent IT to protect associated unique combinations of hardware, software, and human resource skills. Accordingly, firms patent when they want to erect barriers to imitation of their IT-based strategic initiatives so as to protect their revenue generating streams. Moreover, IT patents which are intangible knowledge asset can be considered system resources (Black and Boal 1994; Miller and Shamsie 1996), which are connected to other resources such as the underlying IT infrastructure, business process, software applications or the skill/training of the personnel through a complex resource network configuration. Therefore, we conceptualize IT patent as a key resource in IT industry for gaining competitive advantage.

3. Hypotheses Development

3.1. IT Patent Stock and Market Value

IT patent stock generated by a firm is a result of its superior IT infrastructure, IT human resources, and IT related intangibles. However, the financial returns from investments in IT patents remain unclear. Although it has been suggested that IT resources may be imitated and substituted by competitors, and hence may not directly enhance firm performance (e.g. Wade and Hulland 2004), IT resources that are patented may become a source of sustainable value to the firm holding the patent as they provide protection from copycats that try to mimic the patented products and methods. To the extent IT innovations are valuable and patents can help protect this value, an increase in IT patent stock should lead to higher market value of a firm.

A patent also creates a valuable real option by providing the firm an exclusive right to develop new innovations (Bloom and Reenen 2002). Given the uncertainty about the extent of potential benefits from patented technology and the irreversibility of the cost involved in exercising the option (i.e., develop and commercialize a product based on the patented technology), patent can be considered as a real option (Bloom and Reenen 2002; Fichman 2004). Enabled by a patent's legal protection, a firm can wait and watch before making extensive, mostly irreversible, sunk cost investments in further research and development, training, as well as expensive marketing and advertising to promote their new products based on patented technology. In the presence of uncertainty about the market conditions, this flexibility to delay investments generates valuable real options (Bloom and Reenen 2002). Thus, the real option lens suggests that IT patent stock should lead to valuable real options. The value of these real options accessible to a firm, in turn, will be reflected in the market value of the firm. Therefore, we posit:

***H1**: A firm's IT patent stock is positively associated with the firm's market value.*

3.2. Innovation Orientation and Impact of IT Patent on Firm Value

Innovation orientation of a patent can have significant impact on its market value. Researchers suggest that the outcomes of explorative and exploitative innovations may differ (Levinthal and March 1993; March 1991). Specifically, we argue that explorative innovation will lead to higher market value than exploitative innovation. As discussed above, a patent creates a real option that reflects the value a firm places on its ability to choose the timing of its investments in its patented technologies (Bloom and Reenen 2002). The option value increases with the increase in the expected value of potential returns, variance of potential returns, and/or managerial flexibility in the structuring/exercise of options (Fichman 2004). The expected value of potential returns will be higher for explorative innovations as these innovations are likely to lead to long-term performance gains due to creation of new knowledge whereas exploitative innovations provide short-term performance gains due to their focus on efficiency (Auh and Menguc 2005; March 1991). Further, the variance of potential returns is also higher for explorative innovation as these gains are more uncertain (Levinthal and March 1993).

The effect of explorative innovation is more likely to be radical in terms of the magnitude of transformation in conjunction with work processes, product or service development, or technology implementation. Such innovations, when successful, can be paradigm breaking, positively rewarding, and long lasting. However, due to the high uncertainty involved in the implementation of explorative innovation, the outcomes are likely to be more volatile than those associated with exploitative innovation. Therefore, as per the real options theory, the value of explorative innovation is greater than exploitative innovation. Accordingly, we posit:

> ***H2****: The more exploratory innovation orientation of a firms' patent portfolio, the stronger the association between IT patent stock and the firm's market value.*

3.3. Moderating Role of Environmental Uncertainty

Environmental uncertainty has been characterized in terms of dynamism and complexity (Dess and Beard 1984; Keats and Hitt 1988). Firms in industries that have high complexity face a more complex environment, and it is difficult to predict its competitors' action. Lewin et al. (1999) argue that high complexity leads to more explorative innovation as firms attempt to compete by engaging in radical organizational adaptations through intensified exploration strategies. Since intense competition leads to erosion of profits, a firm can protect and grow its market share and profits by differentiating from other firms. This requires investment in innovation, in particular heavy investments in explorative innovation (Rowley et al. 2000). Consequently, firms in a highly complex environment need to focus on building exploratory innovations that differentiate them from the competition and improves their financial performance. Therefore, we posit:

> ***H3****: In industry environments exhibiting higher levels of complexity, the moderating effect of explorative innovation orientation (on the relationship between IT patents and firm value) will be stronger.*

Environmental dynamism, which refers to the volatility and unpredictability of the changes a firm has to deal with, may result from changes in technologies, variations in customer preferences, and fluctuations in product demand or supply of materials (Jansen et al. 2006). Given that dynamic environments make current products and services obsolete, researchers suggest that a firm should create new products and services for meeting the needs of emerging markets by engaging in explorative innovation (Jansen et al. 2006; Zahra 1996). Based on a survey of firms in software industry, Zahra and Bogner (2000) find that firms operating in a dynamic environment can get higher profits by developing radically new products, which are more likely to be a result of explorative innovation. Rowley et al. (2000) also suggest that firms operating in unstable environments should focus on explorative innovation due to the high uncertainty about future directions and high likelihood of environmental disturbances. The primary argument in these studies is that the existence of environmental uncertainty increases the rate of radical innovation required to survive and therefore firms need to invest in exploration. Accordingly, we posit:

> ***H4****: In industry environments exhibiting higher levels of dynamism, the moderating effect of explorative innovation orientation (on the relationship between IT patents and firm value) will be stronger.*

4. Data and Methods

4.1. Data and Variables

Our data come from two sources. First, the patent data, originally constructed by Hall et al. (2001), were obtained from the National Bureau of Economic Research (NBER).[3] Second, we obtained firm-level measures from the *Compustat* database. Because the USPTO does not provide a unique identifier for each firm across years, and patenting firms may change company names over time, Hall et al. (2001) provide the way to match the assignees of the patents in the NBER data to firms from *Compustat* (see also, Hall et al. 2005; Hall and MacGarvie 2010). Following their method, we matched the NBER data with financial data from *Compustat* for

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[3] The NBER data have been updated through 2006 and are available on websites: https://sites.google.com/site/patentdataproject/Home.

publicly traded firms. Because the USPTO published new guidelines for software patentability on March 29, 1996, we choose our sample period to be 1998-2006. We recorded patents by their filing year, rather than granted year, as there may be arbitrarily long lags between application year and granted year (see, Benner and Tushman 2002). In this study, we focus on IT industry which consists of 13 sub-industries based on the 2002 four-digit North American Industry Classification System (NAICS). (Appendix A)

IT Patent. We used patent technology class (either International Patent Classification or U.S. patent classes) to categorize a patent as an IT patent (e.g., Bessen 2011; Hall and MacGarvie 2010), which we present in the Appendix B (due to space limitations). Using patent stock measure in our observation windows (1998~2006), our final panel dataset, excluding firms that have no patent stock, contains 9,149 firm-year observations with 1,384 unique IT firms.

