Partnership Ecosystem of IC Design Service Companies: Case of Taiwan

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Abstract--**The continuously evolving IC industry has driven an IC design service to become an emerging sub-industry to the semiconductor value chain. This emerging business manages the entire chip development manufacturing process and applies third party's resources when and where its customer needs them. To keep the customer as their main focus and deliver what the customer truly needs, a strong and committed partnership ecosystem is more important than ever.**

Therefore, the objective of this study is to explore the partnership network of Taiwan's IC design service companies by applying the co-evolutionary theory in business ecosystem. The partnership network is analyzed together with the corporate data such as revenues and milestones. The finding shows that, the firms have accumulated and created their competitive advantage through partnership with various leading manufacturers, IP vendors, and EDA tool providers in order to leverage their technological capabilities over time. While the production ecosystem is being localized in Taiwan based on the benefit of the complete value chain, the IP ecosystem is more internationalized.

This study contributes to the understanding on the characteristics of the emerging business in a highly competitive environment. It should also provide policy implications for the industry stakeholders and government about new opportunities in high competitive value chain.

I. INTRODUCTION

High competitive pressure resulting from the rising costs of fabrication and design, technology uncertainty, and consumer price squeeze has led to the semiconductor industry undergoing structural change [4]. As the IC manufacturing process has evolved into sub-wavelength technology nodes, the manufacturing technology has become very complicated and requires detailed knowledge to integrate the complex process technologies in each IC production step along the entire supply chain. It is difficult for most companies to conduct independent technology development and innovation. Many outsourcing tasks originated from the IC companies creating opportunities not only in manufacturing, packaging and testing but also in design business.

Continuously evolving character of the semiconductor industry has driven the IC design service in becoming an emerging sub-industry in the semiconductor value chain. The business model of an IC design service company is the fabless ASIC (Application-Specific Integrated Circuit) model which is a logical progression of the trend to outsourcing in the semiconductor industry. It offers a complete line of IC design services based on the customers' needs and provide services through foundry manufacturing. Unlike fabless IC design houses, IC design service companies do not have their own chips. The major function of IC design service company is to act as a intermediary between design and manufacturing, providing IC designers with an IP library, IP integration and customized modification, and IC manufacturing process technique to reduce not only the development cost but also design time. It also provides turnkey solutions to produce ASICs and/or handle the manufacturing process in the comprehensive supply chain. Thus, customers can focus their technical capability on specialty area and utilize increased amount of company resources for market development [5], [8].

Although the semiconductor industry has been researched extensively by several researchers, there are a few studies that focus on these IC design service companies. According to Lin et al. [8], the core competences of a successful IC design service company would have been similar to that of a fabless IC design house. However, due to their different functionalities, the core competence and key success factors between them may vary, thus further study will be required. Based on an IC design service company' business model which has to provide services to their customer by managing its resources and third party's resources, the partnership ecosystem should be one of the key success factors providing a competitive advantage. If companies are going to continue to keep the customer as their main focus and deliver what the customer truly needs, a strong and committed partnership ecosystem is more important than ever. Therefore, the objective of this study is to explore the partnership network of Taiwan's IC design service companies by applying strategic alliances in business ecosystem.

This study would provide a better understanding about the business model and core competences of these service companies in Taiwan semiconductor industry. It may be utilized as a reference not only for government but also industry, investors and academics for better understanding about the new emerging companies in the semiconductor industry. It should provide policy implications for government in developed and developing countries which plan to encourage local start-ups or existing SMEs firms to engage in highly competitive IC industry value chain. In order to introduce key stakeholders in the partnership network, an overview on semiconductor value chain will be explained in the next section. Sections III to VII illustrate the theoretical background and conceptual framework, the methodology and data, main findings, conclusion and implication, respectively.

II. RESEARCH SETTING: SEMICONDUCTOR VALUE CHAIN

The IC industry started a disruptive structural change from integration towards disintegration with the emergence of the foundry business in the mid-1980s. Before then, IC industry was dominated by IDM (Integrated Design Manufacture), which not only does design but also manufacture its own chips. IDM is an integrated firm conducting chip design, production, marketing, supply chain management and after sale support. Nowadays, several IDMs have changed their business characters to fabless or have adopted fab-lite approach of using foundries for leading edge process and continuing to manufacture internally anything that does not require a leading-edge fab. Firms in the semiconductor value chain can be divided into two groups, design and manufacturing. Those industries with main activities dealing with designing chips are Silicon IP (Intellectual Property) provider, EDA (Electronic Design Automation) tool vendor, and fabless. Foundry and packaging & testing are industries involved in manufacturing the chip.

Foundry refers to a company that processes that processes and manufactures of silicon wafers. Fabless is a company which designs chips but contracts out their production rather than owning its own factory. EDA tool vendor is a company design and develop software tools for designing electronic systems such as printed circuit boards and integrated circuits. The tools work together in a design flow that chip designers use to design and analyze entire semiconductor chips. IP provider refers to a fabless/chipless firm which does not provide physical chips to its customers but merely facilitate the customer's development of chips by offering certain functional blocks such as a Microprocessor. From time to time, firms in the semiconductor industry are redesigning their business model not only within the company itself, but also at the collaborative interaction between the firm and its partner.

