DOCTOR OF PHILOSOPHY

The innovation value chain and export performance

a study of Taiwanese manufacturing industries

Wan-Lin Hsieh

2013

Aston University

The Innovation Value Chain and Export Performance:

A Study of Taiwanese Manufacturing Industries

Wan-Lin Hsieh

A Thesis Submitted for the Doctor of Philosophy

Aston University

May 2012

Aston University

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Thesis Summary

This thesis involves the secondary data of 1806 innovative manufacturing firms derived from the database of 2nd Taiwanese Innovation Survey. Three topics are researched.

The first topic investigates the innovation value chain (IVC) in Taiwanese manufacturing firms. Previous IVC studies are all done in developed countries such as UK, Ireland, Northern Ireland and Switzerland, and it leaves the gap of those non-developed countries. The result shows the overall knowledge sourcing pattern of Taiwanese manufacturing firms presenting a complementary relationship which is consistent to the previous IVC studies. The main innovation input is still derived from internal R&D which suggests more utilisation of external knowledge may boost innovation outcome. Product innovation does enhance firm growth while process innovation reduces a firm's productivity. *The second topic* uses the lens of IVC to investigate the difference of the innovation process from knowledge linkages to value added between high-tech and low- tech sectors. The findings indicate (1) there are significant differences in the IVC between high- and low-tech sectors, however these are defined; (2) how you define 'sector' matters i.e. the nature of the high-tech and low-tech differences varies depending on whether the technology definition is carried out at the industry or firm level; and (3) the high uncertainty of innovation cause the difficulty to predict firm performance especially for those firms with high intensity of innovation. *The third topic* investigates the innovation-exporting relationship and explores the determinants of export performance. Product innovation enhances export performance once a firm enters international markets while process innovation affects negatively on a firm's likelihood of being an exporter. Furthermore, IP protection is found to affect directly export performance positively.

Key words: Innovation value chain, Export, Taiwan, Manufacturing firms, High- tech and low- tech sectors

Dedication

This thesis is dedicated to my beloved family:

Dad
Mom
&
Brother

for their endless love, encouragement and support

I also want to delicate this thesis to all my family members who have always been there for me, especially to the memory of the departed soul of my Granddad who passed away during my PhD study.

In addition, I dedicate this thesis to my supervisors

Professor James (Jim) H. Love
&
Dr Panagiotis (Vasilis) Ganotakis

for their wonderful supervision

Acknowledgments

I would like to express my heartiest appreciation to my supervisors, Professor Jim Love and Dr Vasilis Ganotakis, for their invaluable guidance and advice. Without your continuous support and incredible patience, I will never finish this PhD thesis especially in such a short period, two years. I am here to show my sincere gratitude to your wonderful supervision. Furthermore, I would also like to express my deep appreciation to Dr Mu-Yen Hsu from College of Commerce, National ChengChi University and the Taiwan Innovation Database. Without them, I would not be able to complete this research.

I would like to take this opportunity to thank those who have been supporting me during this PhD study journey. First of all, the biggest thankfulness is to my parents and brother for their endless concern and support. I also want to thank all my friends who have been there for me.

Finally, I would also like to thank everyone who has helped me during this PhD study and especially Prof Sam Aryee, Liz Bridges, Jeanette Ikuomola, Ranjit Judge and other people from RDP. There are too many people to thank here, so I would like to give the final thank to all of you who have ever been in my life.

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Chapter 1 Introduction and background of research

1.1 Introduction

The purpose of the first chapter is to give the blueprint of this thesis. The research background is first introduced in section 1.2 to provide an overall view of the research. The research motivation is then drawn to indicate the objectives of the research in section 1.3. In section 1.4, the key research questions which will be raised in the empirical chapters 4, 5 and 6 are listed. A final conclusion in section 1.5 outlines the remaining chapters of the thesis.

1.2 Research background

Innovation is recognised nowadays as a crucial activity for an organization to renew the value of their asset (Baregheh et al., 2009) and to create competitiveness (Schumpeter, 1934; Buehler and Shetty, 1987; Angelmar, 1990; Shepherd and Ahmed, 2000; Miozzo and Dewick, 2002; Siqueira and Cosh, 2008). However, there is a limit of an organization’s internal resources and capabilities to carry on its innovation. In order to enhance its competitiveness, it is not enough only to depend on internal R&D but to collaborate or share resources with other organisations such as suppliers, customers/clients, competitors, public organisations or even some other approaches (i.e. exhibitions or industrial associations). Therefore, the concept of open innovation starts to argue that the elements of a firm’s innovation can be sourced not only internally but also externally (Chesbrough, 2003). Oerlemans et al. (1998) suggest innovation performance is better with its open sourcing activities rather than the limit on internal resources. Furthermore, a firm with absorptive capacity which is argued to identify, assimilate and transform external valuable resources can lead to better innovation performance and competitive advantages (Cohen and Levinthal, 1990).

‘Since the time of Adam Smith, one of the most important principles of economic theory has been that international trade is a necessary (albeit not sufficient) condition for countries to attain high productivity and income levels’ (Inter-American Development Bank, 2001: page 49).

International trade is also one of important issues in current economy no matter from the perspective of macroeconomics or microeconomics. In order to achieve global competitiveness, a nation or a firm tends to export to increase its production and economy. In this way the thesis considers two crucial aspects of firm and national competitiveness: innovation and exporting. Because this research interests in firm-level innovation, a firm’s export will be added as a part of research to contribute on the research of product and process innovation.

1.3 Research motivation and objectives

Followed by the importance of innovation introduced in the previous section and the focused interest on manufacturing industry, this study will concentrate on the innovation of products and processes. Innovation is a knowledge-based process that creates new possibilities through combining a bundle of knowledge (Tidd et al., 2005). Therefore, the interest is raised to investigate the process of innovation from knowledge sourcing via different forms of innovation to the end of value added. The innovation value chain (IVC) is introduced by Roper et al. (2008) as a more explicit framework with econometric modelling. It begins with knowledge sourcing activities from which firms derive knowledge for innovation undertaken, continues with the transformation of the acquired knowledge into new or significantly improved products or processes and finalises the process of innovation by generating added value with knowledge exploitation. Studies of the IVC have been carried out in some developed countries such as Ireland and

Northern Ireland (Roper et al., 2008), Ireland and Switzerland (Arvanitis and Roper, 2009) and the UK (Ganotakis and Love, 2010). However, the lack of studies in non-developed countries brings our interest to investigate the IVC in an advanced developing country, Taiwan.

It is undeniable that the current economic industry has moved toward service industry but manufacturing industry is still the foundation of a nation's economy. Based on this reason, this study focuses on only manufacturing firms but not service firms or not all the industries because of the different characteristics between manufacturing and service industries. Therefore, the first part of this study is to investigate the IVC of Taiwanese manufacturing firms to fill the gap of missing studies in non-developed, Western countries.

Most previous innovation research has focused more on high-tech sectors, with relatively few studies on low-tech sectors, and especially the comparison between high-tech and low-tech sectors. Furthermore, there is an issue relating to "Are firms in high-tech industries really high-tech firms?" and "Are firms in low-tech industries really low-tech firms?". This could due to the evaluation of industrial development and technology diffusion between industries, so that some (possibly many) firms in low-tech industries could actually be high-tech firms and vice versa. For the above reasons, the second part of study aims to compare the IVC of high-tech and low-tech sectors, and to investigate if there is a difference when we define high-tech and low-tech sectors at the industry-level or at the firm-level. This is particularly relevant in the case of Taiwan, where innovation/industrial policy puts a lot of emphasis on 'high-tech' sectors. If the IVC of such sectors differs markedly depending on whether 'high-tech' is measured at industry- or firm-level, this could have important public policy implications.

In addition, because export plays an important role on a nation's economy, this study not only looks into the process of innovation which leads a firm to generate added value but also investigates the effect of innovation on export propensity and performance. While there are a substantial number of studies linking innovation and exporting, there is a lack of such analysis for advanced developing countries, and especially for Taiwan. Furthermore, the simple reason Taiwan is chosen for the study because I am a Taiwanese.

1.4 Research questions

From the three main objectives mentioned in the previous section, there are some questions to be raised in each of the three topics of empirical research.

Topic 1 – The innovation value chain (IVC) of Taiwanese manufacturing industries

Question 1: Is there a complementary or substitute relationship between internal R&D and external knowledge sourcing activities?

Question 2: Is there a complementary or substitute relationship between external knowledge sourcing activities?

Question 3: Which knowledge sourcing activities play a significant role on innovation (both product and process)?

Question 4: How does innovation affect firm performance?

Question 5: What are the effects of other factors on the IVC?

Topic 2 – The comparison on the IVC between high-tech and low-tech sectors.

Question 1: Is there a significant difference in the allocation of manufacturing firms when we define high-tech and low-tech sectors at the industry-level and at the firm-level?

Question 2: What is the difference of knowledge sourcing activities between high-tech sector and low-tech sector?

Question 3: How do knowledge sourcing activities affect innovation differently between high-tech and low-tech sectors?

Question 4: What is the differentiation of innovation's impact on firm performance between high-tech and low-tech sectors?

Question 5: How do these IVC differences vary depending on how hi-tech and low-tech sectors are defined (i.e. at industry- or firm-level)?

Topic 3 – Innovation and export performance

Question 1: How do different types of innovation (product and process innovation) affect export propensity and performance?

Question 2: Do firm-level international linkages affect export propensity and performance?

Question 3: What are the effects of other determinants on export performance?

1.5 Plan of the thesis

The remaining chapters of the thesis are as follows. The literature review is first to be introduced in chapter 2 to show the theories and relevant literature behind this research. This chapter also includes some background information on Taiwan. Chapter 3 introduces the background of the survey and describes the data adopted in the empirical analyses. Chapter 4 investigates the first topic 'the IVC of Taiwanese manufacturing firms'. In chapter 5, the second topic 'the comparison of the IVC between high-tech and low-tech sectors' is examined. Chapter 6 the third topic 'innovation and export performance' examines the effect of innovation on export performance and explores potential determinants of export performance. The final chapter summarises the key findings from the three topics. It also highlights the contributions and gives explicit implications for the research findings. The last part of chapter 7 indicates the limitations of this study and suggests possible future research.

Chapter 2 Literature review and conceptual frameworks

2.1 Introduction

This chapter reviews the theoretical and empirical background for this thesis including the innovation value chain (IVC), determinants of export performance and background information about Taiwan. Schumpeter's (1934) and Tidd et al. (2005)'s classifications of innovation are introduced and the definitions of product innovation and process innovation by OECD (2005a and 2005b) are recalled to highlight the focused innovation indicators in this thesis. Because this thesis is constructed into three empirical studies which are introduced in chapter 4, 5 and 6, this chapter mainly reviews the literature of the theories adopted in the conceptual frameworks which underlie the empirical research. First, product innovation and process innovation are introduced to highlight the core theme of this thesis. Second, the resource-based view and absorptive capacity are introduced to explore the determinants of innovation and the determinants of export performance (the latter will be detailed more in chapter 6). Third, the empirical background is introduced with respect to the Taiwanese economy, and its industrial development, innovation and export performance.

2.2 What is Innovation?

Innovation is a multi-dimensional activity and it can be studied in different disciplines. The foundation of innovation can be traced back to Schumpeter's argument in 1934 that he considers an entrepreneur as an innovator who applies technological innovation to generate a new product/service or a new process for making it (Schumpeter, 1934). In the past years, the term 'innovation' has been utilised widely by both researchers and practitioners across various disciplines such as human resource management, operations management, entrepreneurship, research and development, information technology, engineering and product design, and marketing and strategy. Therefore, inconsistent definitions are used from different perspectives (Damanpour and Schneider, 2006; Baregheh et al., 2009). In the business administration field, innovation research can be classified into two major themes: (1) marketing research (i.e. the causes of innovative behaviour of consumers) which interests in innovative consumers who are supposed to be opinion leaders and could affect other non-innovative followers, and (2) organizational theory and strategic management (i.e. the organizational characteristics of innovative organizations) which concerns the adoption of different forms of innovation and its effect on organizational performance (Subramanian and Nilakanta, 1996). This study examines the models of the IVC and determinants of export performance by using a firm as the unit of analysis, and therefore its focus is firmly on the latter theme.

In general, innovation plays an important role to create value and sustain competitive advantages, so organizations can respond to internal and external dynamic environments (Damanpour, 1991; Zahra and Covin, 1994). The effectiveness of innovation to firm performance and economic growth therefore is typically either to reduce costs or to create increasing revenue (Schumpeter, 1934; Drucker, 1985).

The essence of innovation is about ‘change’ and it may include a wide range of dimensions depending on organizations’ resources, capabilities and business strategies (Schumpeter, 1934; Tidd et al., 2005; Baregheh et al., 2009). Here, we provide two most popular cited classifications of innovation by Schumpter in OECD (1997: 28) and Tidd et al. (2005).

In 1903s, Joseph Schumpter distinguishes innovation into five categories as the below (OECD, 1997: 28):

- Introduction of a new product or a qualitative change in an existing product.

- Process innovation new to an industry.
- The opening of a new market.
- Development of new sources of supply for raw materials or other inputs
- Changes in industrial organization.

Recently, Tidd et al. (2005) re-categorise innovation into four types in a more clearly distinct classification:

- Product innovation: changes in the things (products/services) which an organization offers.
- Process innovation: changes in the ways in which they are created and delivered.
- Position innovation: changes in the context in which the products/services are introduced.
- Paradigm innovation: changes in the underlying mental models which frame what the organization does.

Because this study examines innovation from the perspectives of resources and capabilities but not managerial decision, it emphasizes on the first two types of innovation to subscribe the innovative activities within the IVC and exporting which will be reviewed in the next sections. To be explicit what product innovation and process innovation are, we recall the definition of product and process innovation stated by OECD (Organisation for Economic Co-operation and Development). According to the definition by OECD, ‘a product innovation is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses’ and ‘a process innovation is the implementation of a new or significantly improved production or delivery method’ (OECD, 2005a and 2005b).

2.2.1 Product innovation

A product in terms of business is something a firm uses to meet the market demand and customer satisfaction with the return of profit. It can be tangible in the form of goods or intangible in the form of services. Therefore, the variable of product innovation adopted here can be interpreted as 'the introduction of new or significantly improved goods or services'. There are two indicators often used to measure product innovation such as product innovation decision (i.e. whether a firm introduced new or significantly improved goods/services in the past three years) and innovation success (i.e. the percentage of innovative goods in total sales). (Laursen and Salter, 2006; Tang, 2006; Tsai, 2009)

2.2.2 Process innovation

The process here is referred to a manufacturing procedure to produce product or the delivery of product to markets. Therefore, process innovation adopted here can be interpreted as 'the introduction of new or significantly improved processes which are inserted new technology to produce new or higher quality of products or new or significantly improved approach to introduce/deliver new products' (Reichstein and Salter, 2006; Tang, 2006).

No matter from the dimension of product or process, innovation is clearly an activity to introduce something new or significantly improved in order to achieve value added in the commercial end.

2.3 Homogeneous firms versus firms' heterogeneity

Traditional economics assumes that firms' entities and production function are homogeneous (Marshall, 1920 & 1961; Williamson, 1975). All firms in the same industry are considered sharing the same resources and environment, having equivalent capabilities and producing the identical products. The research of traditional economics typically investigates on either country-level or industry-level, and the hypotheses emphasize on the difference between countries or industries. However, contemporary research has moved toward the belief of inter-firm heterogeneity and the difference between firms is taken into account on the effects on performance and competitiveness (McEvily and Zaheer, 1999). Since the empirical research conducted in this thesis employs firm-level data, it is important that concepts are employed which explicitly allow for elements of firm-level heterogeneity. The next three sections will examine a firm's characteristics and the determinants of innovation and export performance from the perspectives of 'resource-based view'/ 'neo-endowment based theory' and 'absorptive capability'/ 'neo-technology based theory', all of which are concepts relevant to the subsequent empirical research.

2.4 Resource-based view

It is stated that 'resources and products are two sides of the same coin' (Wernerfelt, 1984: 171). In strategic management research, the literature shows its possible perspectives from both resources and products that resources can lead to diversified products whereas products require various resources. Grant (1991:114) states that 'Strategy is the match an organization makes between its internal resources and skills… and the opportunities and risks created by its external environment.' Hence, the resource-based view (RBV) is the foundation for firm strategy and its implication in strategic management acts as a tool to analyse a firm's resources as strength and weakness (Wernerfelt, 1984; Porter, 1985; Barney, 1986; Andrews, 1987).

RBV asserts that a firm's resources and capabilities can lead to competitive advantage if they are valuable, unique, rare and irreplaceable (Barney, 1991; Peteraf, 1993;

Newbert, 2008). These resources and capabilities could be diverse that include tangible and intangible assets such as properties, employment of skilled personnel, organizational and individual experiences, know-how and so on (Wernerfelt, 1984). Overall, stronger internal resources and capabilities can not only directly enhance a firm's performance, but also increase the chance to access external resources such as knowledge from supply chain partners, competitors, consultants, universities and public resources. This can lead to the concept of absorptive capacity which is introduced to enable a firm to identify the valuable external resources, assimilate it, transfer it into internal resources and capabilities and apply it to the commercial end to value added (Cohen and Levinthal, 1990).

2.4.1 Knowledge-based view

Knowledge is considered as a vital resource for a firm to perform better and it is valuable because of being partially explicit and not able to be completely transited. 'We know more than we can say that we know' is stated by Polanyi (1996) to characterise the tacit part of knowledge which is not able to be imitated. Therefore, it is recognised as one of the major resources to sustain a firm's competitiveness and performance. Followed by the previous review on resource-based view, knowledge-based view therefore is highlighted for the later research framework to emphasize the role of knowledge. It has been argued that knowledge can be explicit and tacit, and different types of knowledge vary in their transferability (Grant, 2002). However, the review here on knowledge resources is not going further on its variety, but focuses on the organisations where knowledge is sourced. The quantity of knowledge is difficult to be measured directly, and one common approach is to measure the linkages to different sources of knowledge. Nowadays, knowledge is no longer only sourced from internal R&D but also able to be derived externally, and the model of innovation has become from close to open. Therefore, open innovation perspective is taken as a basis to view the research framework.