Innovation Orientation. We measured innovation orientation of a firms' patent portfolio as the extent to which firms' patenting efforts are anchored in its existing knowledge. Following Benner and Tushman (2002), we coded the prior patents cited by a patent as existing firm knowledge if they were either *repeat citations* (patents the firm had previously cited) or *self-citations* (the firms' own previous patents).[4] We then calculated the degree of exploitation for each patent by dividing the number of existing firm knowledge by total number of citations to prior patents (e.g., as a continuous variable, 0 indicates that the patent was highly explorative; pure exploration, whereas 1 indicates that the patent exploits the prior patents totally; pure exploitation). To measure innovation orientation of a firms' patent portfolio in year *t*, we aggregated all the patents the firm filed in year *t* and calculated the average of the degree of exploitation.

[4] When calculating the amount of existing firm knowledge at the patent level, we subtract the number of self-repeat citations from the sum of the number of self-citations and the number of repeat citations.

Environmental Uncertainty. We characterized environmental uncertainty in terms of *complexity* and *dynamism* based on the extant literature (Dess and Beard 1984; Keats and Hitt 1988; Xue et al. 2011; Xue et al. 2012). We adopted two indicators to measure complexity. The measures are four-firm concentration ratio (CR4) and the Herfindahl index (HHI). Dynamism was measured as the volatility in industry sales and volatility in industry operating income (Keats and Hitt 1988). In the main analysis, for each dimension of environmental uncertainty, we take a weighted average of the measurement items (weighted by their loadings in the underlying principle components) as the single-item measure (e.g., see Xue et al. 2011; Xue et al. 2012). (Continued discussion in Appendix C)

Market Value and Control Variables. Tobin's *q*, which captures the financial performance of a firm, is our main dependent variable. Given that it offers the advantage of capturing short-term performance and long-term prospects based on market value, it has been widely used in prior studies (Bharadwaj et al. 1999; Xue et al. 2012). We included several control variables. R&D intensity was computed as the total amount of R&D expenditures in a given year divided by total sales (Bharadwaj et al. 1999). We also included the natural logarithm of total number of employees as a control for firm size (Hitt and Brynjolfsson 1996). Finally, a set of dummy variables was used to control for time-invariant sector-specific effects (Sectors at the 2002 NAICS four-digit level and year dummies for sample years). Table 1 presents the descriptive statistics for the key variables and the correlations among them. [Table 1]

4.2. Empirical Models and Estimation Procedure

To examine whether IT patent is associated with firms' market value (H1), and whether innovation orientation of a firms' patent portfolio moderates this relationship (H2), we use the following empirical specification:

$$Tobin's\ Q_{i,t} = \beta_0 + \beta_1\ IT\ Patent_{i,t} + \beta_2\ Innovation\ Orientation_{i,t}$$
$$+ \beta_3\ (IT\ Patent_{i,t} \times Innovation\ Orientation_{i,t})$$
$$+ \Sigma\beta_j\ Firm\ Controls_{j,t} + \Sigma\beta_s\ Year\ Dummies_s + \Sigma\beta_k\ Industry\ Dummies_k + \varepsilon_{i,t} \quad (1)$$

Further, to test H3 and H4, we include the environmental uncertainty variable in the model and test the following specification:

$$Tobin's\ Q_{i,t} = \beta_0 + \beta_1\ IT\ Patent_{i,t} + \beta_2\ Innovation\ Orientation_{i,t} + \beta_3\ Environmental\ Uncertainty_{i,t}$$
$$+ \beta_4\ (IT\ Patent_{i,t} \times Innovation\ Orientation_{i,t})$$
$$+ \beta_5\ (IT\ Patent_{i,t} \times Environmental\ Uncertainty_{i,t})$$
$$+ \beta_6\ (Innovation\ Orientation_{i,t} \times Environmental\ Uncertainty_{i,t})$$
$$+ \beta_7\ (IT\ Patent_{i,t} \times Innovation\ Orientation_{i,t} \times Environmental\ Uncertainty_{i,t})$$
$$+ \Sigma\beta_j\ Firm\ Controls_{j,t} + \Sigma\beta_s\ Year\ Dummies_s + \Sigma\beta_k\ Industry\ Dummies_k + \varepsilon_{i,t} \quad (2)$$

In expression (2), when we estimate the model, we replace Environmental Uncertainty with complexity or dynamism. Note that due to multicollinearity, we can include one uncertainty variable at a time. We center the variables comprising the interaction terms by calculating the deviations from their respective mean values to reduce the multicollinearity between the main terms and interaction terms (Pinsonneault and Kraemer 1997; Smith and Sasaki 1979). The variance inflation factors (VIFs) of all the independent variables did not exceed 10. For testing heteroskedasticity, we ran the Breusch-Pagan test and we rejected the null hypothesis that the error variances are all equal ($\chi^2 = 316.87$, $p < 0.01$). In addition, for testing autocorrelation, the Wooldridge test indicated the presence of first-order autocorrelation (AR1) in our panel dataset ($F = 86.85$; $p < 0.01$). To adjust heteroskedasticity and autocorrelation, we employed feasible generalized least squares (FGLS) estimations which estimate efficient results (Wooldridge 2002).

5. Results

Table 2 presents the results of estimating (1) and (2) based on *complexity* and Table 3 shows the estimation results based on *dynamism*. Model 1, 2, and 3 show main (unconditional) effects of independent variable. Model 4, 5, and 6 include the pairwise interactions among IT patent, innovation orientation, and environmental uncertainty. Model 7 presents the result of the three-way interaction between IT patent, innovation orientation, and environmental uncertainty.

