Application of Vertical Disintegration Theory in R&D Effect on Firm Value in Semiconductor Industry

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Abstract--**This paper focuses on the Taiwan integrated circuit (IC) industry because the global market shares of Taiwan IC manufacturing industries are ranked number one. The purposes of study are to compare the differences in the effect of innovation activities on the market value among the IC design, manufacturing, packaging and testing industries and to evaluate whether the tax shields can increase firm value.**

The results statistically indicate that R&D significantly enhance market values in IC design firms, while does not in IC manufacturing firms, indicating IC firm's R&D has a significant impact on the market value in IC design firms. In addition, this investigation concludes that the coefficient of tax shield is insignificant. Finally, the coefficient of book value (equity) in the regression equation is larger than one. The results are consistent with the conservatism principle in the accounting field. Furthermore, we find that the marginal impact of R&D on market values in IC design industries is larger than those in IC manufacturing industries. Under the vertical disintegration structure of Taiwan IC industry, each step of IC manufacturing, packaging and testing stages is fixed with standardized machinery and equipments, so these IC manufacturing stages do not rely on R&D as much as IC design stage does.

I. INTRODUCTION

Although previous literature has explored the relations between innovation and firm value, these studies ignore the differential innovative effect on firm value under the vertical disintegration framework. According to industrial organization theory, vertical disintegration means subdividing an industry into several levels along the value chain, and letting the firms at each level focus on their own specialization. Firms under this structure would produce goods that keep pace with the upstream suppliers and downstream clients or markets. Hence, these enterprises are characterized by reciprocal dependence and mutual support in information sharing, manufacturing, logistics, and innovation.

The framework of Taiwan's IC industry belongs to such vertical disintegration structure. The independent IC firms individually specialize in upstream IC design, midstream IC manufacturing, or in downstream IC packaging and testing sectors. Under the premise that Taiwan's IC design firms ought to respond to their final market trend as soon as possible to satisfy their final market (consumer electronics and PC markets) with their designed products, these IC design firms need to work closely with IC manufacturing foundries to flexibly manufacture versatile products to achieve customers' acceptance. Thus, the reciprocal dependence is profound among upstream IC design and midstream IC manufacturing enterprises. In addition, Taiwan IC packagers and testers continuously provide IC manufacturing firms with reliable turnkey services, illustrating their tight cooperation with each other as well. As we can infer from the above explanations, each sector in Taiwanese IC industry is not only reciprocally dependent, but also mutually supportive to each other. These IC firms' teamwork has enhanced Taiwan to hold the leading position in the worldwide semiconductor industry. The global market shares of Taiwan's foundry IC manufacturing, packaging and testing industries have all been the largest in the world and the global market share of Taiwan's IC design industry has long ranked number two since 2000. These vertically collaborative relationships exclusively seen in Taiwanese semiconductor industry is distinctly different from the integrated device manufacturer (IDM) structure in U.S., Japanese and Korean IC industries [2], [7].

Under this vertical integration structure, all firms in different production stages, including upstream IC design, midstream IC manufacturing and downstream IC packaging and testing firms can provide us with public financial statements of each stage. Specifically, since each step of IC manufacturing, packaging and testing stages is fixed with standardized machinery and equipments, the innovative activity of IC manufacturing or IC packaging and testing industries focus on "process innovation". On the contrary, IC design firms are structured differently according to the applications of final electronic products, the R&D activities of IC design firms are dedicated to "product innovation". It is worthwhile to explore the difference in the effect of innovation and innovative spillover effect on firm value along the industrial value chain.

Because of technological intensity in product innovation for IC design industry, the number of patent is likely to be greater for IC design houses. In addition, firms with the capability of technology innovation contain valuable resources that are easy to absorb knowledge from patents held by other inventors, so they are potential to keep the leading positions in the competitive technology industries [9]. Since Schumpeter [6] and Reinganum [5] even proposed that firms with great innovations in a product market were presumably better off exploiting updated technology, stronger innovative ability accelerate IC design industries to absorb knowledge of other patent. It is inferred that the marginal benefit of an innovation spillover effect (an additional increment to the firm value) is likely to be more valuable to IC design firms.

