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Full Length Research Paper

Application of a scientific approach to evaluate IC industrial supply chain linkage

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The current studies on supply chain management are limited in their analysis of the linkages between firms in related industries. This study estimates the degree of linkages among designers, manufacturers and firms of testing and packaging. Significant linkage is demonstrated by the high correlation coefficients of the RSP ratio in IC industrial supply chain. But the magnitude of linkage is low by regression analysis. This paper has contributed to: (1) the development of strategic relationship by collaboration between upstream and downstream of the chain partners between firms in IC industry; and (2) to enhance robust IC supply chain by utilizing supply chain linkages from mutual cooperation.

Key words: Supply chain linkage, IC industry, regression analysis.

INTRODUCTION

In today's world of interconnected economies companies are no longer stand-alone organizations. Material providers, manufacturers, wholesalers, distributors, retailers, customers, and a host of logistic service organizations realize that in order to survive and prosper; they must compete cooperatively in order to profit, add value, and obtain synergy (Ghaderi et al., 2010). As a result, companies are increasingly collaborating, with other companies - domestically and internationally - especially in their supply chains (SCs). Taiwan's current IC (Integrated Circuit) industry provides a representative, real-world example of both the collaboration within and the competition between the supply chains. Supply chains have traditionally been examined as a set of sequential, vertically organized transactions representing successive stages of value creation (Mabert and Venkataramanan, 1998). While this view allows the examination of operational efficiencies, it tends to restrict the examination of interdependencies at different relationships types that exist among supply chain partners. For example, Choi et al. (2002) indicated that for effective supply chain management how firms interact among themselves to promote establishment strategic relationships. Some investigators have studied long-term cooperative relationships with key suppliers (Carr and Pearson, 1999; Chen et al., 2004). However, firms often use cooperative relationships to reduce the uncertainty in their product markets through information sharing and cross-firm communication in the form of cooperative relationships that range from cooperative marketing to pooled research and development cooperatives (Bresser, 1988). As a result, ensuring stable relationships between suppliers and their customers is important to both parties.

Supply chains from the network-based perspective and from the long-term relationship as to move closer to the realistic relational behaviors for developing a collaborative supply network and to long-term financial stability for both the supplier and the customer. Notably, in the presence of trust, buyers and suppliers act in a risk-prone way by cooperating, rather than risk-averse way by defecting, even with the knowledge of the other party's potential opportunistic behavior and potential losses. In essence, cooperation and trust are self-reinforcing. Initial cooperation results in trust building and the trust developed between supply chain partners enable subsequent cooperation (Nair et al., 2009). Su et al. (2004) pointed four reasons for collaboration among third-party intellectual property providers, they are:

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Table 1. IC supply chain.

	Design	Manufacture	Packaging	Testing
TSMC chain	VIA	TSMC	ASE	
UMC chain	LFT SIS	UMC	SPIL	SPIL KYEC

complementary technology, modules, higher reusable probabilities, and complete collaboration strategy. However, the collaboration mechanism between foundry and fabless design houses is built by the main foundry companies, such as TSMC and UMC (Fang, 2004). These collaborations can be further classified into design collaboration, engineering collaboration, and logistics collaboration.

Supply chain management (SCM) is an integrated philosophy which links immediate upstream provider and downstream customer to effectively and efficiently respond to end users at the right time, right place, and right cost. The essence and success of SCM is the coordination and integration of firms and functions beginning early in the process, in order to efficiently create and deliver products to consumers (Frohlich and Westbrook, 2001). In such an integrated supply chain, benefits include reduced costs, improved processes, and better quality. SCM is an operational approach to procurement. It provides the necessary tools to bridge the gap between policy and procedure to operational management. SCM is a continuous improvement strategy to understand and manage the supply chain through differentiation based on risk and value. For effective implementation of SCM, skilled workers, good processes, and continuous improvement are required.

