Business Type, Value Chain Stage and R&D Performance

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Abstract

The objective of the paper is to explore how business type, which a firm selects according to its core competence and competitive advantage, influences a firm's R&D strategies that in turn affect the performance of it. How the interaction between a firm's business type and industry value chain stage affects the relationship between R&D investments and operating performance is another focus of the paper.

The empirical results are as follows. First, we suggest that the linkage of R&D investment and performance will increase gradually comparing ODM/OEM to OBM firms. Second, we suggest that the value-added effect to performance of the R&D investment by a high-tech firm will be affected by the interaction between its business type and industry value chain stage. Specifically, the path that R&D investments can contribute for the performance of OBM firms at various value chain stages is quite different from that of ODM/OEM firms. R&D investments, on average, generate more significant benefits for OBM companies compared with ODM/OEM firms at the same value-chain stage.

Key Words: R&D Performance, OBM, ODM/OEM, Industry Value Chain, Core Competence.

1. Introduction

This study focuses on how business type, which a firm chooses according to its core competence and competitive advantage, influences a firm's R&D strategies that in turn affects the performance. How the interaction between a firm's business type and industry value chain stage affects the relationship between R&D investment and its performance is another focus of the study.

In an effort to improve production efficiency and to lower costs, a firm has begun to look beyond its own boundaries and consider the overall design of its supply chains. Specifically, a firm appears to be focusing on functions key to competitive advantage and is outsourcing other low-value-added activities to the members in their supply chains (see, for example, Quinn and Hilmer, 1994; McCarthy and Anagnostou, 2004). In terms of inter-company collaborations, a firm is usually aware of that in an intensely competitive environment, such as one under accelerating technological advancement and a market under globalization, self-sufficiency alone will not bring success but with the help of partners firms can considerably improve its competitive capability. A firm's competitive advantage increasingly depends not only on its internal capabilities, but also on the external cooperation relationship with other firms. Clearly, a firm will consider its own core competence and competitive advantage while selecting an adequate business type to operate. Generally speaking, a firm can operate with its own brand manufacturing (OBM), with original design and manufacturing (ODM) or with original equipment manufacturing (OEM).[1]

[1] OEM type evolves out of the joint operations of buyers and latecomer suppliers. Under OEM, the supplier produces a finished good to the precise specification of the buyer. The buyer then sells the product under its own brand name (thereby pursuing the post-manufacturing value-added), and makes the supplier to circumvent the need for investing in marketing and distribution. Under ODM type, the ODM firm carries out some or all of the product design and process tasks that are needed to manufacture a product according to a general product requirement provided by the buyer. ODM provides a mechanism for the suppliers to obtain more of the value-added while still avoiding the risk of launching own-brand products. Under OBM type, the firm develops its own products and

A number of empirical evidence supports the hypothesis that research and development (R&D) investment is a sine-qua-non for enhancing the level of a firm's innovation activities (see, for example, Stokey, 1995). R&D investment by a firm has been viewed as a key factor in strengthening its competitive advantage (Ettlie, 1998; Cheng, 2004; Tsai and Wang, 2004).[2] This is particularly true for high-tech firms. Dutta, Narasimhan and Rajiv (1999) suggest that the R&D capability of a firm is important to obtain a superior performance in a high-tech market because the market is characterized by a shorter product life cycle and a higher percentage of introductions to new products incorporating latest technologies. A great deal of researches (see, for example, Lev and Sougiannis, 1996; Shortidge, 2004) have examined the effect of R&D expenditure (R&D intensity) on the performance of a firm, and many of these researches have showed consistently that R&D investment (R&D intensity) does have a positive effect on the performance of a firm.

Hobday (1995; 2000) proposes an OEM-ODM-OBM migration strategy and suggest that the latecomer suppliers should firstly begin to develop process capabilities, followed by product design capabilities, and finally new product/branding capabilities. From OEM to OBM, the process can be viewed as training for technological learning (Hobody, 2000). Lin (2004) indicates that OEM suppliers usually are much smaller in business scale than their buyers and have limited resources that lead to a disadvantageous bargaining position. Some OEM firms wish to raise their profit margins through getting involved in related value chain activities with higher added value. Forward integration (i.e., OBM) or

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sells those products with its own brand.

[2] Chan, Lakonishok and Sougiannis (2001) find that the firms' R&D spending has grown sharply from 1975 to 1995. For example, the R&D intensity (R&D expense divided by sale) of firms is 1.7% in 1975 and more than doubled by 1995 to 3.75%. Between 1984 and 1997, R&D expenditures rise from \$95.7 billion in 1984 to \$129.9 billion in 1997, an average annual growth rate of 2.41% (Kim and Marschke, 2004).

backward integration (i.e., ODM) seems to be a reasonable alternative strategy for those firms that wish to upgrade their position (Huang and Lo, 2003). Berger and Diez (2006) indicate that production abilities are what an OEM firm needs to maximize its profits. However, when the business type shifts from OEM to ODM, product design capabilities are still required for a firm. For an OBM firm, basic capabilities in marketing, product development and R&D are necessary. On the other hand, a number of studies in marketing field (i.e., Gatignon, Weitz and Bansal, 1990; Doyle, 1990; Mudambi, Doyle and Wong, 1997) suggest that a firm will contemplate its sufficiency of resources and then decide whether to employ OBM. Do firms with distinctive business types (OBM vs. ODM/OEM) have different R&D strategies? What role does business type, which a firm chooses according to its core competence and competitive advantage, play in directing the linkage of R&D capital-operating performance? To our knowledge, none of the previous researches uses a systematic way to relate the choice of business type, R&D strategy and firm performance, let alone analyzing this interesting and meaningful issue.[3]

