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How Does Innovation Impact Firm Performance? Direct versus Mediated Effects of Patent Scale and Scope

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ABSTRACT

How does technological innovation impact the financial performance of technology-intensive firms? From the knowledge-based view, we hypothesized and tested a positive performance effect of patent scale and scope by two samples of patenting-only versus full firm-years of 106 Fabless firms in Taiwan, during 1995 and 2008. Our results show that patent scale generates stronger direct effects than patent scope in both samples; contrastingly patent scope requires mediators to impact performance indirectly in the full-sample, and rarely demonstrates any effect in the patenting-sample. In addition, the fullsample demonstrates a stronger direct or mediated effect of patent than the patenting-sample.

Keywords: Performance; Patents; Technological Innovation Theory; Southeast Asia; Computers and Electronics; Scale and Scope.

How Does Innovation Impact Firm Performance?

Direct versus Mediated Effects of Patent Scale and Scope

How does technological innovation impact the financial performance of technology-intensive firms? One of the key research fields in strategic management has been the identification of performance determinants, along with the explanations of performance variations between firms (Decarolis & Deeds, 1999, Grant, 1996). From the knowledge-based view (KBV), our research attempts to identify what kinds of firm heterogeneity, with a focus on technological innovation, and in what ways determine firm performance. Following Teece's argument (Teece, Pisano, & Shuen, 1997) that the profitable expansion of firms is both a process of exploiting firm-specific capabilities and exploring new ones, we assert that technological innovation, especially when its exploration is disclosed and its exploitation is protected by the patenting institution, is the major firm-specific capabilities to sustain competitive advantage, particularly for technology-intensive firms (Helfat & Raubitschek, 2000).

Since financial figures are composite indicators of firm performance, we tested our hypothesized performance models by two samples consisting of single-business firms of a single technology-intensive industry located in a single economy, for highlighting the performance effect of technological innovation, measured by patent attributes. The prior literature has identified 'industry membership', 'corporate effect' and 'business strategy' as key drivers of business-unit performance (Brush, Bromiley, & Hendrickx, 1999, Hansen & Wernerfelt, 1989, McGahan & Porter, 1997, Rumelt, 1991, Schmalensee, 1985, Stimpert & Duhaime, 1997, Wernerfelt & Montgomery, 1988). Some of the performance studies have empirically supported that 'business-level' factors have greater impacts on performance than either 'industry membership' or 'corporate effect' (McGahan & Porter, 1997; Rumelt, 1991). Moreover, some studies found that organizational factors explain about twice as much variance in financial performance as economic factors (Hansen & Wernerfelt, 1989). Accordingly, we devised three performance models focusing on the firm-specific heterogeneity to explain the financial performance variation amongst single-business firms, as opposed to multi-business corporations in the mainstream performance studies.

In addition to concentrating the business scope of firms on single-business, our research selects technology-intensive as the industry focus. Helfat and Raubitschek (2000) defined technology-intensive firms as those requiring generally more complex coordination of knowledge and activities. However, given such complexity, the question as to whether the performance determinants of technology-intensive firms are any different from those of other firms remains unanswered. Untangling such a puzzle, we set out to identify the performance determinants from the knowledge-based view (KBV) as technological innovation, measured by six attributes of firm-specific patent portfolio.

Although many of the prior studies have proposed a positive relationship between technological innovation and performance, the results have nevertheless been inconsistent. For example, based on a sample of 98 biotechnology firms in the US, Decarolis & Deeds (1999) failed to find empirical support for a positive effect. Whereas, several studies have supported a positive relationship, including a sample of 721 large firms in the UK (Geroski & Machin, 1993), a sample of 50 machine tool manufacturers in Germany (Ernst, 2001), and a sample of 250 technology-leading farms in the Netherlands (Diederen, Meijl, & Wolters, 2001). Specifically using patent portfolio to measure technological innovation, some studies found empirical support that patent can contribute to firm performance (Bloom & Reenen, 2002, Lin, Chen, & Wu, 2006)

Aligning our performance models with the mainstream empirical findings and the assertions of the KBV, we hypothesize *a positive effect of patent scale and scope on financial performance*, particularly for technology-intensive. Perceiving the firm as a collection of productive resources (Penrose, 1959), the theorists from the resource-based view (RBV) suggest that differential performance among firms is fundamentally driven by the firm-specific heterogeneity, in terms of resources, competence and dynamic capabilities, which have been characterized as 'rare, valuable, non-substitutable, and difficult to imitate' (Barney, 1991, Mahoney, 1995, Mahoney & Pandian, 1992, Makadok, 2001, Rumelt, 1984, Teece, Pisano, & Shuen, 1997, Wernerfelt, 1984). Extending from the RBV, perceiving the firm as an institute for the integration of knowledge (Grant, 1996), the KBV theorists identify knowledge as the most strategically important resource and major performance determinant, based on the argument that superior performance comes from the generation, accumulation and application of knowledge (Decarolis & Deeds, 1999, Grant, 1996, Kogut & Zander, 1992, Spender, 1996).

In addition to specify patent as performance determinant, our performance models also compare the performance effects between patent scale and patent scope on multiple performance targets, including profitability, profits, and shareholder value, in order to specify strategic fitness between innovation strategies and performance targets. The economies of scale and scope have been recognized as the major sources of competitive advantage by economists, particularly since Chandler identified the importance of the investment needed to capture the economies of scale and scope inherent in the new technologies (Chandler, 1990, Teece, 1993). As Chandler, most scholars refer economies of scale and scope to the cost-saving benefits from more units of goods or services produced, and wider related activities integrated by a production team. We further extend the benefits of scale and scope from cost-saving to revenue-generation, so posit that such economies of scale and scope are also applicable to the innovation outcomes as superior patent portfolio for a technology-intensive firm to improve its financial performance.

