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開放式商業模式：積體電路產業實證

Open Business Model: An Empirical Study of IC Industry

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摘要：在積體電路 (Integrated Circuit，IC)產業中，同時存在著以整合元件製造商為主體的封閉式的商業模式，以及由虛擬整合廠商組成的開放式商業模式。採行何種商業模式較能使企業獲得較高報酬或承擔較低風險是值得研究的議題。本研究之目的在於檢視IC公司的獲利報酬與其商業模式之間的關係，以在美國NASDAQ 上市之IC公司作為研究標的，蒐集其2000~2007年間的財務數據，並使用 Fama-French三因子模型進行資料分析。研究結果發現，虛擬整合公司的報酬顯著優於垂直整合公司，但承擔的風險亦較高；此外，若考慮景氣循環因素，進一步將資料分為 2000~2003及2004~2007兩期間予以比較，顯示2004年後虛擬整合公司的風險逐步下降，但垂直整合公司的風險卻反而增加。此發現提供了一個有價值的觀點，說明虛擬整合已成為趨勢，在成長的產業中將有更多公司採用開放式的商業模式。本文並運用各產業之案例，闡釋如何運用及一般化本研究之實證結果。

關鍵詞：虛擬整合；垂直整合；積體電路產業；Fama-French三因子模型；開放式商業模式

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Abstract: In the Integrated Circuit (IC) industry, the closed business model which are composed of integrated device manufacturers (IDM) and the open business model which consists of virtual integrated (VI) manufactures are prevalent and both can be well justified. Whether the IDM or the VI model would better position the firms in terms of providing a higher return or less risk in the IC industry remains to be explored. This study aims to examine the relationship between the profitability of IC companies and their business models (IDM versus VI). NASDAQ listed IC companies were selected as research subjects. The data were collected for the period 2000-2007 and analyzed by using the Fama-French three-factor model. The results show that VI companies significantly outperform IDM counterparts; however, they also take higher risks than IDM firms. In addition, a comparison of data between the periods of 2000-2003 and 2004-2007 reveals the risks of IDM firms increased while that of VI firms decreased after 2004. This finding provides a valuable insight that business model of virtual integration has been emerging as a trend and more companies have been adopting open business model in many growing industries. Events within different industries are utilized to generalize the empirical results.

Keywords: Virtual integration; Vertical integration; IC industry; Fama french Three factor model; Open business model

1. Introduction

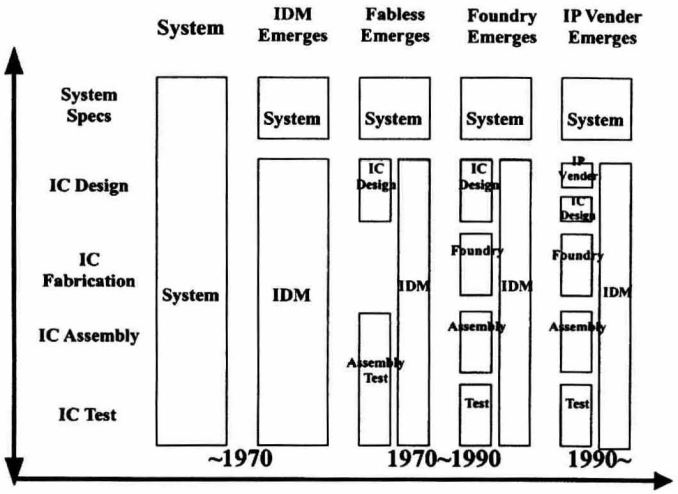
How an industry evolves, has long been of great interest to scholars and managers. For decades, one prominent aspect of industry evolution has been the process of vertical disintegration. Vertical disintegration refers to the emergence of new intermediate markets that divide an integrated production process between two sets of specialized firms in the same industry (Jacobides, 2004). It has been ascertained that the industry life cycle has an impact on the degree of vertical integration of an industry. Stigler (1951) proposed that firms tend to be highly integrated in young industries. As the industry grows and matures, firms prefer a

vertical disintegrated strategy in order to achieve economies of specialization and division of labour. The disintegration process of the personal computer industry is a prevailing example (Christensen *et al.*, 2001; Christensen *et al.*, 2002). Based on the innovation process perspective, Chesbrough (2006, 2007) proposed the concept of "open business model". Firms which adopt the classical closed business model are highly vertical integrated and responsible for carrying out all phases of the innovation process. In open business model, however, firms exploit both internal and external sources of innovation, while maximizing the returns that accrue from both sources. Chesbrough (2006, 2007) suggested that an industry paradigm shift from a close to an open business model. Similar trends have also been found in the integrated circuit (IC) industry (Macher *et al.*, 2002).