Due to the availability of a full ecosystem of suppliers with the required elements to design and manufacture a chip to be sourced from third parties, IC companies began subcontracting activities in order to focus on their core competences. The outsourcing trend also enabled the emergence of IC design service companies which provided solutions including design, wafer manufacturing, packaging and testing, a very labour and time consuming process. Saha [14] and Vagues and Kumar [17] have researched on this emerging trend from the foundries' perspective. In order to maintain the competitive advantage, some leading foundries like TSMC are adopting a new business strategy by forming a strategic alliance to provide complete turnkey service solution to the customers. This emerging business manages the entire chip development manufacturing process and applies third party's resources when and where its customer needs them. Their customers, which usually are IC design houses or system companies, can focus their technical capability on specialty area and utilize increased amount of company resources for market development. In 2012, most of the world's leading IC design services companies are based in Taiwan. They may also gain benefits from the complete IC industry infrastructures in Taiwan.

Taiwan IC industry has distinguished itself from its complete industry value chain from fabless (including IC design houses, IC design services, IP providers and EDA tool vendors), manufacturing to packaging & testing companies. The world-leading IC Foundries and IC Packaging & Testing companies together offer the best deal of one-stop shopping model. By the end of 2012, Taiwan Semiconductor industry consisted of 260 fabless, 15 IC manufacturing companies, 37 packaging and testing houses, 7 substrate suppliers, 11 wafer suppliers, 3 mask makers, and 4 lead-frame companies, etc [15]. There are around 10 design services companies in Taiwan creating total revenue of NT$22 billion in 2012. Apart from partnership with local companies, Taiwanese IC design service companies have also formed international partnerships. In the next section, the theoretical background and conceptual framework are explained.

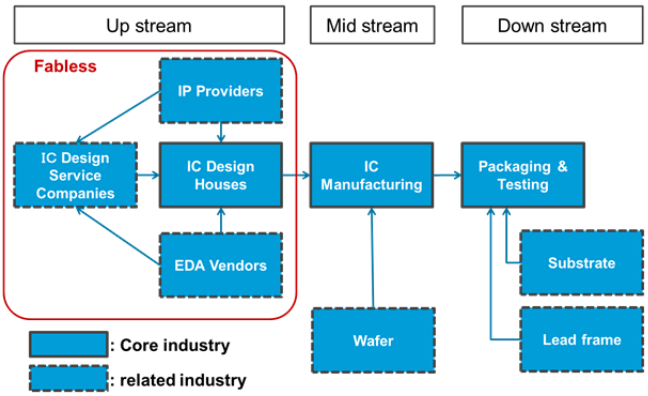

Fig. 1: Disintegrated infrastructure in Taiwan (2012)

III. THEORETICAL FRAMEWORK

In this section, we would like to explain briefly about business ecosystem, co-evolutionary theory and strategic alliance which we used as theoretical background to explain the partnership network of Taiwan IC design service companies.

An innovation often does not stand alone. It depends on accompanying changes in the firm's environment for its own success. These external changes, which require innovation on the part of other actors, embed the focal firm within an ecosystem of interdependent innovations [2]. Moore [12] defined "business ecosystem" as the economic community produces goods and services of value to customers. It refers to the network comprising suppliers, lead producers, competitors, and other stakeholders. Over time, they coevolve their capabilities and roles, and tend to align themselves with the direction set by one or more leadership companies.

Co-evolutionary perspective considers organizations, their populations, and their environments as the interdependent outcome of managerial actions, institutional influences, and extra-institutional changes [16]. It refers to the simultaneous development of organisations and their environment, independently as well as interactively. For co-evolution to occur, the population should consist of heterogeneous firms that have learning capabilities and are able to mutually influence each other [18]. The external environment affects both the firm and the alliance, and the firm and alliance activities also affect environment and therefore any change is co-evolutionary. The notion of the focus of co-evolution at a level between the micro (firm-level) and meso (industry-level) also occurs [19]. Applying the theory of co-evolution to better understand change in firms and their strategic alliances assumes that change may occur in either the dyad of alliance partners or in the alliance-partner dyad simultaneously [6].

Strategic alliances are defined as relatively enduring inter-firm cooperative arrangements which utilize resources from autonomous organizations, covering a variety of contractual forms from joint equity ventures to contracts and less formal working agreements. They are formed by firms wishing to compete together either in dyadic form or as supply chains. Firms actively try to move from competing on an individual basis to competing on a supply chain basis, whilst simultaneously recognising the requirement of competitiveness at firm, alliance, dyad and chain levels. The development of strategic alliances and networks by firms is arguably a co-evolutionary adaptation to the simultaneous selection of individuals, dyads and groups. All alliances were driven by needs from both firms for the partners' critical resources, supporting a resource-based view [6][19].

According to IC design service companies' business model, their revenues come from two main activities which are design service and turnkey production. Despite the technical advances offered by each supplier in the semiconductor supply chain, managing a large number of suppliers which ultimately contribute to the design and production of a complex device is an increasingly challenging task [5]. Therefore, the production and design networks are critical for product quality and cost reduction. The firms might form cooperation, strategic alliance and M&A among companies in order to improve advanced technologies and increase product function and quality and striving for further development [20]. In other words, firms and their strategic alliance partners in the business ecosystem will co-evolve if they can provide strategic value to their partners and customers.