5.1. IT Patent and Market Value

In all Models (1 to 7) of Table 2 and 3, the results suggest that IT patent is positively associated with firms' market value (all βs > 0, $p < .01$). The results show that a firm's IT patent stock is an important intangible asset that contributes to the firm's market value. Specifically, a one-unit increase in IT patent is associated with a 3% increase in firms' market value. Using *IT Patent Citation Stock* also produced consistent results. Thus we find support for Hypothesis 1.

5.2. IT Patent, Innovation Orientation, and Market Value

Model 4 and 7 of Table 2 and 3 present the results of estimating the interaction effects between IT patent and innovation orientation. The coefficients on the interaction term are positive and significant (in Model 4, $\beta = .047$, $p < .05$, and in Model 7, $\beta = .049$, $p < .05$). Contrary to Hypothesis 2, our results indicate that the impact of IT patent on market value is greater for firms with more exploitative (less explorative) innovation orientation. In other words, increase in an exploitative orientation of a firms' patent portfolio strengthens the positive impact of the IT patents on the firm's market value. Thus, Hypothesis 2 is not supported. This finding suggests that IT innovations that are based more on previously used knowledge makes a greater contribution to IT firms' market performance. While this finding does not support our argument based on the real option lens, which favors explorative innovation, it can be understood based on the nature of IT innovations, the focus of our study.[5] IT innovations are often described as complex combinations of hardware and software to solve a particular problem. Due to the complexity of IT innovations, firms' IT patenting activities involving modifying or expanding existing knowledge is likely to be more effective in achieving a synergy with existing technologies, thereby contributing to firm performance.

5.3. The Role of Complexity on IT Patent and Innovation Orientation

Model 7 in Table 2 applies a test of the three-way interaction effects among IT patent, innovation orientation of a firms' patent portfolio, and environmental *complexity* on firms' market value. The coefficient on the three-way interaction term is positive and statistically significant (β = 0.286, $p < .10$), providing some boundary conditions of interaction effect of IT patent and innovation orientation of a firms' patent portfolio (see Model 4). Specifically, this result indicates that the complementary relationship between IT patent and exploitative (explorative) orientation of a firms' patent portfolio is more beneficial to firms' market value in less (more) *complex* environment. This is consistent with our argument that in competitive environment, firms need to differentiate themselves from their competition by engaging in more explorative innovation. In other words, complex environment demands relatively high IT capability in exploration to minimize threat of competitiveness and to stay ahead of the competition (Rowley et al. 2000). These findings provide support for Hypothesis 3. [Table 2]

5.4. The Role of Dynamism on IT Patent and Innovation Orientation

Model 7 in Table 3 applies a test of the three-way effects of IT patent, innovation orientation of a firms' patent portfolio, and environmental *dynamism* on firms' market value. Interestingly, the

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[5] Given that we employed innovation orientation as two ends of a continuum (exploitation and exploration), we also tested for the possibility of inverted U-shaped relationship between degree of exploration (or exploitation) and firms' performance reflecting the presence of an optimal balance between exploration and exploitation (Gupta et al. 2006). Specifically, we incorporated the quadratic terms for innovation orientation in the model. However, the results indicate that there are no curvilinear exploration-performance effects for IT patent in the IT industry.

coefficient on the three-way interaction term is positive and statistically significant (β = 0.483, p < .10), suggesting that in more dynamic environments firms engaging in more exploitative innovation tend to benefit more from IT patents in terms of market value. This finding suggests that exploitation-oriented firms can get higher returns from IT patents in more dynamic industry. Thus, Hypothesis 4 is not supported. [Table 3]

In sum, our results indicate that when firms innovate on their IT capability through patenting, the market performance of firms operating in *more complex* or *less dynamic* environment is substantially higher if the firms oriented their IT innovation in *exploration* rather than exploitation. The results, which present in Appendix D, suggest that our results are robust.

6. Discussion and Conclusion

Our study makes important contributions to the literature. First, consistent with prior research on the economics of patents (Hall et al. 2005; Hall and MacGarvie 2010), our findings demonstrate that the IT patent information including patent counts, cumulative patent counts, and patent citations is positively associated with IT firms' performance in terms of market value. Adopting the perspective of resource-based view (Barney 1991; Wade and Hulland 2004) and employing a sophisticated classification for IT patent based on technological class, this study validates the conjecture that IT patent increases the firms' market performance, especially in the IT industry. Our findings provide an evidence for why firms build their IT capability through IT patent to increase their performance. Second, our study provides new insights into the relationship between IT patent and innovation orientation of a firms' patent portfolio. We find that the impact of IT patent on firm performance is more salient for firms whose patent exhibit more exploitative orientation for innovation, compared to firms with more explorative orientation for innovation. Our results suggest that when IT firms build IT capability through IT patents, adopting an explorative innovation orientation may be detrimental to firm performance. Given the challenges that IT firms' face in developing complex technologies due to the presence of various software and hardware components, innovations that rely on pre-existing knowledge are more likely to lead to successful outcomes, compared to innovations that rely on new knowledge that a firm has not used before. In this respect, our study makes a meaningful contribution to both organizational learning literature and IT capabilities literature. Finally, our findings suggest that firms should tailor their approach to developing IT-based innovations (i.e., exploitation vs. exploration) depending on the nature of their industry environment. Specifically, we find that IT firms operating in more complex environments can increase their market performance by pursuing explorative innovations in their IT patents rather than pursuing exploitative innovations. In complex environments, continuous improvement based on existing IT knowledge may be insufficient for staying ahead of competition. Intensifying competitive pressures require IT firms to be more explorative and radical in their IT innovations. In other words, they need to nurture new sources of competitive advantage using distant search (Levinthal and March 1993). On the other hand, the IT firms operating in more dynamic environments can increase their performance by pursuing more exploitative IT innovations. When environmental changes are fast and dynamic, outcomes of explorative IT innovations tend to rapidly become diffused over such an environment (Levinthal and March 1993), resulting in a "threat rigidity" which motivates firms to give more weight to the exploitation of their existing IT knowledge (Podolny 1994; Staw et al. 1981). Our results related to environmental uncertainty are not consistent with some prior studies that examined multiple industries (e.g., Jansen et al. 2006). This suggests that the interaction between innovation orientation and environment uncertainty may substantially vary across different industries, and remains to be determined by future research.