In summary, we attempt to contribute the literature in the following three aspects, which also motivate our research efforts. First, for the literature of the Knowledge-based view (KBV), our research may provide additional empirical support for its key argument that the firm heterogeneity in knowledge assets, such as patent portfolio, does explain the variance in firm performance, and ultimately lead to competitive advantage, particularly for technology- intensive firms. Second, for the literature of performance studies, we concentrated on the single-business firms of a technology-intensive industry in an emerging economy, in order to reduce the causal ambiguity and complexity between various determinants and financial performance. In terms of empirical setting, our samples consisting of small and medium firms located in emerging economies are expected to provide complementary evidence and strategic implications supporting the performance effects of technological innovation, as opposed to the mainstream performance studies on large firms located in developed economies. Third, for the literature of technological innovation, our findings are analyzed to specify the applicable conditions for a firm to enhance its competitive advantage by comparing contrasting lagging direct versus mediated effects between patent scale versus patent scope on multiple performance targets, in order to further develop the contingent view of innovation strategy.

The following sections will hypothesize our performance model, describe our research methods, including samples and data, variables and measures, and test models, and then discuss our empirical results and research findings.

HYPOTHESIZED PERFORMANCE MODELS

From the knowledge-based view (KBV), we hypothesize a positive performance effect of technological innovation, measured by the attributes of firm-specific patent portfolio. In order to examine whether and indeed how such effect occurs, we empirically tested our hypothesized effect in two consecutive research steps. First, t-tests on four pairs of mean-difference between performance variables of patenting and non-patenting sub-samples are devised to confirm whether or not such effect exists. Second, two performance models of direct and mediated effects are posited to further examine which patent attribute under what conditions generates more or less performance effects.

Whether or not Performance Effects of Patent Exist

Following our hypothesis, if the ownership of patent positively contributes to firm performance, patenting firms or firm-years are expected to perform better than non-patenting firms or firm-years. Accordingly, we posit that patenting sub-samples gain advantage over their countering non-patenting sub-samples. In other words, the t-test results are expected as the mean of performance variables of a patenting sub-sample minus that of a non-patenting sub-sample is significantly more than zero. Because a patenting firms, defined as whose portfolio with at least one patent, may have both patenting and non-patenting firm years, we split our full samples of firm-years into the following four pairs of mutually exclusive sub-samples, as illustrated in TABLE 5, base on only one attribute of patent scale. The test of Hypothesis 1 aims to empirically confirm that our hypothesized positive performance effect does exist, as a foundation to test Hypothesis 2, further examining how much different attributes impact firm performance.

Hypothesis 1*: Firms with a patent perform better than those without any.*

For examining Hypothesis 1 on the performance premium of patents from matrix-dimensions of firm-year and firm-level, we specify the following four types of performance effects tested by four corresponding pairs of patenting versus non-patenting sub-samples.

Patenting firm-year effect (PS – NY). In order to test whether or not a positive performance effect exists at the analysis level of firm-years, we split the Full-Sample (FS) of all firm-years into Patenting Sample (PS), including only patenting firm-years, versus Non-patenting firm-Years of all firms (NY), including patenting and non-patenting firms.

Patenting firm effect (PF – NF). In order to test whether or not a positive performance effect exists at the analysis level of firm, we split the full-sample into Patenting Firm (PF), including both patenting and non-patenting firm-years, versus Non-patenting Firm (NF), including only non-patenting firm-years.

Firm-year effect of patenting firm (PS – NP). In order to test whether or not a positive performance effect exists within the same patenting firm at the analysis level of firm-year, we split the sub-sample of patenting firm (PF) into Patenting Sample (PS), versus Non-patenting firm-years of Patenting firm (NP).

Non-patenting firm-year effect of patenting firm (NP – NF). In order to test whether or not a positive performance effect still sustain for a patenting firm even when whose firm-years without any patent at the analysis level of firm, we split the sub-sample of non-patenting firm-years (NY) into Non-patenting firm-years of Patenting firm (NP), versus Non-patenting Firm (NF).

Performance Model of Patent's Direct Effect

In addition to Hypothesis 1 testing whether or not a positive performance effect of patent exists, we further posit Hypothesis 2 to test more or less performance effects of superior patent portfolio than inferior portfolio by comparing lagging direct versus mediated effects of patent scale versus patent scope attributes. From the aforementioned contingent view of innovation strategy, we posit that different attributes of patent portfolio, even highly correlated with one another as shown in TABLE 3, contribute to different performance targets. For examining how much each patent attribute impacts firm performance, we devised two performance models for testing the degrees of direct and mediated effects of patent attributes. Because we posit a patent variable impacts a performance variable by either direct or mediated effect alternatively, our model only recognizes complete mediator, not partial mediator. In other words, our model of mediated effect, as illustrated in FIGURE 1, only tested the pairs of patent and performance variables without significantly positive coefficient in the model of direct effect.

Hypothesis 2*: Firms with superior patent portfolio perform better than those with inferior portfolio.*

The performance model for testing patent's direct effect is specified as one of six patent variables and its square-term, to reflect the diminishing return to scale, as independent variable (IV), and one of eight performance measures as dependent variable (DV) as listed in Regression C in Figure 1. All regressions include the same control variables (CV) of AGE, SIZE, and RDI (Research & Development Intensity).