The conceptual framework based on the firm's two main activities is shown in Fig. 1. In case of design activities, IC design service companies will partner with a broad type of silicon IP (Intellectual Property) providers and EDA (Electronic design automation) tool providers. In the same way, they have to partner with the leading companies in both foundry and packaging/testing. By managing internal and external resources, a firm can improve its performance. The production and design networks created by using IC design service companies as focal firms can provide a better understanding of this new outsourcing trend. Although, this study is not a fully analyzed co-evolutionary case study, the network will be used as a starting point for explaining the IC design service companies' business models and their performances. In section III, the methodology and data for analyzing the partnership ecosystem will be described.

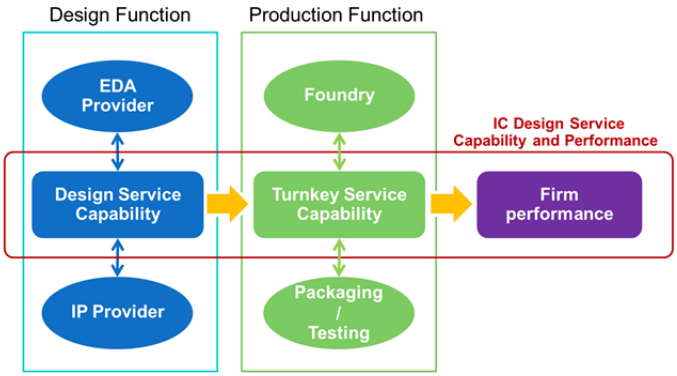

Fig. 2: Conceptual framework

IV. METHODOLOGY AND DATA

Understanding firms and their alliances should be a good starting point for further investigating about the change in the ecosystem. Therefore, the starting point of the case study is based on the partnership network of 6 Taiwan IC design service companies including Global Unichip Corporation (GUC), Faraday Technology Corporation, Alchip, Progate Group Corporation (PGC) and Socle. The companies' general information is shown in Table 1. The network analysis in this study will be separated based on two main service types of IC design service companies which are design network (IP ecosystem) and turnkey (production) network. This is in order to identify the key alliances in each service type. The firms and its partners are classified based on their nationality and business types.

The interviews with Taiwanese industry peers and the secondary qualitative and quantitative corporate data are used to explain the relationship in the network. Only three companies are initial public offering (IPO) firms. Therefore, the breakdown of the revenues of the three firms including GUC, Faraday and Alchip are used for quantitative analysis for complementary explanation about the relationship in the network. Since 2006, the market share of these three companies is more than 90% of Taiwan IC design service. The main findings are explained in the next section.

TABLE 1: LIST OF TAIWANESE IC DESIGN SERVICE COMPANIES

Company	Founded (year)	Number of Employees (S/M/L)	First filed US patent (year)	#US patent (Accessed 12/2013)
Global Unichip Corporation (GUC)	1998	481 (M)	2000	35
Faraday Technology corporation	1993	705 (L)	1998	273
Alchip	2003	241 (S)	-	0
Progate Group Corp. (PGC)	1991	80 (S)	-	0
Socle	2001	130 (S)	2004	2
CMSC	2001	60 (S)	2009	4

V. MAIN FINDINGS

Most Taiwanese IC design service companies are SMEs with employees less than 500. Currently there are around 10 design service firms in Taiwan, creating total revenue of NT$22 billion in 2012. In 2012, Faraday, GUC and Alchip, had market shares of 37%, 41% and 12% of Taiwanese IC design service market, respectively. The three leading firms have more than 90% of total revenue. Taiwanese IC design service market share is shown in Fig. 3. A firm's main revenues are based on two activities: design and turnkey production. The main revenue is from turnkey production where an IC design service companies makes its profit. Therefore, a firm has to push its new design projects to production. The share of the revenue by service type of the three leading companies in 2012 is shown in Fig. 4. Revenues of these three IC design companies are diversified in both sale region and application as shown in Fig. 5 and Fig. 6, respectively. Faraday and GUC's revenues in 2012 are mainly from Korea while that of Alchip is from Japan. Faraday and Alchip's revenues in 2012 are mainly from consumer applications while that of GUC is from communication and computer. Like other fabless firms, IC design service companies had tentatively filed patents early. However only GUC and Faraday, which have their own proven IP portfolio and also sold their proven IPs, have aggressively filed patents. The main advantage of using in-house developed IP is the ability to know the precise effects of packaging and boards on the signal because the company has end-to-end supply chain capabilities and often end-to-end responsibilities. Nevertheless, developing IPs in-houses took huge resources and it does not the main revenues of IC design service companies. This may be a reason why only big firms like GUC and Faraday can invest in IPs.

Based on the IC design service companies' business model, the partnership ecosystem can be analyzed by two networks. The production partnership network and IP ecosystem of these six firms are shown in Fig. 7 and Fig. 8, respectively. Each node represents an individual firm. The node shapes represent different types of firms. The colors represent different countries. The size represents a number of connections to the firm.

In the case of production partnership network, it shows that most of firms in the network are Taiwanese companies. This is resulting from a benefit of Taiwan semiconductor's complete value chain. Taiwan's IC industry has a unique infrastructure of vertical disintegration, characterized by a cluster of IC design, advanced IC foundry and back-end packaging and testing firms. In 2012, the market share of Taiwan foundry and IC packaging and testing firms were number 1 in the world. Taiwanese packaging and testing revenue represented 55.3% of the global packaging and testing revenue. ASE, SPIL and KYEC are common partners of these IC design service companies.