The value chain of electronic industry is usually composed of "upstream", "midstream", and "downstream" sectors. Various stages in the value-added process of electronic industry may incorporate different kinds of technology, as a result of respective specialized innovative efforts of firms (Liker, Collins and Hull, 1999). Sher and Yang (2005) use Taiwanese semiconductor industry as sample, and examine whether firms at various stages along the value chain show different innovative capabilities (patent, R&D intensity and R&D manpower). Sher and Yang (2005) suggest that the relationship between innovative capability and firm profitability is contingent upon the value-added stage of manufacturing process.

[3] Except for Berger and Diez (2006). The result shows that compared to OEM firms, OBM firms display higher innovation activities. However, Berger and Diez (2006) do not touch on how the business type affects R&D performance.

Chin, Lee, Chi and Anandarajan (2006) explore how different stages of the value-added-chain in semiconductor industry influence the relationship between patent citations and firm value (measured by Tobin's Q). Chin et al. (2006) suggest that the stage of the firm in the industry value chain influences the association between patent citations on Tobin's Q. The relationship is largest for those firms in IC design stage followed by IC manufacturing stage and IC packaging and testing stage. However, to our knowledge, none of studies regards the whole electronic industry as a value chain and explores how the interaction between a firm's business type and value chain stage affects the linkage of R&D investment and performance.

The current paper aims to analyze how the business type, which a firm chooses based on its core competence, influences a firm's innovation development strategies and in turn affects its operating performance. This paper further explores how the interaction between a firm's business type and value chain stage affects the performance of R&D activities. This paper will explore the following questions. First, we explore that what is the role of the business type, which is chosen based on its core competence, during the process of turning the innovation capital accumulated through R&D investment into concrete performance? Does different business type influence on the value-added benefit of operating performance brought by R&D investment? Second, we explore that whether different value chain stage of a firm affects the performance of a firm brought by R&D investment? In addition, we examine that whether the value-added benefit of operating performance brought by R&D investment is influenced after the interaction between a firm's business type and value chain stage?

This paper contributes the existing literature in several ways. In recent years, finance and accounting researchers have studied on the influence of various intangible assets (i.e. R&D investment) to firm performance and share price. The contribution of the current paper is to relate intangible assets to strategy research issues and to analyze how does the business type, which is chosen based on its core competence, of a firm affect the linkage between R&D investment and performance. The paper further explores that whether different stage of industry value chain affects the linkage. As for strategy literature, based on resource-based theory, researchers generally state that a firm will take core competence and competitive advantages into consideration while choosing a proper business type. However, no previous researches have studied on whether the choice of business type will influence business innovation investment strategies and its performance. This paper uses large sample data to demonstrate that business type will influence the creation of firm value through formulating strategies that will affect innovation development. This paper presents an important and clear research argument on the choice of business type, the formulation of innovation development strategies and creation of performance.

The remainder of the paper is organized as follows. Taiwanese electronic industry is introduced in section 2. Section 3 presents the literature survey and the research hypotheses. In Section 4, we introduce research design including research period, sample selection criteria, the judgment on a firm's business type, variables measurements, and research methodologies. Section 5 explains the empirical results. Finally, in section 6, concluding remarks are provided.

2. Taiwanese electronic industry

According to the report of "Global Competitiveness in 2005-2006" by World Economic Forum (WEF), Taiwan is ranked fifth overall worldwide in terms of the Growth Competitiveness Index (GCI) which represents long-term economic growing prospects. The outstanding performance of innovation activities of the electronic industry in Taiwan has drawn international attention. In terms of the number of patents, the international patents per capita in Taiwan ranks second in the world, only after the U.S. Taiwan is the only country in East Asia that has closed the gap in innovation activities with the leading Western industrial nations and Japan-the G7 (Breznitz, 2005). On the other hand, Taiwan is a newly industrialized economy with many indigenous firms becoming increasing competitive in a growing range of high-tech industries. Companies like TSMC, and Hong Hai have become major global high-tech firms competing aggressively for market dominance and technological leadership against their more established rivals from the USA, Europe, and Japan (Wong and Mathews, 2005). Furthermore, Taiwan is world-renowned for the excellence of its manufacturing technology, making it, by 2005, the world's second biggest producer of information and communications hardware. Taiwanese corporations have adopted a business model whereby company headquarters in Taiwan is responsible for securing orders, manufacture in Mainland China, and carry out the final shipping from Hong Kong. The combined global market share held by Taiwanese manufacturers exceeds 70% for several key products, including notebook PCs, motherboards, Wireless Local Area Network (WLAN) equipment, and liquid crystal display (LCD) products.

2.1 The value chain of Taiwanese electronic industry

According to the survey by Market Intelligence Center (MIC) and Jen, Lin, Chen and Lee (2006), the value chain of Taiwanese electronic industry is composed of "upstream", "midstream", and "downstream" sectors. Generally speaking, the upstream sector includes semiconductor sub-industry and electronic components (e.g., electrolytic capacitor, passive components, LED, PCB, connector, and storage device) sub-industry, and so on. The semiconductor sub-industry can be divided into four core business modes on the basis of production stages: IC design, IC manufacturing/fabrication, IC packaging, and IC testing. Each stage of value chain has different characteristics. For example, IC design firms are knowledge intensive and require little capital fabrication technology.