References

Auh, S., and Menguc, B. 2005. "Balancing Exploration and Exploitation: The Moderating Role of Competitive Intensity," *Journal of Business Research* (58:12), pp. 1652-1661.

Barney, J. 1991. "Firm Resources and Sustained Competitive Advantage," *Journal of Management* (17:1), pp. 99-120.

Benner, M.J., and Tushman, M. 2002. "Process Management and Technological Innovation: A Longitudinal Study of the Photography and Paint Industries," *Administrative Science Quarterly* (47:4), pp. 676-707.

Bessen, J. 2011. "A Generation of Software Patents." Boston University School of Law.

Bharadwaj, A.S., Bharadwaj, S.G., and Konsynski, B.R. 1999. "Information Technology Effects on Firm Performance as Measured by Tobin's Q," *Management Science* (45:6), pp. 1008-1024.

Black, J.A., and Boal, K.B. 1994. "Strategic Resources: Traits, Configurations and Paths to Sustainable Competitive Advantage," *Strategic Management Journal* (15:S2), pp. 131-148.

Bloom, N., and Reenen, J.V. 2002. "Patents, Real Options and Firm Performance," *The Economic Journal* (112:478), pp. C97-C116.

Choi, C., Kim, S., and Park, Y. 2007. "A Patent-Based Cross Impact Analysis for Quantitative Estimation of Technological Impact: The Case of Information and Communication Technology," *Technological Forecasting and Social Change* (74:8), pp. 1296-1314.

Connolly, R.A., and Hirschey, M. 1988. "Market Value and Patents: A Bayesian Approach," *Economics Letters* (27:1), pp. 83-87.

Dehejia, R.H., and Wahba, S. 2002. "Propensity Score-Matching Methods for Nonexperimental Causal Studies," *The Review of Economics and Statistics* (84:1), pp. 151-161.

Dess, G.G., and Beard, D.W. 1984. "Dimensions of Organizational Task Environments," *Administrative Science Quarterly* (29:1), pp. 52-73.

Duhigg, C., and Lohr, S. 2012. "The Patent, Used as a Sword," in: *The NewYork Times*. NY.

Ernst, H. 2001. "Patent Applications and Subsequent Changes of Performance: Evidence from Time-Series Cross-Section Analyses on the Firm Level," *Research Policy* (30:1), pp. 143-157.

Fichman, R.G. 2004. "Real Options and It Platform Adoption: Implications for Theory and Practice," *Information Systems Research* (15:2), pp. 132-154.

Graham, S.J.H., and Mowery, D.C. 2003. "Intellectual Property Protection in the U.S. Software Industry," in *Patents in the Knowledge-Based Economy*, W.M. Cohen and S.A. Merrill (eds.). Washington, DC: National Academies Press.

Griliches, Z. 1981. "Market Value, R&D, and Patents," *Economics Letters* (7:2), pp. 183-187.

Hall, B.H. 2003. "Business Method Patents, Innovation, and Policy." Cambridge, MA: National Bureau of Economic Research, p. NBER Working Paper 9717.

Hall, B.H., and Harhoff, D. 2012. "Recent Research on the Economics of Patents," *Annual Review of Economics* (4), pp. 541-565.

Hall, B.H., Jaffe, A., and Trajtenberg, M. 2005. "Market Value and Patent Citations," *RAND Journal of Economics* (36:1), pp. 16-38.

Hall, B.H., Jaffe, A.B., and Trajtenberg, M. 2001. "The Nber Patent Citation Data File: Lessons, Insights and Methodological Tools." Cambridge, MA: National Bureau of Economic Research.

Hall, B.H., and MacGarvie, M. 2010. "The Private Value of Software Patents," *Research Policy* (39:7), pp. 994-1009.
Han, K., and Mithas, S. 2013. "Information Technology Outsourcing and Non-It Operating Costs: An Empirical Investigation " *MIS Quarterly* (37:1), pp. 315-331.
Hegde, D., and Sampat, B. 2009. "Examiner Citations, Applicant Citations, and the Private Value of Patents," *Economics Letters* (105:3), pp. 287-289.
Hitt, L.M., and Brynjolfsson, E. 1996. "Productivity, Business Profitability, and Consumer Surplus: Three Different Measures of Information Technology Value," *MIS Quarterly* (20:2), pp. 121-142.
Jansen, J.J.P., Bosch, F.A.J.V.D., and Volberda, H.W. 2006. "Exploratory Innovation, Exploitative Innovation, and Performance: Effects of Organizational Antecedents and Environmental Moderators," *Management Science* (52:11), pp. 1661-1674.
Keats, B.W., and Hitt, M.A. 1988. "A Causal Model of Linkages among Environmental Dimensions, Macro Organizational Characteristics, and Performance," *The Academy of Management Journal* (31:3), pp. 570-598.
Levin, R.C., Klevorick, A.K., Nelson, R.R., Winter, S.G., Gilbert, R., and Griliches, Z. 1987. "Appropriating the Returns from Industrial Research and Development," *Brookings Papers on Economic Activity* (18:3), pp. 783-831.
Levinthal, D.A., and March, J.G. 1993. "The Myopia of Learning," *Strategic Management Journal* (14), pp. 95-112.
Lewin, A.Y., Long, C.P., and Carroll, T.N. 1999. "The Coevolution of New Organizational Forms," *Organization Science* (10:5), pp. 535-550.
Liu, Q., and Wong, K.P. 2011. "Intellectual Capital and Financing Decisions: Evidence from the U.S. Patent Data," *Management Science* (57:10), pp. 1861-1878.
Luftman, J., and Derksen, B. 2012. "Key Issues for It Executives 2012: Doing More with Less," *MIS Quarterly Executive* (11:4), pp. 207-218.
March, J.G. 1991. "Exploration and Exploitation in Organizational Learning," *Organization Science* (2:1), pp. 71-87.
Miller, D., and Shamsie, J. 1996. "The Resource-Based View of the Firm in Two Environments: The Hollywood Film Studios from 1936 to 1965," *The Academy of Management Journal* (39:3), pp. 519-543.
Mykytyn, K., Jr., P.P.M., Bordoloi, B., McKinney, V., and Bandyopadhyaye, K. 2002. "The Role of Software Patents in Sustaining It-Enabled Competitive Advantage: A Call for Research," *The Journal of Strategic Information Systems* (11:1), pp. 59-82.
Nash, H. 2011. "Cio Survey, 2011: A New Age of Innovation," Harvey Nash plc.
Ovide, S., and Letzing, J. 2012. "Tech Patents Soar in Value," in: *The Wall Street Journal*. New York: The Wall Street Journal.
Piccoli, G., and Ives, B. 2005. "Review: It-Dependent Strategic Initiatives and Sustained Competitive Advantage: A Review and Synthesis of the Literature," *MIS Quarterly* (29:4), pp. 747-776.
Pinsonneault, A., and Kraemer, K.L. 1997. "Middle Management Downsizing: An Empirical Investigation of the Impact of Information Technology," *Management Science* (43:5), pp. 659-679.
Podolny, J.M. 1994. "Market Uncertainty and the Social Character of Economic Exchange," *Administrative Science Quarterly* (39:3), pp. 458-483.