Each IC design service company usually partners with one foundry, a big friend. Faraday was spun off from UMC, the world's second largest contract producer of semiconductors in 1993. At that time, Faraday was the first IC Design Service Company in the world. Socle was founded in 2001 and invested by GLOBALFOUNDRIES since December 2009. Socle is now the ONLY design service affiliate of Globalfoundries. GUC, Alchip, and PGC partner with TSMC. In 2001, GUC became TSMC multi-project wafer (MPW) service partner. TSMC's MPW program was initially introduced in October 1998 for 0.25-micron process technology. In 2003, TSMC became GUC's primary shareholder. Alchip has joined TSMC Design Center Alliance (DCA) since 2004. PGC was the first ASIC design service provider and the first ASIC strategic partner of TSMC DCA. As of 2013, GUC, Alchip and PGC have been members of TSMC DCA and Value Chain Aggregator (VCA). Although Alchip announced that it uses open foundry strategy, its main foundry is TSMC. Since 2010, more than 97% total purchase share of Alchip was from TSMC. Unlike other Taiwanese IC design service companies, only CMSC is independent and can contract wafer manufacturing to any foundry including TSMC, UMC and Fujitsu. CMSC was established as a wholly-owned subsidiary of Cadence Design Systems Inc. of the US in 2001. With capital injected by Taiwanese foundry and venture capitals in 2003, Cadence's current stake in CMSC is less than 1%.

IC design services companies benefit from partnership with foundries in term of back-end process control. Usually, when IC designers select a foundry' platform, they rarely

change. Therefore, most of Taiwanese IC design service companies have one-to-one relationship with a foundry. Moreover, it is difficult to tie with multiple foundries when it is related to advanced process nodes.

Interestingly, TSMC, the world largest foundry, has partnership with many IC design service companies. TSMC's DCA, introduced in 2000, is a foundry, industry's first service organization dedicated to helping designers deliver on the promise of system-on-chip (SoC) methodologies. The DCA provides broad service choices from RTL to chips, including full chip placement and routing, RTL-to-GDS implementation as well as offering mixed-signal/analog/RF building blocks. TSMC's VCA program was formed in 2009. VCA members can take a project from design to final shipment. As an extension of TSMC's worldwide sales force, VCA members have to participate in regular customer and technology updates. As part of their commitment, every VCA must participate in TSMC new technology training and pass the exam afterwards. All VCA members are constantly evaluated by TSMC regional sales to assure they provide value-added service to the customers. The VCA program extends TSMC's ability to serve new geographic markets and a broader range of companies.

Each IC design service normally focuses only on specific types of IC products. Each carves out its own particular niche. The technology nodes used by these IC design service companies are also different. For example, in 2012, 48% of GUC's revenue is from 28nm and 40nm when 73% of Alchip's revenue is from 65nm and below. Therefore, the foundry may have one-to-many relationship with IC design services companies in order to seek for new customers to maintain fab utilization rate. The partnership between foundry and IC design service not only maintains competitive advantage by the advanced technology owned by a foundry and an IC design service company, but also increases the number of orders from IC design service companies by providing downstream customers with a complete line of services using abundant database of intellectual property (IP). Close cooperation allows them to accomplish customer project at breeding-edge process technology node. For example, GUC successfully completed advanced 28nm technology test chip tape-out for a customer at TSMC in 2011. In 2012, Socle Tapes out 28nm ASIC design at Globalfoundries. Apart from the manufacturing side, EDA and IP support are also necessary to allow engineers to design ICs to shorten time-to-market.

As process technologies shrink further at sub-nanometer level, the gap between accessible silicon and designers' ability to utilize that space keeps on widening. IP is vital in ameliorating design productivity in advanced design processes [10]. To support IP reuse, the organization must establish a resource structure that is able to provide application-level expertise for each particular IP block. Skills include the ability to address RTL functionality, compliance, synthesis, back-end issues and other challenges that customers face during design implementation. In general, customers do not have the time or resources to become experts in all of the IP they need in their products; vendors must provide the expertise [1].

Although Faraday and GUC have their own IP portfolios, they and other IC design service companies have to rely on other IP providers such as EDA tool vendors, pure IP providers, foundries, fabless companies and also other IC design service companies. The comprehensive IP portfolios are important for IC design service companies' design capability to attract their customers. The more extensive applications an IC design service company can provide, the more business the company will gain, with that more experiences will be accumulated [5][8]. A capability to integrate several proven IPs from different IP providers reflects these IC design service companies' technological capability.

The IP ecosystem network based on these six Taiwanese IC design service companies' partners is shown in Fig. 8. Majority of IP providers are from the US followed by Taiwan. The common IP partners of these six companies are from US and UK. Synopsys, Cadence and Mentor are EDA market leaders. In the SOC era, in addition to M&A of many smaller EDA companies, there are also high rate of M&A of many pure IP providers by EDA market leaders. The pure IP providers like ARM and Imagination are also important for the IP ecosystem.

While the production ecosystem is being localized in Taiwan based on the benefit of the complete value chain, the IP ecosystem is being internationalized. For Taiwanese IC design service companies, It could be said that foundries take a leader role for the change in production ecosystem when international EDA and IP providers, such as Synopsys, Cadence and ARMs, play leading roles in proven IPs in the IP ecosystem.