Before 1980, the IC industry was dominated by integrated device manufacturing (IDM) and system companies which adopting traditional closed business model. An IDM firm is a highly vertical integrated company which includes IC design, fabrication, assembly, and test – all in one company. Thus, an IDM firm not only has to allocate resources to the research and development of products, but also has to build expensive manufacturing/factory facilities. Typical IDM firms, such as Intel, AMD, Siemens, Toshiba, Hitachi, NEC, and most Korean IC firms, appear to be the most prominent in IC product lines at the leading edge of technology, such as DRAMs (Macher *et al.*, 2007).

Since the 1980s, the IC industry has been undergoing a rapid transition from an IDM-dominated industry to a vertically disintegrated structure. The emergence of the dedicated foundries enabled small IC design houses to build their entire product portfolios without any in-house manufacturing capacity. IC design (also called fabless) companies thus focus on designing and marketing IC products, while they outsource manufacturing to foundry service companies such as Taiwan Semiconductor Manufacturing Company (TSMC) and United Microelectronic Corporation (UMC) in Taiwan. By allying with dedicated foundries and assembly/test companies, IC design houses started to grow as a result of the lower entry barrier to the IC business. As a result, the business model of IC industry has become more open when the vertical disintegration emerges. The evolution of the global IC industry is illustrated in Figure 1.

Figure 1
Evolution of Global IC Industrial Infrastructure



Source: Industrial Technology Information Services of the Ministry of Economic Affairs (MOEA)

Although the IC industry has been moving from a vertically integrated to a vertically disintegrated structure, two different business model are prevalent and both can be well justified today. The first system is the traditional closed business model, composed of highly vertical integrated IDM firms. The other system is the open business model, which in contrast to the closed model, consists of independent specialized IC companies, i.e. IC design, IC fabrication, IC assembly/test, etc. Each of the companies concentrates on specific items needed for overall IC production and they are virtually integrated to form a complete value chain. Some scholars described such business model in IC industry as "virtual integration" (Chu, *et al.*, 2005).

In recent years, the virtual integration (VI) business model's share in the global IC industry has grown significantly. Several empirical studies have indicated that firms of VI model achieve higher returns than IDM companies (Chu *et al.*, 2005). The evidence seems to support the VI business model as the more

profitable strategy for IC companies. However, most of the existing literature cannot explain why IDM and VI models coexist if the VI is a superior production system in the IC industry. It is still debated whether the IDM or the VI model can truly better position a firm in terms of providing higher returns or lower risks in the IC industry. Therefore, this study aims to examine the relationship between the profitability (stock return and risk) of IC companies and their business models (IDM versus VI) in order to close this research gap. We propose that IDM companies achieved lower risk than firms of VI model, and therefore still hold some advantages in the IC industry. Based on the findings, this paper also attempts to predict the possible trends of the IC industry in the future.

In the following section, we first review germane literature and formulate hypotheses. Whereafter, we illustrate the research methods and procedures. We then present our results and test the formulated hypotheses. Last, managerial implications and limitations of this study are discussed.

2. Literature Review

2.1. Vertical Integration and Risk Reduction

Previous studies on the relationship between vertical integration and risk reduction have reported conflicting views (Krickx, 2000). The main reason for the controversial results may be hinged on the fact that sources or types of uncertainty were different from one study to another (Sutcliffe and Zaheer, 1998). The relationship between vertical integration and risk reduction was first discussed by using the transactional cost theory. Literature on transaction cost theory defined uncertainty as an increase in the likelihood of opportunistic behaviour by partners, thereby increasing transaction costs of exchange (Williamson, 1975, 1985). Conditions of high uncertainty make it difficult for firms to draw up a complete contract (Teece, 1986). If transaction cost and uncertainty is high, there is strong incentive for firms to substitute internal organization for market exchange. Thus, transaction cost theory proposed that vertical integration is a response to the problem of high uncertainty in order to limit the extent of potential opportunism

by the partners. (Klein *et al.*, 1978; Williamson, 1975, 1985, 1991). John and Weitz (1988), Anderson (1985), and Walker and Weber (1984, 1987) provided empirical evidence for the proposition that vertical integration is an efficient solution to behaviour uncertainties. Helfat and Teece (1987) examined U.S. firms involved in vertical mergers between 1948 and 1979, and found a significant reduction in the systematic risk of the firm following vertical merger transactions. Chatterjee *et al.* (1992) also confirmed that vertical mergers are effective in reducing systematic risk, particularly when the acquiring firm competes in a concentrated market. As a result, this stream of research suggested that vertical integration could reduce a firm's exposure to environmental uncertainty, resulting in a lower risk for the firm.