Performance Model of Patent's Mediated Effect

In order to illustrate how patent attributes indirectly impact financial performance in the absence of their direct effect, we devised a complete-mediating model as Figure 1. Therefore, a pair of patent and performance variable is posited to impact performance either directly or indirectly through mediator.

Lagging direct and mediated effects. Since both mediators are a component of financial performance, our mediating model specifies one-year lag of Regression B, mediator as IV and performance as DV. For comparing lag effect of patent attributes over time (Hall, Griliches, & Hausman, 1986), we specify 1, 2, and 3 lag-years of Regression A, patent as IV and mediator as DV. Contrastingly for direct effects, we tested each pair of patent and performance variables by four regressions, with concurrent (0), 1, 2, and 3 lag-years. Due to the three-year rolling method in constructing our patent portfolio, our models are expected to capture the performance impact of a patent, when filed up to six years before a focal performance year.

RESEARCH METHODS

In order to empirically test our hypothesized performance models, we sampled 1026 firm-years of 106 Fabless firms listed in Taiwan, the second largest economy of Semiconductor industry, during the period of 1995 and 2008. The sample, measures, and test-models of this study are further described as follows.

Sample and Data: Fabless Firms in Taiwan

In order to control for the industry and institution factors impact on performance of technology-intensive firms, our sample focuses on the single-business firms in the same country (Taiwan) and within the same technology-intensive industry (Fabless).

Financial data from TEJ. Fabless firms are identified based on the third-level of industry code, M2324 within the semiconductor industry, from Taiwan Economic Journal (TEJ) Databank, which provides the firm profile and financial data (TEJ, 2008). As a result, our full-sample comprises 1026 firm-years of 106 Fabless firms listed in Taiwan, during the period of 1995 and 2008. In addition to financial data extracted from TEJ databank, we also downloaded the patent application data from Delphion Database (Delphion, 2008). Based on the aforementioned three-year rolling method, we constructed 342 patenting firm-years of 73 Fabless firms during 1994 and 2007[1]. Because 4 firms with patents were not listed or included in our full-sample, the patenting-sample used for our empirical testing comprises of 327 firm-years of 69 fabless firms.

Patent data from Delphion. Patent data for our sampled firms was taken from the Delphion patent database, which carries detail accounts for companies and patents filed with the USPTO. The Delphion database pieces together the corporate structure of the patent filing companies in order to produce accurate patent lists for each company, including their subsidiaries. We initially retrieved all the patents applied by our sample firms, but included in our analysis were those filed patents which had been subsequent granted to ensure our investigated patents are of relevance. Our final patent data is comprised of 3,279 patents applied and granted during 1994 and 2007. It should be noted, not all of these companies were in the sample for all years.

Variables and Measures: Performance and Patent

Our hypothesized models specify 8 performance variables as dependent variables (DV), 6 patent variables as independent variable (IV), 3 control variables (CV), and 2 mediators (MV), with 'firm-year' as the level of analysis, as illustrated in FIGURE 1. TABLE 2 lists the type, short code, definition, mean, standard deviation of each variable and TABLE 3 lists correlations of Full-sample. As discussed

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[1] We used the patent dataset collected during our prior research Chen, J. H., Jang, S.-L., & Wen, S. H. 2010. Measuring technological diversification: Identifying the effects of patent scale and patent scope. . *Scientometrics*, 84(1): 265-75.

earlier, we specify only one patent variable and one performance variable when testing direct effects, in order to demonstrate the strategic fitness between technological innovation and performance target; therefore, the issue of multicolinearity caused by high correlations among independent variables is minimized in our models.

The reasons to specify and the measures to quantify our specified variables and their definitions are elaborated as the following.

Financial performance as dependent variable. Both performance models of direct and mediated effect specify three performance dimensions, including profitability, measured by *return on equity* (ROE), profits, measured by *net income* (NI), and shareholder value, measured by *market value approximated* (MVA, market value minus capital invested). From the dimension of profitability, we prefer 'return on equity' to 'return on assets' (ROA), because our sampled Fabless firms have minimal fixed assets when outsourcing the semiconductor manufacturing to foundry-firms. From the dimension of the shareholder value, we prefer 'market value approximated' (Coles, McWilliams, & Sen, 2001) to 'earning per share' (EPS) to reflect the premium value created by the firm. TABLE 3 shows that the correlations among three performance variables are below 0.19, which attests to their adequacy to demonstrate the contingent impacts of performance determinants. For each performance variable, we derived another two ranking (RA) and standardized (SD) measures in addition to their original amount. Since our samples are panel data, we grouped all the firm-years in the same year and then ranked and standardize the performance amount, in order to alternatively test for minimizing the performance impact from the industry or economic cycle. However, no standardized MVA is derived due to less firm-years per year (50%) than ROE and NI, because MVA is not available until a firm is formally listed and traded in the stock market. Because the higher ranking with smaller figure, in fact, indicates better performance, we hypothesize a negative sign of ranking variables as positive performance effect.

Patent scale and scope as independent variable. As aforementioned, our study identifies patent attributes to represent the firm-specific level of technological innovation. The majority (65%) of 106 sampled firms had filed their patents with the USPTO. Because the USPTO usually takes around 18 months to examine the application, and more importantly, the filing time of patent represent the completion of innovation, we assigned all the patent data to each applicable firm-year based on the filing time, instead of grant time.