The current studies on supply chain management are limited in their analysis of the linkages between firms (Rose-Anderssen et al., 2005; Rungtusanatham et al., 2003). This study provides further evidence on linkage performance within the framework of SCM. Specifically, the key objective of this present research is to examine estimate the level of operational linkage among IC manufacturers and their main independent designer and firms of testing and packaging. The correlation coefficient of the return of daily stock price (RSP) was used as the measure of the degree of linkage. This linkage could indicate the impact of changes in demand for IC and market value of IC firms. The second objective, using regression analysis, was to estimate the impact of each IC manufacturer's profit ability on the RSP of each designer and each firm of testing and packaging. The results of this study are useful (a) to the IC industry for developing strategies for market value, profitability; and (b) for developing strategies to improve supply chain relationships to enhance robust IC supply chain and mutual cooperation.

MATERIALS AND METHODS

Materials

The Taiwan IC industry has established itself as a comprehensive upstream-downstream collaborated supply chain domestically. By the end of 2004, Taiwan semiconductor industry consisted of 260 IC fables houses, 8 wafer suppliers, 4 mask makers, 13 fabrication companies, 35 packaging houses, 34 testing houses, and 14 substrate suppliers, 18 chemical suppliers, etc..

The design phase of the IC industry occurs in the upstream segment of the supply chain. The products undergo polishing and production in the manufacturing stages of the chain. The IC manufacturing includes three types of manufacturing companies-foundry, dynamic random access memory (DRAM) and integrated device manufacturer (IDM). Foundry is a factory where devices like integrated circuits are manufactured for specific customers. DRAM is a type of random access memory that stores each bit of data in a separate capacitor within an integrated circuit. However, IDM is a semiconductor company which simultaneously designs and manufactures integrated circuit products. Along with other smaller foundries, the world's two largest ones, TSMC and UMC, are located in Taiwan. Testing and packaging is a downstream segment and some companies provide both testing and package services.

The Taiwan IC industry has established itself as a comprehensive upstream-downstream collaborated supply chain domestically. The structure of IC industry in Taiwan consists of a series of designer (upstream), manufacturer (midstream) and firm of testing and packaging (downstream) working together cooperatively in a collaborated chain. The complete upstream-through-downstream collaborated relationship combined with a high utilization on production capacity make the industry successful globally. Although the Taiwan Stock Exchange (TSE) comprises hundreds of independent suppliers, this research identified the top 6 that have been listed most frequently in the various issues of Taiwan Semiconductor Industry Yearbook. These are considered the permanent or long-term coordinate firms, as contrasted to the many short term suppliers engaged as the models and characteristics of IC manufacture change. TSMC and UMC are currently the two largest IC manufacturers (or foundries) in the world.

Through the interviews, the design, manufacturing, packing and testing, companies participating in TSMC supply chain are respectively VIA, TSMC, and ASE; while the participating companies for UMC are SIS, UMC, and SPIL. Even though LFT is also one of the designers for UMC, it was only recently listed in the TSE; therefore, this study selects SIS as the upstream partner of UMC to compare against the TSMC chain (Table 1). Also, the choice of the suppliers for this research was dependent upon obtaining adequate data to conduct time series estimation. These firms are listed on the Taiwan Stock Exchanges. Data on these firms were obtained from the database, an annual publication of Taiwan Institute of Economic Research, a leading institute in Taiwan. To ensure data reliability, the data collected from the database were cross-checked with information obtained from the

Table 2. Regression analysis.

			T-stat	R2	Durbin-Watson
TSMC chain	a1	0.281	0.046*	0.020	2.005
	a2	0.116	0.040		
UMC chain	a1	-0.028	0.039*	0.023	2.101
	a2	0.119	0.038		

Note: 1. Time period: 2002/1~2003/9; 2. *statistical significant of coefficient at 95% and above.

Taiwan Company Handbook. This investigation found no discrepancies in the data set. In sampling, it was tried to ensure that the sample companies fulfill two minimum criteria: firstly, the annual turnover is more than one million of dollars, and secondly, the employee strength is more than 100.The full names of all company are listed in the Appendix A. In order to properly compare across the time periods as well as companies, the study computes the reward ratio, return on adjusted daily stock price (RSP) which tabulated by the Taiwan Economic Journal database. The RSP was used as the measure of profitability for the period 2002/1/1-2003/9/30.