2.5 Absorptive capacity

Absorptive capacity has become an important issue, regardless whether it is in academic research or an industrial field. There are various literature and empirical studies which show that it is a crucial capability for a firm to innovate and achieve a higher level of competitiveness (Cohen and Levinthal, 1990; Kogut and Zander, 1992; Zahra and George, 2002; Todorova and Durisin, 2007; Vanhaverbeke et al., 2008; Fabrizio, 2009; Grimpe and Sofka, 2009; Murovec and Prodan, 2009). Cohen and Levinthal (1990) firstly introduce the term absorptive capacity as a firm's capabilities to recognize valuable external knowledge and to assimilate and apply it to a commercial end. Zahra and George (2002) consider absorptive capacity as a dynamic capability and reconceptualise it as two parts, potential and realised absorptive capacity. And the whole process of absorptive capacity is modelled as knowledge acquisition, assimilation, transformation and exploitation. In the era of open innovation, innovative activities are no longer processed within an organization but exceed a firm's boundary to access external resources (Chesbrough, 2003). In order to lead to a successful innovative activity, it is important to have the capability to indentify valuable knowledge. Todorova and Durisin (2007) recall Cohen and Levinthal's (1990) capability to recognize the value, to emphasize this important element.

Fabrizio (2009) claims that the value generated from external knowledge will be different because of a firm's own actions and resources which help a firm identify value, and assimilate and apply it. This study measures absorptive capacity based on employee capabilities and resources a firm provides to enhance employee's capabilities.

Therefore, the indicators of absorptive capability are measured as 'employee qualification' and 'employee training' which will be detailed in the later section.

2.6 Firm characteristics

From the perspectives of the resource-based view and absorptive capacity, there are a number of firm characteristics which are often used to examine product and process innovation. These firm characteristics can be classified into resource indicators (i.e. size, age and subsidiary) and capability indicators (i.e. employee qualification and training).

2.6.1 Size and age

Firm size and age are two factors typically taken as control variables in innovation research because larger and longer established firms are considered to have more resources, greater capabilities and strategic freedom than smaller and young firms (Duysters and Hagedoorn, 2002). Although the positive effect of firm size and age on the internal resources and capabilities, previous studies have found inconsistent results of the direct size or age impact on innovation.

There is no consistent approach to measure firm size but it is usually measured by either the number of employee (Thornhill, 2006) or the sales (Wakasugi and Koyata, 1997; Link and Rees, 1990; Mansfield, 1986). In this study, firm size is measured by the number of employee of the year the survey was conducted. In terms of firm age, it is measured as a binary variable because there is no data for the actual number of years since firms established. Therefore, the dummy variable of firm age is defined as whether a firm was established within 3 years.

2.6.2 Group membership

A group-company, also called corporate group, consists of a collection of parent and subsidiary companies. These subsidiary companies function as an individual economic entity but with their parent company's control to share common resources. It is proposed that a firm connecting with others is able to derive more resources and generate better performance. Khanna and Rivkin (2001) suggest that a group-company can serve as a functional substitute to boost the profitability of its member companies via filling the institutional voids in emerging economies. However, a subsidiary may derive the results of innovation activities directly from its parent company or other members within the group which actually reduce a firm to engage in innovation activities. Therefore, although stronger resources could be derived as being a part of a group company, it is not always the case of its positive effect on innovation.

2.6.3 Employee qualifications and training

Employee qualifications are here measured as the percentages of employee with qualifications (equivalent to or higher than university degree), and training is indicated by a dummy variable indicating whether the firm undertook employee training in the last three years.

It is indicated by some previous research that more employees in a firm with a certain level of expertise can increase the absorptive capacity (Liao et al., 2007; Roper et al., 2008; Grimpe and Sofka, 2009). Because employee qualifications are an indicator of employee skills and possibly employee productivity, and specific training can enhance employee's particular skills for innovation, these two indicators, employee qualifications and training are supposed to affect positively on innovation performance.

2.7 The innovation value chain

Innovation is a knowledge-based process that creates new possibilities through combining a bundle of knowledge (Tidd et al., 2005) and an organization should innovate in order to renew the value of their asset endowment (Baregheh et al., 2009). The previous research has argued and demonstrated that innovation is recognized as one of the crucial inputs to a firm's competitive advantages (Schumpeter, 1934; Shetty and Buehler, 1987; Angelmar, 1990; Shepherd and Ahmed, 2000; Miozzo and Dewick, 2002; Siqueira and Cosh, 2008). Due to the movement to global competitive era, manufacturers need not only to produce new products but also present the new products quickly with better quality, a lower price and enough quantity to meet market demand. Speed, efficiency and quality are three indicators of a firm's process innovation (manufacturing process and organizational innovation) to sustain in globalized competitive market environment (Wheelwright and Clark, 1992; Kirner et al., 2009). Furthermore, the business environment has shifted towards a more service oriented economy and most manufacturers not only provide tangible products but also offer relevant services (intangible products) (Marshall, 1982). Due to the fast changing environment, it is important for a firm to keep creating new products (goods or services) in the market (goods/service innovation) and to keep developing capabilities to produce or market new goods or services to customers (process innovation) (Tidd et al., 2005). Therefore, this study focuses on process-driven and product-driven innovation to achieve competitive advantages.

The innovation value chain (IVC), the flow of the value added innovation process, comprises of three key stages: beginning with the input of resources, followed by innovative activities and resulting in an increased performance for a firm. A firm's successful innovation with added value leads to a better performance in terms of the growth of productivity, sales, exporting growth and employment (Roper et al., 2008; Roper and Love, 2002; Klomp and Leeuwen, 2001).

In Roper et al. (2008)'s study of innovation activities of manufacturing firms in Ireland and Northern Ireland, innovation value chain was explored by econometric modelling. A firm's successful innovation with added value leads to a better performance in terms of the growth of productivity, sales, exporting growth and employment (Klomp and Leeuwen, 2001; Roper and Love, 2002; Roper et al., 2008). This study aims to develop Roper et al. (2008)'s model of the IVC by covering a wider range of knowledge sourcing and innovation activities.

2.7.1 Knowledge sourcing

In the era of open innovation, the boundary of knowledge sourcing is no longer limited within an organization (i.e. internal R&D) but extended to external resources such as external R&D, forward linkages (i.e. customers or clients), backward linkages (i.e. suppliers), horizontal linkages (i.e. competitors or other companies), public linkages (i.e. universities or government) and other linkages (i.e. exhibitions or industrial associations). These linkages to either internal or external resources are indentified as different types of knowledge sourcing activities which is at the beginning of the IVC and considered as the inputs of innovation activities (Chang and Robin, 2010; Ganotakis and Love, 2010; Roper et al., 2008). Based on the view of absorptive capacity, internal R&D enhances a firm's capability to absorb external knowledge, so complementary relationship exists between internal and external knowledge (Ganotakis and Love, 2010; Roper et al., 2008; Veugelers and Cassiman, 1999). However, some empirical studies indicate that a firm with internal R&D actually reduce the probability to link to external knowledge with substitution relationship (Schmidt, 2010; Love and Roper, 2001).

Therefore, knowledge sourcing as the first part of the IVC aims to investigate whether a substitution or complementarity relationship between knowledge sourcing activities exists in Taiwanese manufacturing industry (More detail will be introduced in chapter 4).

2.7.2 Innovation production

As mentioned in the previous section, this study focuses on product and process innovation with three indicators: a dummy variable of product innovation (i.e. whether a firm engaged in product innovation in the past three years), a quantitative variable of innovation success (i.e. the percentage of innovative goods in total sales) and a dummy variable of process innovation (i.e. whether a firm engaged in process innovation in the past three years). In this part of innovation production, the determinants of innovation are viewed mainly from the perspectives of resource-based view and absorptive capacity. They include the crucial factor 'knowledge sourcing activities' (the beginning of the IVC) and other proposed determinants such as internal resources and capabilities and other factors (more empirical studies of this stage are discussed in chapter 4).

2.7.3 Firm performance

The final result of an innovation activity is to generate value. Therefore, the three innovation indicators are examined on firm performance which is measured by three indicators, employee growth (the percentage of increased employment between 2004 and 2006), sales growth (the percentage of increased sales between 2004 and 2006) and productivity (the ratio of sales to employee in 2006). In addition to the innovation indicators, some other factors are also used as control variables such as internal resources and capabilities (more empirical studies of this stage are discussed in chapter 4).

2.8 Innovation and exporting

2.8.1 What is exporting?

People trade resources, material, goods and services in order to derive something they do not have in their local areas. The record of international trading activities started since the materials/goods exchange between East and Western countries. These trading activities include importing and exporting from the perspectives of purchase and selling. They provide more choices and selections of goods and services for customers/clients to advance a country's living standard and to build up positive competitions between enterprises. In this dynamic economic era, countries have tried to enhance their exporting development in order to keep high and rapid production and to increase economic growth. Furthermore, it also has been claimed that exporting activities can affect currency values, governments' monetary policies, shape public perception of competitiveness and determine a country's capacity to import (Czinkota, 1994). In order to expand business, some companies focus on not only domestic markets but also foreign markets to increase their market share. Hence, even small firms are found that they tend to enter international markets at a much earlier age than in the past (Reynolds, 1997).

Since exporting has prevailed over the international trade research, the determinants of export performance can be explored by neo-endowment theory and neo-technology theory. From the economic scale of investigation, it can be examined from the perspectives of macroeconomics (country-level) and microeconomics (firm-level).

From the macroeconomic perspective, the topics of exporting research have been focused on a country's GDP growth (Sheehey, 1990; Hsiao and Hsiao, 2006), national productivity and accumulation of foreign exchange (Czinkota, 1994). From the microeconomic perspective, a firm's productivity, R&D and innovation reveal their importance in exporting research (Aw et al., 2000 and 2007; Katsikeas et al., 2000). This study will estimate exporting activities at the firm-level from microeconomic perspective because our interest here is to investigate the relationship between a firm's innovation and exporting while allowing for other determinants of exporting.

2.8.2 Export performance

Before reviewing the literature of export's determinants, this section reviews first how the previous research measure exporting performance.

The microeconomics of exporting research can consider if a firm engages in export activities. Thus the first indicator of exporting can be measured as a dummy variable, export decision (i.e. whether a firm engages in export activities). Once a firm is taken account as an exporter, the research will also investigate on how a firm performs in export activities. The export performance can be considered as a firm's international sales performance which focuses on the sales of exporting goods. From the dimension of sales figure, the intensity of exporting can be measured as a quantitative variable, export intensity (i.e. the ratio of international sales to total sales). In the previous studies, these two are the most popular measures of export performance (Wakelin, 1998; Roper and Love, 2002; Gourlay et al., 2005; Roper and Love, 2002; Ganotakis and Love, 2012). However, export performance can also be measured from the dimension of the export geography. Internationalisation is viewed as a process of a firm's gradual increase on foreign markets that are served, and the number of geographic foreign markets a firm serves can be interpreted as its degree of internationalisation (Calof, 1993; Beamish and Munro, 1987; Balcome, 1986; Johanson and Vahlne, 1977; Hirsch and Baruch, 1974).

Because of a lack of sales figures of exported products, this study examines a firm's exporting performance by the degree of internationalisation. The degree of internationalisation is considered as a firm's geographic extent of exporting markets can be taken into account of a firm's export performance. Therefore, the exporting in the later analyses will be measured as dummy exporting (i.e. whether a firm engaged in export activity) and exporting intensity (i.e. the number of foreign countries a firm exported its products).

2.8.3 Determinants of exporting

The research on international trade can be viewed at country-level or firm-level. A country's natural endowment, industrial development and technology determine its competitiveness, while a firm with internal resources and capabilities also determined by the endowment of an environment/ a country where it is located. Except the endowment resources, capabilities and environment, export performance is also affected by management perspective such as company strategy, director's decisions and preference of markets.

In general, the most common two different perspectives adopted by the previous researchers to frame the model of international trade's determinants are neo endowment (resource-based) theory and neo technology theory (Roper et al., 2006). First, the neo endowment model focuses on the resources of materials, labour capital and more recently human capital and knowledge. Second model neo-technology view is built up from the traditional technology based models such as technology-gap theory of trade (Posner, 1961; Hufbauer, 1970) and product life-cycle theory of trade (Hirsch, 1965; Vernon, 1966; Dollar, 1986).

2.8.3.1 Neo-endowment based model

From the view of macroeconomics, there is always a limit on the resources existing in the world. Every country has its own natural endowment, population and terrain which could facilitate diverse advantages. Heckscher-Ohlin theorem looks at the factor endowments perspective on international trade based on the assumption of perfect competition where factor-price equalisation exists. It states that a country tends to produce and export the goods based on its abundant resources and import those materials/goods which are lacked in its domestic resources (Jones, 1956-1957). Heckscher-Ohlin-Samuelson Model adds Stolper-Samuelson theorem to consider the cost issue which includes the relative trade prices and wage rate and it leads the model to a broader endowments concern.

In Heckscher-Ohlin-Samuelson, "countries specialize in the production and export of products in which they have a comparative cost advantage caused by relative abundance of a certain factor of production" (van Dijk, 2002: 4).

Diverse resources in every country are evaluated by neo-endowment models to cause different strength affecting on its cost and capacity of production. The factors of natural endowment will therefore become one of the determinants of a country's competitive advantages. For example that some Middle East countries like Saudi Arabia, Iraq and Iran have plentiful crude oil. Colombia and Brazil have the best climatic elevation conditions to produce coffee.

"More generally, countries export products they can produce more cheaply in return for products that are unavailable domestically or are cheaper elsewhere" (McEachern, 2011: 399).

A country with an abundance of unique nature resources indeed has more competitive advantages but it is not the only determinant. Except the natural materials, labour capital and geography are also important factors affecting a country's competitiveness (Davis, 1995).

Some recent studies narrow down the economic scale of export activities from macroeconomics to microeconomics and look at international trade at firm-level. Wakelin (1998) evaluates the relationship between innovation and export behaviour at the firm-level. Her neo endowment model views a firm's competitive advantage based on factor endowments. It is argued that advantages could be generated if a firm has a natural monopoly of a particular factor or is located in somewhere with plentiful specific factors. Because the production of a firm does not only rely on the productive materials but also other factors of business, the model then is extended to include other different dimensions of organizational resources from the perspectives of labour and capital. This extended model can effectively be considered as the resource-based view model of a firm's competitiveness which is suggested by several microeconomics-level empirical studies as the determinants of exporting (Roper and Love, 2002; Roper et al., 2006; Singh, 2009). Furthermore, absorptive capacity, defined as the ability of a firm to assimilate external knowledge to enhance internal knowledge and then apply it to generate value added, is also implicit in the neo-endowment model. Therefore, the neo-endowment theory on the determinants of export can be examined from the perspectives of both the resource-based view and absorptive capacity.

2.8.3.2 Neo-technology based model

The neo-technology based model comprises technology-gap theory and product life cycle theory to look at the effects of distinct technology related factors. A country with more advanced technology can benefit the domestic companies at the early stage and enhance its international competitiveness. It is argued that technical changes and development may affect trade because it takes some time for other countries to imitate the technology innovated by the initial country. During this period of technology diffusion, comparative cost differences may induce trade in particular goods (Posner, 1961). Even if two countries have the same endowments, the outputs of production will still be different if one country has superior technology than others. For instance, advanced countries such as USA, United Kingdom, Germany and Japan could have more advanced technology which may be applied on the same resources in a more efficient way or discover new natural resources. As what has been mentioned that new technology could benefit the originating country, however, the pioneering advantage will last only until the new technology or innovative products are imitated. The product life cycle theory states that firms in the originating country where a new product introduced will have a clear competitive advantage. However, the introducing firms' initial advantages will decrease because other foreign companies' access to the available and imitated technology. These competitors could be more beneficial in their own domestic markets and expand their business to catch up with the international markets. It pushes the initial innovative firms to continue R&D to maintain their leading position in the product lines. Lutz and Green (1983) state that advanced technology countries usually have dynamic process of product life cycle and it keeps the companies being able to bring out the next and further generations of products or sometimes discover a brand new market.

Viewing the technology based model of exporting performance at the firm-level, a firm's investment or achievements in adopting new technology is highlighted and the development of innovative products or process are emphasized. In this open innovation era, a firm's innovation structure has exceeded its organizational boundary. The inputs of a firm's innovation activities depend on not only its internal resources and capability but also its capabilities to access linkages/networking with external resources (Chesbrough, 2003). These external supports could be available from other organizations and the environment/industry where a firm is located. Therefore, in addition to the intra or inter-firm innovation activities, the regional or national innovation system can also support the growth of export industries and enhance firms' global competitiveness (Nelson, 1993; Metcalfe, 1997; Mowery and Oxley, 1995).

2.8.4 Innovation and exports

The determinants of export performance from the perspectives of neo endowments based theory and technology based theory have been considered in the previous section. This section specifically focuses on the effect of innovation on exporting.

The link between technological change and internationalisation was initially examined at the country- or industry-level (Fagerberg, 1988; Dosi and Soete, 1988). In general, the measures of international competitiveness are frequently used to compare the difference between countries for government reports, national economic policy or some mass media/publications, and 'a country's competitiveness refers to its ability to create, produce and distribute goods/services in international trade while earning rising returns on its resources' stated by Scott and Lodge (1985: p.3). Hence, product and process innovation become a major resource of comparative advantages in international trade. The macroeconomics research on innovation and export suggests that innovation enhances a country or an industry's competitiveness (Fagerberg, 1988; Dosi et al., 1990; Wakelin, 1997). However, the investigation of international trade at the macroeconomic level is not able to determine the diverse firm behaviours on exporting. Accordingly, some scholars consider the heterogeneity between firms and start to conduct research of innovation-exporting model at the firm-level (Wakelin, 1998;

Sterlacchini, 1999; Roper and Love, 2002; Gourlay et al., 2005; Girma et al., 2008).

There are some studies using R&D as an indicator of innovation to examine the relationship of innovation-exporting (Hirsch and Bijaoui, 1985; Kumar And Siddharthan, 1994; Wakelin, 1998). However, it has been shown that R&D is not the only element of innovation and innovation activities could also be facilitated by other external knowledge such as the linkages to suppliers, customers, competitors, consultants, universities and exhibitions (referred to chapter 4). It is also argued that innovation is the essential determinant of export performance rather than R&D activities itself: “what really matters for exporting is product innovation rather than R&D, because the ability to compete in international markets is ultimately influenced by the firm’s capacity to successfully market new and improved products, rather than its investment in research activity.” (Ganotakis and Love 2011: 280). Overall, innovation has suggested to be an crucial effect on exporting in many studies such as the following countries like the UK (Wakelin, 1998; Bleaney and Wakelin, 2002; Roper and Love, 2002; Ganotakis and Love, 2010), Italy (Sterlacchini, 1999; Basile, 2001), German (Roper and Love, 2002; Lachenmaier and Wößmann, 2006), Ireland and Northern Ireland (Roper et al., 2006), China (Guan and Ma, 2003) and India (Kumar and Siddharthan, 1994). There is no unique measure of innovation and exporting in the previous empirical studies and the effect of innovation on exporting varies with different measurement and firm characteristics.

