Patent portfolio diversity, Technology strategy, and Firm value.

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1.1 The Authors

Year	Authors	Title	Journals
2001	Chen/Lin	A **resource-based view** of IT outsourcing: Knowledge sharing, communication, and coupling quality	APMR, 6 (2)
2002	Lin/Chen	The effects of formation motives **and inter-firm diversity on the performance of strategic alliance**	APMR, Vol.7
2004	Chen/Lin	The effects of environment, knowledge attribute, organizational climate, and firm characteristics on knowledge sourcing decision	R&D Management , 34(2)
2006	Chen/Wu/ Lin	Evaluating the **development of high-tech industries**: Taiwan's science park	TFSC, 73(4)
2006	Lin/Chen	Fostering product innovation in industry networks: The **mediating role of knowledge integration**	IJHRM, 17
2006	Lin/Chen/ Wu	Patent portfolio synergy, technology strategy, and firm performance	IEEE
2007	Wu/Chen/ Lin	Contingency view on **technological differentiation and firm performance**: evidence in an economic downturn	R&D Management 37(1)
2007	Wu/Lin/Ch en	Examining **governance-innovation relationship in the high-tech industries**: Monitoring, incentive and a fit with strategic posture	IJTM, Vol.39
2007	Lin/Chen/ Wu	**Predicting citations to biotechnology patents** based on the information from the patent documents	IJTM, Vol.40

1.2 The definition of terms

- Patent Portfolio：a set of one or more patents.
- Technology Strategy [3]： How a firm can reduce risk and tap into business opportunities by effectively holding a collection of different technologies, markets or resources.
- Synergy: the value of a technology portfolio can add up to more than the sum of its separate parts.
- Firm Value：Long term and short term.

[3] M. Sadowski and A. Roth, “Technology leadership can pay off,” Res. Technol. Manage., vol. 42, no. 6, pp. 32–33, 1999.

1.3 The Background

- In knowledge-based economy, how the technology managers to corporate technological assets and to develop new technological capabilities ?
- Resource-based view/Competence-based view/capability-based view [16] [19]: Successful firms have the ability to identify, cultivate , and exploit core competencies that are the roots of sustainable competitive [9] (exploit)
- Product/market perspective[18]:increasingly multi-technology and multi-product. (explore)

Diversity or not?

What's the strategy?

[9] C. K. Prahalad and G. Hamel, "The core competence of the corporation," Harvard Bus. Rev., vol. 68, no. 3, pp. 79–91, 1990
[16] M. E. Porter, Competitive Advantage. New York: Free Press, 1985.
[18] O. Granstrand, P. Patel, and K. Pavitt, "Multitechnology corporations: Why they have distributed rather than distinctive core competencies," Calif. Manage. Rev., vol. 39, no. 4, pp. 8–25, 1997.
[19] J. B. Barney, "Firm resources and sustained competitive advantage," J. Manage., vol. 17, pp. 99–120, 1991.

1.4 The Questions

- The characteristics of a valuable technology portfolio
- The relationship between technology diversity strategy and firm value

- **H1:** The BTD (Broad Technology Diversity) of a firm's technology portfolio will be positively associated with its performance.
- **H2:** The CFD (Core Feld Diversity) of a firm's technology portfolio will be negatively associated with its performance.

2.1 Technology Portfolio Strategy

- Some researchers[3] [11] support “Diversification” to reduce the risk
- Some researchers [12] [13] argue “Synergy creation” is more important than just “risk reduction”

[11] R. Amit and J. Livnat, “Diversification and the risk-return trade-off,” Acad. Manage. J., vol. 31, no. 1, pp. 154–166, 1988.
[12] E. Norton, “Don’t manage your strategic acquisitions like stock portfolios,” Acad. Manage. Exec., vol. 8, no. 4, pp. 86–87, 1994.
[13] M. Lubatkin and S. Chatterjee, “Extending modern portfolio theory into the domain of corporate diversification: Does it apply?,” Acad. Manage. J., vol. 37, pp. 109–136, 1994.