In contrast to the prediction of transaction cost theory, some scholars presented an alternative argument that high levels of technological uncertainty may act in the opposite direction with regard to vertical integration. For example, Balakrishnan and Wernerfelt (1986) proposed a negative relationship between technological uncertainty and vertical integration, especially if the degree of the competition is high. They pointed out that firms would rather have markets handle a technology that could quickly be obsolete than committing to it through vertical integration. From a strategic management perspective, firms facing rapid technological change require greater flexibility (Harrigan, 1984, 1985; Porter, 1980) which would induce the formation of informal forms of cooperation (e.g. non-equity agreements) in order to preserve strategic flexibility. In sum, these lines of reasoning suggest that high technological uncertainty results in a decreased rather than an increased degree of vertical integration (Henderson and Clark, 1990; Robertson and Gatignon, 1998). Several studies have also provided empirical support for the proposition that uncertainty associated with technology is likely to discourage vertical integration. For example, Heide and John (1990) and Walker and Weber (1984) found that technological unpredictability (defined as the inability to accurately forecast the technical requirements in the relationship) significantly reduces the expectation of continuity in buyer-supplier relationships.

A possible reason of these contradictory findings in the literature is that different sources or dimensions of uncertainty may have different implications for

vertical integration (Krickx, 2000; Sutcliffe and Zaheer, 1998). In order to solve this inconsistency, different types of uncertainty are introduced by researchers in order to clarify the nature of the relation between vertical integration and risk reduction. Sutcliffe and Zaheer (1998), for example, distinguished among three main sources of uncertainty: primary uncertainty, competitive uncertainty, and supplier uncertainty. Primary uncertainty refers to a lack of knowledge about states of nature, while competitive uncertainty is defined as the uncertainty arising from the actions of potential or actual competitors. Additionally, supplier uncertainty is the behavioural uncertainty arising from the actions of the exchange partner firms. The authors found that primary and competitive uncertainty were negatively associated with the decision to vertically integrate, but supplier uncertainty was positively related to the vertical integration decision. Moreover, Chesbrough and Teece (1996) identified two types of technological innovation, namely autonomous innovation and systemic innovation. Autonomous innovation refers to innovations that can be pursued independently of others. In contrast, systemic innovation can be realized only in conjunction with complementary innovations. Chesbrough and Teece (1996) suggest that when an innovation is autonomous, a decentralized virtual organization can manage development and commercialization tasks quite well. However, an integrated company may be able to resolve the challenges in information sharing and coordinating for a systemic innovation.

2.2. Fama-French Three Factor Model

The Capital Asset Pricing Model (CAPM), developed by Sharpe (1964), and Lintner (1965), provides a framework in predictions for equilibrium expected returns on risky assets. Specifically, it states that the expected excess return over the risk-free interest rate of an asset equals a coefficient, times the (mean-variance efficient; market β) market portfolio's expected excess return over the risk-free interest rate (as illustrated in equation 1). The CAPM has been widely used in applications, such as estimating the cost of capital for firms and evaluating the performance of managed portfolios (Fama and French, 2004).

$$E(R_{it}) - R_{ft} = \beta_{iM}[R_t - R_{ft}] \quad (1)$$

R_{it} : return of a portfolio at time t
R_{ft}: the risk-free interest rate at time t
R_t : return of market portfolio at time t

The CAPM hypothesizes that the expected return of a security depends only on the sensitivity of its return to the market return (market β). Empirical evidence has shown, however, that market β does not suffice to describe the expected return of a security. Other factors that seem to significantly add to the explanations of a security's expected return provided by market β include a firm's market capitalization (Banz, 1981; Keim, 1983) and book-to-market ratio (Fama and French, 1992, 1996a). Accordingly, Fama and French (1993, 1996b) added size and value factors to the market risk factor in the CAPM to provide a better description of expected returns, and this is known as the Fama-French three factor model. This model posits a relationship between a security's expected return and its risk can be measured by its exposure to three risk factors: market factor, size factor (the return difference between small and large firms), and book-to-market ratio factor (the return difference between high book-to-market ratio firms and low book-to-market ratio firms). The Fama-French three factor model is illustrated in equation 2:

$$E(R_{it}) = R_{ft} + \beta_{iM}[R_t - R_{ft}] + \beta_{iSMB}\,SMB_t + \beta_{iHML}\,HML_t \quad (2)$$

SMB: the return difference between small and large firms
HML: the return difference between high book-to-market ratio and low book-to-market ratio firms

The Fama-French three factor model evidently does a good job of explaining and predicting the variation of stock returns (Arshanapalli *et al.*, 1998; Fama and French, 1996b). Therefore, this model has been used in a number of studies to examine the influence of mergers and acquisitions (Maheswaran and Yeoh, 2005) or brand value (Madden *et al.*, 2006) on a firm's stock return and risk. The

Fama-French three factor model is explained in detail in Fama and French (1992, 1993).