Rowley, T., Behrens, D., and Krackhardt, D. 2000. "Redundant Governance Structures: An Analysis of Structural and Relational Embeddedness in the Steel and Semiconductor Industries," *Strategic Management Journal* (21:3), pp. 369-386.

Schaaper, M. 2003. "A Proposal for a Core List of Indicators for Ict Measurement," *the UNCTAD Expert Meeting on Measuring Electronic Commerce as an Instrument for the Development of the Digital Economy*, Geneva.

Schankerman, M., and Pakes, A. 1986. "Estimates of the Value of Patent Rights in European Countries During the Post-1950 Period," *The Economic Journal* (96:384), pp. 1052-1076.

Scherer, F.M. 1983. "The Propensity to Patent," *International Journal of Industrial Organization* (1:1), pp. 107-128.

Smith, K.W., and Sasaki, M.S. 1979. "Decreasing Multicollinearity : A Method for Models with Multiplicative Functions," *Sociological Methods & Research* (8:1), pp. 35-56.

Staw, B.M., Sandelands, L.E., and Dutton, J.E. 1981. "Threat Rigidity Effects in Organizational Behavior: A Multilevel Analysis," *Administrative Science Quarterly* (26:4), pp. 501-524.

Teece, D.J. 1998. "Capturing Value from Knowledge Assets: The New Economy, Markets for Know-How, and Intagible Assets," *California Management Review* (40:3), pp. 55-79.

Wade, M., and Hulland, J. 2004. "Review: The Resource-Based View and Information Systems Research: Review, Extension, and Suggestions for Future Research," *MIS Quarterly* (28:1), pp. 107-142.

Weiss, M. 2011. "Apc Forum: Driving Competitive Strategy through Thought Leadership," *MIS Quarterly Executive* (10:4), pp. 201-202.

Wernerfelt, B. 1984. "A Resource-Based View of the Firm," *Strategic Management Journal* (5:2), pp. 171-180.

Wooldridge, J.M. 2002. *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: MIT Press.

Xue, L., Ray, G., and Gu, B. 2011. "Environmental Uncertainty and It Infrastructure Governance: A Curvilinear Relationship," *Information Systems Research* (22:2), pp. 389-399.

Xue, L., Ray, G., and Sambamurthy, V. 2012. "Efficiency or Innovation: How Do Industry Environments Moderate the Effects of Firms' It Asset Portfolios?," *MIS Quarterly* (36:2), pp. 509-528.

Zahra, S.A. 1996. "Technology Strategy and Financial Performance: Examining the Moderating Role of the Firm's Competitive Environment " *Journal of Business Venturing* (11:3), pp. 189-219.

Zahra, S.A., and Bogner, W.C. 2000. "Technology Strategy and Software New Ventures' Performance: Exploring the Moderating Effect of the Competitive Environment," *Journal of Business Venturing* (15:2), pp. 135-173.

Tables

Table 1. Correlation Coefficient among Key Variables

	Mean	Std.	1	2	3	4	5	6	7	8
1. Tobin's q	0.911	1.038	1.000***							
2. IT Patent Stock	-2.430	1.730	0.082***	1.000***						
3. IT Patent Citation Stock	-0.710	2.125	0.136***	0.860***	1.000***					
4. Innovation orientation	0.329	0.291	0.024	0.087***	0.106***	1.000***				
5. Employee	-1.137	2.058	-0.281***	-0.139***	-0.159***	0.027*	1.000***			
6. R&D intensity	-1.870	1.432	0.250***	-0.010	0.009	-0.007	-0.356***	1.000***		
7. Complexity	0.301	0.111	0.009	0.008	0.035***	0.017	-0.058***	-0.089***	1.000***	
8. Dynamism	1.086	0.066	-0.098***	0.031**	-0.074***	0.030**	0.030***	-0.054***	0.008	1.000***

Note: The table presents pair-wise correlation coefficients among key variables used in our empirical analysis. *, **, *** Correlation coefficients that are significant at the 10%, 5%, and 1% levels, respectively.

Table 2. FGLS Regression (Complexity)

Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Dependent variable: Tobin's q	ln(Y)	ln(Y)	ln(Y)	ln(Y)	ln(Y)	ln(Y)	ln(Y)
IT patent	0.031*** (0.005)	0.030*** (0.007)	0.031*** (0.005)	0.024*** (0.007)	0.031*** (0.005)	0.031*** (0.007)	0.037*** (0.009)
Innovation orientation		0.004 (0.031)		0.017 (0.032)		-0.001 (0.032)	-0.057* (0.031)
Complexity			0.205 (0.207)		0.182 (0.210)	0.850*** (0.301)	0.600** (0.306)
IT patent x Innovation orientation				0.047** (0.019)			0.049** (0.019)
IT patent x Complexity					-0.005 (0.042)		-0.010 (0.068)
Innovation orientation x Complexity						0.245 (0.249)	0.084 (0.253)
IT patent x Innovation orientation x Complexity							0.286* (0.169)
Employee	-0.016*** (0.004)	-0.018*** (0.006)	-0.016*** (0.004)	-0.014*** (0.005)	-0.017*** (0.005)	-0.020*** (0.006)	-0.033*** (0.008)
R&D Intensity	0.041*** (0.008)	0.051*** (0.011)	0.043*** (0.008)	0.065*** (0.010)	0.039*** (0.008)	0.050*** (0.011)	0.005 (0.013)
Control variable	Year Sector	Year Sector	Year Sector	Year Sector	Year Sector	Year Sector	Year Sector
Observations	5,611	2,881	5,611	2,881	5,611	2,881	2,881
Wald χ^2	2242.86	1401.28	2239.26	1366.52	2257.40	1419.33	1621.30

Note: Significance: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Models include year or sector (NAICS 4-digit) dummies. All of the variable in the interaction terms have been centered. We adopt two indicators to measure complexity; four-firm concentration ratio and the Herfindahl index. We take a weighted average of the measurement items (weighted by their loadings in the underlying principle components) as the single-item measure.