2.2 Synergy Through Corporate Technology Diversity

- Support Diversity:
  - Firm's long-term value can be improved through increasing diversity and matched with emerging business opportunities.[18]
  - Empirical studies [20][21] [22]:positive relation between technological diversification and firm's performance
- The Risk of Diversity:
  - Larger debt capacity and access to free cash flow tend to undertake nonvalue maximizing investments. Over diversification that can generate negative synergy and diseconomies of scope."dediversified" firms enjoy subsequent improvements in stock market performance.[23][24]
  - Diversified firms have lower average Tobin's Q rations than single-segment firms [15]

[15] L. Lang and R. M. Stulz, "Tobin's Q, corporate diversification, and firm performance," J. Pol. Econ., vol. 102, no. 6, pp. 1248–1280, 1994
[18] O. Granstrand, P. Patel, and K. Pavitt, "Multitechnology corporations: Why they have distributed rather than distinctive core competencies," Calif. Manage. Rev., vol. 39, no. 4, pp. 8–25, 1997.
[20] A. Gambardella and S. Torrisi, "Does technological convergence imply convergence in markets? Evidence from the electronics industry," Res. Policy, vol. 27, no. 5, pp. 445–463, 1998.
[21] M. Singh, I. Mathur, K. C. Gleason, and A. Etebari, "An empirical examination of the trend and performance implications of business diversification," J. Bus. Econ. Studies, vol. 7, no. 2, pp. 25–51, 2001.
[22] W. P. Lloyd and J. S. Jahera Jr., "Firm-diversification effects on performance as measured by Tobin's Q," Man. Decision Econ., vol. 15, no. 3, pp. 259–266, 1994.
[23] A. B. Jaffe and J. Lerner, "Reinventing public R&D: Patent policy and the commercialization of national laboratory technologies," Rand J. Econ., vol. 32, no. 1, pp. 167–198, 2001.
[24] R. Comment and G. A. Jarrell, "Corporate focus and stock returns," J. Fin. Econ., vol. 37, pp.

2.3 Synergy Through Focusing on Core Technologies

Capabilities-based theory [25] and Core competences[6] :

- The firm must ensure that each part of the portfolio is integrated into and contributes to the core competences. The firm should concentrate only on core business activities they can do best.
- A firm should put all of its eggs in similar baskets.[26]Pursuit of the unique can be a viable resource strategy.[27]
- However, the measures and data typically have only a weak connection to capabilities-based theory

[25] T. Joseph and J. R. Pandian, “The capabilities-based view within the conversation of strategic management,” Strategic Manage. J., vol. 13, no. 5, pp. 363–380, 1992.
[26] S. Chatterjee and M. Lubatkin, “Corporate mergers, homemade diversi-fication, and changes in systematic risk,” Strategic Manage. J., vol. 11, no. 4, pp. 255–268, 1990.
[27] J. W. Medcof, “The capabilities-based view and transnational technological strategy,” J. High Technol. Manage. Res., vol. 11, no. 1, pp. 59–74, 2000