Wakelin (1998) finds that innovators and non-innovators behave differently on exporting and the diverse effects of innovation on exporting indicate that the heterogeneity also exists within the group of innovators. Only until the recent research, scholars start to apply similar model to examine the relationship between innovation and export. In the below section, we will conclude the results of innovation-export relationship from those studies adopting similar measures of innovation to this study. Roper and Love (2002) find that product innovation has positive effect on export decision (i.e. whether a firm engages in export) in both observed countries, the UK and Germany, while no impact is found on export intensity (i.e. the ratio of international sales to total sales). Ganotakis and Love (2011) suggest that, as being new technology based firms in the UK, product innovation increases the probability of exporting but a firm's successful innovation (the percentage of innovative products in total sales) does not increase its export (more empirical studies are discussed in chapter 6).

2.9 Empirical background – Taiwan

2.9.1 Taiwanese economy and industrial development

Taiwan is a small island located in Eastern Asia (see figure 2.1). Although the area is only around 36,000 square kilometres and lacks for natural resource endowments, Taiwan is recognized as its rapid economic growth especially in the half of the twentieth century. The uninterrupted growing economy lasts for nearly two decades since 1960s with an average annual increase of 9.5 percent in real GDP[1] and continues its high GDP growth with an average of nearly 7 percent until year 2000 (see table 2.1 and figure 2.2) (Wang, 2010; Taiwan Executive Yuan, 2011). The prospered economy entitles Taiwan as one of the East Asia's economic 'Tigers'[2]. Moreover, Taiwan is famous as its limited contagion by the Asian Financial Crisis in 1997 and its rapid restoration economic recovery helped avoid financial collapse. Nowadays, Taiwan is listed as the stage of transition from 2 to 3 in World Economic Forum 2010 (see more detail in the later section 2.9.2). The stages of development are defined by two factors,

[1] The currency exchange rate of New Taiwan dollar (NTW$) to U.S. dollar was 5 to 1 at the beginning when the New Taiwan dollar was released in 1949. The value of NTW dollar decreased to 38 to 1 with the lowest point 40 to 1 in 1960s (Yu and Wang, 2005).

[2] The four Asia's economic Tigers are Hong Kong, Taiwan, South Korea and Singapore.

which are the level of GDP per capita at market exchange rates, and the extent to which countries are factors driven, measured by the share of exports of mineral goods in total exports (goods and services). It is considered that stage 2 includes developing countries while stage 3 embraces developed countries. Therefore, Taiwan is considered as an advanced developing country which is on the transition from developing country to developed country (Sala-i-Martin X. et al., 2010)

The early stage of Taiwanese development can be traced back to the years of being the colonies of Dutch (1624 - 1662) and Japan (1895 - 1945), especially during the period of being occupied by Japan, infrastructure, education and agricultural technology were developed to manufacture/derive goods/materials in Taiwan and export to Japan. After World War II, Kuomintang started its governance in Taiwan and carried on the development of agriculture and light industries such as electrical power, textile and fertilizer (Lui and Qiu, 2001).

In 1980s, Taiwan government decided to build new industries toward high-tech oriented industries with its advantages of manpower and Government policy to appeal to the foreign direct investment. The cooperation between Taiwanese firms and foreign multinational enterprises also expand Taiwan’s economy with its customer-driven supply chains. However, the decrease of profit and the threat from the new emerging countries force Taiwan to accelerate the upgrading of its industries and to move toward the higher position in the global supply chain from 1990s. Generally, Taiwanese development can be divided into five stages as (1) Land reform and reconstruction (1949 - 1952), (2) Import-substituting industrialization (1953 - 1957), (3) Export promotion (1958 - 1972), (4) Industrial consolidation and new export growth (1973 - 1980) and (5) High technology and modernization (1981 - present) (The World Bank, 1993).

Figure 2.1 The location of Taiwan

Aston University

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Resource: The World Factbook (Central Intelligence Agency, 2012)

Figure 2.2 Taiwan GDP and the growth rate (%)

Aston University

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Resource: 2010 Statistical Yearbook of the Republic of China (Taiwan Executive Yuan, R.O.C., 2011)

Government policy has always been a vital catalysis to the development of Taiwanese economy and technological innovation such as ‘Act of Encouragement of Investment’, ‘Statute for Upgrading Industries’, ‘Scientific Technology Basic Law’, ‘Statute for Industrial Innovation’ and ‘Law for the Development of the Cultural and Creative Industries’ (Sun, 2010). It has also been criticized that the instrument the Taiwanese government employs is more top-down policy such as providing government research funding and resources to target industries (Lin et al., 2010). Furthermore, the Government also encourages the cooperation between industries and universities to stimulate knowledge innovation and technology development by combining diverse resources (Chen and Xiao, 2011).

Except the Government policy, the special industrial network in Taiwan has enhanced its economy. This kind of industrial network collaboration bases on not only the benefit/profit gained but also the special relationship (Guan-xi) because of the connection of family business and personal relationship (Fong, 2001). Redding (1990) indicates that the core value of the Chinese society in which the firms operates due to the ‘cultural artifact’ of Chinese business firms’ managerial structure. Furthermore, the ‘Guan-Xi’ enhances the flexibility and reduces the risk because its networking makes firms to derive materials and customers easier. Intra-firm trading sometimes does not have a formal collaboration but only relies on belief based on the previous trading experience and shares cognition systems (Hamilton and Kao, 1990, Si-Tu, 1995). There is an interesting saying in Chinese society that ‘You Guan-Xi, Mei Guan-Xi; Mei Guan-Xi, You Guan-Xi’. The first and third ‘Guan-Xi’ mean ‘relationship’, and the second and fourth ‘Guan-Xi’ mean ‘okay/fine’. The entire sentence means everything will be fine if you have a relationship, however, things may not work smoothly if you have no relationship. This indicates that ‘Guan-Xi’ play an important role in the Chinese society.

Because of this kind of relationship ‘Guan-Xi’, firms are more willing to share resource within their networking via ‘Guan-Xi’ to reduce risks and enhance their competitiveness.

Table 2.1 Taiwan GDP and the growth rate (%)

Resource: 2010 Statistical Yearbook of the Republic of China (Tiawan Executive Yuan, R.O.C., 2011)

The development of different science parks provides the environment of industrial innovation. Hsinchu Science Park, the first Taiwanese science park established in 1980 to connect industries and universities, is a place to increase the interaction between organizations, firms and universities. Afterwards, several science parks were established such as Tainan Science Park (established year: 1996), Kaohsiung Science Park (2001), Southern Hsinchu Science Park (2001), Taichung Science Park (2003) and so on (Association of Industries in Science Parks, 2012). Taiwanese Government organizes them into three sections, Hsinchu Science Parks, Southern Taiwan Science Parks and Central Taiwan Science Parks, and their mainly focus industries are shown in figure 2.3.

Figure 2.3 The Industries Distribution of Science Parks

Resource: Association of Industries in Science Parks, 2012

2.9.2 Taiwanese innovation and global competitiveness

Taiwanese industries were aided by the cheap labour cost at the early stage of the economic development. However, the advantage of cheap labour cost no longer exists due to the change of industrial structure and comparative labour markets from China or other developing countries. The competitive advantages of Taiwanese industries have been changing from efficiency-driven stage to innovation-driven stage (As what it is stated previously, it is listed at the stage of transition from 2 to 3. Also see table 2.2 for the weight of the three main subindexes at each stage of development.), and manufacturers engage more and more in innovation activities. Nowadays, Taiwan is recognized as a remarkable East Asian country of which industry shifted from imitation to innovation (Hu and Mathews, 2005) and its successful government innovation policies to facilitate industrial innovation (Kraemer et al., 1992; Chang and Robin, 2010). The Government also set up many projects, such as 5-year Teng-Long Industrial Innovation Project[3], to encourage enterprises' engagement in innovation and support their transformation from traditional manufacturing to value added innovation. Furthermore, the Government also set up Taiwan Intellectual Property Management System (TIPS)[4] to assist organizations to manage their internal IPs.

According to the Global Competitiveness Index 2010 - 2011 report by World Economic Forum (WEF), Taiwan ranks 13th globally and 4th within Asian countries, and 7th globally in terms of innovation and sophistication factors[5] (Sala-I-Martin et al., 2010). The Innovation for Development Report 2010 – 2011by Europeans Business School (EBS)

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[3] Teng-Long Industrial Innovation Project is set up by Industrial Development Bureau, Ministry of Economic Affairs and available from the website: http://www.taiwan-innovation.org.tw/index.php [Accessed on 25 March 2012].

[4] TIPS is set up by Industrial Development Bureau, Ministry of Economic Affairs and available from the website: http://www.tips.org.tw/ [Accessed on 25 March 2012].

[5] Business sophistication is defined as being conducive to higher efficiency in the production of goods and services (World Economic Forum 2010, Schwab).

also indicates that Taiwanese innovation capacity is listed as 9^{th} of 130 countries (EBS, 2011). It shows that the activities engaged to innovation enhance Taiwanese global competitive advantages.

Table 2.2 The weight of the three main subindexes at each stage of development

Resource: The Global Competitiveness Report 2010-2011 (Schwab, 2010)

2.9.3 Taiwanese exports

The level of Taiwanese economy and development is considered to lie between developing and developed countries and the exporting plays an important role in the Taiwan economy. Figure 2.4 indicates the trend of exporting growth which the percent of total export in GDP is 40.8% in 1990 and gradually increases to 63.8% in 2010 (see table 2.2) (Taiwan Bureau of Foreign Trade, 2012). Recently, several free trade agreements have proliferated in East Asia over the past several years. However, Taiwanese diplomatic status restricts its participation in this greater economic integration largely. A landmark trading agreement was formed in 2010 which is the Economic Cooperation Framework Agreement (ECFA) signed with People’s Republic of China (The World Factbook, 2012). Although China is one of Taiwan’s biggest exporting markets and a growth of exports to China is predicted, the advantages and disadvantages of ECFA are still unknown, and can only be estimated.

Figure 2.4 1990 to 2011 Taiwan export (million US$) and the growth rate (%)

Resource: Taiwan Bureau of Foreign Trade statistics (Taiwan Bureau of Foreign Trade, 2012)

Table 2.3 1990 to 2011 Taiwanese international trade and its proportion of export to GDP

Resource: Taiwan Bureau of Foreign Trade statistics (Taiwan Bureau of Foreign Trade, 2012)

Chapter 3 Research methodology

3.1 Introduction

This chapter will introduce the survey and the data adopted for the empirical analysis. Firstly, the philosophy underpinning this research is illustrated and the method designed to reach the research purpose. The following three chapters have their own objectives. Chapter 4 aims to develop the innovation value chain of Taiwanese innovative manufacturing firms. Chapter 5 examines differences in innovation value chain between high-tech and low-tech sectors. Chapter 6 examines the relationship of innovation-export and other factors determining a firm's export performance. The purpose of these objectives is in the same sense to generalise results/findings, therefore, quantitative means are chosen here for the test. The appropriate econometric models will be introduced in chapter 4, 5, and 6 separately such as probit, tobit, linear OLS regression and Zero-inflated negative binomial regression because each topic has its own proper models. Secondly, the data adopted here is the secondary data derived from the dataset of 2nd Taiwan Innovation Survey which is cooperated between some universities in Taiwan and funded by Government. The background of the dataset will be introduced and the summary statistics of the data will also be described.

3.2 Research philosophy

Blaikie (1993) and Fleetwood (2007) argued that ontology is about what is the truth or the nature of reality and it investigates on what kind of existing things and how they look like. Moreover, it also examines their interaction and the mode of existence. Therefore, ontology is the root of description on existing things and events. However, the ontology of social science is not universal. Social scientists/researchers have different notions of the nature of science and the method to unite knowledge is still undertaken.

Epistemology is originally from a Greek word ‘epistêmê’ and it is the basic feature of research paradigm which outlines the research structure including research question raised, approaches adopted and explanation interpreted (Kuhn 1970; Crotty 1998). It addresses ‘the nature of knowledge, its possibility, scope and general basis’ (Hamlyn, 1982) which refers to the philosophy of knowledge, adequate belief of assumptions placed in the research and how to obtain valid knowledge (Johnson and Duberley 2000). Bryman and Bell (2007) state that positivism is an epistemological stance which believes that knowledge is the phenomena we experience and it should be able to be observed and measured. It leads to two practical methods utilized on the process of research such as quantitative or/and qualitative methods via deduction or inductive process (Myers and Avison 2002). The purpose of this study is to examine the innovation value chain framework under Taiwanese manufacturing industries and the effects of innovation on exporting performance. From the positivist perspective and deductive approach, the secondary data is adopted to test the relationships and valid data is evaluated to generalise final results and conclusion. Quantitative methods with statistical analysis and econometric models are therefore adopted here to evaluate the research questions.

3.3 Research method

3.3.1 Data collection

Quantitative researchers collect data mostly via questionnaire surveys, structured interviews, experimental methods and official databases (Delanty, 2000). Quantitative methods overall are approaches which illustrate theoretical concept through interpretation of numerical results. It provides evidence of how a phenomenon works with a scientific way (Straub et al., 2005). The researchers tend to apply the procedures of the natural sciences on social science under the positivist paradigm to generalize their findings (Bryman, 1992) and the assumptions are created to measure and observe the social world and become appropriate measures to the general population.

In this study, the secondary data, an official Taiwanese innovation dataset, is adopted and the quantitative methods chosen are statistical analysis and econometric models. Statistical analysis is applied to describe the characteristics of the data and econometric models are adopted to evaluate the research frameworks. Because there are different research frameworks in chapter 4, 5 and 6, the more detail of econometric models adopted in each chapter will be interpreted in the following chapters.

3.4 Description of survey

This section will describe the background of Taiwan Innovation Survey including the 1st Taiwanese Technological innovation survey (1st TIS) and be followed by the detail description of 2nd Taiwanese Innovation Survey (2nd TIS). A brief introduction to 1st TIS is illustrated to inaugurate the beginning of formal industrial innovation study in Taiwan. However, the limited information about 1st TIS is derived from an empirical research paper 'A Survey for Technological Innovation in Taiwan' published in 'Journal of Data Science' (Wang et al., 2003) because there is no available access to the 1st TIS data.

The 1st formal innovation survey called 1st Taiwanese Technological Innovation Survey, which is also called 1st Taiwanese Innovation Survey (1st TTIS or 1st TIS) was undertaken from 1st August 2001 to 31st July 2002 by investigating firms' innovation between 1998 and 2000. In order to compare research results to other countries and connect with international innovation research, 1st TIS was designed according to CIS[6]

[6] CIS (Community Innovation Survey) is a survey conducted every 4 years by the members of European countries to collect the information of innovation activities and measure their progress (Hellebrandt, 2007).

III (Community Innovation Survey III) conducted by European Union. The 1st TIS belongs to a cross-sectional data and the main goal of the Survey is to investigate R&D activities and technological innovation. The paper 'A Survey for Technological Innovation in Taiwan' reports that 300 largest domestic enterprises comprise around 70% of R&D expense in Taiwan which indicates that the majority of R&D activities are concentrated on larger organizations. There are 50.2% of firms engaged in technological innovation with 51.1% in manufacturing sector and 49.3% in service sector. Because we do not have the raw data of the 1st TIS and the 1st TIS is not adopted in this study for any analysis, we will not go into 1st TIS for further description but move to 2nd TIS.

Follow by an introduction to 1st TIS, the following will focus more on 2nd TIS where the research data derived. The 2nd TIS is also a cross-sectional data which was carried out from 1st August 2007 to 31st October 2007 by the two-stage method, which are telephone, post/mail and face to face interviews. It was conducted by a project team consisting of several universities in Taiwan and the dataset was released in December 2009. The objective of the survey is to investigate innovation activities undertaken during 2004 and 2006 by enterprises (with 6 or more employees) in manufacturing and service industries, and the subjects are set up as executives, senior managers, vice general manager or above, or their authorised employees.

The purpose of this survey is to collect empirical data to illustrate Taiwanese national innovation system and do further comparison with other countries. In order to connect innovation research with other countries, the project team of 2nd TIS absorbs the experience from OECD and refers to OSLO manual 2005, then designs the survey based on CIS4 (Community Innovation Survey IV). Moreover, the design of survey also considers the fact of being at a different stage of industrial development, so there are some measurements adjusted accordingly. The overall innovation activities are categorized as technology and non-technology related innovation and the survey is set up as into two parts and with three different questionnaires, A, B and C. The questionnaire A comprises companies' basic information, non-technology related innovation and its impacts, and the target observations are all industries including both manufacturing and service industries. The questionnaire B (to firms in manufacturing industries) and C (to firms in service industries) contain the same information such as technology related innovation and its impacts, knowledge sources of innovation, protection and restriction of innovation, and number of employment and sales figures in 2004 and 2006.

In order to collect convincing and valid data, the first stage of telephone selection is to check whether a firm engaged in innovation during 2004 and 2006. If a firm did not engage in innovation during 2004 and 2006, it would be not leaded to the second stage of survey. The selective firms entered the second stage of survey, postal survey, and the questionnaire was sent to. For those 5,000 largest enterprises[7], the first two stages are skipped and they are contacted for a face-to-face interview to complete the questionnaire.

The observations are based on the first 5,000 largest enterprises and random sample selection based on the industrial classification[8] and firm size[9] on the rest[10]. The total

[7] The five thousands largest enterprises were based on the list in the publication 'Top 5000 enterprises' published by China Credit Information Service, Ltd.
[8] The industrial classification is based on the method from OECD and Taiwanese National Science Council.
[9] The four different levels of firm size are 'micro' 6- 19, 'small' 20- 49, 'medium' 50- 249 and 'large' 250- 499 employees.
[10] The rest was based on Industry, Commerce and Service Census by Directorate- General of Budget, Accounting and Statistics, Executive Yuan, R.O.C. Taiwan.

sample comprises 4,563 manufacturing firms and 5,454 service firms (10,017 in total) in which 2,560 firms are from the top 5,000 enterprises and 7,457 firms are from the general population of Taiwanese industries.