Particularly, according to USPTO statistics based on 1985 to 1999 data, the annual patent citation frequency of IC design firms is 6.68 on average, which is much higher than that of IC packaging and testing firms (3.77) and that of IC manufacturing firms (3.4). As such, IC design firms, which rely heavily on product innovation, have little similarities in production processes and more difficulty in process imitation from other intra-industry firms. Hence, the spillover effects are expected to be stronger for IC design firms which are mainly involve in product innovation than in IC manufacturing, and packaging and testing firms. This paper investigates the difference in the R&D spillover effect in product and process innovation.

Most of Taiwan firms are located in Hsinchu Science-based Industrial Park (HSIP), industrial clustering speeds up knowledge flows within the clustered enterprises, government, academies and institutions [1], [9]. It is critical to highlight the contrast in spillover effect for Taiwan IC firms. The aims and objectives of this paper are to effectively discuss the degrees to which innovation or innovation spillover effect increases firm value among IC industrial value chain. The study will assess the patent and R&D effect on firm value. This work compares the innovation effect on firm value between firms which have tax rewards and those without tax rewards. The contribution of this paper is to incorporate industrial structure in exploring the spillover effect on firm evaluations.

Background

According to the statement in [10] and [11], Taiwan's IC Industry is concentrated surrounding Hsinchu Science Industrial Park where numerous producers are interconnected and interdependent in production, marketing, operation, logistics and technology diffusion. Due to clustering theory, agglomeration of Taiwan's IC industry creates a pooled platform for workers with specialized skills to exchange experiences and share information. The modulation, coordination and integration of these neighboring IC firms allow Taiwan's IC industry to efficiently handle abrupt crises, continuously upgrade technological levels and flexibly develop new products.

Specifically, the framework of Taiwan's IC industry belongs to vertical disintegration structure. The independent IC firms separately specialize in upstream IC design, midstream IC manufacturing, or downstream IC packaging-and-testing sectors. Under the premise that Taiwan's IC design firms ought to respond to their market demand as soon as possible to satisfy their final market (consumer electronics and PC markets) with their designed products, these IC design firms need to work closely with IC manufacturing foundries to flexibly manufacture versatile products to achieve customers' acceptance. Thus, the reciprocal dependence is manifest among upstream IC design and midstream IC manufacturing enterprises. In addition, Taiwan IC packagers and testers continuously provide IC manufacturing firms with reliable turnkey services, strengthening their tight cooperation with each other as well. As we can see from the above explanations, each sector along Taiwanese IC industry production is not only reciprocally dependent, but also mutually supportive to each other. These IC firms' team works have enhanced Taiwan to hold the leading position in the worldwide semiconductor industry.

II. DATA AND SAMPLE

This paper focuses on IC technology, which is generally considered to be an excellent example of a growing and innovative industry. We choose firms which are classified as Taiwan IC industry to investigate the effect of core technology on IC market share and firm values. This paper applies firm level data including market share, financial and innovative variables to explain firm value for our sample firms. For financial variables, we obtain firm value, book value, earnings, tax rate, R&D spending, sales revenue and risk-free interest rate for each Taiwan firm from TEJ database.

III. METHODOLOGY

A. R&D impact difference on firm value along IC value chain

In this section, we use R&D as the innovative ability proxy. To investigate the innovative impact on firm value under the vertical disintegration framework, we further divide the IC firms into several groups along the production value chain. We model patent indicator in Ohlson model [4], [8]. Our model can be written as:

$$P_{i,t} = a + \beta_0 bv_{i,t} + \beta_1[X^B_{i,t}(1-\tau_{i,t}) - rbv_{i,t-1} - RD_{i,t}] + \beta_2[RD_{i,t}\tau_{i,t}] + \beta_3 R_{it} + e_{i,t} \quad (1)$$

$$P_{i,t} = a + \beta_0 bv_{i,t} + \beta_1[X^B_{i,t}(1-\tau_{i,t}) - rbv_{i,t-1} - RD_{i,t}] + \beta_2[RD_{i,t}\tau_{i,t}] + \beta_3 SR_{it} + e_{i,t} \quad (2)$$

where Pi,t, bvi,t, RDi,t, and SRi,t, are marekt value, book value of equity, R&D expenditure and R&D spillover from other companies within the same industry. This study follows Cuneo and Mairesse [3] to estimate the R&D stock based on R&D expenditures for current and past two years as Eq. (3):