The midstream sector of electronic industry usually includes optoelectronics (e.g., LCD) sub-industry, computer peripherals (e.g., keyboard) sub-industry, networking communication equipments (e.g., modem, and switch hub) sub-industry and so forth. The downstream sector includes computer channel sub-industry and computer equipments (e.g., desktop PCs, notebook PCs, mobile phone and DSC) sub-industry, and so forth. Various stages in the value-added process of electronic industry may incorporate different kinds of technology, as a result of respective specialized innovative efforts of firms (Liker et al., 1999).

3. Literature survey and research hypotheses

Griliches (1981) suggest that firm value is made up of assets in place and intangible assets, and the value created by intangible assets relies on the stock of innovation capital (i.e., R&D expenditure). Sougiannis (1994), and Lev and Sougiannis (1996) use the Almon lag procedure (1965) to estimate the lag effect of R&D expenditures and suggest that R&D investments can contribute for operating performance. Hsieh, Mishra and Gobeli (2003) suggest that there exists a positive relationship between R&D intensity and firm performance. Generally speaking, a firm's R&D intensity signifies the strategic importance of innovation to the firm. Although a high level of R&D intensity does not ensure successful innovations, firms that invest more in R&D are more likely to be able to compete on the basis of innovativeness and technology breakthrough (O'Brien, 2003). However, Lin, Lee and Hung (2006) suggest that R&D capital of firms with specific categories of technology might contribute to their performance, while those with other categories of technology might have no or even negative effects on firm performance.

Hobday (1995) proposes an OEM-ODM-OBM migration strategy and suggest that the latecomer suppliers should firstly begin to develop process capabilities, followed by product design capabilities, and finally new product/branding capabilities. Berger and Diez (2006) suggest that OBM firms compared with ODM firms, display higher innovation activities. Gatignon et al. (1990) and Mudambi et al. (1997) suggest that a firm will evaluate its sufficiency of resources and then decide whether to employ OBM. Weerawardena, O'Cass and Julian (2006) suggest that firms operating within a competitive industry tend to pursue innovative ways of implementing activities of the value chain, derived through establishing distinctive learning capabilities and that innovation improves a brand' s performance. Consequently, we summarize hypothesis as follows.

H1：The value-added effect to operating performance of the R&D investment by a high-tech firm will be influenced by its business type. The relevance of R&D investment and operating performance will increase gradually comparing ODM/OEM to OBM.

Sher and Yang (2005) use Taiwanese semiconductor industry as sample, and examine whether firms at various stages along the value chain show different innovative capabilities (i.e., R&D intensity). Sher and Yang (2005) suggest that the relationship between innovative capability and firm profitability is contingent upon the value-added stage of manufacturing process. There exists a significant positive relationship between R&D intensity and IC designing firm performance. There is a positive relationship between R&D manpower and firm performance for both IC manufacturing (foundary) and IC packaging and testing firms. Chin et al. (2006)

suggest that the stage of the firm in the industry value chain influences the association between patent citations on Tobin's Q. The relationship is largest for those firms in IC design stage followed by IC manufacturing stage and IC packaging and testing stage. Consequently, we summarize hypotheses as follows.

H2：The value-added effect to operating performance of the R&D investment by a high-tech firm will be influenced by the interaction between its business type and value chain stage.

H3：For high-tech firms at the same stage of their value chains, comparing with ODM/OEM business type firms, OBM firms will have better operating performance through their R&D activities.

4. Research design

4.1 Research period and sample selection criteria

According to the survey by MIC, the computer hardware sector accounts for around 90% of the total shipment value of Taiwan's electronic industry (Information Industry Yearbook, 2006). In this study, we use listed computer hardware companies as our research sample. We collect these high-tech companies' five-year (2001-2005) historical annual data, which are available from the TEJ (Taiwan Economics Journal) database. The following criteria are used to select the research sample: (1) Firms have a December fiscal year-end for all sample periods. (2) Firms in the semiconductor industry are excluded because IC design houses are mostly OBM manufacturers while IC foundries or IC testing companies mostly conduct ODM/OEM. Firms in the networking communication equipments industry are excluded because the nature of the industry differs greatly from that of other computer hardware industries. (3) There must be no less than three firm-years observations for the empirical variables. The selection process produces 18 sub-industry groups (i.e., notebook PC, case, PCB, etc.), 214 companies, and 946 firm-years observations.