2.3. Research Hypotheses

This section contains research hypotheses based on existing literature and research reports. In general, IC companies that adopt the VI model concentrated on a specific segment of the value chain that fits with firms' capabilities. For IC manufacturers (e.g. foundries, assembly/test companies), specializing in production can exploit scale economies, reduce costs and expand the range of potential end-user applications for semiconductors (Macher *et al.*, 2007). The emergence of independent IC foundry and assembly/test companies also allows small IC design houses to build their product lines without substantial capital investments for internal production capacities. Accordingly, fabless IC firms are able to focus on IC design and product development to achieve higher returns. Through such strategic alliances, those specialized IC companies create competitive advantages to achieve higher returns than IDM firms. In addition, IC companies today have matured to the extent that they are more likely to face autonomous, rather than systemic, technological innovation. According to Chesbrough and Teece's (1996) assumption, a decentralized virtual organization could manage development and commercialization tasks quite well when an innovation is autonomous. Thus, virtually integrated organizations are expected to be more profitable than their IDM counterparts.

According to IC Insights, the sales contribution of fabless IC companies was less than 10% of the total sales of the semiconductor industry before 2000. In 2006, the market share of fabless firms in the IC industry increased to 20%, and IC Insights further predicted that this share is likely to increase to more than 25% in 2011 (McGrath, 2007). These market reports suggest that the virtual integration model is growing in popularity. As for the profits of companies adopting virtual integration models, the revenues of IC designers achieved an annual growth of 16% in 2006, compared to a 9% growth for the entire IC industry. Sales from the fabless semiconductor market have grown at a compound annual growth rate (CAGR) of 25% from 1998 through 2004, compared to a 9% CAGR for the entire

IC industry (McGrath, 2007). Moreover, Chu *et al.* (2005) found that firms adopting the virtually integration strategy have enjoyed higher ROA and ROE than firms in the IDM group in Taiwan's IC industry. The evidence further supports the fact that the revenue of firms adopting virtual integration were continuously improving. Therefore, we hypothesize that:

H1: The return of virtually integrated firms is significantly higher than that of IDM firms.

Inconsistent conclusions have emerged from previous studies concerning the relationship between vertical integration and corporate risk. Therefore, the impact of adopting the IDM or the virtual integration model on a firm's risk cannot be deduced. From an industry life cycle perspective, the IC industry is reaching its maturity stage. Thus, technological uncertainty in the IC industry today is less likely to be attributed to new inventions or discoveries. Williamson (1985) proposed behavioural uncertainty as the main driver of vertical integration decisions. This study thus proposes that technological uncertainty does not seem to be the critical factor influencing an IC firm's vertical integration decision. Instead, the risks of IC firms are more likely to be determined by demand and behavioural uncertainties of partner firms. Therefore, the impact of vertical integration on an IC firm's risk may best be explained from the transaction cost theory perspective.

According to the transaction cost theory, vertical integration is a solution to the problem of high asset specificity and behavioural uncertainty (Williamson, 1979). Masten, *et al.* (1991) argued that firms should integrate vertically to take advantage of reduced internal organization costs. In general, vertical integration allows firms to avoid an increase in the cost of market exchanges that arise from uncertainty, asset specificity and opportunism. Hence, vertical integration can be utilized by large IC firms as a viable means to reduce their risk. In other words, firms adopting the VI model in the IC industry may face higher risks than vertically integrated IDM companies.

Moreover, virtually integrated companies generally focus on a certain segment of the value chain of IC products. Thus, firms of VI models usually

provide narrower ranges of products or services compared to IDM companies. From a diversification point of view, firms using the VI model are more sensitive to changes in the economic cycle than highly integrated and diversified IDM firms. As a result, virtually integrated companies may face higher market risks than IDM companies. Based on previous discussions, it is reasonable to expect that vertical integration will help reduce corporate risk in the IC industry, reflected in the volatility of stock price. Therefore, we hypothesize:

H2: The risk of virtually integrated firms is significantly higher than that of IDM firms.

3. Research Methodology

3.1. Research Subjects

IDM and VI business models have their own distinct advantages and are both prevalent in today's global IC industry. However, neither model has proven superior. Therefore, it seems insightful to explore whether the IDM or the VI can better position IC companies in terms of providing higher returns or less risk. This study attempts to examine this issue from the perspective of equity investment. If an investor intends to profit from the entire IC industry, he or she can invest the shares of an IDM company. Another option would be for an investor to own shares in IC design houses, IC foundries, IC assembly/test companies, and other specialized IC companies, which implies that the investor has virtually owned shares of an IDM company. Assuming that the stock prices of a firm fairly and efficiently reflect its financial performance, the difference in profitability between IDM and VI business models could be revealed by comparing the return and risk of these two investment strategies.

In this study, IC companies whose stocks or ADRs traded on the U.S. stock exchanges at any time between January 1, 2000 and December 31, 2007 are selected as research subjects (as listed in Appendix A). These subject firms are further categorized into two subgroups, namely the IDM subgroup and the VI subgroup according to their business model. The classification of firms' business

models is based on the method suggested in the *Semiconductors Industry Annual Report* published by the Ministry of Economic Affairs (MOEA), Taiwan (Ministry of Economic Affairs 2002), which has been cited in previous studies (Chu *et al.*, 2005). More specifically, the IDM subgroup contains IDM companies in the IC industry. Firms that adopting the VI model, including the independent IC design houses, foundry service firms, assembly firms, and test firms, are categorized as the VI subgroup.