Methodology

Stock price is conventionally taken as the ultimate financial indicator of the company's overall performance that is, economic value and wealth effects (Mitchell and Stafford, 2000; Hertzel et al., 2008). Hence, this research used the stock prices as the performance measurement indicator. However, in order to properly compare across the time periods as well as companies, the study computes the reward ratio, Return on Stock Daily Price (SR) (Ramcharran, 2001; Vickery et al., 1999):

$$\text{Return on Stock Price (SR)} = \ln \frac{p_i}{p_{i-1}}$$

Where Pi is the daily stock closing prices on day i. The study uses the adjusted daily stock price tabulated by the Taiwan Economic Journal database to calculate the SR. SCM and business performance has been the focus of numerous studies using from firms' data. Mitra and Singhal (2008) demonstrated that the stock market reacts positively to integration among supply chain partners. Ramcharran (2001) used simple regression to indicate significant linkages by P/E ratio between suppliers and automobile manufacturers. The study replicated the Ramcharran (2001) methodology to estimate the degree of linkage. The impact on profitability (as measured by the RSP) of this interdependence is estimated by using simple regression analysis:

$$RSP_t^m = a_1 RSP_{t-1}^d + a_2 RSP_{t+1}^p \quad (1)$$

where RSP_t^m = the RSP of each manufacturer of the SC in the current period RSP_{t-1}^d = the RSP of each designers of the SC in the previous period RSP_{t+1}^p = the RSP of firms of testing and packaging of the SC in the later period t = time period (daily).

A lagged impact between RSP_{t-1}^d on RSP_t^m and RSP_t^m on RSP_{t+1}^p are assumed. This is reasonable since the current demand (profitability) for final products is based on order rot inputs from designers placed in the previous period. If a_1 >0 and significant, the manufacturer is impacted by the profitability of the designers. If a_2 >0 and significant, the firms of packing and testing impacted by the profitability of the manufacturer. The magnitude of linkage can be inferred as low if 0< a_1 <1, 0< a_2 <1, and high if a_1 >1, a_2 >1. Coefficient of determination is the best measurement of goodness of fit of the linear model. This coefficient shows to what extent the change taking place in the dependent variable is accounted for by independent variable or variables. This is a good indication of the explanatory power of the regression model (Colak, 2010). Correlation coefficient (R) is the measurement of the relationship between two variables and ranges between -1 and +1. The following definitions are given for the power of correlation coefficient:

(i) 0.00 - 0.49 Weak correlation,
(ii) 0.50 - 0.74 Medium correlation,
(ii) 0.75 - 1.00 Strong correlation.

RESULTS

The article organizes the experiment results in two sections. The first section tabulates the correlation coefficients of the RSP. The second section is the regression analysis. The correlation coefficients of the RSP are listed in Table 3 and 4. A correlation coefficient of approximately 0.30 is used as an indicator of an acceptable level of interdependence (Colak, 2010). The main implication of this high level of dependency is that the output of these designers is heavily dependent on the demand for IC designers, manufacturers and firms of testing and packaging. Therefore, strategies to maintain profitability and market share have to reflect this linkage. Demand forecasting, with a focus on business cycles, needs to be emphasized to formulate an effective production strategy.

The regression results of Equation 1 for each auto manufacturer are presented in Table 2. The slope coefficient (a1) measures the change in the RSP of each IC manufacturer in the current period when the RSP of

Table 3. Correlation coefficients of TSMC.

	TSMC chain		
	VIA	**TSMC**	**ASE**
VIA	-		
TSMC	0.519**	-	
ASE	0.517**	0.683**	-

1. Time period: 2002/1~2003/9; 2. **Correlation coefficient significantly different from zero at the 0.01 level.

Table 4. Correlation coefficients of UMC.

	UMC chain		
	SIS	**UMC**	**SIP**
SIS	-		
UMC	0.521**	-	
SIP	0.491**	0.704**	-

1. Time period: 2002/1~2003/9; 2. **Correlation coefficient significantly different from zero at the 0.01 level.

the designer changes by one unit in the previous period. Also, the slope coefficient (a2) measures the change in the RSP of each IC manufacturer in the current period when the RSP ratio of the firms of testing and packaging by one unit in the later period. The magnitude of linkage both in TSMC chain and UMC chain can be inferred as low. Even the slope coefficient (a2) is negative and significant. Like the results of other studies on performance, this study provides further evidence on linkage performance within the framework of SCM.