4.2 Criteria to judge a firm's business type

The paper divides the sample into the OBM type sub-sample and the ODM/OEM type sub-sample:

1. We judge a firm's business type by referring to related studies provided by MIC. For example, a report named "The state of play and trend analysis of the mobile devices industry in East Asia" provides detailed description about the business types of Taiwanese mobile phone corporations (MIC, 2004).
2. We judge a firm's business type by the business items shown in its home pages.
3. We judge a firm's business type by related news provided by Taiwan Securities & Futures Institute.
4. We judge a firm's business type year by year according to its annual reports. (1) If the sample firms explicitly indicate that they adopt ODM/OEM in the annual reports, we then classify such firms into ODM/OEM sub-sample. (2) If the sample firms explicitly indicate that they employ OBM, or do not mention any subcontracting activities in their annual reports, we then classify such firms into OBM sub-sample. (3) For firms that manufacture diverse products, we decide their business type by the manufacturing mode of their major products (i.e., products with highest revenue contribution). If the sample firms explicitly state that their main product is an ODM/OEM business, we then classify such firms into ODM/OEM sub-sample. If the sample firms explicitly state that their main product is an OBM business, we then classify such firms into OBM sub-sample. (4) If the sample firms indicate that OBM and ODM/OEM make equal

contribution in the annual reports, in our main empirical analysis, we classify such firms into OBM sub-sample. Furthermore, given that ODM/OEM companies tend to sell their products to only a few outside customers (i.e., outsourcing clients), we use their major clients' revenue contribution (excluding sales to related parties) as a reference to check the validity of our classification.

We use the above criteria to thoroughly check the sample, and divide 214 sample firms into OBM type sub-sample with 461 firm-year observations and ODM/OEM sub-sample with 485 firm-year observations.

4.3 Empirical model and variables definition

4.3.1 Empirical model derivation

Following Lev and Sougiannis (1996; 1999), we establish eq. (1) to identify the effect of R&D capital on accounting earnings by a production function.

$$OI_{it} = F(TA_{it}, IA_{it}) \tag{1}$$

where OI_{it} is the operating income of firm *i* in year *t*. TA_{it} is the tangible asset of firm *i* in year *t* and IA_{it} is the intangible asset of firm *i* in year *t*. The R&D capital is included in the intangible assets. Eq. (1) shows that both tangible and intangible assets can contribute to a firm's accounting earnings. While both operating income and tangible assets (at historical costs) are reported in financial statements, the value of intangible assets (i.e., R&D capital) is not reported under GAAP and needs to be estimated. We single out the R&D capital from the intangible assets and define RDC_{it} as the sum of all unamortized historical R&D expenditures:

$$RDC_{it} = \sum_{k}^{N} \alpha_{ik} RD_{it-k} \tag{2}$$

where α_{ik} is the contribution of per dollar R&D expenditure in year *t-k*

(k=0,1,…,N) to the subsequent operating income. R&D expenditures are expected to contribute to the current and future operating income, and in turn, to accounting earnings. Substituting eq. (2) into eq. (1) gives eq. (3) as shown below.

$$OI_{it} = F\left(TA_{it}, \sum_{k}^{N} \alpha_{ik} RD_{it-k}, OIA_{it} \right) \tag{3}$$

where OIA_{it} are other intangible assets excluding R&D capital. The estimated equation, scaled by total sales to avoid heteroscedasticity, as shown in eq. (4) is our empirical model.

$$\frac{OI_{it}}{S_{it}} = \alpha_0 + \alpha_1 \frac{TA_{it-1}}{S_{it}} + \alpha_2 \frac{SA_{it-1}}{S_{it}} + \sum_{k=0}^{N} \alpha_{3k} \frac{RD_{it-k}}{S_{it}} + \varepsilon_{it} \tag{4}$$

OI_{it} : annual operating income, before depreciation, R&D expenses, and selling, general & administrative expenses, of firm i in year t.

S_{it} : firm i annual sales revenue in year t.

TA_{it-1} : firm i total assets at the beginning of the year t.

SA_{it-1} : firm i selling, general & administrative expenses at the beginning of the year t.

RD_{it-k} : firm i R&D expenses at year t. The Index k is a lag operator ranging from zero to some value N that is determined by our estimation process.

ε_{it} : disturbance term.

To mitigate the problem of omitted variables, Lev and Sougiannis (1996) introduce advertising expenses as another variable of intangible asset into their empirical model. The effect of advertising expenses on subsequent accounting earnings is often short-lived (typically one to two years only), compared with that of the R&D expenditure (Hall, 1993). Therefore, Lev and Sougiannis (1996) replace the lag structure of advertising capital with (single) current advertising expenditure (i.e., advertising intensity).

Cooper (1994) suggests that marketing strategy plays a central role in bringing technology resulted from R&D activities to the market. Lin et al. (2006) indicate that commercialization orientation is a firm's tendency to contribute efforts and resources to bring its technological capabilities and R&D results to the market. Wuyts, Stremersch, and Dutta (2004) use selling, general & administrative (hereafter SG&A) expenses to proxy a firm's effort in the commercialization of their technology assets.

However, about 35% of our sample firms do not make any provision for product promotion, and thus, their advertising expense is zero. In contrast, only around 0.8% of the sample firms register zero expense in the SG&A item. In our main analysis, we replace the advertising expenses with the SG&A expenses to mitigate the problem of omitted variables and to gain a better insight to the issue. We also use current SG&A expenses to replace the lag structure of SG&A expenditures.

Since annual R&D expenses (R&D intensity) for most firms are relatively stable over time, a multicolinearity problem may be suffered in the estimation of the R&D lag structure, $\sum_{k=0}^{N} \alpha_{3k} \frac{RD_{it-k}}{S_{it}}$, in eq. (4). We use the Almon lag procedure (1965) to solve the question. The implementation procedure we use to determine the coefficients (i.e., α_{3k}) is described in Appendix 1.