As our data is drawn from annual patent record, one measurement issue is worth noting: the episodic nature of patenting activity (Geroski, Reenen, & Walters, 1997). Firms, particular smaller and younger ones as our sample, might undertake single innovation projects that last substantially longer than a year. With the measurement base being the one-year period, these firms are likely to be overlooked and considered as non-innovating firms even though they do carry a continuous stream of innovative activity whether in deepening or widening their technological capacity. Therefore, we used all measures of patent portfolio on a 3-year period. That is, we take an accumulative count of their patent quantity and patent class configuration in a spell of three years, covering the current focal year plus the prior two years. Such data collection based on a three-year period rather than the typical 1-year period has also been adopted by scholars in assessing innovation persistence (Roper & Hewitt-Dundasb, 2008).

Both performance models specify three variables of patent scale and another three of patent scope, whose patent portfolio was constructed on the basis of a moving time window of three years as stated previously. Simple *patent count* (COUNT), *new-class count* (NEW_C), and *minor-class count* (MINOR_C) are specified to measure different aspects of patent scale. Patent counts are more frequently used to approximate innovative output (Cohen & Levin, 1989). We measured patent count in terms of the number of firm's patent applications in a spell of three years. This approach equating patent scale with patent size is consistent with another similar analysis (Fai & von Tunzelmann, 2001). However, in response to the criticism that simple patent counts are inherently limited by their ability to capture the underlying heterogeneity amongst patents (Cohen & Levin, 1989, Griliches, Hall, & Pakes, 1987), our research incorporates the notion of patent scope into two patent-scale variables.

New-class count is defined as the patent number in the new technology class of the current patent portfolio as compared with the prior portfolio, to represent the level of new technology exploration. In addition, *minor-class count* is defined as the patent number in the minor technology class in the current portfolio to represent the level of non-major or less competitive technology exploitation. We followed Narin & Noma's approach in computing the concentration of company patents within a few selected classes (Narin & Noma, 1987). We defined minor-class as IPC, which is not one of four major IPCs, including G06F, H01L, G11C, and G11B, representing 45% of 3279 patents in our samples, as listed in TABLE 4.

In addition to patent scale, 'patent-breadth' has also been recognized as a key determinant of patent value (Gilbert & Shapiro, 1990, Klemperer, 1990, Reitzig, 2003). In particular, the number of International Patent Classification (IPC) assigned to each patent is commonly used to measure the scope of a patent (Chen, Jang, & Wen, 2010, Lerner, 1994, Wen & Chen, 2007). However, because a simple class-count measure might be affected by the initial size of patent portfolio, we derive three variables to represent patent scope, including *diversity index* (DIV), *new-class ratio* (NEW), and minor-class *ratio* (MINOR).

In consistent with various previous studies (Garcia-Vega, 2006, Hall, Griliches, & Hausman, 1986), we constructed the measure of patent diversity based on a Herfindahl Hirschman Index (HHI) of concentration using Delphion patent data. The focal level of aggregation for the classes of technology follows the classification of the four-digit IPC code, and each patent can be regarded as pertaining to a specific technological class as assigned by the USPTO. Our patent sample is composed of 72 technological classes; with technological class indexed by $j = 1, \ldots, 72$, we obtain the variable that measures the extent of patent diversity as follows:

$$DIV = 1 - \sum_{j=1}^{72} \left(\frac{N_{ijt}}{N_{it}} \right)^2$$

Thus, the diversity index ranges between zero and one, where a value of zero represents a firm concentrating on one technology only, and contrastingly, a value approaching one represents a firm with an even distribution of patents across the n technological classes. Following the definitions in the sub-session of patent scale, we then derived *new-class ratio* by computing the patent number in the new technology classes, and *minor-class ratio* by computing the patent number in the minor technology classes as a proportion to the total patent count in its focal portfolio. Because the higher its minor-class ratio, the more the firm diversifies away from the industry's technology mainstream; therefore, a positive performance effect is posited due to less competitive in minor technological fields.

We would like to highlight the value added to devise similar constructs as new-class and minor-class innovation into different attributes of patent scale and patent scope, for crystallizing the idiosyncratic strategic fitness between innovation strategy and performance target. To illustrate, a firm which has applied 15 patents in the given time period, of which 5 pertaining to new technological classes has a new-class ratio of 0.33, whereas this ratio for another firm who has in the same period, 7 patents, of which 5 pertaining to areas that the firm has not previously involved with, is 0.71. While the patent count for the new technology class is the same, ceteris paribus, we argue that the former firm is likely to be less diversified than the latter from the perspective of patent scope. This new-class ration focuses on innovation activities involving in new technology areas, and signifies the notion of diversifying and expanding; it might or might not be in concordance with the diversity (DIV) index, which expresses the state of the distribution.

Revenues and productivity as mediators. Our performance model specifies two mediators, *revenues* (REV) and *productivity* (PRO). *Revenues* represent a firm's capability to utilize its patent portfolio in product market. *Productivity,* defined as net income per employee, represents the efficiency of its human capital. Based on the assertion that superior patent portfolio enhance a firm's competitive advantage in terms of market power and operational efficiency, we posit that revenues or productivity completely mediate patent's performance effect, when its direct effect (or the result of Regression C, patent as IV and performance as DV) is not significantly positive.

Test Models

For testing whether or not the performance effect of patent exists as Hypothesis 1, we split the full-sample into 4 pairs of mutually exclusive patenting versus non-patenting sub-samples. Using ROE as an example, TABLE 5 illustrates the matrix-dimensions and firm-year counts of each pair of sub-samples. Then, we conducted 56 t-tests ((8DV+6MV)*4 pairs) on the mean-differences of 8 performance variables and 6 measures of 2 mediators between each pair.