$$R_{it} = RD_{it} + (1-\delta)RD_{it-1} + (1-\delta)^2 RD_{it-2} \quad (3)$$

Since technological innovation are great for IC firms, the coefficient should be positive, ie. . If this is the case, we would expect innovations to be more highly valued for IC design firms since IC design firms emphasize more on innovation than IC manufacturing, packaging and testing firms. We compare the coefficient of the innovation variable among different industrial sectors along the IC value chain. The sample are categorized into two groups, $\tau it=0$ and $\tau it\neq 0$, depending on whether there is tax rewards. One is the firms which have tax rewards ($\tau it=0$). Otherwise, firms belong to the other group ($\tau it\neq 0$). We employ two groups to run regression. The regression of the group ($\tau it\neq 0$) lacks the variable of tax shields. We examine whether the R&D has a

significant impact on the market value of the company by testing whether β3 equals 0. If β3 is greater than 0, then the innovation and the market value are related positively.

According to clustering theory, when an IC firm develops a pioneering technology, other companies within the same industry will attempt to learn such skill. The novel technological concept will stimulate other companies in the same field to innovate more advanced technology of next generation. Tsai and Chen [10] define this process of learning technological skills from another firm within the same industry as the "intra-industry spillover effect. This study selects the R&D spillover from other companies within the same industry as the spillover effect proxy in Eq. (2) as:

$$SR_{ik} = \sum_{j \neq i} R_{jk}$$

B. Patent impact difference on firm value along IC value chain

In this section, we use patent as the innovative ability proxy. This study runs the regression (3) to ascertain the difference in patent impact on firm value among the product innovation and process innovation group firms, respectively. Investors do not necessarily think that the more the IC firms invest in R&D expenses, the higher the company's market value will rise; in IC industry. R&D should be the company's most important basis for creating new products. The ultimate goal of an IC company's R&D is to develop patents. Patents can guarantee the company, in the future, a few years of exclusivity to any techniques they entail, so a company owning core technology patents has a wider variety of products than other companies do, and in turn, has chances of increasing the company's profits. As a result, investors will give better evaluations to companies with multiple patents. We thus established Eq. (4) to discuss impacts patents have on company market value:

$$P_{i,t} = a + \beta_0 bv_{i,t} + \beta_1[X^B_{i,t}(1-\tau_{i,t}) - rbv_{i,t-1} - RD_{i,t}] + \beta_2[RD_{i,t}\tau_{i,t}] + \beta_4 Pat_{it} + e_{i,t} \quad (4)$$

The coefficient β_4 captures the patent effect on firm value. To compare the patent effect on firm value for the product innovation with that for process innovation, this study applies the t-statistics to examine the significance of the coefficient β_4.

IV. EMPIRICAL RESULTS

A. Impact of R&D on firm value

We list the main empirical results. The first purpose of study is to compare the differences in marginal effect of R&D on the market value between firms with and without tax rewards in the IC design industry (Table 1). We observe the difference between coefficients of patent between firms with and without tax rewards in the IC design industry (Table 2). Research results indicate that the coefficient of R&D is statistically and significantly positive in IC design industry and IC testing industry, while is not in IC manufacturing industry. T-test result indicates that coefficient of book value β_0 is significantly positive, reflecting that investors tend to give companies with high book values better credit. Investors are willing to pay higher stock prices to buy companies with high book values. The results statistically indicate that R&D significantly enhances market values in IC design firms, but R&D does not affect the value of IC manufacturing firms. This indicates that IC design firms mainly engage in product innovation, while IC manufacturing, packing and testing firms mainly focus on process innovation. IC design firms rely more on R&D than IC manufacturing and testing firms to increase their market value. In addition, this investigation concludes that the coefficient of tax shield is insignificant. Investors tend to give better ratings and evaluation to companies with higher excess earnings. Finally, we find the coefficient of equity in the regression equation is larger than one for all the industrial sectors along the IC value chain, suggesting that market value is larger than that of equity book value. The results are consistent with the conservatism principle in the accounting field.