VI. CONCLUSIONS AND IMPLICATIONS

The development of strategic alliances and networks by firms is arguably a co-evolutionary adaptation to the simultaneous selection of individuals, dyads and groups. Firms and their strategic alliances in the business ecosystem will co-evolve if they can provide strategic value to their partners and customers. The IC design service companies and foundries tend to have close partnership. IC design services companies benefit from partnership with foundries in terms of back-end processes while foundries gain sale forces from the design service companies in order to maintain their fab utilization. The leading EDA tool vendors and IP providers play an important role in the IP ecosystem. Most IC design service companies have to partner with them in order to gain comprehensive IP portfolio to attract the customers.

IC design service companies are an essential piece of the semiconductor ecosystem, as well as Silicon Foundries, EDA and IP vendors. Taiwanese IC design service companies benefit from the complete production value chain. However, they have to rely on other IP providers in other countries,

especially from the US. For Taiwan, R&D investment in design at advanced technology node is necessary. Strategic alliances between IC design services and foundries are also important interdependent relationship for value creation in the Taiwan semiconductor value chain. For other developing countries without manufacturing infrastructure, there is still a niche for investors since the mature technology nodes (65nm and below) are being standardized and commercialized and the IC designers can send source codes to foundry in a remote country. The opportunities are based on seeking customers, customizing and integrating the commercialized IPs and connecting with manufacturers. In addition, the expertise designer resource will be the main factor for running the IC design service company.

For further research, understanding the specialty in reusing IPs and IP portfolio of the IC design service companies will be an interesting focus for reviewing one of core competences. The semiconductor industry is a significant industry for both developed and developing countries. The evolution of the design and process technology in the US, EU, Japan, Korea and China should be further studies. The partnership network of IC design service in a country without manufacturing infrastructure is also interesting to explore the key success factors of this emerging business in the semiconductor industry. Learning capabilities of firms coevolving in the networks should also be identified.

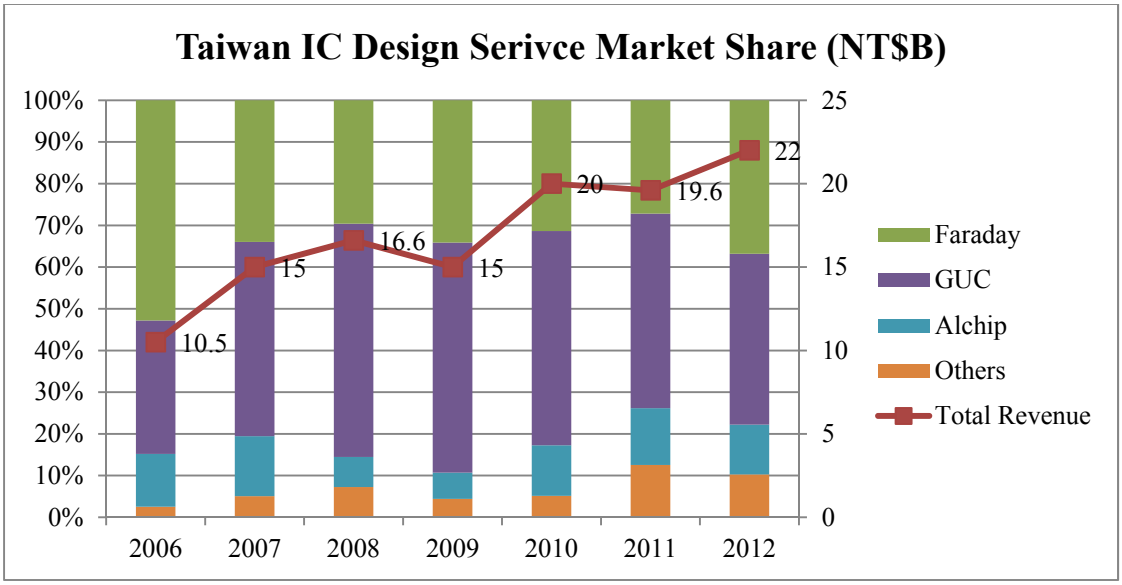

Fig. 3: Taiwan IC design service market share from 2006 to 2012 (NT$B)