For testing more or less the performance effect of patent impacts as Hypothesis 2, we compared the results of fixed-effect regressions on the panel data of full-sample and patenting-sample. This performance study chose fixed-effect model, instead of random effect, because of the assertion that not specified firm-specific attributes impact financial performance overtime. In comparison, the full-sample includes both patenting and non-patenting firm-years, so a positive effect indicates the patent premium exists of strong technology-innovators when competing with weak technology-innovators with no patent at all. Then, we tested each sample by 192 regressions (6IV*8DV*4 lag-years) for illustrating the lagging direct effects of patent scale and patent scope, and then by 576 regressions (6IV*8DV* 2MV*2 steps * 3 lag-years) for illustrating the lagging mediated effects.

RESULTS & DISCUSSIONS

The test results generally support our hypothesized positive performance effects of patent attributes. In comparison, the t-tests on Hypothesis 1 render stronger empirical support, than the pool regressions on Hypothesis 2. Such comparative findings imply that patent filing is a power indicator of innovation capabilities of a technology-intensive firm, so no matter what kinds of and how much its patent attributes, a patenting firm, whose portfolio has at least one patent, does gain competitive advantage over the non-patenting firms and even during non-patenting firm-years.

In addition, the results that the full-sample demonstrates stronger direct and mediated effects of patent than the patenting-sample, imply that the patent premium is stronger when competing with both strong and weak technology-innovators than when competing with other patenting firms. Such findings help to explain why the empirical support on the hypothesized positive performance effect of patent portfolio has been inconclusive. When the sample only includes patenting firms or patenting firm-years, the patent premium may be hardly observed and substantiated. In the real business world, patenting firms are competing against both patenting and non-patenting firms; therefore, the empirical results of full-sample provide not only stronger support of our hypothesis, but also more applicable managerial implications for patent or innovation strategies.

In a contrast to the general support on the existence of patent's positive effect on financial performance, our findings that some pairs of patent and performance variables fail to demonstrate our hypothesized positive performance effect, also support our proposed contingent view of patent or innovation strategies. Given the positive performance of patent, different patent attributes impact different performance target by different ways, direct versus mediated effects, concurrent versus lagging effects. The following further discuss our research findings and managerial implications.

Hypothesis 1: Positive Performance Effects of Patenting Firm

As shown in TABLE 5, we split the full-sample into 4 pairs of patenting and non-patenting sub-samples, whose summary statistics listed in TABLE 6. Before t-tests, these comparative sample-profiles already demonstrates the existence of patent premium of patenting firm-years. For three performance variables and two mediators, the patent premium of the patenting sample over the full samples range from 75% of shareholder value (MVA) to 107% of revenues (REV), while with one exception that their profits (NI) are only 32% of the full-sample. In terms of control variables about firm profiles, the patenting-sample are 1.5 years senior, hires 69% more employees, and spends only half of RDI than the full-sample.

The t-tests results on the mean-differences between four pair of sum-samples are listed in TABLE 7. Most of the results support our hypothesized positive performance effects of patenting firms at both firm-year and firm-levels. Such supportive results indicate the patent premium exists even when a patenting firm does not have filed any patent within three-year rolling window, when testing its non-patenting firm-years against non-patenting firms (NP-NY). The t-test results of original and annually standardized performance-values also generally support our proposition that the patent premium of the patenting firm-year effect (PS-NY) is the largest and that of the non-patenting firm-year effect of patenting firms (NP-NF) is the smallest among 4 pairs of sub-samples. However, the measures of performance ranking demonstrate contrasting impacts: the patenting firm effect (PF-NF) is the largest, while the firm-year effect of patenting firm (PS-NP) is the smallest. Such contrasting outcomes suggest, although patent premium of patenting firms over non-patenting firms is less than patenting firm-years over non-patenting firm-years in the amount measures, firms with patent or innovation capability can win much higher rankings than their competitors without any. Different relative effects between amount and ranking measures also suggest an added value to include ranking measures in performance studies, such that ranking measures are more applicable to medium and small firms due to less scale-biased toward larger firms than amount measures.

Hypothesis 2: Stronger Direct Performance Effects of Patent Scale

As discussed in Test Models, we tested Hypothesis 2 by 192 regressions for lagging direct effects and 576 regressions for lagging mediated effects of patent scale and patent scope on each sample of 1026 firm-years or 327 patenting firm-years. To present all test results is very challenging; therefore, the direct effect of *patent count* (COUNT) with zero lag year is selected for illustrating the regression model and comparing the different results between two samples, because that is the strongest performance determinant among six patent variables as TABLE 8a and TABLE 8b.

Owning to missing values of some specified variables, only 921 firm-years of full-sample and 317 firm-years of patenting sample are tested; while market value approximated (MVA) is tested by even less firm-years, because its data is not available until formally listed. The significantly negative signs of the square term of patent count (COUNT_SQ) support our proposition of diminishing return to scale of patent's performance effects, which are generally supported by most of significant direct and mediate effects. Estimated maximum as the turning point of performance measures are calculated for the supportive results as well.

Table 9 listed the supportive lagging direct effects of applicable pair of patent attributes and performance variables (mediators). Among three dimensions of financial performance, both samples rejected the positive effect of patent on *return on equity* (ROE), with only one exception, *New-class count* (NEW_C) in patenting sample. Between two types of patent attributes, patent scale demonstrates stronger direct effects than patent scale in both samples; particularly, three variables of patent scope impact performance only in the full-sample. Within each type of patent attributes, *minor-class ratio* (MINOR) is the strongest determinant among scope variables; contrastingly, *minor-class count* (MINOR_C) is the weakest among scale variables. Such contrasting results suggest the added value to incorporate both scale and scope terms in the performance studies, even when both variables derived from a similar notion.