3.2. Research Methodology

For the purpose of our research, we created two portfolios:

1. IDM portfolio, which is composed of firms adopting the IDM business model.
2. VI portfolio, which is composed of firms adopting the VI business model.

These two portfolios are value-weighted and re-balanced monthly. More specifically, the weight of each company in either the IDM or the VI portfolio is given by the company's market capitalization (market value of all outstanding common stock) relative to the market capitalization of all the companies in the portfolio. These weights are recalculated at the end of each month. The financial data used in this study are obtained from the Center for Research in Security Prices (CRSP).

After data collection, the Fama-French three factor model was used to assess the returns and risks of IDM and VI portfolios. The results of returns and risks of these two portfolios were then compared in order to explore the impact of business models on firm performance in the IC industry. The Fama-French three factor model posits a relationship between a security's expected return and its risk, which can be measured by its exposure to three risk factors: (1) market factor ($R-R_f$): market return minus risk-free return; (2) size factor (SMB): the return difference between small and large firms; and (3) book-to-market factor (HML): the return difference between high book-to-market ratio firms and low book-to-market ratio firms. The model used in this study can be illustrated using the following equation:

$$R_{it} - R_{ft} = \alpha_{it} + \beta_{iM}[R_t - R_{ft}] + \beta_{iSMB}SMB_t + \beta_{iHML}HML_t + \varepsilon_{it} \quad (3)$$

R_{it} : return of portfolio at time t

R_{ft}: the risk-free interest rate at time t

R_t : return of market portfolio at time t

SMB: the return difference between small and large firms at time t

HML: the return difference between high book-to-market ratio firms and low book-to-market ratio firms at time t

In this study, the NASDAQ index was used to represent the market portfolio. In addition, one-month Treasury Bill rate proxies the risk-free interest rate.

According to Chan *et al.* (2001) and Madden *et al.* (2006), two parameters from the Fama-French regression that are of particular importance in diagnosing a portfolio's performance are the intercept term (α_{it}) and the market beta (β_{iM}). A positive α_{it} indicates that a portfolio has outperformed its risk-adjusted benchmark; a negative α_{it} indicates underperformance compared with the benchmark. The market beta (β_{iM}) estimates the market risk associated with a portfolio. Market beta equals to 1 indicates that the risk of the portfolio performs as expected. Market betas less (or greater) than 1 indicate that the portfolio performs with less (or more) risk than expected.

4. Results

4.1. Descriptive Statistics

In this section, we first provide some descriptive statistics on the IDM, VI, and market portfolios. There are 96 monthly returns on the portfolios. The mean monthly return on the IDM portfolio is 0.53 per cent while, during the same time period, the VI portfolio on average returned 1.19 per cent. As predicted, the average return on VI portfolios is greater than that of IDM portfolios. In comparison, returns on the NASDAQ, which proxies the market return, averaged -0.13 per cent per month.

The graph in figure 2 illustrates the cumulative value of IDM, VI, and market portfolios. If $1,000 was invested in January 2000, the VI portfolio yielded $1,580.57 by the end of 2007, which was higher than the $1,120.93 generated by the IDM portfolio and $651.78 created by the NASDAQ index. These results show that IC companies that adopt the VI model create more value than the IDM and market portfolio. Although IDM companies create less value than virtually integrated companies, the cumulative returns of IDM firms are still higher than the market average.

Figure 2

Monthly Returns Comparison for Portfolios

4.2. Results of Fama-French Analysis

The descriptive analysis on cumulative returns described in the above section does not take risk into account. In the following, we employ the Fama-French three-factor model to adjust for risk to analyze returns on each portfolio. The Fama-French regression results of the two portfolios appear in Table 1.

Table 1

The Fama-French Regressions Results

Portfolio	α	β	β_{SMB}	β_{HML}
IDM	0.30	0.85*	0.17**	-0.22**
VI	1.59**	1.36	-0.09	0.14*

Note: *p<0.05 ; ** p<0.01

The results of the Fama-French analysis are discussed as follows:

(1) Risk-adjusted returns

Although the α coefficient of the IDM and VI portfolios were both positive, only the α coefficient of the VI portfolio was significantly different from 0. The results suggested that virtually all companies who use the VI model exhibit significantly higher risk-adjusted returns than that of IDM models and the market portfolio. However, the risk-adjusted returns on IDM companies do not significantly outperform the market average.

(2) Market Beta

The IDM portfolio displayed below-average market risk (market β=.851), which is significantly different from the standard benchmark value of 1. Conversely, the market β of the VI portfolio is not significantly greater than or less than 1, suggesting that share price volatility of virtually integrated IC companies is not significantly different from the market risk.