4.3.2 Variables definition

Operating income

Similar to Lev and Sougiannis (1996), the operating income of firm *i* at year *t* is measured as reported operating income before depreciation expenses, R&D

expenses, and SG&A expenses. Depreciation expenses, R&D expenses, and SG&A expenses are excluded from (added back to) operating income since those items represent largely ad hoc write-offs of the independent variables in eq. (4)- tangible and intangible assets.

Firm value chain stage

We decide a firm's value chain stage according to the survey by MIC and Jen et al. (2006):

1. We classify a firm into the upstream stage of value chain of electronic industry if a firm belongs to the following sub-industries: (1) DRAM, (2) Passive components, (3) ODD (CD-ROM), (4) Connector, (5) LED, and (6) PCB.
2. We classify a firm into the midstream stage of value chain if a firm belongs to the following sub-industries: (1) Power supply, (2) Motherboard, (3) Case, (4) Computer peripheral, (5) Monitor, and (6) LCD.
3. We classify a firm into the downstream stage of value chain if a firm belongs to the following sub-industries: (1) Desktop PC, (2) Notebook PC, (3) Mobile phone, (4) DSC (digital still camera), (5) PDA, and (6) Consumer electronics.

Furthermore, the paper employs the ordinary least squares (OLS) method to estimate and uses the method of White (1980) to compute the *t* values to account for heteroskedasticity.

5. Empirical results analysis

5.1 Descriptive statistics

Table 1 presents descriptive statistics of variables in empirical research. Pearson correlation coefficients between key variables to be used in the regression analysis are shown in Table 2. From table 1, the mean values of operating income (i.e., $\frac{OI_{it}}{S_{it}}$) over all firms, OBM sub-sample, and ODM/OEM sub-sample are 13.43%, 15.07%, and 11.86%, respectively. The operating income of OBM firms, on average, is higher than that of ODM/OEM firms. The mean values of current year R&D intensity (i.e., $\frac{RD_{it-0}}{S_{it}}$) over all firms, OBM sub-sample, and ODM/OEM sub-sample are 3.57%, 4.11%, and 3.05%, respectively. The current year R&D intensity of OBM firms, on average, is higher than that of ODM/OEM firms. In addition, the R&D expenditures of OBM firms over the sample period, on average, are higher than those of ODM/OEM firms.

Insert Table 1

Insert Table 2

5.2 The effects of R&D expenditures on the performance of OBM and ODM/OEM firms

Table 3 shows the effects of R&D expenditures on the performance of OBM and ODM/OEM firms. From table 3, 1% of R&D expenditure, on average, will contribute to 0.6471% of total operating performance for all sample firms. The average duration of R&D benefits is two years (excluded the current year). There exists a negative (but insignificant) relationship between the current year R&D intensity and current year operating performance.

For the OBM group, 1% of annual R&D expenditure will create -0.4344% of significant operating performance in the same year, but will produce 0.6193%, 0.8784%, and 0.3428% of significant operating performance in the following three years respectively. In average, 1% of R&D expenditure will contribute to 1.406% of total operating performance for the OBM group and the effect will last for approximately four consecutive years. In terms for the ODM/OEM group, 1% of annual R&D expenditure will result in -0.1827% of operating performance (insignificant) in the same year and deliver around 0.0926% of total operating performance. In addition, the R&D investment does not present significantly lagged effect on this group. Consequently, the empirical results support the hypothesis H1.

We provide an explanation on the relatively insignificant impact of R&D on the ODM/OEM group. In order to obtain steady ODM/OEM orders from leading global companies, ODM/OEM manufacturers also devote to continuous R&D activities to meet the requirements of its clients. However, these R&D activities are considered a relationship-specific investment. That is to say, the investment will become futile once customers terminate their orders or change their ODM/OEM products, leading to humongous losses for the ODM/OEM manufacturers.

Insert Table 3

5.3 The effects of R&D expenditures on the performance of OBM and ODM/OEM firms of different industry value chain stages

Table 4 demonstrates the impact of R&D expenditures on the performance of OBM and ODM/OEM firms at different industry value chain stage. For OBM firms, R&D expenditure presents the most significant benefit at the midstream stage of value chain, followed by downstream stage, and then upstream stage. As for ODM/OEM companies, R&D expenditures generate the most and least significant results at the downstream stage and upstream stage respectively. For example, for the same OBM group, 1% of R&D expenditure, on average, will contribute to 0.6348%, 3.2399%, and 1.158% of total operating performance for upstream, midstream and downstream stages, respectively. In contrast, for the same ODM/OEM group, 1% of R&D expenditure, on average, will contribute to -0.3622%, 1.9572%, and 2.082% of total operating performance for upstream, midstream and downstream stages. Therefore, we conclude that due to the firms' fundamental differences, R&D activities will lead to different results for OBM firms and ODM/OEM companies. The path that R&D investments can contribute for the performance of OBM firms at various industry value chain stages is quite different from that of ODM/OEM firms. Based on the above findings, our empirical results support the hypothesis H2.

According to table 4, for firms in the upstream stage of value chain, 1% of R&D expenditure, on average, will produce 0.6348% of total operating performance for the OBM group and -0.3622% of total performance for the ODM/OEM group. For firms in the midstream stage of value chain, 1% of R&D expenditure, on average, will contribute to 3.2399% of total operating performance for the OBM group and the effect will continue for two years (excluded the current year). In contrast, 1% of R&D investment, on average, will contribute to 1.9572% of total performance for the ODM/OEM group and the effect will be temporary. For firms in the downstream stage of value chain, 1% of R&D expenditure, on average, will contribute to 1.158% of total operating performance for the OBM group and the effect will continue for two years (excluded the current year and next year). However, 1% of R&D expenditure, on average, will contribute to 2.082% of total performance for the ODM/OEM group and the effect will last for two years. In summary, R&D expenditures, on average, generate more significant benefits for OBM companies compared with the ODM/OEM firms at the same value chain stage. Based on the above findings, our empirical results partly support the hypothesis H3.