Hypothesis 2: Stronger Mediated Effects of Patent on ROE

Because our performance models posit patent attributes impact performance alternatively through direct or mediated effects as illustrated by Complete-Mediating Model in FIGURE 1, we found both patent scale and patent count impact ROE through the mediator of *productivity* with one lag-year. TABLE 10 listed the supportive lagging mediated effects of applicable pair of patent attributes and performance variables. *Productivity* serves as a stronger mediator than *revenues* (REV). In comparison, most direct effects extend their impact up to three lag-years; while most mediated effects only sustain for one year.

As a summary, we found *Diversity index* (DIV) impacts *net income* directly; while neither ROE nor MVA when testing Full-sample. Contrastingly, when testing Patenting-sample, patent scope doesn't impact performance with one exception: *minor-class ratio* (MINOR) impacts performance indirectly through *productivity*. Such exceptional results imply that the blue-ocean strategy works for a patenting firm to outperform among technology-innovators by developing its innovation beyond industry mainstream.

CONCLUSION

Our test results generally support our hypotheses that firms with a patent or superior patent portfolio perform better than those without any or with inferior portfolio. In addition, some contrasting results between patent scale versus patent scope, between direct and mediated performance effects, and between Full-sample and Patenting-sample, suggest the importance of strategic fit between patent or innovation strategy and performance targets. Different dimensions of strategic orientation, such as minor-class orientation for patenting firms, influence the strategic outcomes differently. For future research, further tests using more applicable measures on a much larger sample may help to facilitate the generalization of our findings to broader contexts. For example, by expanding the sample to include multiple industries and countries, any future studies could include other technology-intensive industries, such as foundry and biotechnology, or more Fabless firms in the US, Japan and Korea.

In conclusion, by comparing the t-test results on mean-differences of performance between four pairs of patenting versus non-patenting sub-samples, we found empirical support of our hypothesis that firms with a patent perform better than those without. Using the fixed effect model, we further compared lagging direct and mediated effects among scale and scope attributes of patent portfolio. Our results show that patent scale generates stronger direct effects than patent scope in both samples; contrastingly patent scope requires mediators to impact performance indirectly in the full-sample, and rarely demonstrates any effect in the patenting-sample. In addition, the full-sample of 921 firm-years demonstrates a stronger direct or mediated effect of patent than the patenting-sample of 317 firm-years. Our result comparison implies that a patenting firm with superior patent portfolio may not perform better than another patenting firm with less patent scale or scope, given the positive performance effect generally over non-patenting firms. Our findings may contribute to specify the applicable conditions for a firm to enhance its competitive advantage via patent portfolio by proposing a contingent view of innovation strategies.

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(Note: TABLEs 1, 3, 4, 6, 8a, 8b are not listed in this manuscript to meet AIBSEAR page-requirement.)

TABLE 1: Firm attributes of sampled versus Semiconductor-leading firms, 2007[1]

TABLE 3: Correlations of Full Sample

TABLE 4: Top 4 IPC[1] Major Classes Held by Sampled Firms

TABLE 6: Comparative summary statistics of Full Sample and 5 sub-samples for t-tests

TABLE 8a: Direct effects of patent scale (COUNT) of Full Sample (lag-year=0)

TABLE 8b: Direct effects of patent scale (COUNT) of Patenting Sample (lag-year=0)

TABLE 2: Summary statistics and variable definitions of Full Sample

Type	Variable	Description	Unit	Mean	SD	Max	Min	Definition
Dependent (Performance)	ROE	Return on Equity	%	7.45	42.67	117	-888	Net Income / Average Equity
	ROE_RA	ROE Ranking	N	42.42	26.76	100	1	
	ROE_SD	ROE standardized	%	0	0.98	2.59	-6.78	
	NI	Net Income	Million NTD	327	1916	34800	-5675	Revenues - total costs
	NI_RA	Net Income Ranking	N	42.42	26.76	100	1	
	NI_SD	Net Income standardized	Z	0	0.99	9.48	-3.15	
	MVA	Market Value Approximated	Billion NTD	5.33	20.27	298.13	-4.32	Market Value - Amount of Capital Invested
	MVA_RA	MVA Ranking	N	31.00	22.11	84	1	
Mediator	REV	Revenues	Million NTD	2202	5589	74800	0	Revenues
	PRO	Employee Productivity	Thousand NTD	1040	4640	29288	-99557	Income before tax / number of employee
Control	AGE	No. of Years	N	8.24	4.88	23	0	Performance Year - Established Year
	EMP	Employee Log	Z	4.62	0.96	7.67	1.10	Log of Employee Headcount in Performance Year
	RDI	R&D Intensity	%	27.57	166.21	4135	0	R&D Expenses / Revenue in Performance Year
Independent (Patent Scale)	COUNT	Patent Count	N	8.65	37.36	604	0	The total number of patent applications submitted by a firm over a three-year period.
	NEW_C	New-class Count	Z	1.15	2.66	20	0	Patent Count * New-class Ratio
	MINOR_C	Minor-class Count	Z	4.62	16.31	224.10	0	Patent Count * Minor-class Ratio
Independent (Patent Scope)	DIV	Diversity Index	%	0.13	0.22	0.74	0	$DIV = 1 - \sum_{j=1}^{72}\left(\frac{N_{ijt}}{N_{it}}\right)^2$,calculated based on 3-year portfolio.
	NEW	New-class Ratio	%	0.11	0.25	1	0	The number of patents in the new technology class as a proportion of the present total patent count of the firm over a three-year period.