Table 3. FGLS Regression (Dynamism)

Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Dependent variable: Tobin's q	ln(Y)	ln(Y)	ln(Y)	ln(Y)	ln(Y)	ln(Y)	ln(Y)
IT patent	0.031*** (0.005)	0.030*** (0.007)	0.032*** (0.005)	0.024*** (0.007)	0.032*** (0.005)	0.032*** (0.008)	0.026*** (0.008)
Innovation orientation		0.004 (0.031)		0.017 (0.032)		-0.014 (0.032)	-0.012 (0.032)
Dynamism			-0.227 (0.144)		-0.218 (0.142)	-0.545*** (0.207)	-0.641*** (0.211)
IT patent X Innovation orientation				0.047** (0.019)			0.044** (0.019)
IT patent X Dynamism					0.141** (0.056)		0.146* (0.078)
Innovation orientation X Dynamism						0.117 (0.422)	-0.098 (0.431)
IT patent X Innovation orientation X Dynamism							0.483* (0.270)
Employee	-0.016*** (0.004)	-0.018*** (0.006)	-0.016*** (0.004)	-0.014*** (0.005)	-0.018*** (0.005)	-0.022*** (0.006)	-0.021*** (0.006)
R&D Intensity	0.041*** (0.008)	0.051*** (0.011)	0.042*** (0.008)	0.065*** (0.010)	0.035*** (0.008)	0.042*** (0.011)	0.045*** (0.011)
Control variable	Year Sector	Year Sector	Year Sector	Year Sector	Year Sector	Year Sector	Year Sector
Observations	5,611	2,881	5,611	2,881	5,611	2,881	2,881
Wald χ^2	2242.86	1401.28	2235.60	1366.52	2294.19	1433.29	1447.38

Note: Significance: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Models include year or sector (NAICS 4-digit) dummies. All of the variable in the interaction terms have been centered. We adopt two indicators to measure dynamism; sales volatility and income volatility. We take a weighted average of the measurement items (weighted by their loadings in the underlying principle components) as the single-item measure.

Appendix A. Description of U.S. IT industries based on the 2002 4-digit NAICS

4-digit NAICS	2002 Industry Title	Total observations	Total firms	Patenting observations[a]	Patenting firms
3341	Computer and Peripheral Equipment Manufacturing	1,037	209	647	125
3342	Communications Equipment Manufacturing	1,987	332	1,151	181
3343	Audio and Video Equipment Manufacturing	205	38	124	20
3344	Semiconductor and Other Electronic Component Manufacturing	2,655	421	1,951	269
3345	Navigational, Measuring, Electromedical, and Control Instruments Manufacturing	2,814	455	1,967	291
3346	Manufacturing and Reproducing Magnetic and Optical Media	64	14	21	4
5111	Newspaper, Periodical, Book, and Directory Publishers	595	105	122	16
5112	Software Publishers	4,680	821	2,011	300
5161	Internet Publishing and Broadcasting	766	127	126	15
5181	Internet Service Providers and Web Search Portals	839	227	160	40
5182	Data Processing, Hosting, and Related Services	455	74	114	15
5191	All Other Information Services	35	6	12	2
5415	Computer Systems Design and Related Services	2,402	430	743	106
	Total	18,534	3,259	9,149	1,384

Note: [a] We labeled each observation as patenting observations if patent stock is greater than zero. Thus, about half of observations (*n* = 4,822) have no patent in a year for the firm (i.e., only have patent stock due to their previous patenting history).

Appendix B. IT Patent

We identified those technology classes that relate to software and/or hardware patents and categorize all the patents within these technology classes as IT patents. First, we identified all the US patent classes in which 20 software firms patented and categorize patents falling in these classes as software patent. Top 20 firms were selected by sales of their calendar 2006 revenues from NAICS 511210 group (i.e., software publishers). These firms are Microsoft, Oracle, SAP, Sunggard data system, Symantec, CA, Electronic Arts, Adobe, Amdocs, Intuit, Konami, Dassault systems, Autodesk, BMC Software, Cadence design systems, Activision, Business objects, Compuware, BEA systems, and Comverse Tech.

We ruled out those classes where the share of patents among the top 20 software firms was under 20%. Further, we also included any additional technology classes that had been classified as software patent class in prior research (Bessen 2011; Graham and Mowery 2003; Hall 2003). Next, we identified hardware patents by adopting the classification employed in prior studies (Choi et al. 2007; Schaaper 2003). Finally, we re-examined some patent technology classes that are open to dispute. Three coders, who are specialized in information technology, validated and re-classified these patent classes after reading definition of these classes in detail. The inter-rater reliability for the coding of IT patent was 0.94, suggesting a high level of agreement. The resulting categorization of IT patents consists of 25 technology classes related to hardware patents and 22 technology classes related to software patents (see Table B1).

In line with prior research (Hall et al. 2005; Hall and MacGarvie 2010; Liu and Wong 2011), we computed the patent stock measure in year t for firm i using a single depreciation rate (ρ) for patent value. Further, consistent with prior research, we assumed that the depreciation rate, ρ, is 20%. We also calculated the R&D stock in year t for firm i using a same depreciation rate. Our empirical results are not sensitive to the chosen value of depreciation rate (e.g., 0.2, 0.15, etc.). We then scaled the patent stock by the R&D stock (Griliches 1981; Hall et al. 2005; Hall and MacGarvie 2010; Liu and Wong 2011). In addition, in order to account for the quality difference across patents, and to fix the biases due to the use of simple patent counts, we constructed a citation-weighted patent count by considering the number of citations a patent receives (Hall et al. 2005; Hall and MacGarvie 2010). Then, we computed the citation weighted patent stock, and scale it by the R&D stock (Liu and Wong 2011).