Insert Table 4

5.4 Sensitivity analysis- the effects of different classified way on the empirical results

To examine the influence of different classified way on the empirical results, we reclassify sample firms into three groups: the firms operating business with "pure" OBM type, the firms operating business with "pure" ODM/OEM type, and the firms operating business with hybrid type (i.e., OBM/ODM).

Table 5 shows the result of the stricter classified way of sample firms. The total benefits that R&D expenditures can contribute for "pure" OBM firms, on average, are higher than those for "pure" ODM/OEM firms. Therefore, our results are robust with respect to alternatively classified ways.

Insert Table 5

6. Conclusions

This paper is based on the concept of core competence to explore the interrelationship of business type, value chain stage and R&D performance. One main and interesting finding in this paper is that firm's business type will influence the value-added effect to operating performance of the R&D investment by a high-tech firm. The linkage between R&D investment and operating performance will increase gradually comparing ODM/OEM to OBM. Another interesting finding is that the value-added effect to operating performance of the R&D investment by a high-tech firm will be influenced by the interaction between its business type and value chain stage. Specifically, the path that R&D investments can contribute for the performance of OBM firms at various industry value chain stages is quite different from that of ODM/OEM firms. R&D expenditures, on average, generate more significant benefits for OBM companies compared with the ODM/OEM firms at the same industry value chain stage.

Appendix

The primary objective in the estimation of the distributed lags is to derive efficient estimates of the total effect of R&D expenditures on operating income. In view of data availability and actual estimation process, we thus use a four-year period (current year plus three preceding years) in all sample firms.

A breakdown of eq. (4) over the four years is as follows:

$$\frac{OI_{it}}{S_{it}} = \alpha_0 + \alpha_1 \frac{TA_{it-1}}{S_{it}} + \alpha_2 \frac{SA_{it-1}}{S_{it}} + \alpha_{30} \frac{RD_{it-0}}{S_{it}} + \alpha_{31} \frac{RD_{it-1}}{S_{it}} + \alpha_{32} \frac{RD_{it-2}}{S_{it}} + \alpha_{33} \frac{RD_{it-3}}{S_{it}} + \varepsilon_{it} \quad \text{(A1)}$$

The Almon lag method assumes that the lagged coefficients of the model (i.e., α_{3k}) follow a polynomial in k (k=3 in our model). Therefore, for a polynomial of degree two (with a second-order type):

$$\alpha_{3k} = a + bk + ck^2 \quad \text{(A2)}$$

This can be broken down as follows:

$$\alpha_{30} = a + b0 + c0^2 = a$$
$$\alpha_{31} = a + b1 + c1^2 = a + b + c$$
$$\alpha_{32} = a + b2 + c2^2 = a + 2b + 4c$$
$$\alpha_{33} = a + b3 + a3^2 = a + 3b + 9c$$

Each α_{3k} coefficient is then replaced by the corresponding polynomial equation.

$$\frac{OI_{it}}{S_{it}} = \alpha_0 + \alpha_1 \frac{TA_{it-1}}{S_{it}} + \alpha_2 \frac{SA_{it-1}}{S_{it}} + a \frac{RD_{it-0}}{S_{it}} + (a+b+c) \frac{RD_{it-1}}{S_{it}} + (a+2b+4c) \frac{RD_{it-2}}{S_{it}} + (a+3b+9c) \frac{RD_{it-3}}{S_{it}} + \varepsilon_{it} \quad \text{(A3)}$$

The lagged part of eq. (A3) can be expresses as follows:

$$\sum_{k=0}^{3}\alpha_{3k}\frac{RD_{it-k}}{S_{it}} = \sum_{k=0}^{3}(a + bk + ck^2)\frac{RD_{it-k}}{S_{it}} = aW_{ot} + bW_{1t} + cW_{2t}$$

where, $W_{ot} = \sum_{k=0}^{3}\frac{RD_{it-k}}{S_{it}}$, $W_{1t} = \sum_{k=0}^{3}k\frac{RD_{it-k}}{S_{it}}$, $W_{2t} = \sum_{k=0}^{3}k^2\frac{RD_{it-k}}{S_{it}}$.

We can rewrite eq. (4) as follows:

$$\frac{OI_{it}}{S_{it}} = \alpha_0 + \alpha_1\frac{TA_{it-1}}{S_{it}} + \alpha_2\frac{SA_{it-1}}{S_{it}} + aW_{ot} + bW_{1t} + cW_{2t} + \varepsilon_{it} \qquad \text{(A4)}$$

This transformation allows us to replace the four highly correlated variables with three explanatory variables (W_0, W_1, W_2), which are much less correlated. Thus three R&D coefficients are estimated: *a*, *b*, and *c*. An regression by OLS estimation procedure is applied to eq. (A4) to determine coefficients *a*, *b*, and *c*. We can thus obtain the coefficients of eq. (4), α_{30}, α_{31}, α_{32}, α_{33}. In addition, eq. (A4) allows the derivation of the variance-covariance matrix of α_{30}, α_{31}, α_{32}, α_{33} from the variance-covariance matrix of *a*, *b*, and *c*. We can thus compute each *t* value of α_{30}, α_{31}, α_{32}, α_{33}, and make statistics inference.