2.4 Two Levels of Technology Diversity

Hierarchical structure

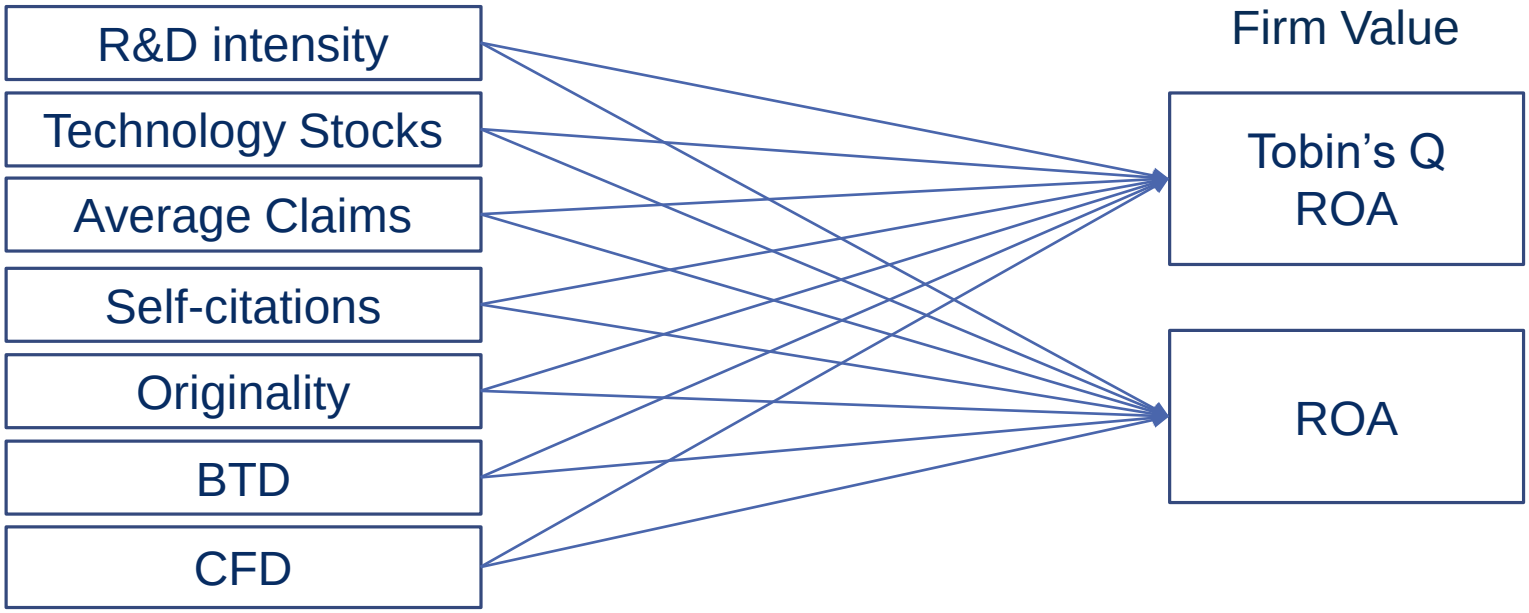
- First level: Classification schemes. broadly categorize technology into several main technology types. (mechanics, electronics, and chemistry…)
- Each of the first-level types can be classified into several second-level technology fields.
- In line with academic disciplines or industrial classification schemes (International Patent Classification & U.S. Patent Classification)

The type of Diversity

Type	Definition	Example
BTD (Broad Technology Diversity)	The Extent on broadly defined first-level technology area.	Digital camera requires a diversified portfolio technologies(optics, operating systems, mechanics, digital image processing and electronics…)
CFD (Core Feld Diversity)	The extent on a narrowly defined second-level technology area.	Intel holds a huge number of patents on CPU technology and became dominant position which create long-lasting monopoly rents.

3.1 Hypotheses

- H1: The BTD of a firm's technology portfolio will be positively associated with its performance.
- H2: The CFD of a firm's technology portfolio will be negatively associated with its performance.



Control Variables: Firm size, Category, Repeated data in different years, R&D intensity, Patents per assets

3.2 Sample Firms and Data

Database

- USPTO (The United States Patent and Trademark Office)
- NBER Patent Citation Data File (National Bureau of Economic Research)：U.S. patents citation data over 30years (originality, generality, backward citation lags, and self-citation.) provides a venue to link to the COMPUSTAT database.
- COMPUSTAT： A database complied by Standard & Poor's and includes accounting and financial data. It began in 1962.