TABLE 1 THE REGRESSION RESULTS OF R&D IMPACT ON FIRM VALUE IN IC DESIGN FIRMS IN 2005 FOR THE FIRMS WHICH HAVE TAX REWARDS AND THE FIRMS WITHOUT TAX REWARDS

$$P_{i,t} = a + \beta_0 bv_{i,t} + \beta_1[X^B_{i,t}(1-\tau_{i,t}) - rbv_{i,t-1} - RD_{i,t}] + \beta_2[RD_{i,t}\tau_{i,t}] + \beta_3 R_{it} + e_{i,t}$$

		$\tau_{it}=0$		$\tau_{it}\neq 0$	
		N=16		N=34	
		Coefficient	T-value	Coefficient	T-value
Intercept		410,992	0.65771	-1,397,671	-1.65948
bv_{it}	β_0	10.81495	3.899811***	34.0753	30.58461***
$X_{it}^B(1-\tau_{it})-r_t bv_{it}-RD_{it}$	β_1	4.489975	2.632687***	16.4113	28.50841***
$RD_{it}\tau_{it}$	β_2	-	-	23.2534	0.69643
R_{it}	β_3	2.690101	1.896115	4.7443	5.341638
R^2		0.96293		0.996767	
Adjusted R^2		0.95366		0.996321	

Notes: * p<0.1; ** p<0.05; *** p<0.01
N=observation number

From the analysis results of Eqs. (1) and (2), the spillover coefficient of IC manufacturing industry and IC packaging and testing industry are negative, indicating that the spillover of R&D has a negative impact on the market value of the company. Only the spillover coefficient of IC packaging and testing industry is significant, indicating that the negative effect of R&D spillover on market value is more significant in the IC packaging and testing industry than in other IC industries. The implication of the negative relationship between R&D spillover and the market value in the IC packaging and testing industry is that IC testing and packaging imitate other firm's skills easily. The free-riders of the R&D spillover will reduce the profit of the technology innovator, hence reducing the willingness to innovate further. Especially for IC testing and packaging firms which focus on process innovation and clustered in Taiwan, the R&D development of other intra-industry firms substantially reduce the innovation and economic values of external firms.

B. Impact of patent development on firm value

We use the granted number of patents as the variable. From the empirical results, the patent effect on firm value is significant for the IC design firms which have tax rewards in 2010 (Table 2), while patent effect on firm value is insignificant for firms which do not have tax rewards (Table 2). The patent development becomes more and more important for market value for firms which have tax rewards. In addition, the coefficient of tax shield is not significant for the firms which do not have tax rewards. These results prove the effectiveness of encouraging innovation of Taiwanese tax regulations. Taiwanese government has provided tax rewards to IC firms whose patent development enhances their market value.

V. CONCLUSIONS

This study focuses on Taiwan firms in IC industry to explore the innovation effects on firm value. The paper chooses patent and R&D as the innovation indicators and empirically explores how R&D and patents effects induce firm's market value. Also, the findings reflect that investors tend to give companies with high book values better credit. For IC design, manufacturing, packaging and testing industries, investors are willing to pay higher stock prices to buy companies with high book values. In addition, investors tend to give better ratings and evaluation to companies with higher excess earnings.

In particularly, the empirical results exhibit negative relations between the innovative spillover effects and firm's value for IC testing and packing firms. These findings do not support that the spillover effect derived from other companies' innovative activities can stimulate a firm's internal process of production innovation, thereby improving its performance. The result is consistent with the criticism that claims industrial clustering and knowledge spillover hinder innovation or firm productivity. Especially for IC testing and packaging firms which focus on process innovation and clustered in Taiwan, the R&D development of other intra-industry firms substantially reduce the innovation and economic values of external firms.

In addition, the analysis results show that the patent development becomes more and more important for market value for firms which have tax rewards. These results prove the effectiveness of encouraging innovation of Taiwanese tax regulations. Taiwanese government has provided tax rewards to IC firms whose patent development enhances their market value.

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TABLE 2 THE REGRESSION RESULTS OF PATENT IMPACT ON FIRM VALUE IN IC DESIGN FIRMS IN 2010 FOR THE FIRMS WHICH HAVE TAX REWARDS AND THE FIRMS WITHOUT TAX REWARDS

		$\tau_{it}=0$		$\tau_{it}\neq0$	
		N=19		N=44	
		Coefficient	T-value	Coefficient	T-value
Intercept		-9,906.83	-0.06233	-1,894,636	-1.37876
bv	β_0	2.027267	1.610371	15.61358	5.434124
$X_{it}^{B}(1-\tau_{it})-r_t bv_{it}-RD_{it}$	β_1	0.329492	0.333785	10.27678	3.901418
$RD_{it}\tau_{it}$	β_2	-	-	-1.10138	-0.10692
Pat_{it}	β_3	14,427.3***	5.764562	-20,071.2	-0.99595
R^2		0.99809		0.99009	
Adjusted R^2		0.99771		0.98907	

Notes: * p<0.1; ** p<0.05; *** p<0.01
N=observation number

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