(3) Size factor

The β_{SMB} of the IDM portfolio was significantly greater than 0, which suggested that IDM companies exhibited a "reverse size effect". This finding indicated that the larger a company was, the higher returns the market expected for IDM portfolio. In contrast, the β_{SMB} of the VI portfolio was not significantly different from 0, suggesting there is no size effect for VI portfolio.

(4) Book-to-market factor

The β_{HML} of the IDM portfolio was significantly less than 0, indicating that the portfolio consisted of more companies with lower book-to-market ratios. On the other hand, the β_{HML} of the VI portfolio was not significantly different from 0, suggesting that there is no book-to-market effect for VI portfolio.

In order to test the hypothesis of this study, independent sample *t*-tests were used to examine whether α coefficients and market β were significantly different between IDM and VI portfolios. H1 predicts that the return of virtually integrated firms is significantly higher than that of IDM firms. The result of the *t*-test showed that α coefficient of the IDM portfolio was significantly lower than that of the VI portfolio (t=-16.84, p<0.01), indicating that virtually integrated IC companies achieved higher abnormal returns than IDM companies. Therefore, H1 was supported.

Additionally, H2 of this study states that the risk of virtually integrated firms is significantly higher than that of IDM firms. As expected, the results of the *t*-test showed that the market β of the IDM portfolio was significantly lower than that of VI portfolio (t=-49.01, p<0.01). This suggested that the IDM companies carry with lower risk than virtually integrated companies, which is consistent with the expectation and supports H2.

4.3. The Impact of Industry Life Cycle

Since 2004, the growth rate of the global IC industry has slowed down. Accordingly, the IC industry seems to have reached its maturity stage after 2004. Whether there are changes to the behaviour of the risks and returns of IC companies adopting different business models, one needs further investigation. In the following, we thus split the research period into two sections: (a) January 1, 2000 to December 31, 2003, and (b) January 1, 2004 to December 31, 2007. The changes in risks and returns of IDM and VI portfolios were further examined in order to provide more insight into how specifically the industry life cycle influences returns and risks in IC companies.

The results of the Fama-French regression of two research sections were illustrated in Table 2. A comparison of data between the periods of January 1, 2000 to December 31, 2003 and January 1, 2004 to December 31, 2007 showed that the risk-adjusted returns of the IDM portfolio and the VI portfolio both declined after 2004. These results echoed the data in figure 3, revealing a downturn in the IC industry. In addition, the risk-adjusted return of the VI portfolio still remained greater than that of the IDM portfolio, both pre and post

2004. This indicates that virtually integrated companies produce a higher return than IDM firms in the long run. In terms of risk, the market β of the IDM portfolio was significantly lower than that of the VI portfolio, both pre and post 2004, similar to the situation without considering the factor of industry cycle. Although the result again confirms that IDM companies are exposed to lower risk than virtually integrated companies, a comparison on risk before and after 2004 revealed that the risk of the IDM portfolio increased while the risk of the VI portfolio decreased. This finding suggests that the advantage of risk reduction for IDM firms seems to be diminishing.

Table 2

The Fama-French Regressions Results (Time Separated)

Portfolio	α	β	β_{SMB}	β_{HML}
IDM (2000~2003)	1.0064	0.8438	0.2058*	-0.2656**
IDM (2004~2007)	-0.3599	0.9606	0.0274	-0.0734
VI (2000~2003)	3.3444**	1.4000	-0.1622	0.1453
VI (2004~2007)	0.1214	1.3074	-0.1423	0.0137

Note: *p<0.05；** p<0.01

5. Discussion and Conclusion

5.1. Discussions

In this study, we found that the risk-adjusted return of the VI portfolio was significantly greater than that of the IDM portfolio. At the same time, the results of this study revealed that the risk of stock returns of the IDM portfolio was significantly lower than that of the VI portfolio. Basing on these findings, we suggest that there is a trade-off between risk and return when deciding whether to adopt the IDM or the VI business models in the IC industry. Under the assumption of efficient markets, we may infer that although IDM companies produce relatively lower returns compared to firms adopting the VI model, they are also exposed to lower risks. In contrast, IC companies based on the VI model may be

able to achieve higher returns, but they are also suffered from higher risks.

We have investigated the risks and returns within the IC industry prior to and after 2004 by further considering the effect of industry cycle. Although the risk-adjusted returns of the IDM and VI portfolios have both decreased due to a downturn in the global IC industry since 2004, the VI portfolio achieved higher risk-adjusted returns than the IDM portfolio as predicted, both pre and post 2004. Therefore, we may conclude that firms adopting the VI model enjoy higher financial returns than IDM companies in general. In terms of market risk, the results of this study showed that the VI portfolio is exposed to higher risk than the IDM portfolio, both pre and post 2004. This finding indicates that there is a long-term risk advantage for IDM firms compared to firms adopting the VI model within the IC industry. The risk-return trade-off between IDM and VI business models seems to be robust in the IC industry.