Table B1. IT Patent Classes with Software and Hardware Patent

Types of IT patent	US Class	Description	Literature
Software Patent	341	Coded data generation or conversion	[a, d]*
	345	Computer graphics processing and selective visual display systems	[a, b, d, e, f]
	370	Multiplex communications	[a, d, e, f]*
	380	Cryptography	[a, c]*
	382	Image analysis	[a, b, c, d, e, f]
	700	Data processing: generic control systems or specific applications	[a, c, d, e, f]
	701	Data processing: vehicles, navigation, and relative location	[a, c, e, f]*
	702	Data processing: measuring, calibrating, or testing	[a, c, d]
	703	Data processing: structural design, modeling, simulation, and emulation	[a, c, d]
	704	Data processing: speech signal processing, linguistics, language translation, and audio compression/decompression	[a, b, c, d]
	705	Data processing: financial, business practice, management, or cost/price determination	[a, c, d, e, f]
	706	Data processing: artificial intelligence	[a, c, d, e, f]
	707	Data processing: database and file management or data structures	[a, b, c, d, e, f]
	710	Electrical computers and digital data processing systems: input/output	[b, c, d, e, f]
	711	Electrical computers and digital processing systems: memory	[b, c, d, e, f]
	713	Electrical computers and digital processing systems: support	[b, c, d, e, f]
	714	Error detection/correction and fault detection/recovery	[b, d, e, f]*
	715	Data processing: presentation processing of document, operator interface processing, and screen saver display processing	[a, b, c, d, e, f]
	717	Data processing: software development, installation, and management	[a, b, c, d, e, f]
	718	Electrical computers and digital processing systems: virtual machine task or process management or task management/control	[d]*
	726	Information security	[a, d]*
	902	Electronic funds transfer	[a, c]*
Hardware Patent	235	Registers	[d, e, f]*
	318	Electricity: motive power systems	[e, f]
	340	Communications: electrical	[d, e, f]*
	342	Communications: directive radio wave systems and devices (e.g., radar, radio navigation)	[e, f]
	343	Communications: radio wave antennas	[e, f]
	348	Television	[d, e, f]*
	349	Liquid crystal cells, elements and systems	[e, f]
	353	Optics: image projectors	[e, f]
	358	Facsimile and static presentation processing	[b, d]*
	361	Electricity: electrical systems and devices	[e, f]
	365	Static information storage and retrieval	[e, f]
	367	Communications, electrical: acoustic wave systems and devices	[e, f]
	375	Pulse or digital communications	[a, e, f]*
	379	Telephonic communications	[e, f]
	381	Electrical audio signal processing systems and devices	[a, e, f]*
	386	Television signal processing for dynamic recording or reproducing	[e, f]
	395	Information Processing System Organization	[c]*
	438	Semiconductor device manufacturing: process	[e, f]
	455	Telecommunications	[d, e, f]*
	505	Superconductor technology: apparatus, material, process	[e, f]
	708	Electrical computers: arithmetic processing and calculating	[e, f]
	709	Electrical computers and digital processing systems: multicomputer data transferring	[b, d]*
	712	Electrical computers and digital processing systems: processing architectures and instruction processing (e.g., processors)	[c, d, e, f]*
	716	Data processing: design and analysis of circuit or semiconductor mask	[a, e, f]*
	719	Electrical computers and digital processing systems: interprogram communication or interprocess communication (ipc)	[d, e, f]*

Note: (a) Bessen, 2011; (b) Graham & Mowery, 2003; (c) Hall, 2003; (d) New added way for classifying software patent in this research; (e) Choi et al., 2007; (f) Schaaper, 2003. * We qualitatively reclassified these US patent classes into either software patent or hardware patent by examining definition of these classes in detail with three experts.

Appendix C. Environmental Uncertainty

We calculated CR4 and HHI for each NAICS four-digit industry and each year. Lower value of CR4 and HHI represent an industry that is less concentrated and more competitive (Han and Mithas 2013). We measured the volatility of industry sales using a two-step procedure. First, the natural logarithm of the total sales of four-digit NAICS industries was regressed against an index variable of years, over a period of past five years with rolling windows. We expect that the standard error of the regression coefficient captures the unpredictability or volatility of the sales growth rate. Then, we took the antilog of the standard error of the regression coefficient as the measure of sales volatility. The same approach was used to derive the volatility of industry operating income. Table C1 contains correlations across the measures. Because the two measures for each construct were highly correlated with each other and are interchangeable in reflecting the environmental uncertainty, we converted the multi-item measures of each dimension of uncertainty into single-item measure. Using principle component analysis (PCA), we extracted two factors from the measures identified above (see Table C1 for factor loadings). The pattern of factor loadings supports the existence of two dimensions corresponding to complexity and dynamism. Subsequent confirmatory factor analysis (CFA) supports the overall validity of the two-factor model (Chi-square = 388.70; GFI = 0.96; CFI = 0.94; NFI = 0.94). Cronbach's Alpha for the two factors are above 0.6, suggesting acceptable reliability for exploratory analysis.

Table C1. Measurement of Environmental Uncertainty

			Correlation			Loading	
	Mean	Std.	1	2	3	Complexity	Dynamism
Complexity							
1. 4-firm concentration	0.506	0.147				**0.683**	0.093
2. Herfindahl index	0.104	0.089	0.774			**0.709**	-0.064
Dynamism							
3. Sales volatility	1.054	0.041	-0.028	0.104		0.047	**0.827**
4. Income volatility	1.134	0.124	-0.021	0.070	0.565	-0.095	**0.540**
Average Variance Extracted						0.793	0.660
Cronbach's Alpha						0.883	0.601

Appendix D. Robustness Checks

***Alternative Specifications and Measures*:** To check the robustness of our results, we re-estimated our models using various alternative specifications (see Table D1). These estimates corroborate the three-way interaction between IT patent, innovation orientation of a firms patent portfolio, and environmental uncertainty. The overall results based on different specifications are broadly similar to the FGLS results.