3.5 Descriptive statistics of adopted data

The main purpose of this study is to look at the innovation value chain and export of manufacturing firms in Taiwan. Therefore, the following sections will focus on the data description of only manufacturing firms which are 4,563 in total. Although service industries have developed very quickly in Taiwan recent years and the Taiwanese economy has shifted from industrial economy toward knowledge and service economy, manufacturing sectors still play an important role on Taiwanese economy. However, the development of the emerging countries such as China, Brazil, Russia and India has threatened Taiwanese industrial competitiveness. Government therefore has urged enterprises to upgrade their position within international supply chain from subcontractors to service-added manufacturers in order to maintain Taiwanese international competitiveness (Council for Economic Planning and Development, 2010).

There are four types of innovation activities, which are product, process, marketing and organizational innovation, in the questionnaire. However, this study will focus on product innovation and process innovation (Both are defined as technology-related innovation mentioned earlier.) due to their highly relevance to manufacturing firms. Base on the previous literature review, product innovation and process innovation are indicated as three different variables which are a dummy variable of product innovation (i.e. whether a firm engaged in product innovation in the past three years), a quantitative variable of innovation success (i.e. the percentage of innovative goods in total sales), and a dummy variable of process innovation (i.e. whether a firm engaged in process innovation in the past three years). The research model comprises knowledge sourcing, innovation activities and exporting activities and the indicators of firm characteristics and performance. Within these 4,563 observations, those firms without both product and process innovation were asked to skip the questions of knowledge sourcing activities. Therefore, those firms without information of knowledge linkages are dropped and the remaining observations applied to this study are 1806 innovative manufacturing firms (i.e. a manufacturing firm with at least product or process innovation). These firms are located in 36 different industries classified by the survey (see appendix 1for the description of each industry code) and this research combines some highly related industries and reclassified them to 13 industries (See table 3.1).

The total observations adopted here for demonstrating the innovation value chain and export of Taiwanese innovative manufacturing industry are 1,806 technology-related innovative manufacturing firms with 55% engaged in product innovation, and the average of innovation success is 59.18% with 1,258 valid observations. There are 57% of firms engaged in process innovation while 27% of innovators have both product and process innovation.

Most firms (1541 firms, 85.33%) have knowledge through R&D activities with 82% internally and 30% externally. Although, there are high percentages of linkages to internal and external R&D, the data shows that the knowledge to innovative activities in these firms is sourced simultaneously from different organizations. It is argued in the previous literature that R&D is not the only resource to innovation (Crépon et al., 1998; Lööf and Heshmati, 2002) and the boundary of innovation knowledge has become extensive. Except R&D knowledge, the knowledge flows to innovation activities in Taiwanese manufacturing industries have moved from inter-organizational to intra-organizational. These knowledge sources in sequence are forward knowledge to (73%), backward knowledge (63%), other knowledge[11] (63%), horizontal knowledge (59%) and public knowledge (47%).

As it is argued that firm characteristics such as firm age, size (Klette and Johansen, 1998) and group membership, have a potential impact on firms' knowledge gathering, transformation and exploitation, and does the quality of human resources such as employee degree and training courses (Freel, 2005; Liao et al., 2007) The average of firm size is located as the size of medium firms (201.83 which is between 50 and 500 employees). Based on the levels of firm size, there are 1024 small firms (less than 50 employees), 585 medium firms (more than or equal to 50 employees but less than 500) and 197 large firms (more than or equal to 500 employees). The majority of these innovative firms are small and medium firms which are almost 90% and it shows that Taiwanese small and medium firms are quite active in the engagement of innovation activities. Moreover, additional resources such as public financial support and market strategy, being an exporter, will also affect on the efficiency of absorbing knowledge and innovation activities. The above factors are also reported in table 3.2.

[11] Other knowledge sources include conferences, exhibitions, scientific journals, industry association, and institutions for the standards of technology and so on (see Appendix A2).

Table 3.1 Industry classification

Industry description	Amount	Industry code in 2nd TIS
(1) Non-metallic mineral and quarrying	40	6, 23
(2) Food, beverages and tobacco	75	8, 9, 10
(3) Textiles, wearing apparel, leather, paper and printing	218	11, 12, 13, 14, 15, 16
(4) Natural resources (petrileum, coal, rubber, plastic and wood) manufacturing	93	17, 21, 22, 32
(5) Basic and fabricated metal	246	24, 25
(6) Others	48	33
(7) Machinery repair and insallation, energy supply, and wasterwater and pollution remediation	20	34, 35, 36, 37, 38, 39
(8) Construction	156	41, 42, 43
(9) Chemical material and products, medical goods	131	18, 19, 20
(10) Electronic Parts and Components Manufacturing	244	26
(11) Computers, Electronic and Optic Products Manufacturing	162	27
(12) Electrical Equipment Manufacturing	102	28
(13) Machinery and transportation equipment	271	29, 30, 31

Resource: The classification is based on the 2nd Taiwanese Innovation Survey (TIS) and reclassified.

Table 3.2 Summary Statistics and variable description

	Total 1806 firms		
Variable description	**Mean**	**S.D.**	**N**
Innovation indicators			
Product innovation success (%)	59.18	30.749	1258
Product innovation (0/1)	0.55	0.498	1806
Process innovation (0/1)	0.57	0.495	1806
Product and product innovation (0/1)	0.27	0.442	1806
Knowledge sourcing activities			
Internal R&D – R&D being undertaken within the firm (0/1)	0.82	0.384	1806
Percentage Internal R&D – R&D being undertaken within the	28.73	27.496	1519
External R&D – R&D being outsourced to other organizations	0.30	0.457	1806
Percentage External R&D – R&D being outsourced to other	8.47	18.205	1519
Forward knowledge derived from clients or customers (0/1)	0.73	0.444	1806
Backward knowledge derived from suppliers, consultants or	0.63	0.483	1806
Horizontal knowledge derived from other companies such as	0.59	0.491	1806
Public knowledge derived from universities or public	0.47	0.499	1806
Other knowledge derived from conferences, industry	0.63	0.483	1806
Internal resources			
Firm size (employee number)	201.83	664.526	1806
Subsidiary (0/1)	0.16	0.371	1806
Firm age (0/1, 0= three years or more, 1= less than three	0.06	0.237	1806
Firm capability			
Employee degree – percentage of workforce with university or	47.38	28.925	1684
Training – courses provided specific to the introduction of	0.75	0.436	1806
Government assistance			
Financial support on the firm's innovation activities (0/1)	0.67	0.472	1575
Variable description	**Mean**	**S.D.**	**N**
Market strategy			
Export (0/1)	0.66	0.475	1806
Original Equipment Manufacturers ; OEM[12] (0/1)	0.55	0.498	1806
Original design manufacturer; ODM[13] (0/1)	0.51	0.500	1806
Original brand manufacturer; OBM[14] (0/1)	0.34	0.474	1806

[12] An original Equipment Manufacturer (OEM) is a firm which manufactures products or components ordered by a company and retailed under that company's brand name.
[13] An original design manufacturer (ODM) is a firm which designs and manufactures specific products but eventually branded by another firm for sale.
[14] An original brand manufacturer (OBM) is a firm which sells a product made in whole or in part by a second firm as its own branded product.

Chapter 4: The innovation value chain of Taiwanese manufacturing industry

4.1 Introduction

The purpose of this chapter is to demonstrate the innovation value chain (IVC) of Taiwanese manufacturing industry. First of all, firms engage in knowledge sourcing activities with either complementarity or substitutability relationship. Secondly, not only R&D but also other knowledge resources could influence on a firm's innovation activities via knowledge transformation with the variances of a firm's characteristics. Finally, the value added process of innovation will reflect on firm performance which is measured by employment growth, sales growth and productivity. The IVC framework adopts probit, tobit and linear regression models to highlight the issues raised above. The data used to demonstrate the IVC in this chapter comprises 1806 innovative manufacturing firms derived from 2nd Taiwanese industry Innovation Survey and these firms are classified into 13 industries (see table 3.1)

4.2 Conceptual framework of the innovation value chain

The objective of the whole concept in this chapter is to model the process that generates knowledge linkages among different organizations; transforms knowledge and ultimately exploits it via innovation activities that generate added value and firm growth. According to the resource based view, a firm can generate a competitive advantage if it possesses resources that are unique and difficult for competitors to imitate (Wernerfelt 1984; Grant, 1991). In order to increase a firm's competitiveness, innovation activities have exceeded organizational boundaries. Open innovation hypothesizes that knowledge flows do not only exist inside an organization but also link to other organizations to derive external knowledge (Chesbrough, 2003; 2006). The requirement of various resources and knowledge forces a firm to enhance its capability for not only absorbing but also utilizing external knowledge. Absorptive capacity is highlighted as an important capability to recognize, acquire and shape valuable external knowledge into innovation for value added (Cohen and Levinthal, 1990; Zahra and George, 2002; Todorova and Durisin, 2007). Therefore, the overall conceptual framework in this chapter is consistent with the perspectives of resource-based and capability of a firm with special focus on business growth and development (Cohen and Levinthal, 1990; Foss, 2004).

The innovation value chain was firstly introduced as a series of innovation processes comprising idea generation, conversion and diffusion (Hansen and Birkinshaw, 2007). It is considered as a strategic approach tool that a manager can use in order to assess the strength and weakness of the whole innovation process. Roper et al. (2008) incorporated the knowledge production function into the innovation value chain approach which brings a more embedded structure focusing on knowledge sourcing, knowledge transformation, exploitation of innovation activities and value production. Although the main structure of the IVC focuses on the importance of external and internal knowledge, the IVC also further explores potential factors influencing this process of value production.

4.2.1 Innovation inputs_ knowledge sourcing

The IVC begins with knowledge sourcing activities which highlight the relationship between these sourcing behaviors. R&D is considered as the only source of knowledge for innovation at the beginning of innovation research (Freeman and Soete 1997; Crépon et al., 1998; Lööf and Heshmati, 2002). However, it has been suggested that a firm without R&D activities is still able to innovate products (Shia et al. 2002). More studies find that not only internal R&D but also external knowledge sources may generate innovation based on the concept of open innovation (Chesbrough, 2003; 2006).

In this chapter, seven different types of knowledge sourcing linkages are identified that might shape firms' innovation: internal R&D (Shelanski and Klein 1995; Roper et al. 2008; Ganotakis and Love 2010), external R&D (Veugelers and Cassiman 1999; Ganotakis and Love 2010), forward linkages to customers (Lundvall 1988; Joshi and Sharma 2004; Roper et al. 2008), backward linkages to either suppliers or consultants (Lundvall 1988; Horn 2005; Smith and Tranfield 2005; Roper et al. 2008; Heidenreich 2009), horizontal linkages to either competitors or other companies (Hemphill 2003; Link et al. 2005; Roper et al. 2008), public linkages to either universities or public research centres (Roper et al. 2004; Del Barrio-Castro and Carcia-Quevedo 2005) and other linkages to exhibitions, professional associations or technical standards (Harris and Li 2009; Reychav 2009).

It is argued by Irwin and Klenow (1996) that more organizations included in knowledge sharing can reduce firms' investment on R&D. This kind of substitution relationship between internal R&D and external knowledge sourcing is also suggested by Love and Roper (2001) and Schmidt (2010). However, substitution is not the only existing relationship between internal and external knowledge sources. Internal R&D has been recognized as an important determinant to enhance a firm's absorptive capacity which enables a firm to recognize and acquire valuable external knowledge (Cohen and Levinthal, 1990). Moreover, the evidence of complementary relationship between internal R&D and external knowledge sourcing activities has been found in several research by Ganotakis and Love (2010), Roper et al. (2008), Roper and Love (2005), Laursen and Salter (2006) and Veugelers and Cassiman (1999). Therefore, the first assumption in this sector is what pattern of complementarity or substitutability exists between firms' knowledge sourcing activities.

Except the influence between these knowledge sources, there are other factors affecting on the sourcing behaviors. From the perspective of resource-based view, a firm with stronger internal resources (firm size, group membership and employee skill) is expected to be less necessary to derive external knowledge and this is also demonstrated in Schmidt (2010)'s study. Another external impact can be from public financial support for innovation and it may increase the probability of knowledge sourcing activities (Edquist 2005). Moreover, being an exporter can also increase the chance of access to different knowledge sources, as exporting firms are more likely to seek, and make use of, external knowledge sources (Love and Ganotakis 2010).

The purpose of the first stage of the innovation value chain is therefore to establish the determinants of different types of (internal and external) knowledge sources, and to explore the nature and extent of any complementarities or substitutability between them.

The equations below are given in order to evaluate the probability that a firm will engage in each of the seven knowledge sourcing activities.

$$KS^*_{ji} = \beta' KS_{ki} + \gamma'_0 RI_{ji} + \gamma'_1 CI_{ji} + \gamma'_2 GFS_{ji} + \gamma'_3 EX_{ji} + \varepsilon_{ji}, \quad j,k \equiv 1,7$$

$$KS_{ji} = 1 \text{ if } KS^*_{ji} > 0; \; KS_{ji} = 0 \text{ otherwise,} \qquad \text{(Eq. 4.1)}$$

where; *KSji* stands for the ith firm's knowledge sourcing activity j (or k), and $j,k = 1,2,3,4,5,6,7$, $i = 1,......,n$. The error term ε_{ji} is assumed to follow a multivariate normal distribution with mean zero and variance-covariance matrix V, where V has values of 1 on the leading diagonal and $\rho jk=\rho kj$ for $j\neq k$. KS_{ki} represents the firm's other knowledge sourcing activities. If β is positive this would suggest a complementary relationship between the knowledge sourcing activities; negative β would suggest a substitute relationship. RI_{ji} and CI_{ji} are two sets of indicators of the firm's resource base and capacity, as indicated earlier. γ_0 is expected to be negative as the argument of resource- based view suggests that stronger internal resource will reduce the requirement of external knowledge. GFS_{ji} reflects access to government financial support for innovation and upgrading, and the coefficient here (γ_1) is expected to be positive. The last element, EX_{ji}, is included in order to control for the exporting behaviour of the observed firms. Except domestic environment and organizations, firms can derive knowledge from other countries through export activities. It has been argued that knowledge can be derived during exporting (Love and Ganotakis 2010). The possession of superior technological knowledge by foreign firms can be the main motivation for collaborative agreements to be formed between them and Taiwanese firms. It is therefore important for the effect of exporting in the formation of collaborative agreements to be controlled in order for complementarities between knowledge sources to be effectively singled out.

4.2.2 Innovation production

The second link in the innovation value chain is the process of knowledge transformation which translates the knowledge sourced by firms and exploits it into innovation outputs. In this process, an innovation or knowledge production function is used to model the knowledge transformation activities (Geroski 1990; Harris and Trainor 1995) and the effectiveness of which are believed to be influenced by a number of firm characteristics, the strength of a firm's resource-base and also the firm's managerial and organizational capabilities (Griliches, 1992; Love and Roper, 1999). Based on Pittaway et al. (2004) the innovation outputs will be measured by using three indicators. Two indicators are dummy variables of product and process innovation in order to indicate whether or not a firm introduced a new or significantly improved product/process, and a variable capturing innovation success which considers the proportion of sales derived from innovative products.

Knowledge derived from different sources is expected to have different effects on product or process innovation (Joshi and Sharma, 2004; Roper et al., 2006). Based on the concept of absorptive capacity (refer to chapter 2), it is argued that internal R&D enhances a firm's capability to engage in the linkages to external knowledge for a firm's innovation activities (Cohen and Levinthal, 1990) and it is indicated by some studies that internal R&D does increase innovation in terms of different forms. Roper et al. (2008) demonstrate that a firm with internal R&D is more likely to engage in product and process innovation and increase the success of innovation. However, the non-significant effect is found on the innovation success when the sample only includes product innovators. Forward knowledge linkages only affect on product innovation (both decision and success measures) but not on process innovation. Backward knowledge and horizontal knowledge boost a firm to engage in both product and process innovation but not increase the percentage of innovation success. Public knowledge does not influence significantly innovation in terms of any form.

A firm with different internal resources and capabilities are also expected to have various impacts on innovation activities. Employees are required to have professional knowledge to access external knowledge and this can be well- educated technicians and technological specialists (employee degree) or training courses (Rothwell and

Dodgson 1991; Frenz et al. 2004). Furthermore, exporting activity and governmental financial support are also listed as factors affecting innovation (Love and Ganotakis, 2010). Therefore, the innovation production function is listed as below:

$$I_i = \phi_0^{'} KS_{ki} + \phi_1^{'} RI_{ji} + \phi_2^{'} CI_{ji} + \phi_3 GFS_i + \phi_4 EX + \varepsilon_i \qquad \text{(Eq. 4.2)}$$

Where I_i is an innovation output indicator (k=1,…,7), that indicates the alternative knowledge sources identified earlier. RI_{ji} and CI_{ji} are two sets of indicators of the firm's resource base and capacity, as indicated earlier. GFS_{ji} reflects access to government financial support for innovation and upgrading so the coefficient here (ϕ_3) is expected to be positive. *EX* stands for a dummy variable of export, *εi* is the error term and other variable definitions are as above.