After comparing the changes in the risks of the IDM and VI portfolios before and after 2004, however, we did find that the risks of the IDM portfolio increased significantly since 2004 while the risks of the VI portfolio decreased. These results may be attributed to the strengthened strategic alliances and technological collaborations among virtually integrated companies after years of collaborating experience - they have facilitated information and facilities sharing. Growing collaborative networks among specialized IC companies have greatly reduced the costs of transactions between contracted partners. Hence, the market risk of the VI model has been reduced substantially in recent years. This finding provides a possible explanation for the increasing enormous number of specialized IC firms world-wide. On the other hand, due to the rising R&D and installation costs within the IC industry, the risk advantage of IDM companies is eroding, which is reflected in the increase of their stock risk. In recent years, IDM companies have been cutting back on capital expenditure and outsourcing manufacturing or non-core design activities to fabless or foundry companies. Some IDM companies have even transformed to a Fabless or Fablite (used to describe IC firms with low possession of semiconductor fabrication facilities) structure. These observed trends seem to support the findings of this study.

The empirical results of this study show that firms based on the VI model

achieved higher returns than IDM firms, which suggests that induced collaboration has enabled fabless firms and foundry service firms to use less capital and to grow faster than most IDM companies. This finding provides a reasonable explanation for the fact that the proportion of production value from specialized manufacturers within the IC industry has been rising continuously. The results of this paper are also consistent with the findings of Chu *et al.* (2005), which suggests the effectiveness of the VI model to increase a firm's profitability. Although evidence seems to support the VI model as a more profitable structure, previous studies could not explain why IDM and VI business models still coexist. Our study showed that although IDM companies produce lower returns compared to firms based on the VI model, they are also exposed to a lower risk than virtually integrated firms. In other words, IDM companies still maintain their advantages of lower risk to compete with firms based on the VI model. As a result, our findings provide a possible explanation for the coexistence of IDM and VI business models in the IC industry.

The coefficients of size factor and the book-to-market factor provided additional insight into the nature of the IC industry. Accumulative evidence has shown that small company stocks (those with low market capitalization) generally have higher risk-adjusted returns than large company stocks (Banz, 1981). Smaller companies are less efficient, have high financial leverage, and have greater difficulty in obtaining external resources (Chan and Chen, 1991). Therefore, higher returns on small firms are expected as a compensation for such distressing risks, which is frequently referred to as the size effect. However, the positive size factor coefficient (β_{SMB}) of the IDM portfolio in this study suggests a "reverse size effect" of IDM firms where the larger the size is, the higher the stock return. A potential explanation of this result is that R&D expenditure and equipment investments of an IDM company are enormous. Thus, only large scale companies in the IC industry are capable of reaching economies of scale to reduce unit costs, and hence, produce a higher return.

In the early years, the construction of a 6-inch wafer required only about US$500 million. During the era of 8-inch wafers, a factory cost between US$0.5 and US$1.5 billion. Now the construction of a 12-inch wafer fabrication costs

US$2.5 billion and the 65nm production design costs at least US$45 million. Only a few IDM firms are able to afford such an enormous investment independently. Although the use of 12-inch wafers can significantly reduce the unit cost, the increasingly unaffordable and substantially higher investment costs are the key factors that drive IDM firms to increase their outsourcing activities and strategic alliances with specialized IC companies (Fabless and Foundries). Some IDM firms are even transitioning themselves toward Fablite structures, which suggest that the industry may be changing towards virtual integration in the future.

On the other hand, the negative book-to-market factor coefficient (β_{HML}) suggests that the IDM portfolio consists of companies with a low book-to-market ratio. This finding indicates that the market is still optimistic about the growth potential of IDM companies. Although there is an increased share of the VI model within the IC industry, IDM firms currently still occupy around 80% of the market. The major European, US, and Japanese IDM companies are still in possession of more comprehensive patents and advanced production technologies. Some industry observers have projected that due to their advantages in new product or technology developments and superior capabilities of independent innovation, IDM companies will still dominate the IC industry in the future (LaPedus, 2005). Consequently, there is still a debate over whether the IDM and VI models would grow or decline in the future.

5.2. Theoretical Implications and Generalizations

It is concluded that the VI portfolio has higher return and higher risk than the IDM portfolio. This result is consistent with the common concept that high return always goes with high risk. But, a more detailed breakdown shows the risks of the VI portfolio decreased since 2004 while the risks of the IDM portfolio increased. The results support Chesbrough's (2006, 2007) proposition that the industry paradigm is shifting to open business model. This finding provides a valuable insight that business model of virtual integration has been emerging as a trend and more companies have been adopting open business model in many growing open industries, such as IC industry, consumer electronic industry, PC industry and so on. Here, the open industry means the platform of collaboration

among participators in the industry has been operating efficiently for a long time. Thousands of newly enterprises emerge and disappear every day. What could managers draw some implications from our empirical finding?