An advantage of the Almon method over other distributed lag methods is that it allows various shapes of the lag distribution of α_{3k}, depending on the polynomial fitted. Thus a polynomial of degree one results in a monotonically increasing or decreasing distribution of α_{3k}, and a polynomial of degree two results in an increasing then decreasing distribution of α_{3k}.

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Table 1 Descriptive statistics

Variable	Mean	Std. Dev.	Max.	Min.	Variable	Mean	Std. Dev.	Max.	Min.
$\frac{OI_{it}}{S_{it}}$ (A)	0.1343	0.1224	0.6425	-0.7674	$\frac{RD_{it}}{S_{it}}$ (D)	0.0305	0.0417	0.5459	0
$\frac{OI_{it}}{S_{it}}$ (B)	0.1507	0.1196	0.568	-0.1904	$\frac{RD_{it-1}}{S_{it}}$ (A)	0.0344	0.0405	0.5459	0
$\frac{OI_{it}}{S_{it}}$ (D)	0.1186	0.1231	0.6425	-0.7674	$\frac{RD_{it-1}}{S_{it}}$ (B)	0.0391	0.0393	0.3202	0
$\frac{TA_{it-1}}{S_{it}}$ (A)	1.3642	1.0207	8.2945	0.1565	$\frac{RD_{it-1}}{S_{it}}$ (D)	0.03	0.0412	0.5459	0
$\frac{TA_{it-1}}{S_{it}}$ (B)	1.5185	1.0775	7.5017	0.2303	$\frac{RD_{it-2}}{S_{it}}$ (A)	0.0347	0.0413	0.5459	0
$\frac{TA_{it-1}}{S_{it}}$ (D)	1.2167	0.9409	8.2945	0.1565	$\frac{RD_{it-2}}{S_{it}}$ (B)	0.0391	0.0388	0.3202	0
$\frac{SA_{it-1}}{S_{it}}$ (A)	0.0377	0.0324	0.5161	0	$\frac{RD_{it-2}}{S_{it}}$ (D)	0.0305	0.0432	0.5459	0
$\frac{SA_{it-1}}{S_{it}}$ (B)	0.044	0.0396	0.5161	0.006	$\frac{RD_{it-3}}{S_{it}}$ (A)	0.0374	0.0544	0.6106	0
$\frac{SA_{it-1}}{S_{it}}$ (D)	0.0316	0.022	0.2012	0	$\frac{RD_{it-3}}{S_{it}}$ (B)	0.0394	0.0472	0.6106	0
$\frac{RD_{it}}{S_{it}}$ (A)	0.0357	0.0446	0.571	0	$\frac{RD_{it-3}}{S_{it}}$ (D)	0.0355	0.0605	0.5725	0
$\frac{RD_{it}}{S_{it}}$ (B)	0.0411	0.0468	0.571	0					

Note:

1. A, B and D represent all sample, OBM sub-sample, OEM sub-sample, respectively.

Table 2 Pearson correlation coefficients

	$\frac{OI_{it}}{S_{it}}$	$\frac{TA_{it-1}}{S_{it}}$	$\frac{SA_{it-1}}{S_{it}}$	$\frac{RD_{it}}{S_{it}}$	$\frac{RD_{it-1}}{S_{it}}$	$\frac{RD_{it-2}}{S_{it}}$	$\frac{RD_{it-3}}{S_{it}}$
$\frac{OI_{it}}{S_{it}}$	1						
$\frac{TA_{it-1}}{S_{it}}$	-0.117***	1					
$\frac{SA_{it-1}}{S_{it}}$	0.311***	0.179***	1				
$\frac{RD_{it}}{S_{it}}$	0.137***	0.357***	0.265***	1			
$\frac{RD_{it-1}}{S_{it}}$	0.214***	0.241***	0.233***	0.808***	1		
$\frac{RD_{it-2}}{S_{it}}$	0.229***	0.151***	0.171***	0.6***	0.77***	1	
$\frac{RD_{it-3}}{S_{it}}$	0.163***	0.077**	0.073**	0.404***	0.463***	0.687***	1

Note:

1. Asterisks indicate significance at the 1% (***), 5% (**), and 10% (*) levels in a two-tail test.

Table 3 The effects of R&D expenditures on the performance of OBM and ODM/OEM firms

Model: $\frac{OI_{it}}{S_{it}} = \alpha_0 + \alpha_1 \frac{TA_{it-1}}{S_{it}} + \alpha_2 \frac{SA_{it-1}}{S_{it}} + \sum_{k=0}^{N} \alpha_{3k} \frac{RD_{it-k}}{S_{it}} + \varepsilon_{it}$										
	Regression coefficients								Adj-R^2	F Value
	α_0	α_1	α_2	α_{30}	α_{31}	α_{32}	α_{33}	$\sum_{k=0}^{3} \alpha_{3k}$		
All Sample	0.1012*** (7.989)	-0.0243*** (-2.967)	1.1713*** (3.809)	-0.1803 (-0.472)	0.3838** (2.141)	0.4438# (1.6)	-0.0002 (-0.621)	0.6471	0.1696	39.6***
OBM N=461	0.0826*** (7.473)	-0.0104* (-1.72)	0.6766*** (2.635)	-0.4344# (-1.558)	0.6193*** (2.745)	0.8784*** (3.509)	0.3428# (1.539)	1.406	0.274	35.72***
ODM/ OEM N=485	0.103*** (6.306)	-0.0392** (-2.487)	1.9164*** (5.725)	-0.1827 (-0.426)	0.1071 (0.723)	0.168 (0.734)	0.0002 (0.628)	0.0926	0.1949	24.43***