4.2.3 Firm performance_ value added

The final link in the innovation value chain is that of knowledge exploitation, the process by which firm performance is influenced by innovation (Geroski et al., 1993). External knowledge acquired and transformed into specific product or process innovation and captured in innovation outputs can theoretically enhance firm performance. Moreover the process of innovation, that ultimately generates added value, provides the indirect link between firms' knowledge sourcing activities and performance. To model this value added process, an augmented production function is adopted that includes the innovation output measures together with a number of other variables proposed to affect a firm's performance, such as internal sources and capacity, (firm size, firm age, subsidiary, employee degree) as well as export activity, which has been suggested to not only affect a firm's innovative activity but to have a significant effect on a firm's performance (Love et al. 2010). In terms of the recursive innovation value chain, we regard the innovation output indicators as necessarily predetermined before the exploitation process which may lead to improvements in firm performance. The augmented production function is expressed as

$$BPERF_i = \lambda_0 + \lambda_1 INNO_i + \lambda_2 X_i + \tau_i \qquad \text{(Eq. 4.3)}$$

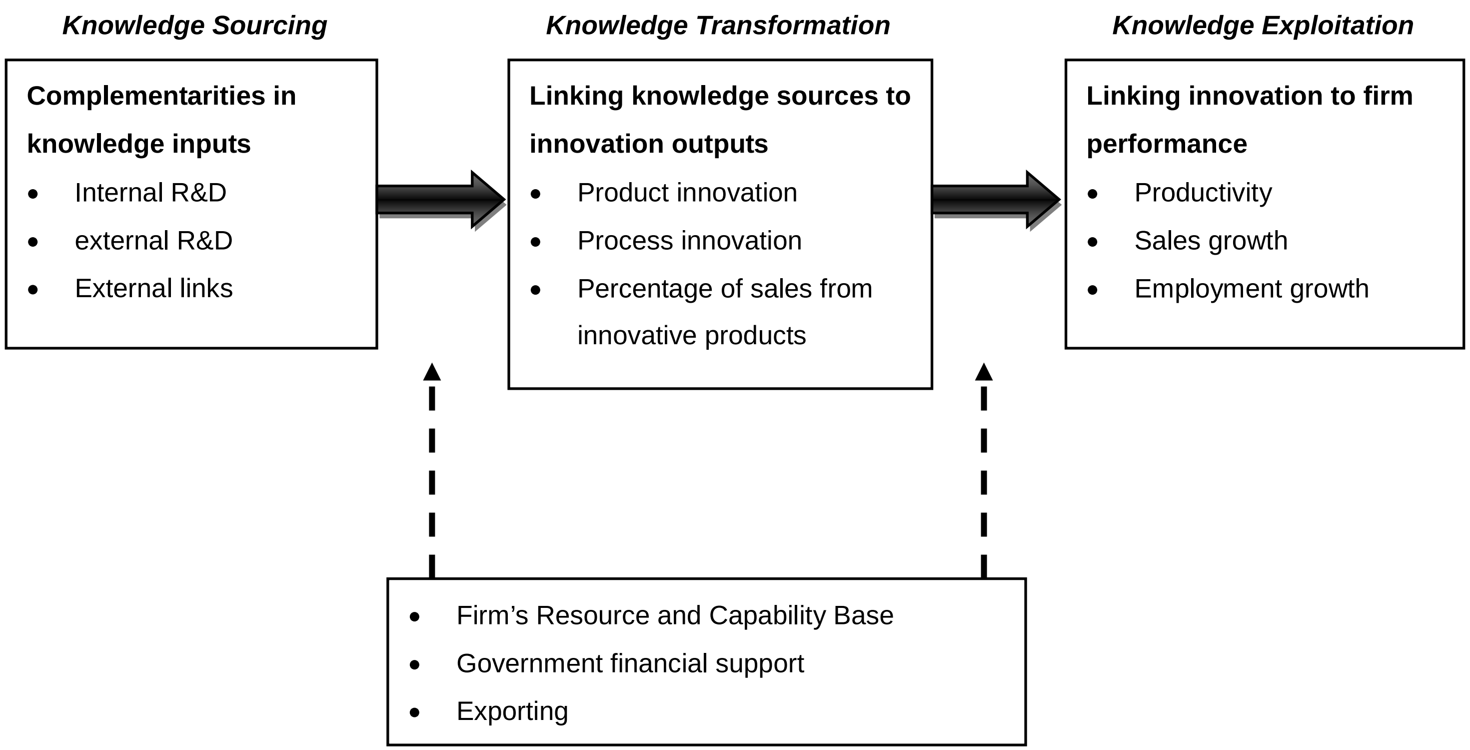
Where $BPERF_i$ is an indicator of business performance (e.g. labour productivity or output per employee, sales growth or employment growth), $INNO_i$ is a vector including innovation outputs measures for both process and product innovation, and *Xi* is a set of firm specific variables that are hypothesized to have effect on firm performance. A visual overview of the complete innovation value chain approach is shown in Figure 4.1

4.3 Methodology

This section will present the methods used to estimate the IVC comprising knowledge sourcing equation and innovation production function, and the econometric issues resulted from operationalising equations.

There are seven different types of knowledge sourcing activities proposed at the beginning of the innovation value chain. The most efficient approach to estimate these simultaneous knowledge sourcing equations (Eq. 4.1) would be multivariate probit (MVP). It was proposed by Ashford and Sowden (1970) to estimate several correlated binary variables jointly. However, the suggested knowledge sharing activities here are similar to the added potential for simultaneity between knowledge sourcing activities. It is claimed that the efficiency gained from MVP will decrease when the vectors of independent variables are strongly correlated (Greene 2005). Except the issue of similarity of independent variables, moreover, other difficulties are faced when adopting MVP practically in using survey-based data. Firstly, any gains in statistical efficiency by using the simultaneous estimation approach will be offset due to a larger number of missing values. Secondly, in practice, achieving convergence with an MVP estimator places some limits on the degree of simultaneity which it is possible to include. However, it is undesirable because what is of interest here is the complementary or substitute relationship between knowledge sourcing activities. Thirdly, the derivation of marginal effects is important in order to gain a better understanding of the innovation value chain, something that is less straightforward with MVP in relation to simpler modeling framework. Therefore, seven single equation probit models are used instead of the MVP approach (Roper et al. 2008). While sacrificing some statistical efficiency, this approach provides substantial gains in terms of the number of valid observations, the ability to reflect more fully the relationship between knowledge sourcing activities and the ability to identify readily interpretable marginal effects.

Figure 4.1 The Innovation Value Chain: structure and key indicators



There are different methods selected to estimate innovation production function and the appropriate estimation approach is applied depending primarily on the nature of the dependent variable of the equation (Eq. 4.2). A simple bivariate probit model is used when the indicator of innovation is product or process innovation decision as a dummy variable. However, for the case of innovation success (% of sales derived from new or significantly improved products), a tobit model will be adopted as the variable has both upper and lower bounds (0 to 100 %) (McDonald and Moffitt 1980). The linear OLS regression model is applied on the last step of innovation value chain to measure firm performance.

When operationalising equation 4.3, two main econometric issues arise here to be discussed. First, whether if heterogeneity exists in performance results. Second, whether if there is potential endogeneity of the innovation output measures. The argument by Caves (1998) with a survey data states even in narrowly defined industries, there can be very large variations existing in business performance. An empirical study also has been done by Lööf and Heshmati (2002) using extensive data on innovation and innovative activities to support this statement. One outcome of the heterogeneity issues is sample selection issues. The Heckman test is a simple test of the null hypothesis of no sample selection bias (Heckman 1979), therefore, is used here in order to investigate the existence of sample selection bias for the case of innovation success, i.e. whether innovative firms cannot be regarded as a group of firms that is randomly selected. The result of the Heckman test shows that probability > chi2 is 0.4826 (more than 0.1) so there is no evidence showing the existence of sample selection bias.

There are several reasons to cause endogeneity of variables in a regression such as omitted variable biased, measurement error and simultaneity/ reverse causation. A number of studies have discussed the potential endogeneity of innovation output measures in models of business performance, and many potential approaches have been adopted including two-stage estimation methods (e.g. Crépon et al., 1998) and the simultaneous estimation of the innovation and augmented production functions (e.g. Lööf and Heshmati, 2002). In this study , in order to investigate whether a firm's innovative activity is endogenous to firm performance a number of Hausman tests are carried out for different specifications of a firm's innovative activity (product/process innovation, innovation success) and for all measures of firm performance (sales growth, employee growth and productivity). The individual p-value of all the results are found to be 0.3638 (sales growth), 0.8710 (employee growth) and 0.7923 (productivity) which are all more than 0.05, so it can be concluded that no endogeneity exists.

4.4 Empirical analysis

The 1806 manufacturing firms are used here for the analysis of the innovation value chain which can be separated into three parts, knowledge sourcing, innovative activities and firm performance.

4.4.1 Knowledge sourcing

The innovation value chain begins with firms' knowledge sourcing activities (Eq. 4.1) and there are two issues raised to highlight the interests at this stage. First, what pattern of complementarity or substitutability exists between firms' knowledge sourcing activities; and second, what other factors determine firms' knowledge sourcing behaviour.

In terms of potential complementarity or substitutability among knowledge sourcing activities, strong evidence of complementarity is found to exist between knowledge sourcing behaviors of Taiwanese manufacturing firms.

Irwin and Klenow (1996) indicate that Sematech, a consortium formed by U.S. government, is proved to induce members' overall R&D expense. A substitution relationship between internal R&D and external knowledge resources has also been found by Love and Roper (2001) and Schmidt (2010). However, the results in table 4.1 shows that the internal R&D activity is complementary to external knowledge sourcing such as external R&D and horizontal sourcing, and it is consistent with the argument of Veugelers and Cassiman (1999), Roper et al. (2008), and Ganotakis and Love (2010). It is notable that firms engaged in R&D internally have more probability to connect to their supply chain partners especially competitors while firms outsourcing their R&D are more likely to derive knowledge from public organizations. Furthermore, the strong complementary relationship between forward, backward and horizontal knowledge sourcing activities shows that there is high intensity of knowledge sharing within supply chain system in Taiwanese manufacturing industries, and these supply chain partners tried to share knowledge through other linkages as well as public linkage. In figure 4.2, the strongest coefficient can be found between public organizations and other resources such as exhibitions, industry associations and journals. The explanation can be firms deriving knowledge from public organizations are more likely to attend industrial events and to derive knowledge from other linkages. It shows other linkages play an important role on knowledge sharing although they are highly dynamic (Reychav, 2009)

In term of other determinants of knowledge sourcing, there are weak effects of internal resources on external knowledge sourcing, but strong effects on internal R&D. Firm size, measured by the number of employees, has a positive significant influence on internal

R&D with an inverted U shape which means that internal R&D increases with firm size, but at a decreasing rate. There is another interesting result shown on firm age that a firm established less than three years significantly influence on internal R&D behavior and less likely to connect with their competitors. It shows that young firms enhance knowledge stock internally rather than absorb external knowledge which also reflects that older firms have more capability to handle the knowledge sharing with competitors and other companies. Another factor determining firms' engagement in internal R&D is employee training which shaping employee's capability to their development. Firms have stronger capabilities, such as a firm with higher percentage of employee with degree and training courses, are also more likely to have the linkage to external R&D.

Except the determinants of internal resources and capabilities, there are other two factors, government financial support and export, interesting to discuss. The government financial support has negative significant on the linkages to backward and other knowledge. The explanation can be the major reason for a firm to derive knowledge from suppliers and via exhibitions/industrial associations is to reduce cost or enhance its finance resource. The last factor, being an exporter, positively affects internal R&D. It is consistent to Love and Ganotakis (2010)'s argument which claims that a firm being an exporter has more chance to learn from foreign partners or derive information from overseas markets. Therefore, it provides an opportunity to access to superior international technological knowledge to utilize on its R&D for being competitive.

4.4.2 Innovation activities

The second part of innovation value chain is the transformation of knowledge into product or process innovation represented by the innovation production function (Eq. 4.2). The main interest here is the contribution of each knowledge source to a firm's innovative effort. Estimations of the innovation production function for the three innovation output measures of product innovation, product innovation success and process innovation are reported in table 4.2 and 4.3 (The results are expressed in terms of marginal effects.).

The result highlights the importance of R&D investment in terms of product and process innovation. Internal R&D, as expected, has a positive and significant impact on product innovation as well as innovation success whereas external R&D positively influence on process innovation especially in term of R&D percentage. The estimates suggest that firms with internal R&D are 13.1% more likely to introduce a product innovation while at the same time internal R&D was found to increase the sales derived from innovative products by 6.72 percentage points. Firms that have engaged in external R&D, especially with more R&D percentage, are 0.2% more likely to introduce a process innovation in relation to firms that have not. The fact that external R&D has a significant effect on process innovation whereas internal R&D does not is not a surprising result as external R&D is often used as a way of improving a firm's manufacturing/operational process while internal capabilities and skills are focused for the introduction of innovative products that can provide a firm with a competitive advantage over its competitors (Beneito et al., 2009; Ganotakis and Love, 2011).

Table 4.1 Knowledge sourcing

Variables	Internal R&D	External R&D	Forward knowledge	Backward knowledge	Horizontal knowledge	Public knowledge	Other knowledge
Knowledge sources							
Internal R&D	-	0.121 *** (0.031)	-0.024 (0.032)	0.039 (0.039)	0.081 ** (0.038)	0.019 (0.043)	0.034 (0.038)
External R&D	0.060 *** (0.017)	-	0.031 (0.025)	0.011 (0.029)	0.043 (0.029)	0.089 *** (0.033)	-0.031 (0.031)
Forward knowledge	-0.011 (0.018)	0.038 (0.027)	-	0.034 (0.030)	0.116 *** (0.031)	0.002 (0.036)	0.066 ** (0.032)
Backward knowledge	0.017 (0.019)	0.015 (0.028)	0.028 (0.027)	-	0.261 *** (0.028)	0.096 *** (0.035)	0.150 *** (0.030)
Horizontal knowledge	0.033 * (0.018)	0.037 (0.026)	0.096 *** (0.025)	0.241 *** (0.027)	-	0.010 (0.033)	0.073 ** (0.029)
Public knowledge	0.007 (0.020)	0.081 *** (0.031)	0.005 (0.029)	0.089 *** (0.033)	0.016 (0.034)	-	0.530 *** (0.022)
Other knowledge	0.014 (0.022)	-0.026 (0.034)	0.060 * (0.032)	0.168 *** (0.035)	0.081 ** (0.036)	0.601 *** (0.021)	-
Resource indicators							
Employment	0.0003 *** (0.0001)	-0.00004 (0.00006)	0.00002 (0.00004)	0.00006 (0.00004)	0.00005 (0.00004)	8.56×10^{-06} (0.00004)	-0.00004 (0.00006)
Employment-squared	-1.41×10^{-08} *** (0.000)	9.28×10^{-09} (0.0000)	-3.93×10^{-10} (0.0000)	-2.56×10^{-09} (0.0000)	-1.9×10^{-09} (0.0000)	2.13×10^{-10} (0.0000)	2.31×10^{-08} (0.0000)
Firm age	0.051 ** (0.025)	0.076 (0.054)	0.053 (0.044)	0.045 (0.052)	-0.142 ** (0.056)	-0.050 (0.063)	0.012 (0.053)
Subsidiary	-0.006 (0.026)	-0.049 (0.034)	-0.025 (0.035)	-0.011 (0.039)	0.007 (0.038)	0.040 (0.044)	-0.020 (0.038)
Capability indicators							
Employee qualification	-0.0001 (0.0003)	0.001 * (0.0004)	-0.001 (0.0004)	0.0003 (0.0005)	0.0004 (0.0005)	0.0004 (0.0006)	0.00009 (0.0005)
Employee training	0.106 *** (0.024)	0.074 ** (0.029)	0.034 (0.029)	0.060 * (0.032)	0.038 (0.0005)	-0.0004 (0.038)	0.054 (0.034)
Government financial support	0.005 (0.019)	0.037 (0.026)	0.009 (0.025)	-0.132 *** (0.027)	0.016 (0.029)	0.051 (0.035)	-0.110 *** (0.027)
Export	0.069 *** (0.021)	0.022 (0.028)	0.042 (0.027)	0.017 (0.030)	0.013 (0.031)	0.044 (0.035)	0.008 (0.030)
Observations	1492	1492	1485	1492	1492	1492	1492
Log likelihood	-577.784	-889.759	-832.987	-822.914	-914.147	-716.463	-618.261

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1. All the figures in the table are marginal effects generated from probit models. All models include industry dummies

Except R&D effort, there are also other knowledge sourcing behaviors have significant effects positively or negatively on product innovation success and process innovation. The linkage to horizontal knowledge has strong negative effects on product innovation success which reflects the more connection with competitors or other companies will reduce the percentage of innovative products in sales. Similar results can be found in Roper et al. (2008) but with non-significant effect. The explanation can be the effect of sharing the successful innovative products within these collaborative firms. For example, an innovative firm which develops new products with a competitor may have to share some of the resulting shares and or profits with the competitor, thus reducing the overall share of innovative products in the firm's portfolio. Furthermore, the efforts of firms' knowledge sourcing activities to public organizations and other linkages are opposite on product innovation success and process innovation. However, as the result shown in previous section, knowledge sourcing, the strongest complementary relationship is between public and other knowledge sourcing. It shows that firms derive knowledge from various linkages to enhance both product and process innovation although one could be more important than the other due to firm type and strategy.

Although the rest of knowledge sourcing activities have no direct impact on product or process innovation, indirect influence still exists due to the complementary relationship between knowledge sourcing activities. For example, a firm with linkages to forward knowledge has an indirect effect on process innovation success through either horizontal or other knowledge sourcing. This indirect effect is an 'absorptive capacity' effect of the type envisaged by Cohen and Levinthal (1990) and Zahra and George (2002). Therefore, even where the direct effects of knowledge sourcing on innovation are insignificant, their overall effect could still play a significant role due to the balance between 'direct' and 'absorptive capacity' effects.

Apart from knowledge sourcing activities, other factors also prove to be important in shaping a firm's innovation activities. Firm size has a significant impact (an inverted U-shaped relationship) on both product and process innovation. Firm age is positively associated to product innovation but with no significant effect on process innovation. There is no evidence showing that being a subsidiary benefits a firm in terms on accessing extra resources, on the contrary it appears to reduce the probability of a firm introducing a process innovation. In terms of a firm's capacities, employee degree and training course both show the increase on a firm's product innovation but decrease on process innovation. Furthermore, export has a strong positive coefficient with product innovation success and it shows being an exporter can increase the percentage of innovative product in sales.

Table 4.2 Innovation production_ internal & external R&D (0/1)

Variables	**Product innovation: decision**	**Product innovation: success**	**Process innovation: decision**
Knowledge sources			
Internal R&D (0/1)	0.131 *** (0.037)	6.728 * (3.601)	0.024 (0.037)
External R&D (0/1)	0.045 (0.028)	1.834 (2.414)	0.041 (0.028)
Forward knowledge	-0.011 (0.029)	-3.720 (2.620)	-0.006 (0.030)
Backward knowledge	-0.002 (0.029)	-1.751 (2.621)	0.020 (0.030)
Horizontal knowledge	0.025 (0.028)	-4.793 * (2.471)	-0.026 (0.028)
Public knowledge	-0.024 (0.032)	-4.593 * (2.752)	0.043 (0.032)
Other knowledge	-0.0002 (0.034)	4.673 (2.924)	-0.085 ** (0.034)
Resource indicators			
Employment	0.0002 *** (0.00007)	-0.005 (0.005)	0.00009 ** (0.00004)
Employment-squared	$-3.03\text{x}10^{-08}$ ** (0.0000)	$3.56\text{x}10^{-07}$ (0.0000)	$-6.86\text{x}10^{-09}$ *** (0.0000)
Firm age	0.090 * (0.048)	-2.450 (4.589)	-0.024 (0.054)
Subsidiary	0.015 (0.038)	0.059 (3.120)	-0.031 (0.038)
Capacity indicators			
Employee qualification	0.003 *** (0.0005)	0.018 (0.042)	-0.0004 (0.0005)
Employee training	0.056 * (0.032)	0.031 (2.976)	-0.025 (0.031)
Government financial support	-0.0010 (0.028)	1.617 (2.433)	0.041 (0.028)
Export	0.025 (0.030)	4.715 * (2.682)	-0.019 (0.030)
Observations	1492	1027	1492
Log likelihood	-920.876	-4458.528	-986.901

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1. All the figures in the table are marginal effects generated from Probit/Tobit models. All models include industry dummies.