5.2.1. Theoretical Supports

Business model innovation is one of the most profound ways to differentiate a business nowadays. The definition of innovation used to be synonymous with invention. It was the realm of R&D exclusively. In the open business model, it's about commercialization. It is about business model innovations as much as products and processes. The integration of the business activities extends the business processes across organizations. How to innovate in the 21st century global economy is all about the ability to create value, capture value, scale up, and integrate technologies internal as well as external. Chesbrough (2006, 2007) argued that open business models foster collaborations with customers and suppliers to everyone's benefit. The more companies learn about open business models, the more they realize how much they have to change their own innovation activities to take full advantage of the paradigm shift. It is not simply a matter of searching for new technologies. To thrive, companies must adapt their business models to make them more open to external ideas, technologies and paths to the markets.

5.2.2. IC Industry Event and Evidence

It was announced on March 2, 2009 that Intel and TSMC (Taiwan Semiconductor Manufacturing Company) would collaborate on Atom-platform chip production. Intel, which prides itself on doing chip manufacturing in-house, is lending its Atom technology including processes, IP and design flows to TSMC. TSMC is the largest contract chip manufacturer in the world.

The collaboration between Intel and TSMC would create a win-win game. The shift is part of Intel's effort to push its x86 architecture, which is used in the vast majority of the world's personal computers and servers, into a wider array of lower-cost consumer devices such as Netbook and mobile internet devices (MID). All products that emerge from the collaboration will be Intel-branded products.

Collaborating with TSMC, Intel could focus on its core business and leverage TSMC's production excellence to other considerable big-volume low-price market without huge capacity investment. As a result, Intel would not only reduce its risk for less capital expenditure on fab but also increase its return with new market expansion. For its part, TSMC can complement the new CPU product lines and further promote the innovative business model of IC foundry service. The winning of Intel business would not only improve the utilization of TSMC advanced process capacities but also attract more IDM players to follow Intel's suit. Via such TSMC could improve its return, market position as well as reduce risk. The ramifications of strategic behaviour of Intel, the leading IDM player, and TSMC, the dominant foundry manufacturer, confirm the empirical findings of the research. This event also provides an empirical evidence for the spread of open business model in the IC industry.

5.2.3. Generalizations

Recently, Sony has agreed to build a strategic alliance with Taiwan's Foxconn Electronics (Hon Hai Precision Industry Co. Ltd.) for the production of LCD TVs for the Americas region. Foxconn is the world's largest contract electronics manufacturer, making advance products such as the iPod and iPhone for Apple, PCs for HP and more.

Under the agreement, Sony is concentrating internal resources towards areas that contribute to product differentiation, such as R&D, engineering and design, while also establishing a structure that enables the company to bring attractive products to market at the earliest possible opportunity. At the same time, Sony will outsource production of its popular TVs to Foxconn Electronics in order to reduce massive fixed asset expenditure and production cost, as well as to improve profitability and business expansion.

This strategic alliance provides another empirical evidence of the adoption of virtual integration strategies in a different growing industry. Managers could find other empirical evidences of open business model in many industries such as PC, Notebook/Netbook, telecommunication products, pharmaceuticals and Bioscience resulted from the trend of globalization and collaboration.

5.3. Limitations and Future Research

Several limitations of this investigation should be noted. First, stock return and risk were used as proxy variables for a firm's profitability in this study. However stock return and risk may not fully reflect the financial information of a company's return and risk. Future studies may incorporate other financial models or methodologies to compare the performance between IDM and VI business models. Second, because of the nature of the Fama-French three factor model, only IC companies listed on the U.S. stock exchange were selected as research subjects. Future work could employ other methodologies that allow for more IC companies world-wide to be analysed in order to obtain a more comprehensive understanding of advantages and disadvantages of IDM and VI business models in the IC industry.

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Appendix A

Portfolio IDM	
Intel	Analog Devices
TI	Spansion
STMicroelectronics	National
Freescale	Maxim
Sony	Atmel
NEC	Fairchild
AMD	Sanyo
Micron	On semi
Infineon	Vishay
IBM	Cypress
Matsushi	

Portfolio VI			
Qualcomm	Agrelent	Alliance	MIPS
Broadcom	Silicon Laboratories	Amkor	MPS
Nvidia	Silicon Storage	AMCC	Pericom
Sandisk	Zoran	Catalyst	PLX
Marvell	Lattice	Chipmos	Semtech
Xilinx	Cirrus	DSP	Sigma Designs
Agere	ESS	Exar	Silicon Motion
Altera	TSMC	Himax	Standard Microsystems
PMC	UMC	Intersil	Transwitch
Conexant	Chartered	Linear	Vitesse
Qlogic	SMIC	Logic Devices	Zarlink
Adaptec	Actel	LSI	Zilog