TABLE 5: Matrix of mutually-exclusive 4 pairs of 5 sub-samples, split from Full-sample

Full-Sample (FS: 1026[1])	Patenting Firm-years	Non-patenting Firm-Years (NY: 699)	Sub-samples	Pair of Sub-samples
Patenting Firms	Patenting Sample (PS: 327)	Non-patenting firm-years of Patenting firms (NP: 394)	all firm-years of Patenting Firms (PF: 721)	Pair III: PS - NP (PF = PS + NP)
Non-patenting Firms	N/A	all firm-years of Non-patenting Firms (NF: 305)	all firm-years of Non-patenting Firms (NF: 305)	N/A
Pair of Sub-samples	Patenting Sample (PS)	Pair IV: NP - NF (NY = NP + NF)	Pair II: PF - NF (FS = PF + NF)	Pair I: PS - NY (FS = PS + NY)

Note 1: The number shows the firm-year count in each sub-sample, using ROE as an example.

TABLE 7: T-test results on the mean-difference of patenting minus non-patenting sub-samples

Type	Variables	Sub-sample	Original (+)	Ranking (-)	Standardized (+)
Performance Variables as Dependent Variables (DV)	ROE / Return on Equity	PS[2] - NY[2]	9.2* [1]	-2.3	0.2*
		PF[2] - NF[2]	12.1*	-8.5*	0.3*
		PS - NP[2]	4.89*	1.7	0.1
		NP - NF	9.9*	- 9.3*	0.3*
	NI / Net Income	PS – NY[3]	733.0*	-11.6*	-0.5*
		PF - NF[3]	401.7*	-13.4*	0.3*
		PS - NP[3]	696.0*	-7.1*	0.4*
		NP - NF[3]	86.1	- 10.2*	0.1*
	MVA / Market Value Approximated	PS - NY	7.6*	-14.8*	N/A
		PF - NF	5.7*	- 15.9*	
		PS - NP	7.0*	- 10.9*	
		NP - NF	1.3	- 9.2*	
Mediator Variables (MV)	REV / Revenues	PS - NY	3446.9*	- 18.8*	0. 68*
		PF - NF	2059.7*	- 21.7*	0.4*
		PS - NP	3177.4*	- 11.6*	0.6*
		NP - NF	613.2*	- 16.4*	0.1*
	PRO / Productivity	PS - NY	1527.4*	- 5.5*	0.4*
		PF - NF	1104.2*	- 8.9*	0.3*
		PS - NP	1325.3*	- 2.2	0.3*
		NP - NF	474.3	- 7.9*	0.1*

Notes:

1. * indicates the difference between two means is not equal to 0 at 95% confidence level.
2. Definitions of 5 sub-samples, whose statistics listed in TABLE 5:
   - PS = Patenting Sample including only patenting firm-years, also tested for direct and mediated effects.
   - NY = Non-patenting firm-Years of all firms, including patenting and non-patenting firms.
   - PF = all firm-years of Patenting Firms, including patenting and non-patenting firm-years.
   - NF = all firm-years of Non-patenting Firms, including non-patenting firm-years only.
   - NP =Non-patenting firm-years of Patenting firms.
3. Implication of mean-difference between two sub-samples:
   - PS - NY for patenting firm-year effect, the advantage of Patenting Sample over Non-patenting firm-Years.
   - PF – NF for patenting firm effect, the advantage of Patenting Firms over Non-patenting Firms.
   - PS - NP for firm-year effect of Patenting Firms, the advantage of Patenting firm-years over Non-patenting years.
   - NP - NF for Non-patenting firm-year effect of Patenting Firms, the advantage of Non-patenting firm-years of Patenting firms over those of Non-patenting firms.