Table 4.3 Innovation production_ internal & external R&D (%)

Variables	Product innovation: decision	Product innovation: success	Process innovation: decision
Knowledge sources			
Internal R&D (%)	0.0009 * (0.0005)	0.142 *** (0.049)	0.001 (0.001)
External R&D (%)	0.0003 (0.0008)	0.082 (0.068)	0.002 ** (0.001)
Forward knowledge	-0.014 (0.030)	-3.888 (2.671)	-0.010 (0.030)
Backward knowledge	-0.0008 (0.029)	-1.357 (2.630)	0.024 (0.030)
Horizontal knowledge	0.029 (0.028)	-5.005 ** (2.505)	-0.021 (0.028)
Public knowledge	-0.020 (0.033)	-4.311 (2.795)	0.056 * (0.032)
Other knowledge	0.0006 (0.034)	4.993 * (2.949)	-0.089 *** (0.034)
Resource indicators			
Employment	0.0003 *** (0.0001)	-0.004 (0.005)	0.0001 (0.0001)
Employment-squared	$-3.17\text{x}10^{-08}$ ** (0.0000)	$1.95\text{x}10^{-07}$ (0.0000)	$3.19\text{x}10^{-09}$ (0.0000)
Firm age	0.094 * (0.048)	-1.205 (4.696)	-0.017 (0.055)
Subsidiary	0.004 (0.038)	-0.287 (3.245)	-0.028 (0.039)
Capability indicators			
Employee qualification	0.003 *** (0.0005)	0.015 (0.043)	-0.001 (0.0005)
Employee training	0.102 *** (0.034)	3.440 (3.191)	0.005 (0.033)
Government financial support	0.003 (0.029)	1.520 (2.482)	0.038 (0.029)
Export	0.039 (0.030)	5.056 * (2.714)	-0.014 (0.030)
Observations	1447	996	1447
Log likelihood	-903.283	-4325.856	-951.456

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1. All the figures in the table are marginal effects generated from Probit/Tobit models. All models include industry dummies.

4.4.2 Firm performance

The final element of the innovation value chain is concerned with the relationship between innovation outputs and firm performance (Eq. 4.3). The main focus here is on the impact of innovative indicators on a firm's growth (sales and employment) and productivity (sales/employees). In table 4.4, the first half presents the model including the relationship between product innovation decision (dummy) and performance whereas product innovation success (%) replaces the dummy variable to be modelled in the second half. A firm introducing product innovation is found to increase firm growth in terms of employment and sales, and the innovation payoff is similar to that uncovered by studies in western countries such as Ireland and Northern Ireland (Roper et al., 2008) and United Kingdom (Ganotakis and Love, 2010). However, it shows that the percentage of innovative products in total sales affects significantly on firm growth in those western countries but not in Taiwan the results shown as in table 4.4.

What is surprising here is the fact that process innovation has a negative and significant effect on productivity regardless of whether innovation is included as product innovation decision or innovation success. However, as a new process innovation takes some time to be successfully implemented within an organization in the sense that it takes time for employees to be trained and adjusted to the new process, it is reasonable to expect that its benefits will not be observed straightly after its implementation and negative productivity can be often observed during this period of adjustment (Criscuolo and Haskell, 2003).

In terms of the control variables used, a U shaped relationship was observed between firm size and firm performance with all three measurements when the modeled was inclusive of product innovation decision. Similar results albeit with non-significant effect were found in Roper et al. (2008) for the cases of employment and sales growth, but converse result for the case of productivity. Furthermore, being an exporter was found to have non-significant negative effect on firm performance, of the result being contrary to the study in UK with the observations of new technology based firms (Ganotakis and Love, 2010). However, similar findings were found in studies carried out in German (Bernard and Wagner, 1997), Columbia, Mexico and Morocco (Clerides et al., 1998) and Italy (Castellani, 2002).

Table 4.4 Performance estimations

Variables	**Product innovation decision indicators**		
	Employment growth	**Sales growth**	**Productivity**
Constant	-0.270 (0.064)	4.848 (3.241)	247598.3 (116116.3)
Innovation activities			
Product innovation	0.202*** (0.054)	2.101* (1.244)	32969.51 (23580.94)
Process innovation	0.079 (0.071)	-1.325 (1.324)	-47713.19** (20691.52)
Resource indicators			
Employment	-0.0004** (0.0002)	-0.0008* (0.0004)	-50.162*** (17.899)
Employment-squared	$7.13\text{x}10^{-08}$** ($2.77\text{x}10^{-08}$)	$1.78\text{x}10^{-07}$** ($7.78\text{x}10^{-08}$)	.0026788*** (0.001)
Firm age	-0.036 (0.064)	7.326 (7.970)	10483.65 (59630.65)
Subsidiary	0.391* (0.207)	-1.686 (1.124)	-33458.04** (13463.67)
Capacity indicators			
Employee qualification	0.0004 (0.0005)	-0.055 (0.041)	-495.1341 (695.333)
Employee training	0.021 (0.048)	-0.525 (2.095)	-19299.95 (24990.83)
Government financial support	-0.034 (0.073)	-1.101 (1.800)	-12169.41 (31792.31)
Export	-0.021 (0.048)	-2.358 (1.789)	-59284.71 (38979.14)
Observations	1492	1492	1492

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1.

Table 4.4 Performance estimations (cont.)

Variables	Product innovation success indicator		
	Employment growth	**Sales growth**	**Productivity**
Constant	-0.141 (0.092)	7.788 (4.685)	388502.5 (223504)
Innovation activities			
Product innovation	-0.001 (0.001)	0.018 (0.022)	-1041.723 (904.663)
Process innovation	0.134 (0.088)	-1.815 (1.731)	-51713.63** (23918.52)
Resource indicators			
Employment	-0.0005* (0.0003)	-0.0008 (0.0008)	-139.359** (60.495)
Employment-squared	8.18×10^{-08} (5.16x10-08)	2.74×10^{-07} (2.11×10^{-07})	0.028** (0.013)
Firm age	-0.078 (0.089)	10.968 (11.183)	22724.58 (81300.83)
Subsidiary	0.559* (0.292)	-2.930 (1.860)	-35404.64** (17166.54)
Capacity indicators			
Employee qualification	0.0008 (0.0006)	-0.086 (0.060)	-623.765 (1014.744)
Employee training	0.056 (0.076)	0.118 (3.234)	-10945.25 (47421.09)
Government financial support	0.005 (0.099)	-2.106 (2.891)	-23415.21 (44188.15)
Export	0.007 (0.067)	-4.174 (2.815)	-70572.71 (56167.75)
Observations	1027	1027	1027

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1.

4.5 Conclusions

The key results of the estimation are summarized in figure 4.2, 4.3, 4.4, 4.5 and 4.6. Because of the complex complementary relationship between knowledge sourcing activities, the knowledge sourcing activity process presented separately in figure 4.2. Figures 4.3 and 4.4 picture the relationship between knowledge sources, innovation outputs and different measures of firm performance depending on whether innovation decision or innovation success is used as a measure of product innovation output respectively. The same models in figures 4.5 and 4.6 but with R&D percentages measured as internal and external R&D knowledge sourcing.

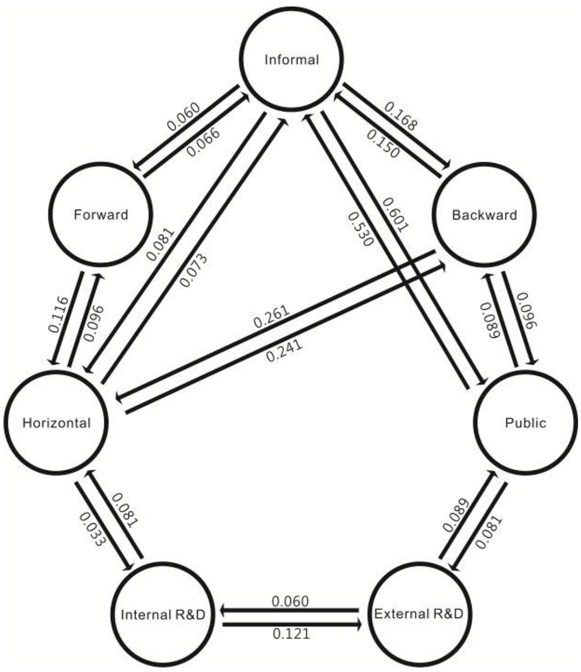
Results point out the direction of a complementary relationship between internal R&D and external knowledge sources, as well as of a strong complementary relationship between all external knowledge sourcing activities themselves. Moreover, the usage of other resources by a firm appears to increase the probability to engage in the sourcing activities such as suppliers, customers, competitors, universities and government research institutions. R&D regardless of whether they are internal or external are still important elements affecting on innovation but is proved not the only resource. One of the surprising results is that the proportion of employees with graduate degrees does not lead to the usage of any the knowledge sourcing considered except external R&D, however, the significant effect on product innovation was found. Another surprising result is that government financial support neither encouraged firms to engage in knowledge sourcing activities nor increased innovative activities, but decreased the activities linking to backward and other knowledge.

Finally, by investigating the entire innovation value chain (for the case of Taiwanese innovative manufacturing firms), the direct and indirect role that variables such as a firm's internal resources and capacity, government financial support and exporting activity play on a firm's knowledge sourcing, innovative activities and performance are better understood and observed. In comparison with the results of Roper et al. (2008) for Ireland and Northern Ireland (See the results of 'product innovator only'), and Arvanitis and Roper (2009) for Switzerland (See the results of 'product innovator only'), they all show strong complementarities between knowledge sources and there is complementary relationship between a firm's internal and external knowledge. There is some difference on the knowledge sources to determine product or process innovation. However, the common knowledge source as the determinant of innovation is internal R&D and it shows that R&D still play an important role no matter in developed or advanced developing countries. Internal R&D has positive effect on innovation success in Roper et al. (2008) and Arvanitis and Roper (2009)'s studies and this consists the same result in this study. Generally, there are more significant effects of knowledge sources on innovation activities found in Western countries (Roper et al. 2008 and Arvanitis and Roper 2009) compared to the study in Taiwan. The results indicate the innovation activities of Taiwanese manufacturing firms are still determined more directly by the knowledge from internal R&D. It shows that the more openness of innovation model in developed countries than in the advancing developing country, Taiwan, which suggests Taiwanese innovative manufacturers may utilize external knowledge more effectively for innovation, perhaps to enhance their absorptive capacity in terms of knowledge transformation because the effectiveness of external knowledge do not significantly apply directly on innovation. Another common significant determinant of innovation is employment with degree that it affects product innovation positively but negatively on process innovation.

Furthermore, the decision of Taiwanese innovative manufacturing firms to introduce innovative products was found to significantly affect firm growth (employment and sales) which is consistent with the results in the study of Roper et al. (2008), but with the converse result on productivity. Roper et al. (2008)'s study shows the positive impact on productivity and no evidence of significant relationship was found between innovation and productivity for Swiss firm in Arvanitis and Roper (2009)'s study. The surprising negative significant effect in this study is explained in the previous section that it may take time to benefit from process innovation. Furthermore, because the data is cross-sectional data, it is not like panel data which can interpret fully the causal inference between dependent and independent variables.

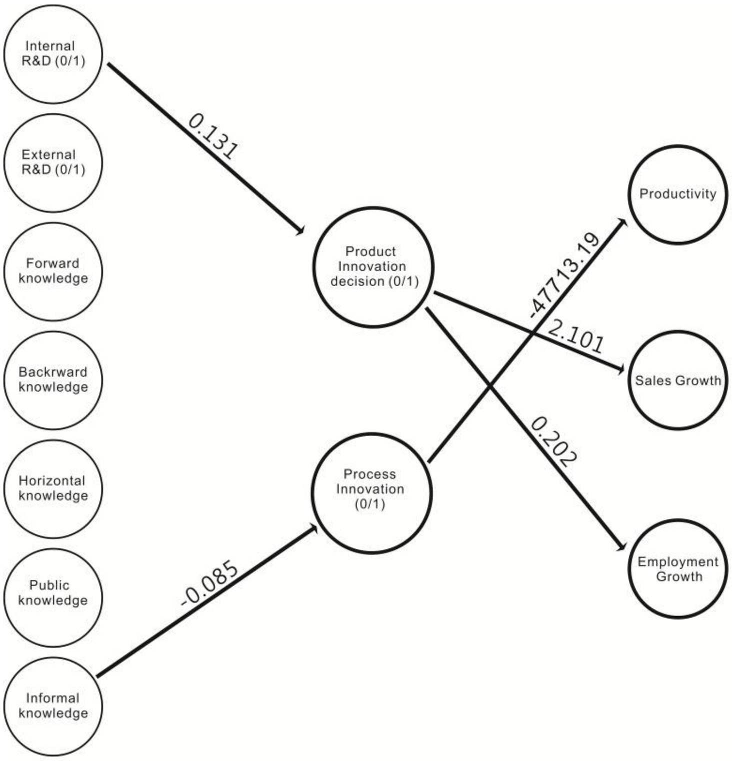
The limitation in this chapter is the lack of information about knowledge sourcing activities of those non-innovative manufacturing firms. Therefore, the results are able only to generalize to all innovative manufacturers in Taiwan but not including those non-innovative ones. This is something what the future research can be done.

Figure 4.2 Knowledge sourcing



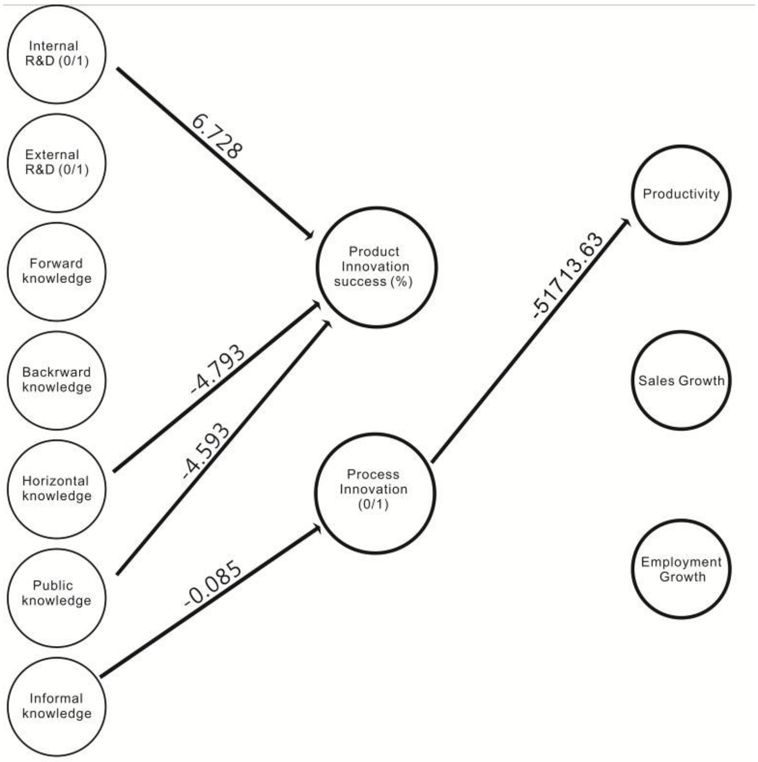
Source: the current study

Figure 4.3 The innovation value chain (R&D dummy and product innovation decision)



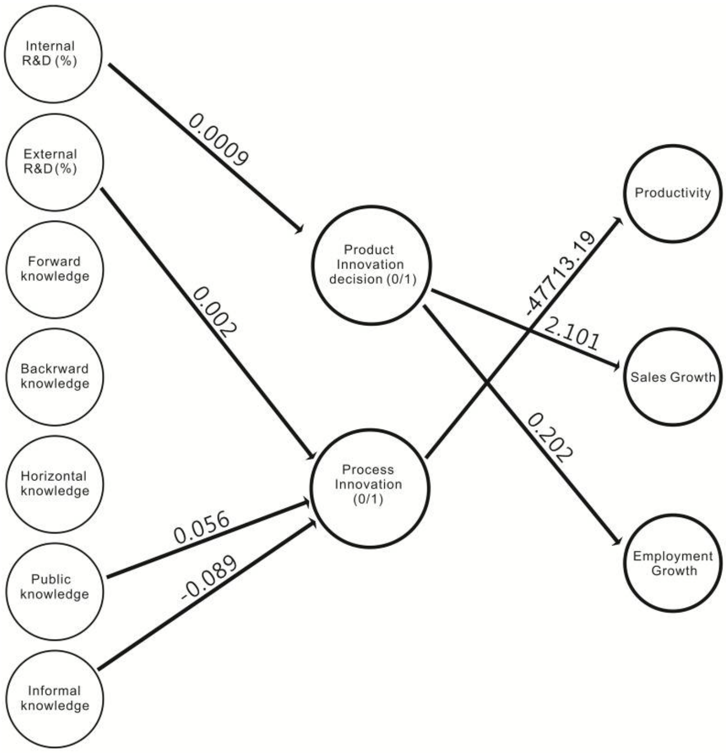
Source: the current study

Figure 4.4 The innovation value chain (R&D dummy and innovation success)



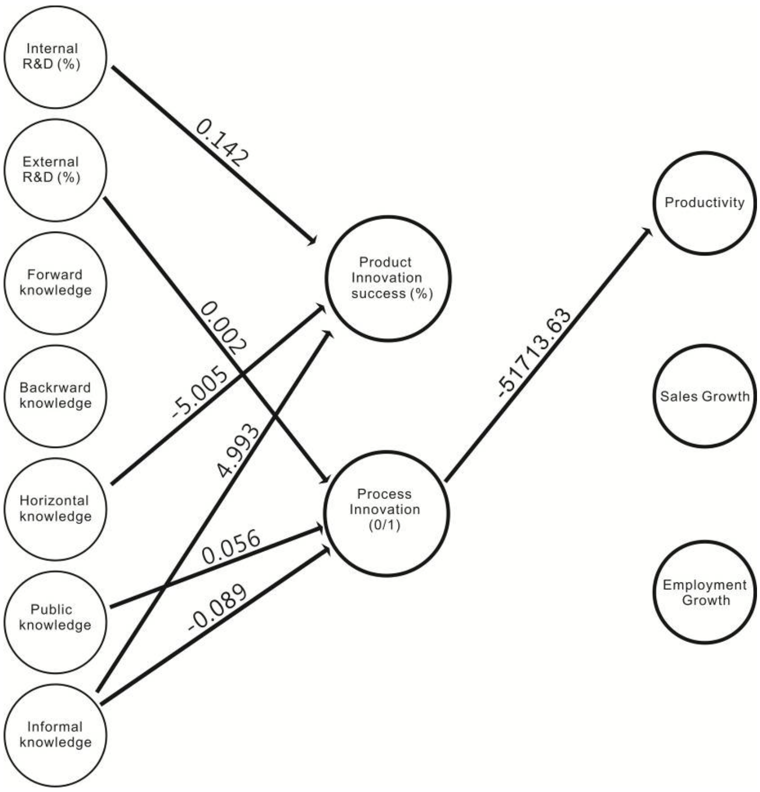
Source: the current study

Figure 4.5 The innovation value chain (R&D % and product innovation decision)



Source: the current study

Figure 4.6 The innovation value chain (R&D % and innovation success)



Source: the current study

Chapter 5 Innovation value chain: a comparison of high-tech and low-tech sectors

5.1 Introduction

The model of the innovation value chain (IVC) has been introduced in the previous chapter. The purpose of this chapter is going to highlight the difference between the IVC of high-tech and low-tech in aspect of industry level and firm level. Previous research has focused on the innovative activities in high-tech sectors as R&D has always been considered as an important role to generate innovation (Freeman and Soete, 1997), but it largely ignored the importance of low- and medium-tech sectors. From Hatzichronoglou's (1997) definition, low- and medium-tech firms actually also engage in R&D activity although generally with a lower percentage of turnover in comparison with high-tech firms. Furthermore, it has been argued that R&D investment is not the only factor determining innovation success. More and more researchers start to attach a higher importance to low- and medium-tech sector (Bender, 2004; von Tunzelmann and Acha, 2005; Robertson and Patel, 2007; Tsai and Wang, 2009). A special issue of the journal 'Research Policy[15]' in 2009 also focused on the difference and importance of innovation in low- and medium-tech sectors. Therefore, this chapter firstly introduces high- tech and low- tech sectors along with differentiating 'sector' at the industry-level and the firm-level. Secondly, it evaluates the effect of high- tech on the IVC with three steps of analysis separately on industry- level and firm- level. Finally, it concludes the results with the difference of the IVC between high-tech and low-tech sectors and discusses whether defining high- and low-tech at industry or firm level significantly affects the nature of the estimated IVC.