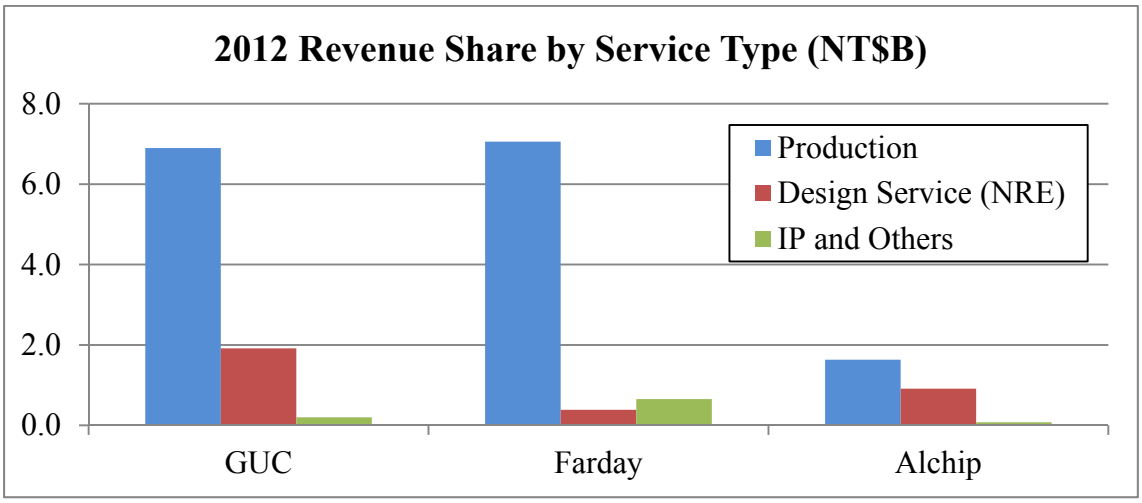

Fig. 4: Revenue share by service type (NT$B) in 2012

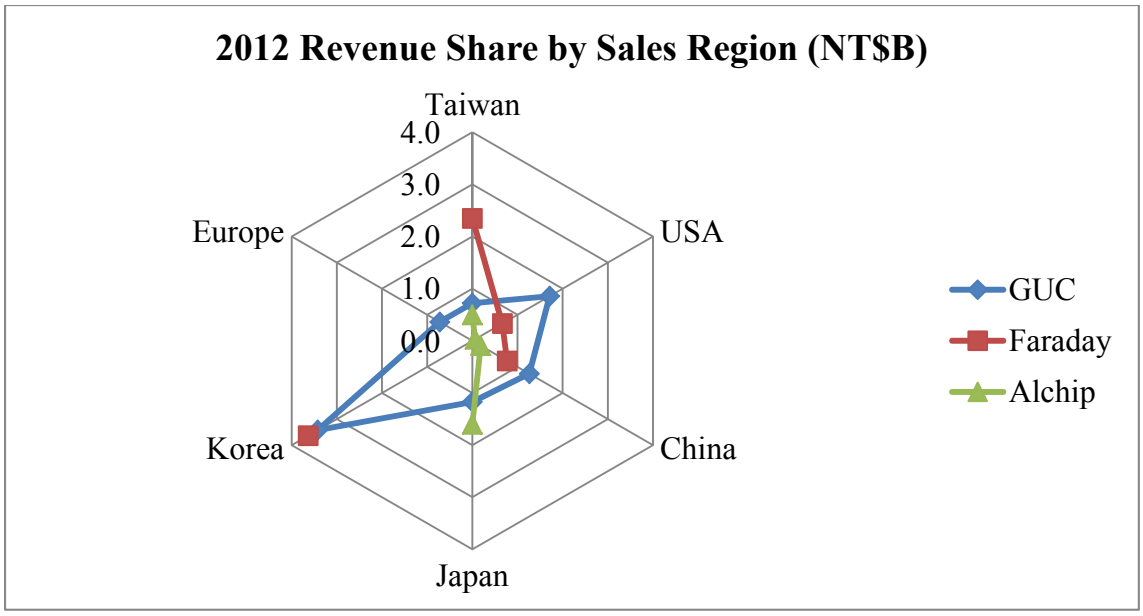

Fig. 5: Revenue share by sale region (NT$B) in 2012

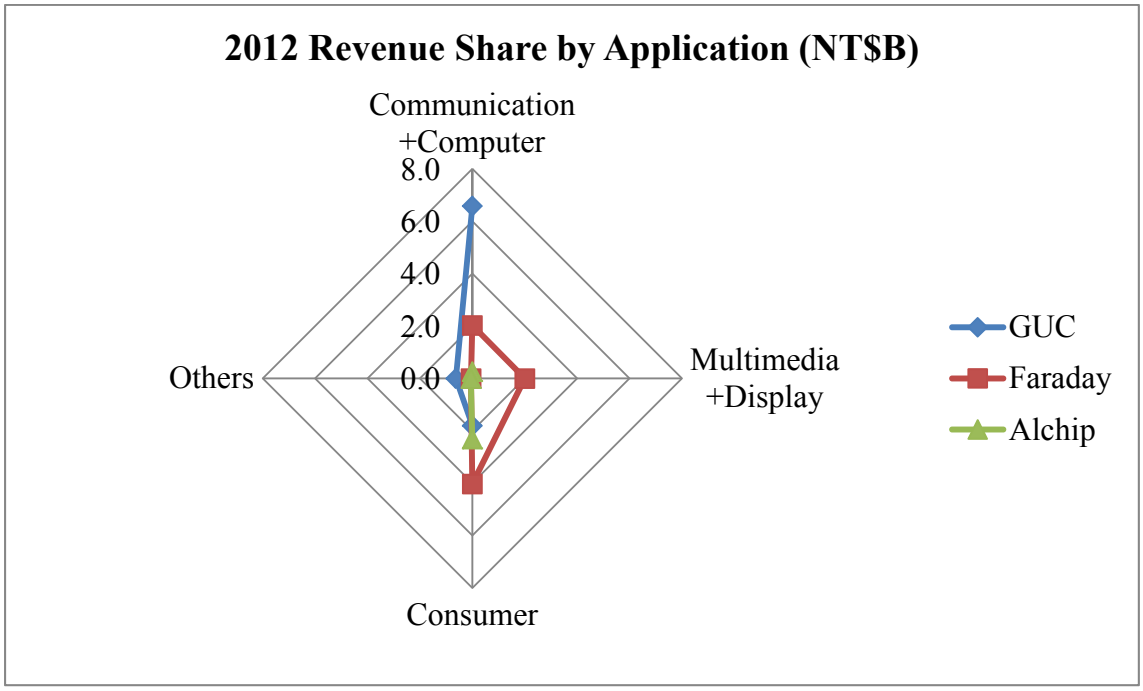

Fig. 6: Revenue share by application (NT$B) in 2012

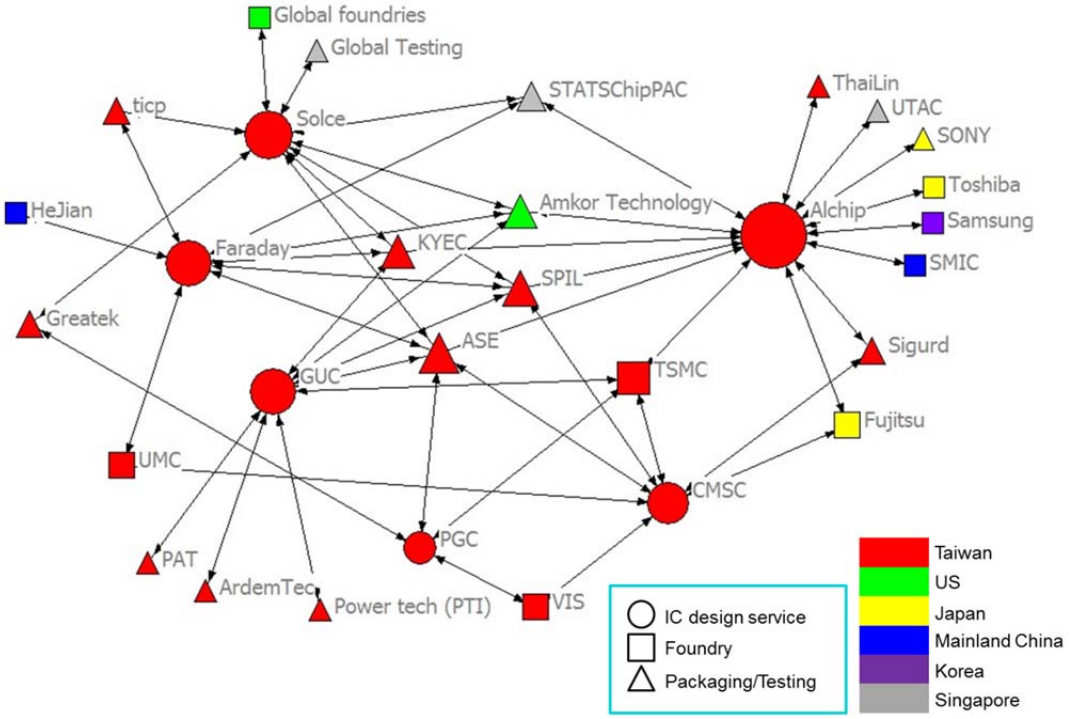

Fig. 7: Production partnership network in 2012

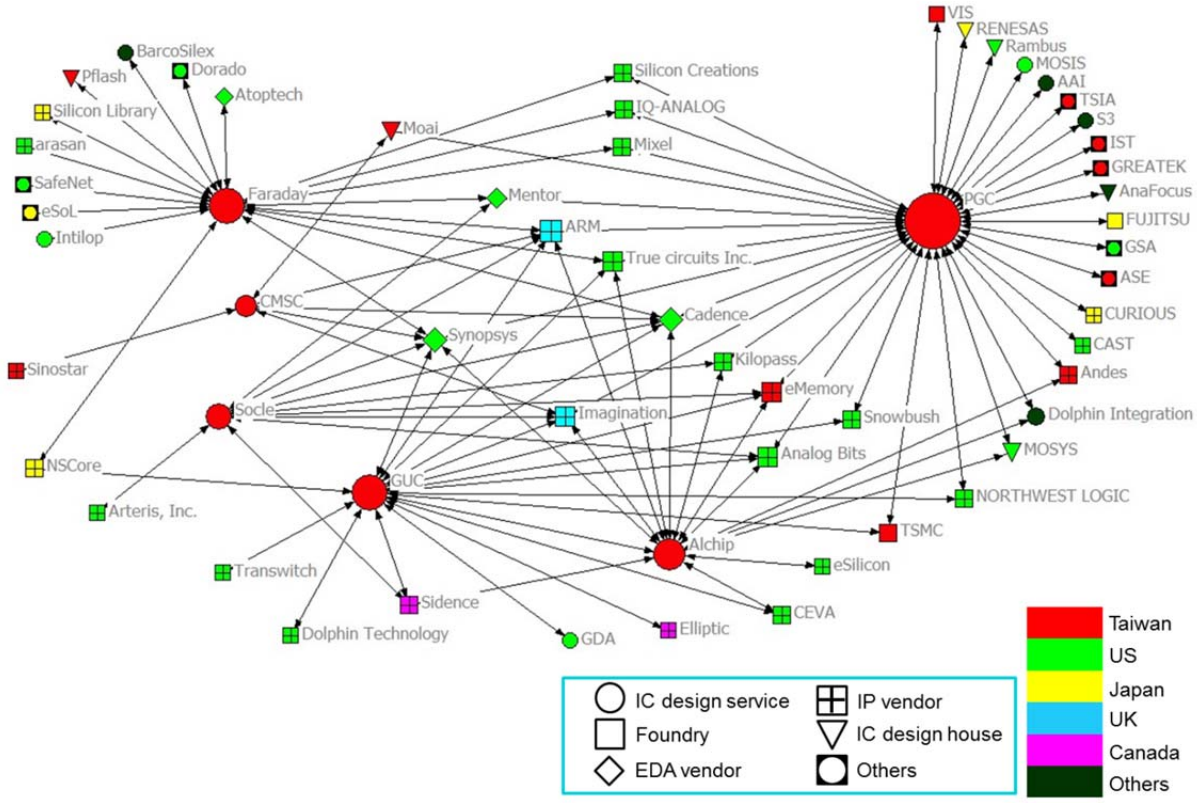

Fig. 8: IP ecosystem in 2012

REFERENCES

[1] Abrishami, R., "Design How-To Vendors must support IP reuse in SoC", EETIMES, December 19, 2002, Retrieved 12/12/2013 World Wide Web, http://www.eetimes.com/document.asp?doc_id=1277898,

[2] Adner, Ron and Kapoor, R., "Value creation in innovation ecosystem: How the structure of technological interdependence affects firm performance in new technology generations", *Strategic Management Journal*, Vol.31, pp.306-333, 2010

[3] Balconi, M. and Fontana, R., "Entry and innovation: an analysis of the fabless semiconductor business", *Small Business Economic*, Vol.37, pp. 87-106, 2011

[4] Brown, C. and Linden, G., "Chips and Change: How Crisis Reshapes the Semiconductor Industry", the MIT press, 2009

[5] Hurtarte, J. S., Wolsheimer, E. A., Tafoya, L. M., "Understanding Fabless IC Technology: Communications engineering series", Elsevier Inc., 2007