DISCUSSION

The aim of this paper is to estimate the degree of linkages among designers, manufacturers and firms of testing and packaging. Next, we discussed how the paper addressed the main objectives.

Developing strategic relationship

The higher the correlation of RSP, the higher the collaboration between upstream and downstream of the chain partners is. Tables 3 and 4 both showed that there is a significant pair-wise positive correlation among design, foundry and packing and testing for both TSMC and UMC chains. Thus, this represented that there was a financial effect correlation among chain partners in both TSMC and UMC chains. In other words, the supply chain collaboration does provide mutually collaborated impact on each other's stock prices. Supply chains have traditionally been examined as a set of sequential, vertically organized transactions representing successive stages of value creation (Mabert and Venkataramanan, 1998). While studies in supply chain management have emphasized the importance of collaboration and cooperation among supply chain partners, one cannot ignore the fact that companies do not always collaborate or cooperate. The identification of volatility, disruption, and opportunities in the firm's supply and demand environments is an important aspect of SCM. At times, companies choose not to extend a contract and exit an existing relationship. A supplier may increase price at the time of product shortage thereby engaging in opportunistic behavior. While this view allows firms to operate efficiently, it tends to restrict the examination of interdependencies at different levels that exist among supply chain partners. For example, demand uncertainty in the IC manufacturing industry, resulting from business cycles and lack of information, is one of the major risks facing IC manufacturing. The concept of supply uncertainty, as related to supply chain linkages, it is important not only to develop effective supply chain management, but also how firms interact among themselves to establish strategic relationships (Choi et al., 2002).

Robust IC supply chain

Mutual cooperation among chain relationship is the goal for developing a collaborative supply chain. Fichman and Levinthal (1991) denoted a relationship endures over

time, a supplier and a buyer stand to develop idiosyncratic interaction routines that allow them to communicate and collaborate more effectively. The results of our study show that TSMC developed a collaborative relationship with its upstream and maintained a supply network from upstream and longitudinal supply perspectives. This point is agreed with Dyer and Singh (1998) who indicated long-term relationships are a driver of complementary resources and sustained competitive advantage. Therefore, this study suggests that a firm can benefit from harnessing complementarities in supply chain relationship, and that such benefits can accrue more strongly to firms that foster durable linkages.

Conclusion

This paper has contributed to developing strategic relationship between firms in related industries and to enhance robust IC supply chain. Considering the growing importance of measuring supply chain linkages to aid risk assessment and develop profit-maximizing strategies, this article estimated the level of operational linkage among designers, manufacturers and firms of testing and packaging and analyzed implications for strategic planning. Since the demand in IC industry is “derived” from the demand for IC, the concept of linkages is appropriately applied to firms comprising a vibrant sector of the Taiwan economy.

The results indicate a significant level of interdependence, or linkage, with little impact on profitability. With volatility in IC sales and industrial unrest, suppliers will have to devise strategies related to sales diversification and production planning mainly based on forecasting and risk assessment techniques. As previous discussion, it is important not only to develop effective supply chain management, but also how firms interact among themselves to establish strategic relationships. Additionally, risk assessment, utilizing information on linkages, is important for demand management and developing profit maximizing strategies. This understanding may help managers estimate the degree of linkages among chain partners. If managers have a better perspective of how their strategies are influenced by their context, they may examine the impact of such influence on their sales diversification and production planning.

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APPENDIX A

Appendix A. IC Companies in Taiwan.

	Abbreviation	Full name
Designer	SIS	Silicon Integrated Systems Corporation
	VIA	VIA Technologies, Inc.
	MT	MediaTek Inc.
Manufacturer	TSMC	Taiwan Semiconductor Manufacturing Company Limited
	UMC	United Microelectronics Corporation
Firms of packaging/Testing	ASE	Advanced Semiconductor Engineering, Inc.
	SPIL	Siliconware Precision Industries Co., Ltd.
	KYEC	King Yuan Electronics Co., Ltd.