FIGURE 1: Complete-Mediating Model

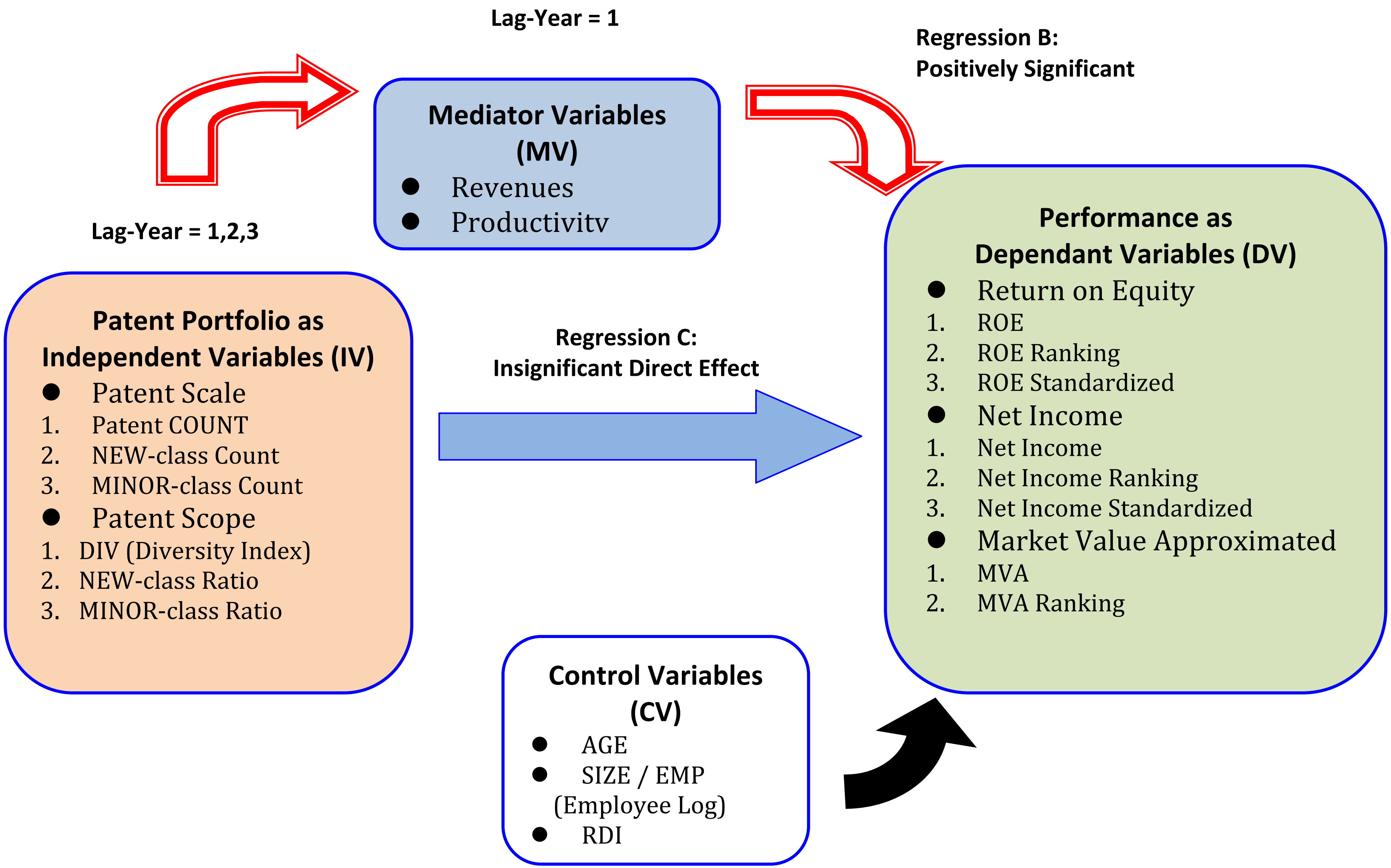

TABLE 9: Comparison of direct and lagging effects between Full and Patenting Samples

Patent (IV)	Performance (DV)	Return on Equity ROE	ROE_RA	ROE_SD	Net Income NI	NI_RA	NI_SD	Market Value MVA	MVA_RA	Mediator REV	PRO
Patent Scale	COUNT		[5]		0,1, 2,3[1]	0^[2]	0	0#,1, 2,3[9]	0#,1, 2,3^	0,1,2,3[4]	0#
	NEW_C	2^[6]		0^,2^	0,1, 2,3#	0#,1, 2	0,1, 2,3#	0#,1#, 2#,3#	0#,1#[3]	1^,2,3	0
	MINOR_C				0,1, 2,3	0[8]	0	0#,1, 2,3	0,1, 2^,3^	0,1,2,3	0#
Patent Scope	DIV						0#,1#, 2#,3#				
	NEW						2#,3#		0#[7]		0#
	MINOR				0#,1 #, 2#		0#		0#,1#, 2#	1#,2#, 3#	0

Notes:

1. <u>0, 1, 2, 3</u> indicate the number of years of significant <u>lagging effect</u> in the focal pair of IV and DV.
2. ^ indicates only the patenting-sample has significant effect; while the full-sample has not.
3. # indicates only the full-sample has significant effect; while the patenting-sample has not.
4. Pure numbers without either ^ or # indicate both samples have significant effect.
5. Blank indicates no significantly positive effect between the focal pair IV and DV.
6. Red-color indicates the patenting-sample dominates the performance effect than the full-sample (all ^).
7. Blue-color indicates the full-sample dominates the performance effect than the patenting-sample (all #).
8. Green-color indicates both samples have the same performance effect (all pure number).
9. Black-color indicates mixed performance effect between two samples.

TABLE10: Comparison of mediated and lagging effects between Full and Patenting Samples

Patent (IV)	Mediator (MV) (DV)	Revenues (REV) NI	MVA	Productivity (PRO) ROE	NI	MVA
Patent Scale	COUNT	NI_SD(1#)		ROE(1#) ROE_RA(1#) ROE_SD(1#)	NI_RA(1#) NI_SD(1#)	
	NEW_C		MVA_RA (2^,3^)	ROE(1#) ROE_RA(1#) ROE_SD(1#)		
	MINOR_C	NI_SD(1#)		ROE(1#) ROE_RA(1#) ROE_SD(1#)	NI_RA(1#) NI_SD(1#)	
Patent Scope	NEW			ROE(1#) ROE_RA(1#) ROE_SD(1#)	NI(1) NI_RA(1#) NI_SD(1)	MVA(1#) MVA_RA (1#)
	MINOR	NI_SD (2#,3#)	MVA (2#,3#)	ROE(1#) ROE_RA(1#) ROE_SD(1#)	NI(1^) NI_RA(1#) NI_SD(1)	MVA(1)

Notes:

1. All notations are specified as TABLE 9.
2. Patent variable of DIV and Performance variable of ROE when REV as mediator are not listed, because of <u>no mediated effects</u> for all pairs of focal IV and DV