[6] Hynes, N. and Wilson, J., "Co-evolution dynamics in strategic alliances: The influence of the industry lifecycle", *Technological Forecasting & Social Change*, Vol. 79, pp. 1169-1175, 2012

[7] Kandampully, J., "Innovation as the core competency of a service organization: the role of technology, knowledge and networks", *European Journal of Innovation Management*, Vol. 5, No. 1, pp. 18-26, 2002

[8] Lin, Y. T., Yang, Y. H., Kang, J.S. and Yu, H.C., "Using DEMATEL method to explore the core competences and causal effect of the IC design service company: An empirical case study." *Expert Systems with Applications*, Vol. 38, No. 5, pp. 6262-6268, 2011

[9] Liu, X. W., "Benefits for TSMC gaining operational control of Global UniChip Corp.: Wafer Foundry + IC Design, 1+1>2", March 15, 2003, Retrieved 13/11/2013 World Wide Web, http://www.globalunichip.com/7-0_content.php?M1=20071025211024

[10] Marketandmarkets, "Semiconductor Intellectual Property Market, Silicon IP Market (2012-2017): Global Forecasts & Analysis", April 2012, Retrieved 17/12/2013 World Wide Web, http://www.marketsandmarkets.com/Market-Reports/semiconductor-silicon-intellectual-property-ip-market-651.html

[11] Mascarenhas, B., Baveja, A. and Jamil, M., "Dynamic of core competencies in leading multinational companies", Califonia Management Review, Summer, Vol. 40 No. 4, 1998, pp. 177-32

[12] Moore, J. F., "The Death of Competition: Leadership & Strategy in the Age of Business Ecosystems". New York: Harper Business, 1996