Sample

- Step1: Identify TOP 150 assignees that received more than 100 U.S. patents during a three-year period between 1985-1999 (15 years)
- Step2: Eliminate government-owned institutions, foreign companies, or those firms without complete records in COMPUSTAT.
- Final Sample: 94 firms large U.S. technology firms with sizeable patent portfolios. (1,275 observations after removing missing values data)

3.3.1 Dependent Variables

ROAs (Short-term)

- It is displayed as a percentage calculated by dividing a firm's annual earnings by its total assets. (稅前息前折舊前淨利除以平均資產總額)

Tobin's Q (Long-term)

- It represents the ratio of the market value of its assets to replacement costs of the firm's assets.

$$\frac{\text{公司市場價值 (公司股票的市值+債務資本的市值)}}{\text{重置成本 (當天要買下所有上市公司的資產所需資金)}}$$

- High Q-ratio : If competitive advantage can be maintained. (If not, the Q-ratio would back to a level with the industry average)
- Approximate Q (explain at least 96.6% of the variability of Tobin's Q) =

$$\frac{MVE + PS + DEBT}{TA}$$

MVE：The product of share price and common stock shares outstanding.
(普通股市值，流通在外普通股乘以股價)
PS：The liquidating value of outstanding preferred stocks.(流通在外特別股市值)
DEBT：The value of the firm's short-term liabilities net of its short-term assets, plus the book value of the firm's long-term debt.
(流動負債減去流動資產再加上長期負債帳面值之和)
TA：The total assets of the firm. (總資產帳面值)
Observation period：5years

3.3.2 Control Variables

Firm size

The logarithm of total assets as a control variable for firm size effects.(總資產取自然對數作為衡量公司規模之指標)

Category

- Different industry has different asset and performance. NBER database categorizes patents into 6 categories
  (1)Chemical; (2) Computer/Communication; (3) Drug/Medical;
  (4) Electrical/Electronic; (5) Mechanical; (6) Others Firms

Repeated data in different years

This study used data from 1985-1999, and we treated the data from the same firm in different years as repeated measures of the same subject.(SAS MIXED procedure)

R&D intensity

A firm's R&D expenditures ÷ its total assets

Patents per assets

Represent the flows and stocks of the firm's technology assets.

3.3.3 Independent Variables

Characteristics of a Technology Portfolio

- Patent Claims：As an indicator of the “scope” or “richness” of a firm’s patent portfolio.
- Self-citations：It reflects the degree of unique, independent.
- Herfindahl-type index (HHI)：a measure of the size of firms in relation to the industry and an indicator of the amount of competition among them.(產業集中度，越大越集中，壟斷程度越高)

$$HHI = \sum_{i=1}^{N}(X_i/X)^2 = \sum_{i=1}^{N} S_i^2$$

X=市場總規模。X_i=i企業規模

$S_i = X_i / X$——第i個企業的市佔率 N=該產業內企業數

BTD (Broad Technology Diversity)

$$\mathrm{BTD} = \sqrt{1 - \sum_{i=1}^{6}\left(\frac{X_i}{\sum X_i}\right)^2}.$$

X_i=1 to 6 (six categories)

CFD (Core Feld Diversity)

$$\mathrm{CFD} = \sqrt{1 - \sum_{j=1}^{N_i}\left(\frac{Y_j}{\sum Y_j}\right)^2}.$$

N_i=6,4,4,7,6,9

(Each categories' subcategories)

Y_j=1 to N_i

(the number of patents of the core category belong to its subcategories)

3.3.3 Independ Variables

	Variables	Description
	R&D intensity	A firm's R&D expenditures divided by its total assets.
*	Technology stocks	The number of patens received by a firm during the previous three years divided by its total assets.
	Average claims	The average of patent claims in a firmís patent portfolio. An indicator of the "scope" or "richness" of a firm's patent portfolio.
	Average self citation ratio	The average percentage of patent citations that the assignee cites its own previous patent inventions. This measure reflects the degree to which the inventions in a technology portfolio are unique, independent, and with less knowledge spillovers.
	Originality	A Herfindahl-type index to measure the extent to which a patent cites previous patents that belong to a wide range of technological fields.
*	Broad Technology Diversity (BTD)	A Herfindahl-type index to measure the degree to which a firm built a diversified repertoire of technology portfolio in six broadly defined technological categories.
*	Core Field Diversity (CFD)	A Herfindahl-type index to measure the degree to which a firm built a diversified repertoire of technology portfolio in its primary technology category.