Note:

1. Numbers in ( ) are t value through revision of White (1980). Asterisks indicate significance at the 1% (***), 5% (**), and 10% (*) levels in a two-tail test. # indicates statistically significance at the 15% level (two-tailed).
2. The regression coefficients of R&D expenditures (i.e., α_{30}) have transformed by the Almon lag procedure.

Table 4 The effects of R&D expenditures on the performance of OBM and ODM/OEM firms of different value chain stages

Model: $\frac{OI_{it}}{S_{it}} = \alpha_0 + \alpha_1 \frac{TA_{it-1}}{S_{it}} + \alpha_2 \frac{SA_{it-1}}{S_{it}} + \sum_{k=0}^{N} \alpha_{3k} \frac{RD_{it-k}}{S_{it}} + \varepsilon_{it}$

Business Type	**Value chain Stage**	**Regression coefficients**							Adj-R^2	F Value
		α_1	α_2	α_{30}	α_{31}	α_{32}	α_{33}	$\sum_{k=0}^{3}\alpha_{3k}$		
OBM	Up N=172	-0.004 (-0.514)	0.0733 (0.568)	-0.1725 (-0.56)	-0.0619 (-0.275)	0.214 (0.833)	0.6552** (2.44)	0.6348	0.0469	2.68**
	Middle N=186	-0.0268*** (-2.661)	0.4733** (1.967)	0.5029 (0.633)	1.3516*** (5.841)	1.2343*** (2.725)	0.1511 (1.257)	3.2399	0.5542	47***
	Down N=103	-0.0255# (-1.633)	1.203*** (3.873)	-0.4541 (-0.688)	0.3253 (0.994)	0.6792* (1.691)	0.6077* (1.701)	1.158	0.4138	15.4***
ODM/ OEM	Up N=229	-0.0535** (-2.271)	1.3504*** (3.655)	-0.4128 (-1.181)	-0.0445 (-0.346)	0.0936 (0.496)	0.0016 (0.57)	-0.3622	0.3055	21.06***
	Middle N=165	-0.0868*** (-3.163)	0.9037** (1.995)	1.7964*** (2.631)	0.3031 (0.824)	-0.2573 (-0.518)	0.115 (0.488)	1.9572	0.4678	29.83***
	Down N=91	-0.0347*** (2.813)	0.1672 (0.298)	0.9726* (1.888)	0.717*** (3.917)	0.3927 (1.349)	-0.0002 (-0.648)	2.082	0.3414	10.33***

Note:

1. Numbers in ( ) are t value through revision of White (1980). Asterisks indicate significance at the 1% (***), 5% (**), and 10% (*) levels in a two-tail test. # indicates statistically significance at the 15% level (two-tailed).
2. The regression coefficients of R&D expenditures (i.e., α_{30}) have transformed by the Almon lag procedure.

Table 5 The effects of R&D expenditures on the performance of OBM and ODM/OEM firms- strictly classified way of sample firm

Model: $\frac{OI_{it}}{S_{it}} = \alpha_0 + \alpha_1 \frac{TA_{it-1}}{S_{it}} + \alpha_2 \frac{SA_{it-1}}{S_{it}} + \sum_{k=0}^{N} \alpha_{3k} \frac{RD_{it-k}}{S_{it}} + \varepsilon_{it}$										
	Regression coefficients								Adj-R^2	F Value
	α_0	α_1	α_2	α_{30}	α_{31}	α_{32}	α_{33}	$\sum_{k=0}^{3}\alpha_{3k}$		
Hybrid Sample N=118	0.0667*** (4.294)	-0.0218# (-1.466)	1.3731*** (3.029)	-0.5065 (-1.005)	0.3111 (1.25)	0.6801** (2.034)	0.6005*** (2.713)	1.0852	0.1928	6.59***
P-OBM N=190	0.0723*** (3.422)	-0.0105 (-1.319)	0.7724* (1.942)	-1.0162*** (-2.975)	1.1414*** (4.128)	1.5192*** (4.162)	0.1172 (0.871)	1.7616	0.2388	12.86***
P-ODM/ OEM N=638	0.1076*** (6.765)	-0.0293*** (-2.604)	1.296*** (3.141)	-0.1073 (-0.208)	0.2532 (1.406)	0.289 (0.988)	0.0000 (-0.144)	0.4349	0.185	29.93***

Note:

1. Numbers in ( ) are t value through revision of White (1980). Asterisks indicate significance at the 1% (***), 5% (**), and 10% (*) levels in a two-tail test.
2. P-OBM includes the firms operating business with "pure" OBM type. P-ODM/OEM includes the firms operating business with "pure" ODM/OEM type. The remaining sample firms (e.g., OBM/ODM) are included in Hybrid Sample.
3. The regression coefficients of R&D expenditures (i.e., α_{30}) have transformed by the Almon lag procedure.