[13] Poltronetti, T., "Semiconductor Industry Faces Structural Changes around IP", February/March issue, 2007, Retrieved 5/11/2013 World Wide Web, http://chipdesignmag.com/display.php?articleId=1133&issueId=21

[14] Saha, S. K. (2013). Emerging Business Trends in the Semiconductor Industry. In *2013 Proceedings of PICMET '13* (p. 2744).

[15] TSIA, "Overview on Taiwan Semiconductor Industry (2013 Edition)", 2013, Retrieved 25/12/2013 World Wide Web, http://www.tsia.org.tw

[16] Tsai, F. S., Hsieh, L. H.Y., Fang, S. C. and Lin, J. L., "The co-evolution of business incubation and national innovation systems in Taiwan", *Technological Forecasting & Social Change*, Vol. 76, pp. 629-643, 2009

[17] Vagues, M., & Kumar, S. (2012). Transitioning Semiconductor Foundry Business Model to Complete IC Manufacturing Turnkey Solution Provider. In *2012 Proccedings of PICMET '12* (p. 2754).

[18] Volberda, H. W. and Lewin, A. Y., "Co-evolutionary dynamics within and between firms: from evolution to co-evolution", Journal of Management Studies, Vol. 40, pp. 2111-2135, 2003

[19] Wilson, J. and Hynes, N., "Co-evolution of firms and strategic alliance: Theory and empirical evidence", *Technological Forecasting & Social Change*, Vol. 76, pp. 620-628, 2009

[20] Yuan, B. J. C., Hsieh, J. C. H. and Wang, C., "Foresight for the semiconductor industry in Taiwan", *Foresight*, Vol. 8, No. 5, pp. 45-55, 2006