*Standardized the three variables to avoid undue multi-collinearity

4.1 Results – Model 1A、2A

P-value<0.0001 ✓: significant X: insignificant
▲ : Positive ▼: Negative

	Model 1A		Model 2A	
	Tobin's Q (long-term)		**ROA(short-term)**	
Intercept	0.967** (3.34)		6.085* (2.31)	
[Tech=1] Chemical	0.099 (1.52)	X	1.166 (1.29)	X
[Tech=2] Computer/Communication	0.229* (2.40)	✓ ▲	1.146 (1.02)	X
[Tech=3] Drug/Medical	0.194* (2.01)	✓ ▲	5.352** (4.60)	✓ ▲
[Tech=4] Electrical/Electronic	0.107 (1.27)	X	3.439** (3.41)	✓ ▲
[Tech=5] Mechanical	0.014 (0.19)	X	1.356 (1.50)	X
Firm size (log assets)	-0.419** (-5.35)	✓ ▼	-0.762 (-1.10)	X
Average Claims	0.010+ (1.69)	X	-0.081 (-1.42)	X
Originality	-0.793* (-2.45)	✓	3.752 (1.07)	X
Average self-citation ratio	1.095** (3.21)	✓ ▲	8.605* (2.47)	✓ ▲
R&D intensity	0.132** (3.79)	✓ ▲	-1.924** (-4.40)	✓ ▲
Technology Stocks (TS)	0.0248 (0.68)	X	-0.078 (-0.22)	X
Broad Technology Diversity (BTD)	-0.061* (-2.34)	✓ ▼	-0.895** (-3.26)	✓ ▼
Core Field Diversity (CFD)	-0.032 (-1.30)	X	0.103 (0.35)	X

Higher performance In these three categories

Quantity ≠ Quality

The HHI doesn't reflect the originality

The firms might need complementary assets to exploit the value of the TS

Not support H1: The BTD of a firm's technology portfolio will be positively associated with its performance.

- Strategic alliances & joint ventures might be more effective than internal R&D.
- Diversified patent portfolio has less chance to dominate than strategically focused on the core areas.

Not support H2: The CFD of a firm's technology portfolio will be negatively associated with its performance.

4.1 Results – Model 1A、2A

Not support H1: The BTD of a firm's technology portfolio will be positively associated with its performance.

Not support H2: The CFD of a firm's technology portfolio will be negatively associated with its performance.

- However….
  - This sample contains "only" large firms that received more than 100 patents during the previous 3years. (Many of them received more than 1000 patents)
  - It may be unrealistic to ask those large firms focus on specific small areas. The result is INCONSISTET.
- Therefore…
  - There might be "interaction effects" between BTD/CFD and technology stocks.

4.2 Results – Model 1B、2B

P-value<0.0001 ✓: significant X: insignificant
▲ : Positive ▼: Negative

	Model 1A	Model 1B	Model 2A	Model 2B
[Tech=3] Drug/Medical	0.194 (2.01)	0.227 (2.37)	3.352 (4.00)	3.272 (4.31)
[Tech=4] Electrical/Electronic	0.107 (1.27)	0.147^{+} (1.74)	3.439** (3.41)	3.435** (3.40)
[Tech=5] Mechanical	0.014 (0.19)	0.047 (0.64)	1.356 (1.50)	1.368 (1.50)
Firm size (log assets)	-0.419** (-5.35)	-0.418** (-5.34)	-0.762 (-1.10)	-0.449 (-0.64)
Average Claims	0.010^{+} (1.69)	0.009 (1.61)	-0.081 (-1.42)	-0.079 (-1.36)
Originality	-0.793* (-2.45)	-0.664* (-2.07)	3.752 (1.07)	4.356 (1.24)
[illegible]	[illegible]	[illegible] (3.07)	[illegible]	[illegible]
[illegible]	[illegible]	[illegible] (3.95)	[illegible]	[illegible]
Technology Stocks (TS)	0.0248 (0.68)	0.0089 (0.25)	-0.078 (-0.22)	0.018 (0.05)
Broad Technology Diversity (BTD)	-0.061* (-2.34)	-0.058* (-2.25)	-0.895** (-3.26)	-0.841* (-3.06)
Core Field Diversity (CFD)	-0.032 (-1.30)	-0.042^{+} (-1.66)	0.103 (0.35)	0.014 (0.05)
TS × BTD		-0.008 (-0.40) X		0.471* (2.00) ✓ ▲
TS × CFD		-0.049** (-2.68) ✓ ▼		-0.053 (-0.26) X