[15] Special issue: Innovation in Low- and Medium- Technology Industries. Vol. 38(3) pp.441-570 (April 2009) Edited by Paul Robertson, Keith Smith and Nick von Tunzelmann.

5.2 High-tech and low-tech sectors

High-tech (also called high-technology) can be referred to knowledge-intensive and dynamic environment and a major indicator is R&D (Research and Development) intensity which was used by OECD in 1986[16]. R&D intensity is measured by the ratios of R&D investment to sales, production or value added ratios. Therefore, 'high-tech' represents a sector with higher R&D intensity. It has always been an important sector in the issue of innovation because of R&D being as a vital input and the linkage to technical change at the beginning of innovation research (Freeman and Soete, 1997). Despite the fact of higher R&D intensity in high-tech sectors, low-tech sectors also engage in R&D activities (Hatzichronoglou's 1997). Furthermore, the extent of resources driving innovation has been stretched outside organizational boundary, and R&D has been criticized not the only determinant of innovation success (Chesbrough, 2003; 2006). Low-tech sector hence reveals the value and importance on innovation research.

With the change from an industrial economy to a service and knowledge economy, different patterns of innovation derived from this economy revolution have been predicted by Pavitt's taxonomy of innovative firms (Pavitt 1984). Innovation is no more an exclusive activity of high-tech sector but diffused as an inspiration to sustain competitiveness in all industries. More attention therefore is attached on low-tech sector and different innovation patterns, such as process, organisational and marketing innovations, of low- and medium-tech sector are demonstrated (Heidenreich 2009). Moreover, it has also been demonstrated that different knowledge searching patterns exist in high-tech and low-tech sectors. Firms in high-tech industries tend to access

[16] OECD defined six high- tech industries in 1986 by using 1980 data and there is a review conducted in 1992 which remains the same result. The major indicator based on R&D intensity which is higher relative to other manufacturing industries.

knowledge from universities or suppliers for innovation success while firms in low-tech industries are more likely to derive knowledge from customers or competitors (Grimpe and Sofka 2009). High-tech sector is also considered as more technology producing industries while low-tech is more technology using industries (Hauknes and Knell 2009), and it causes various knowledge sourcing behaviours due to different requirement. It has been argued that the difference of innovative activities between high-tech and low-tech sectors exists, but only rarely does research carry out the comparison on both. Therefore, this chapter focuses on the comparison of high-tech and low-tech sectors and highlights the difference of the IVC.

Most previous research considered ‘sector’ as ‘industry’ such as high-tech sector/industry (Liu and Buck 2007; Coad and Rao 2008), manufacturing sector/industry (Schmiedeberg 2008) or electricity sector/industry (Jamasb and Pollitt 2011). However, a sector is defined as the gathering of the same type or characteristic and it does not only mean an industry but also others such as a sector of small and medium firms (Lee et al. 2010). This research therefore defines high-tech sectors as either high-tech industries or high-tech firms, and the same as low-tech sectors.

High-tech industries and high-tech firms have always been considered as the same sector (Neelankavil and Alaganar 2003; Michael and Jeonpyo 2006) and it lacks the consideration on the possible effect of low-tech firms existing in high-tech industries. They control for the factor of R&D intensity and distinguish high-tech and low-tech sectors by looking at the industry level, however, the neglect of the factor of environment characteristics causes a significant difference from the measurement at the firm-level. Kirner et al. (2009) grouped all industries into high- tech, medium- tech and low-tech industries and argued that low-, medium- and high-tech industries consist of a considerable of mix of low-, medium- and high-tech firms. The statistical results showed the percentage of firms matching their respective sectoral classifications is only between 43% and 55%. This demonstrated that a significant discrepancy exists between the industry classification and firm level as regards R&D intensity. Hence, the first assumption in this chapter is that high- tech industries comprise not only high-tech firms but also low-tech firms, and the same in low- tech industries which consist of high-tech and low-tech firms. Another assumption is that the significant discrepancy exists by looking at the industry-level and the firm-level.

The next sections firstly introduce the definition of high-tech and low-tech industries and high-tech and low-tech firms. Then the comparisons on the IVC of high-tech and low-tech at the industry-level and the firm-level are illustrated. Finally, the difference between conducting research at the industry-level and the firm-level is demonstrated.

5.2.1 High-tech and low-tech industries

There is no united global standard which classifies high-tech and low-tech industries because of the differences between regions and technological environments. The majority of research and projects refer to OECD approaches to classify industries and take R&D intensity as the indicator of high-tech and low-tech sectors. Hatzichronoglou (1997) extends the approach to classify industry by using three major methods, which are sector, product and pattern approaches. The sector approach considers high-tech industry as the high-tech manufacturing sector, medium high-tech manufacturing sector, and high-tech knowledge-intensive service while the product approach can take into account the characteristics of high-tech products. For the patent approach, high-tech is regarded as high-tech patents and biotechnology patents. (Hatzichronoglou, 1997; Peneder, 2003; Eurosat, 2008)

Focusing on manufacturing industries, Hatzichronoglou (1997) categorizes all manufacturing industries into four groups, high-tech, medium and high-tech, medium and low-tech and low-tech. These industries are classified by the sector approach based on the degree of technology intensity (the ratio of R&D expenditure to value added) and listed in a classification table of manufacturing industries (See table 5.1). Furthermore, Hatzichronoglou (1997) also defines a list of high-tech products by the product approach (See table 5.2), which are: aerospace, computers and office machines, electronic telecommunications, pharmacy, scientific instruments, electrical machinery, non-electrical machinery and armament.

Table 5.1 Manufacturing industries classified according their global technological intensity

Aston University

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Source: Revision of High-Technology Sector and Product Classification (Hatzichronoglou, 1997)

Table 5.1 Manufacturing industries classified according their global technological intensity (cont.)

Source: Revision of High-Technology Sector and Product Classification (Hatzichronoglou, 1997)

Table 5.2 High-Technology Products List

Source: Revision of High-Technology Sector and Product Classification (Hatzichronoglou, 1997)

There is no official definition of high-tech industries in Taiwan. Taiwanese Government lists ten emerging industrial orientations based on high value added, high techniques/skills, low pollution and low dependence on energy. These ten industries are related to communication, information technology (hardware and software), consumer electronics, semiconductor, precision and automatic machinery, aerospace, pharmaceuticals and biotechnology, medical machinery, environmental engineering and construction, and high technical materials. Based on these emerging industries, more specific products are considered as an individual industry because of the growth of productivity in some sectors.

To define high-tech industries in Taiwan, Taiwanese Government takes account of input (R&D intensity and R&D employee/total employee) and output (technology and labour productivity) dimensions. Based on the above two indicators and the growth of production within these emerging industries mentioned above, the Ministry of Economic Affairs considers electronics and electrical machinery (Information Industry, semiconductor, consumer electronics, communication and optoelectronics), Chemicals, Biotechnical industry and precision machinery as Taiwanese high-tech industries (Taiwan Ministry of Economic Affairs, 2001). Based on the classification of Taiwanese manufacturing industries, this research includes five high-tech industries and the rest are defined as eight low-tech industries which are named as traditional industries in Taiwan. Table 5.3 shows the list of Taiwanese high-tech and low-tech manufacturing industries classified by this research.

Table 5.3 The classification of Taiwanese manufacturing industries

Industry	Description	Number of firms
Low-tech	Non-metallic mineral and quarrying	40
	Food, beverages and tobacco	75
	textiles, wearing apparel, leather, paper and printing	218
	Natural resources (petroleum, coal, rubber, plastic and wood) manufacturing	93
	Basic and fabricated metal	246
	Machinery repair and installation, energy supply, and wastewater and pollution remediation	20
	Construction	156
	Others	48
High-tech	Chemical material and products, medical goods	131
	Electronic Parts and Components Manufacturing	244
	Computers, Electronic and Optic Products Manufacturing	162
	Electrical Equipment Manufacturing	102
	machinery and transportation equipment	271

Resource: the current study

5.2.2 High-tech and low-tech firms

As what has been mentioned in the previous section, high-tech is mainly defined as a sector with higher R&D intensity. OECD indicates in 2011 that the mean of R&D intensity for each sector are 9.3% (high-tech), 3.0% (medium-high-tech), 0.8% (medium-high-tech) and 0.3% (low-tech)[17] (see table 5.4). In order to classify the sample observations in this research, a clear boundary needs to be set up to define high-tech and low-tech firms. Legler and Frietsch (2007) and Kirner et al. (2009) categorised industries into three sectors, high-tech, medium-tech and low-tech sectors with the boundaries of 2.5% and 7%. Licht and Nerlinger (1998) classified the high-tech and low-tech with R&D intensity 3.5%. Based on OECD mean of R&D intensity and the

[17] The OECD data is sourced from 1991 to 1999.

explicit standard of R&D intensity in the past literature, this research adopts R&D intensity[18] 3.5% instead of 2.5%[19] as the boundary because to distinguish the actual high-tech sectors. High-tech firms hence are defined as firms with R&D intensity equal to or more than 3.5% and those with R&D intensity less than 3.5% are classifies as low-tech firms. Therefore, there are total 382 high-tech firms and 1119 low-tech firms from the 1806 observations with 305 missing data.

Table 5.4 The mean of R&D intensity for high-tech, medium-high-tech, medium-low-tech and low-tech industries

Aston University

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Resource: OECD Directorate for Science, Technology and Industry, Economic Analysis and Statistics Division, 7 July 2011

5.3 Descriptive statistics

The descriptive statistics of the whole sample has been illustrated in chapter 4. This section focuses on the comparison on the descriptive statistics of high-tech and low-tech sectors. First of all, the distribution of high-tech and low-tech firms within high-tech and low-tech industries has been analysed. The figure in table 5.5 shows that only 22.22% of firms in high-tech industries are classified as being high-tech firms (i.e. more or equal to 3.5% of R&D intensity) while low-tech industries presents more accurately in terms of the amount of low-tech firms (70.67%). Therefore, the figures present a significant discrepancy between the industrial classification and the firm-level reality as regards R&D intensity (see table 5.5). Based on how Taiwanese high-tech

[18] R&D intensity is defined as the ratio of R&D investment to total turnover.

[19] The analysis of the comparison between high-tech and low-tech firms by 2.5% has been done but with less significant effects between these two sectors.

industries[20] are defined, the above result shows that the effect of R&D intensity is not a clear differentiating factor when doing the comparison of high- and low-tech industry in this chapter.

Table 5.5 Distribution of high- and low-tech firms within high- and low-tech industries

Sector	High-tech firms (382)	Low-tech firms (1119)	Invalid data
High-tech industries (910)	182 (22.22%)	637 (77.78%)	91
Low-tech industries (896)	200 (29.33%)	482 (70.67%)	214

Resource: the current study

The statistics show there are both high-tech and low-tech firms existing in high-tech industry and the same as low-tech industry, especially high-tech industries include a significant amount of low-tech firms. The contribution of separating comparison of high-tech and low-tech at the industry-level and the firm-level therefore is demonstrated. The second contribution of this chapter demonstrates the significance to do the comparison on the IVC of high-tech and low-tech. Independent sample t-test is carried out to indicate if the tested variables are significantly different between high-tech and low-tech sectors. The results in table 5.6 and 5.7 show that product innovation (decision and success) is significantly different between high-tech industry and low-tech industry but no difference if comparing at the firm-level. Process innovation plays an equal role in high-tech and low-tech no matter measured at the firm-level or the industry-level. As might be expected, the percentage of internal R&D is significantly different for high-tech versus low-tech at firm level, but not at industry level. Most knowledge sourcing activities show a significant difference between high-tech and low-tech sectors regardless of whether this is defined at the industry-level or the firm-level. The exception

[20] Taiwanese high-tech industries are based on two dimensions of input (R&D intensity and R&D employee/total employee) and output (technique and labour productivity).

is linkage to customers. It means a firm as being of high-tech or low-tech will not affect its engagement on customers' knowledge. The results also indicate that firms in high-tech and low-tech sectors are not significantly different on being a subsidiary, young firms and the percentage of employee with higher degree. Another interesting point shown in table 5.7 is that there is also no significant difference on being an exporter between high-tech and low-tech firms. High-tech firms behaviour approximately equally to low-tech firms on exporting. However, firms tend to export if they are in high- tech industries.

Table 5.6 Summary Statistics of high-tech and low-tech industries

		High-tech industries (910)			**Low-tech industries (896)**		
Variable description	**T test**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**
Innovation indicators							
Product innovation success (%)	V	61.07	29.77	645	57.20	31.65	613
Product innovation (0/1)	V	0.62	0.49	910	0.48	0.50	896
Process innovation (0/1)	X	0.57	0.50	910	0.57	0.50	896
Product and process innovation (0/1)	V	0.30	0.46	910	0.24	0.43	896
Knowledge sourcing activities							
Internal R&D (0/1)	V	0.85	0.36	910	0.79	0.41	896
Percentage Internal R&D (%)	X	27.55	25.74	831	30.15	29.43	688
External R&D (0/1)	X	0.32	0.47	910	0.28	0.45	896
Percentage External R&D (%)	X	8.96	18.52	831	7.88	17.81	688
Forward knowledge (0/1)	X	0.74	0.44	910	0.72	0.45	896
Backward knowledge (0/1)	V	0.70	0.46	910	0.55	0.50	896
Horizontal knowledge (0/1)	V	0.63	0.48	910	0.56	0.50	896
Public knowledge (0/1)	V	0.56	0.50	910	0.39	0.49	896
Other knowledge (0/1)	V	0.71	0.45	910	0.55	0.50	896

Note: T test is for the significant difference of each variable between high-tech and low- tech industries. 'x' means no significant difference; 'v' means significant difference, $p<0.05$.

Table 5.6 Summary Statistics of high-tech and low-tech industries (cont.)

		High-tech industries (910)			Low-tech industries (896)		
Variable description	**T test**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**
Internal resources							
Firm size (employee number)	V	270.28	824.59	910	132.30	436.35	896
Subsidiary (0/1)	X	0.16	0.37	910	0.17	0.37	896
Firm age (0/1, 0= three years or more, 1= less than three years)	X	0.05	0.22	910	0.07	0.25	896
Firm capability							
Employee degree (%)	X	47.95	27.35	862	46.78	30.49	822
Training (0/1)	V	0.81	0.39	910	0.68	0.47	896
Government assistance							
Financial support (0/1)	V	0.62	0.49	864	0.72	0.45	711
Market strategy							
Export (0/1)	V	0.75	0.44	910	0.57	0.50	896

Note: T test is for the significant difference of each variable between high-tech and low-tech industries. 'x' means no significant difference; 'v' means significant difference, $p<0.05$.

Table 5.7 Summary Statistics of high-tech and low-tech firms

		High-tech firm (382)			Low-tech firm (1119)		
Variable description	**T test**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**
Innovation indicators							
Product innovation success (%)	X	57.74	30.69	275	58.67	30.76	756
Product innovation (0/1)	X	0.66	0.48	382	0.61	0.49	1119
Process innovation (0/1)	X	0.58	0.49	382	0.60	0.49	1119
Product and process innovation (0/1)	X	0.30	0.46	382	0.31	0.46	1119
Knowledge sourcing activities							
Internal R&D (0/1)	V	0.99	0.10	382	0.79	0.41	1119
Percentage Internal R&D (%)	V	54.30	28.25	382	19.79	20.77	1119
External R&D (0/1)	V	0.22	0.42	382	0.33	0.47	1119
Percentage External R&D (%)	V	4.73	12.44	382	9.77	19.69	1119
Forward knowledge (0/1)	X	0.74	0.44	382	0.73	0.44	1119
Backward knowledge (0/1)	V	0.55	0.50	382	0.66	0.48	1119
Horizontal knowledge (0/1)	V	0.53	0.50	382	0.60	0.49	1119
Public knowledge (0/1)	V	0.40	0.49	382	0.51	0.50	1119
Other knowledge (0/1)	V	0.56	0.50	382	0.66	0.47	1119

Table 5.7 Summary Statistics of high-tech and low-tech firms (cont.)