Table D1. Alternative Specifications for the main model

Variable	**1**	**2**	**3**	Variable	**4**	**5**	**6**
Dependent variable: Tobin's q	ln(Y)	ln(Y)	ln(Y)	Dependent variable: Tobin's q	ln(Y)	ln(Y)	ln(Y)
Specification	FE	RE	GMM	Specification	FE	RE	GMM
IT patent	0.109*** (0.039)	0.041*** (0.013)	0.173*** (0.045)	*IT patent*	0.077** (0.038)	0.040*** (0.013)	0.150*** (0.044)
Innovation orientation	-0.097* (0.051)	-0.049 (0.045)	-0.111* (0.067)	*Innovation orientation*	-0.109** (0.052)	-0.054 (0.045)	-0.133* (0.069)
Complexity	3.678*** (0.751)	0.696* (0.406)	2.630*** (0.805)	*Dynamism*	-0.385 (0.342)	-0.542* (0.314)	-0.544 (0.432)
IT patent X Innovation orientation	0.073** (0.036)	0.061** (0.028)	0.106** (0.048)	*IT patent X Innovation orientation*	0.065* (0.036)	0.057** (0.028)	0.107** (0.049)
IT patent X Complexity	0.664*** (0.246)	0.010 (0.099)	0.856*** (0.274)	*IT patent X Dynamism*	0.185 (0.170)	0.232* (0.137)	0.185 (0.207)
Innovation orientation X Complexity	0.041 (0.513)	-0.010 (0.420)	0.587 (0.658)	*Innovation orientation X Dynamism*	0.676 (0.667)	0.386 (0.627)	0.379 (0.855)
IT patent X Innovation orientation X Complexity	0.514* (0.322)	0.524** (0.261)	0.305 (0.424)	*IT patent X Innovation orientation X Dynamism*	0.482* (0.353)	0.068 (0.426)	0.376 (0.611)
Tobin's q_{t-1}			0.341*** (0.031)	*Tobin's* q_{t-1}			0.344*** (0.031)
Employee	-0.206*** (0.043)	-0.041*** (0.012)	-0.341*** (0.053)	*Employee*	-0.221*** (0.043)	-0.042*** (0.012)	-0.356*** (0.054)
R&D Intensity	-0.256*** (0.029)	0.013 (0.016)	-0.187*** (0.035)	*R&D Intensity*	-0.261*** (0.029)	0.012 (0.016)	-0.189 (0.036)
Control variable	Year	Year Sector	Year Sector	*Control variable*	Year	Year Sector	Year Sector
Observations	2,282	3,102	2,502	*Observations*	2,282	3,102	2,502
Wald χ^2	-	921.69	1054.57	*Wald* χ^2	-	919.07	1025.47

Note: Model 1-6 are reported using fixed-effects (Model 1 and 4), random-effects (Model 2 and 5) with AR1 adjustment (*xtregar* procedure in STATA), and dynamic GMM estimation (Model 3 and 6, *xtdpdsys* procedure in STATA). Significance: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Selection Bias**:** To address potential endogeneous selection bias, we re-estimate our models using a *propensity score matching* method (Dehejia and Wahba 2002). The basic principle of the propensity score is to use some observable variable (e.g., firm size, R&D intensity, and environmental uncertainty) to predict the probability of possessing IT patent in the firm. This allows the direct comparison of firms' market value that have similar characteristics (propensity scores), where one firm has IT patent stock while the other does not. Matching firms in this way should substantially reduce any remaining selection bias issues. We used logit regression to calculate propensity score for whether IT patent stock exist in the firm or not with observed explanatory variables (see Table D2). After matching with propensity score, the estimate on the difference in market value (i.e., Tobin's *q*) change for these two groups is positive and significant (*Diff*. = .147, S.E. = .030, $t = 7.89$, $p < .001$). Thus, statistically significant differences in market value between firms with and without IT patent stock indicate that IT patent has significant influence on firms' market value. These results suggest that IT patent is not endogenous in our analysis.

Table D2. Logit Regression Model for Propensity Score Estimation

Independent Variable	**Estimate**
Employee	0.584*** (0.015)
R&D Intensity	0.309*** (0.017)
Complexity	-0.312 (0.222)
Dynamism	3.413*** (0.390)
Constant	-1.980*** (0.520)
Log likelihood	-6699.658
Observations	11,346

Note: Standard errors are in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

***Time-Split Analysis*:** Another concern may be the effects of idiosyncratic economic events (e.g., dot-com crash, the 9/11 terrorist attacks, and the ensuing recession) on IT firms' market value in our sample period (1998-2006). Although we control the impact of specific year using year dummies in our model, we conducted a time-based split analysis to examine whether the contribution of IT patent was affected by economic events. Thus, we ran regressions for the two periods before and after 2001 (period 1: 1998-2001, period 2: 2002-2006, see Table D3). The overall results varying in time periods are qualitatively similar to our main results. Thus, we can conclude the economic events such as a dot-com crash did not affect our results.

Table D3. Estimation Results for Subset (before and after dot.com crash)

Variable	1	2	3	4
Dependent variables: Tobin's q	**1998-2001**	**2002-2006**	**1998-2001**	**2002-2006**
Environmental factor	Complexity		Dynamism	
Specification	FGLS	FGLS	FGLS	FGLS
IT patent	0.027*** (0.008)	0.028*** (0.009)	0.148*** (0.011)	0.027** (0.010)
Innovation orientation	0.027 (0.049)	0.031 (0.022)	-0.168*** (0.043)	0.031 (0.025)
Complexity	0.191 (0.399)	-0.620 (0.534)		
Dynamism			-1.582*** (0.266)	-0.503** (0.241)
IT patent X Innovation orientation	0.043* (0.037)	0.052** (0.020)	0.119*** (0.027)	0.043** (0.022)
IT patent X Complexity	0.168*** (0.059)	0.201** (0.087)		
IT patent X Dynamism			0.696*** (0.160)	-0.069 (0.093)
Innovation orientation X Complexity	-0.615 (0.554)	0.254 (0.226)		
Innovation orientation X Dynamism			-0.106 (0.778)	-0.271 (0.346)
IT patent X Innovation orientation X Complexity	0.478** (0.247)	0.012 (0.218)		
IT patent X Innovation orientation X Dynamism			0.365 (0.591)	0.739*** (0.265)
Employee	0.012** (0.005)	-0.046*** (0.005)	-0.170*** (0.015)	-0.048*** (0.006)
R&D Intensity	0.128*** (0.010)	-0.029** (0.011)	-0.008 (0.017)	-0.036*** (0.011)
Control variable	Year Sector	Year Sector	Year Sector	Year Sector
Observations	1,609	1,094	1,609	1,094
Wald χ^2	1036.56	1479.65	2734.41	1379.82

Note: Standard errors are in parentheses. Significance: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.