H1: The BTD of a firm's technology portfolio will be positively associated with its performance. When firms with high TS to capture unexpected new opportunities (which only on the "short term" and only for "large" companies with "complementary" resources)

High TS+CFD= ↓ shareholder value

High TS+BTD= ↑ROA

5. Discussion of findings

1.Two levels BTD & CFD to clarify confusing concepts.

- BTD +Performance =▼ Tobin's Q &▼ ROA → Support RBV
- CFD +Performance = insignificant

2. The Strategy and Quality of patent portfolio is important

- Self citation +Performance = ▲ Tobin's Q & ▲ ROA
  → High quality patents is important.
- Patent claims + performance = insignificant
  → Patent claims may not be able to effectively protect each of its claims. (because competitors can design around.)
- Computer/communication ,drug/medical and electronic/electronic fields are more valuable than others.
  → A firm could enhance its performance by strategically technology portfolio.

3.Consider both Long-term and short-term performance

- Long-term shareholder value : Tobin's Q
  Short-term profitability : ROA
- ▲R&D intensity→▼ROA & ▲Tobin's Q
- ▲Firm size→▼Tobin's Q (ROA insignificant)

5. Discussion of findings

4.Technology Stocks play an critical role in tec. portfolio strategy.

- High TS+BTD= ↑ ROA (Short term)
- High TS+CFD= ↓ Shareholder value (Long term)

5. Limitations and need for further research

1. Data biases
    - Some firms use know-how or trade secrete to protect rather patents.
    - 15-year time observation period (we use multi-level statistical technique to mitigate this problem)
2. Smaller, newly established firms

6. Conclusion

1. Provide an integrative framework to explain two (seeming inconsistent) technology diversity and TS as a moderator.

- CTD：High TS and use profitability (ROA) as a performance measure.
- BTD：Average TS and use shareholder value (Tobin's Q) as a performance measure

2. Patent portfolio represents the technology strategy

Research and managers can compare technology strategies across different firms using numerical scales.

3. Use Herfindahl-type indexes for patent portfolios (BTD and CFD)

Explain how a portfolio of patents could have synergistic effects. BTD is related to diversity literature. CTD is support the capability-based view.

4. Use patent-based bibiometric measures with NBER patent data

To describe the patent portfolio

5. Managers should consider the patent portfolios on performance when allocating R&D resources.

Portfolio of competencies instead of a portfolio of businesses or product families.

7.Supplement information

The difference of Patent strategy for SMEs :

Holgersson, M. (2013). Patent management in entrepreneurial SMEs: a literature review and an empirical study of innovation appropriation, patent propensity, and motives. R&D Management, 43(1), 21-36. (cited by 52)

- Patent propensity is lower in SMEs (small and medium-sized enterprises) than in large firms and that patenting as means for appropriation is of less importance among SMEs.
- In entrepreneurial SMEs, patents were used to attract customers and venture capital, which is of utmost importance for the survival and growth of these firms. Thus, patenting has an important role to play even in firms where the protective function of patents is secondary.

7.Supplement information

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Top Patent Holder Ranking in the U.S. (2000-2015)							
	2000	2003	2005	2008	2010	2013	2015
	187th	218th	184th	106th	55th	15th	12th
	6th	11th	11th	10th	8th	4th	10th

Apple’s NPD：iPod (2001)、iPhone (2007)、iPad (2010)、iWatch (2015)
Sony’s NPD：PS2(2000)、PS3(2006)、PS4(2013)

Rethink the relationship between

Technology and Commercial Success