		High-tech firm (382)			Low-tech firm (1119)		
Variable description	**T test**	**Mean**	**S.D.**	**N**	**Mean**	**S.D.**	**N**
Internal resources							
Firm size (employee number)	V	125.81	307.53	382	211.27	508.58	1119
Subsidiary (0/1)	X	0.12	0.32	382	0.15	0.36	1119
Firm age (0/1, 0= three years or more, 1= less than three years)	X	0.08	0.27	382	0.06	0.23	1119
Firm capability							
Employee degree (%)	X	48.02	30.60	365	45.17	26.64	1065
Training (0/1)	V	0.64	0.48	382	0.79	0.41	1119
Government assistance							
Financial support (0/1)	V	0.77	0.42	382	0.65	0.48	1119
Market strategy							
Export (0/1)	X	0.71	0.45	382	0.71	0.45	1119

Note: T test is for the significant difference of each variable between high-tech and low-tech firms. 'x' means no significant difference; 'v' means significant difference, p<0.05.

These descriptive statistics suggest that whether one defines high-tech and low-tech at the industry-level or the firm-level may indeed matter. The following sections are going to demonstrate the difference of the IVC between high-tech and low-tech industries (5.3.1) and high-tech and low-tech firms (5.3.2).

5.4.1 The comparison on IVC of high-tech and low-tech industries

5.4.1.1 Knowledge sourcing

Knowledge sourcing is the beginning of the IVC and seven types of knowledge linkages have been introduced in chapter 4. The target observations are grouped into high-tech and low-tech industries to be evaluated separately for firms' knowledge sourcing behaviour.

The equation the same as the one in chapter 4 is shown as the below.

$$KS^*_{ji} \equiv \beta' KS_{ki} + \gamma'_0 RI_{ji} + \gamma'_1 CI_{ji} + \gamma'_2 GFS_{ji} + \gamma'_3 EX_{ji} + \varepsilon_{ji}, \quad j,k \equiv 1,7$$

$KS_{ji} = 1$ if $KS^*_{ji} > 0$; $KS_{ji} = 0$ otherwise, (Eq. 5.1)

The results demonstrate that knowledge sourcing activities within either high-tech or low-tech industry appears a pattern of complementarity (see table 5.8 and 5.9). However, the effect of the linkage to competitors on other knowledge sourcing activities is quite different between high-tech and low-tech industries. It has the significant influence on increasing internal R&D and the linkage to customers and suppliers if firms are in high-tech industries, but only significantly affects on the linkage to suppliers and other resources while firms are in low-tech industries. It shows that firms in high-tech industries collaborate with competitors or other companies are more likely to construct the knowledge flow to connect up- and down- stream in its supply chain and engage in internal R&D. Compare to high-tech industries, firms in low-tech industries are more likely to access knowledge by other approaches if they derive knowledge from other companies within supply chain (competitors, customers and suppliers). This reveals that Taiwanese low-tech industries still carry innovation activities inside their organizational boundary and do not build formal channels/contracts to collaborate with others (Chen et al. 2011).

Except the effect from other knowledge linkages, the previous literature has indicated other factors such as firm resources and capabilities, government financial support and exporting, may also influence on the knowledge sourcing activities. In the result of either high-tech or low-tech industry, firm size, measured by the number of employees, shows its positive significant influence on internal R&D with inverted U shape. However, it has the contrary effect on other knowledge linkage with negative influence (U shape with the turning point 1033.06) in high-tech industries but positive impact in low-tech industry (inverted U shape) although non-significant.

Employee degree shows the positive impact on both internal and external R&D activities if firms are in high-tech industries, however, what surprises is the higher percentage of employee with degree actually reduce the probability of internal R&D in low-tech industries. The explanation can be either the purpose of recruiting employment with degree for firms in low-tech industries is not to engage in internal R&D, or those employees directly bring in outside technology/technique because low-tech industries are considered as more technology users (Hauknes and Knell 2009).

The descriptive statistics show that more than 60% of firms in high-tech industries received financial support from Government and even higher (72%) in low-tech industries (Table 5.6). Although lower value of goods produced in low-tech industries, they still play an important role on Taiwanese economy. To develop Taiwanese industries' competitiveness the Government not only support high-tech industries but also put forward constructive policies to upgrade low-tech industries (Chen et al. 2011). As might be expected, Government financial support is positively associated with competitor and public knowledge sourcing in high-tech industries and with customer knowledge sourcing in low-tech industries. However, the opposite result is found to supplier and other knowledge in both high-tech and low-tech industries. The explanation can be the knowledge firms usually derived from suppliers and exhibitions/industrial associations is more financial related.

Table 5.8 Knowledge sourcing_ high-tech industry

Variables	Internal R&D	External R&D	Forward knowledge	Backward knowledge	Horizontal knowledge	Public knowledge	Other knowledge
Knowledge sources							
Internal R&D	-	0.096** (0.047)	-0.015 (0.046)	0.030 (0.048)	0.133** (0.054)	0.046 (0.063)	0.071 (0.047)
External R&D	0.036* (0.020)	-	0.025 (0.032)	0.001 (0.035)	0.022 (0.038)	0.095** (0.044)	-0.030 (0.032)
Forward knowledge	0.0003 (0.023)	0.032 (0.037)	-	0.041 (0.038)	0.171*** (0.042)	0.034 (0.048)	0.012 (0.033)
Backward knowledge	0.009 (0.022)	0.011 (0.040)	0.036 (0.037)	-	0.350*** (0.039)	0.138*** (0.050)	0.068* (0.035)
Horizontal knowledge	0.052** (0.022)	0.018 (0.036)	0.144* (0.035)	0.300*** (0.034)	-	-0.009 (0.047)	0.045 (0.033)
Public knowledge	0.016 (0 .025)	0.084** (0.043)	0.026 (0.039)	0.116*** (0.042)	0.0002 (0.046)	-	0.502*** (0.033)
Other knowledge	0.048 (0.030)	-0.031 (0.049)	0.019 (0.043)	0.086* (0.047)	0.055 (0.052)	0.657*** (0.028)	-
Resource indicators							
Employment	0.0002*** (0.0001)	-0.00003 (0.00004)	0.00002 (0.00004)	0.00003 (0.00004)	0.00002 (0.00004)	0.00006 (0.00006)	-0.0001** (0.0001)
Employment-squared	$-1.12x10^{-08}$*** (0.000)	$4.60x10^{-09}$ (0.000)	$-3.78x10^{-10}$ (0.000)	$-7.34x10^{-10}$ (0.000)	$-2.84x10^{-11}$ (0.000)	$-2.49x10^{-09}$ (0.000)	$4.84x10^{-08}$** (0.000)
Firm age	0.042 (0.031)	0.089 (0.078)	0.083 (0.058)	0.061 (0.063)	-0.165** (0.079)	-0.016 (0.084)	0.031 (0.054)
Subsidiary	-0.011 (0.031)	-0.017 (0.047)	-0.017 (0.045)	-0.051 (0.049)	-0.011 (0.050)	0.011 (0.061)	-0.021 (0.043)
Capability indicators							
Employee degree	0.001* (0.0004)	0.001** (0.001)	-0.001 (0.0006)	0.00002 (0.0006)	0.0006 (0.0007)	0.0004 (0.0008)	0.0001 (0.001)
Employee training	0.060** (0.030)	0.046 (0.042)	0.022 (0.041)	0.108** (0.044)	-0.021 (0.045)	0.0003 (0.054)	0.043 (0.039)
Government financial support	-0.016 (0.021)	0.051 (0.035)	-0.034 (0.032)	-0.134*** (0.032)	0.068* (0.038)	0.117*** (0.043)	-0.096*** (0.028)
Export	0.060** (0.029)	0.030 (0.040)	0.056 (0.039)	0.027 (0.041)	0.012 (0.045)	0.014 (0.051)	0.014 (0.035)
Observations	825	825	825	825	825	825	825
Log likelihood	-286.741	-506.112	-453.384	-417.618	-479.517	-388.368	-306.840

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1. All the figures in the table are marginal effects generated from probit models. All models include industry dummies.Firm age: A firm was established after 1st January 2004. 0: established more than 3 years; 1: establish less than 3 years.

Table 5.9 Knowledge sourcing_ low-tech industry

Variables	Internal R&D	External R&D	Forward knowledge	Backward knowledge	Horizontal knowledge	Public knowledge	Other knowledge
Knowledge sources							
Internal R&D	-	0.142*** (0.042)	-0.042 (0.044)	0.046 (0.058)	0.022 (0.053)	-0.013 (0.058)	-0.018 (0.059)
External R&D	0.089*** (0.027)	-	0.050 (0.038)	0.032 (0.047)	0.072 (0.045)	0.083* (0.048)	-0.026 (0.053)
Forward knowledge	-0.027 (0.029)	0.053 (0.039)	-	0.002 (0.047)	0.037 (0.046)	-0.029 (0.051)	0.144*** (0.052)
Backward knowledge	0.021 (0.032)	0.025 (0.040)	-0.0003 (0.039)	-	0.148*** (0.043)	0.060 (0.047)	0.235*** (0.046)
Horizontal knowledge	0.009 (0.028)	0.060 (0.037)	0.028 (0.037)	0.146*** (0.041)	-	0.017 (0.045)	0.112** (0.047)
Public knowledge	-0.013 (0.034)	0.080* (0.044)	-0.015 (0.045)	0.064 (0.051)	0.022 (0.050)	-	0.542*** (0.034)
Other knowledge	-0.019 (0.035)	-0.030 (0.047)	0.116** (0.046)	0.250*** (0.048)	0.117** (0.051)	0.541*** (0.034)	-
Resource indicators							
Employment	0.0005*** (0.0002)	-0.00004 (0.0001)	0.0002* (0.0001)	0.0003 (0.0002)	0.0004*** (0.0002)	-0.00008 (0.0001)	0.0002 (0.0002)
Employment-squared	$-6.87\text{x}10^{-08}$** (0.000)	$1.49\text{x}10^{-08}$ (0.000)	$-4.62\text{x}10^{-08}$** (0.000)	$-4.53\text{x}10^{-08}$ (0.000)	$-7.65\text{x}10^{-08}$** (0.000)	$5.35\text{x}10^{-09}$ (0.000)	$-3.12\text{x}10^{-08}$ (0.000)
Firm age	0.064 (0.040)	0.077 (0.078)	0.026 (0.065)	0.017 (0.081)	-0.119 (0.076)	-0.100 (0.082)	-0.0002 (0.087)
Subsidiary	0.015 (0.041)	-0.099** (0.046)	-0.030 (0.055)	0.047 (0.062)	0.029 (0.060)	0.088 (0.061)	-0.044 (0.062)
Capability indicators							
Employee degree	-0.0009** (0.0005)	0.0005 (0.0006)	-0.0002 (0.0006)	0.0008 (0.0007)	0.0004 (0.0007)	0.0003 (0.0007)	0.0001 (0.0008)
Employee training	0.163*** (0.037)	0.088** (0.040)	0.046 (0.041)	0.013 (0.048)	0.080* (0.046)	0.006 (0.050)	0.061 (0.052)
Government financial support	0.042 (0.036)	0.011 (0.041)	0.074* (0.043)	-0.125*** (0.045)	-0.034 (0.047)	-0.027 (0.049)	-0.119** (0.049)
Export	0.072** (0.032)	0.007 (0.039)	0.027 (0.039)	0.002 (0.044)	-0.004 (0.043)	0.076* (0.046)	-0.017 (0.049)
Observations	667	667	660	667	667	667	667
Log likelihood	-279.951	-379.265	-370.958	-393.263	-418.821	-319.337	-300.018

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1. All the figures in the table are marginal effects generated from probit models. All models include industry dummies.
Firm age: A firm was established after 1st January 2004. 0: established more than 3 years; 1: establish less than 3 years.

5.4.1.2 Innovation activities

The second element of the IVC is innovation production which has been introduced in chapter 4. In this chapter, the comparison of high-tech and low-tech industries is highlighted as the main point to discuss. Because of different industrial characteristics between high-tech and low-tech industries, it has been suggested that there are different knowledge linkages leading to innovation success. In Pavitt's study, it suggests that a number of electronics sectors (a part of high-tech industries) received knowledge from public linkages (universities, research associations and government laboratories) more than other sectors (Pavitt, 1984). Firms in high-tech industries tend to access universities or suppliers to derive technological knowledge while firms in low-tech industries are more likely to benefit from the knowledge provided by customers or competitors (Grimpe and Sofka 2009). An assumption here is raised that different knowledge sourcing behaviour for innovation exist in high-tech industries from low-tech industries. Therefore, the comparison of the innovation production function between high-tech industry and low-tech industry is listed as the below:

$$I_i = \phi_0^{'} KS_{ki} + \phi_1 HD_i + \phi_2 KS_{ki} HD_i + \phi_{3^{'}} RI_i + \phi_4^{'} CI_i + \phi_5 GFS_i + \phi_6 EX_i + \varepsilon_i \quad \text{(Eq 5.2)}$$

Where *Ii* is an innovation output indicator *(k*=1,…,7), that indicates the alternative knowledge sources identified earlier, HD_i is a dummy variable of high-tech industries, $KS_{ki}HD_i$ is an interaction term representing firms with KS_k in high-tech industries, εi is the error term and other variables are defined the same as in chapter 4.

The result in table 5.10 shows that high-tech industry has a negative significant effect on the decision of product innovation. This may be affected by the fact of more than 50% of firms in high-tech industries are actually low-tech firms. However, firms with internal

R&D activities or the knowledge linkages to suppliers or competitors tend to carry product innovation only if they are in high- tech industries. Most notably with regard to the knowledge linkage to suppliers, the negative impact on product innovation for all firms becomes a positive effect for firms in high- tech industries. This result shows that the decision to engage in product innovation for firms in high-tech industries highly relies on the knowledge derived from suppliers.

No direct significant effect of high-tech industry on product innovation success or process innovation decision was found, but firms with the knowledge linkage to customers are less likely to carry on process innovation if they are in high-tech industries. Although there is no significant difference on firms with the knowledge linkage to customers and process innovation (see table 5.6), it may be that firms in high-tech industries utilised the knowledge derived from customers more on product innovation rather than process innovation. Overall, the results match the assumption that firms in high- tech industries tend to derive knowledge from universities or suppliers for innovation while firms in low-tech industries are more likely to link to customers' knowledge. However, opposite result here shows that the competitors' knowledge affects positively product innovation in the high-tech industries. The explanation can be Taiwanese innovative manufacturing firms in high-tech industries more collaborate with competitors or other companies to engage in product innovation.

Overall, there is a certain knowledge searching strategy to innovation in high-tech and low-tech industries because of different characteristics/demand. However, it has been indicated that there is a kind of special relationship (Guan- Xi) and some informal collaboration between organizations are formed by this kind of private relationship to reduce the risk of uncertainty and share some resources (Gulati 1998). The 'Guan-Xi' here refers to interpersonal connections especially existing in Chinese society which have been used in Xin and Pearce's (196) and Yang's (1994) research. Many Taiwanese companies are family enterprises and the special 'Guan- Xi' of relationship causes an effect on knowledge sourcing behaviour due to Taiwanese culture and society (Chung 2004).

Table 5.10 Innovation production_ high-tech industry effect

Variables	Product innovation: decision	Product innovation: success	Process innovation: decision
Knowledge sourcing			
Internal R&D (0/1)	0.0004 (0.0005)	0.153*** (0.051)	0.0004 (0.0005)
External R&D (0/1)	0.0002 (0.0009)	0.045 (0.082)	0.001 (0.0009)
Forward (0/1)	-0.031 (0.042)	-2.316 (4.013)	0.048 (0.044)
Backward (0/1)	-0.067* (0.041)	1.880 (3.593)	0.037 (0.043)
Horizontal (0/1)	-0.037 (0.039)	-6.059* (3.625)	-0.00004 (0.041)
Public (0/1)	0.014 ()0.047	-7.090* (4.262)	0.042 (0.047)
Others (0/1)	0.013 (0.048)	3.798 (4.196)	-0.120** (0.047)
KS*High-tech Industry			
InterRD*HD	0.157*** (0.053)	-6.986 (5.649)	-0.014 (0.055)
ExterRD*HD	0.015 (0.044)	4.621 (3.854)	0.034 (0.043)
Forward*HD	0.015 (0.059)	-2.011 (5.349)	-0.099* (0.060)
Backward*HD	0.117** (0.056)	-5.859 (5.142)	-0.015 (0.059)
Horozontal*HD	0.102* (0.053)	2.936 (4.985)	-0.030 (0.057)
Public*HD	-0.076 (0.066)	4.609 (5.669)	0.026 (0.064)
Others*HD	-0.002 (0.069)	2.849 (5.931)	0.073 (0.068)
Resource indicators			
Employment	0.0002*** (0.00007)	-0.003 (0.005)	0.00007 (0.00006)
Employment-sq	$-2.69\text{x}10^{-08}$* (0.000)	$9.21\text{x}10^{-08}$ (0.000)	$3.84\text{x}10^{-09}$ (0.000)
Firm age	0.077 (0.049)	-1.707 (4.652)	-0.033 (0.055)
Subsidiary	-0.003 (0.038)	-0.009 (3.220)	-0.022 (0.038)
Capability indicators			
Employee degree	0.003*** (0.0005)	0.014 (0.042)	-0.0005 (0.0005)
Employee training	0.087** (0.034)	4.031 (3.208)	0.0009 (0.034)
Government financial	0.009 (0.029)	1.394 (2.483)	0.030 (0.029)
Export	0.031 (0.030)	5.999** (2.692)	-0.006 (0.030)
High- tech industry (0/1)	-0.221*** (0.073)	11.979 (7.584)	0.023 (0.078)
Observations	1447	996	1447
Log likelihood	-899.020	-4331.7811	-958.6446

Note: Standard errors in parentheses; *** p<0.01, **p<0.05, *p<0.1. All the figures in the table are marginal effects generated from Probit/Tobit models.

Firm age: A firm was established after 1st January 2004. 0: established more than 3 years; 1: establish less than 3 years.

5.4.1.3 Innovation outputs- value added

The end of the IVC leads to the exploitation of knowledge, the innovative activities affecting on firm performance which has been introduced in chapter 4. The assumption raised here is to investigate if innovation happening in high-tech industries has significant effect on firm performance and the equation is listed as the below.

$$BPERF_i = \lambda_0 + \lambda_1 INNO_i + \lambda_2 HDi + \lambda_3 INNO_i HD_i + \lambda_4 X_i + \tau_i \qquad \text{(Eq. 5.3)}$$

Where *BPERFi* is an indicator of business performance (e.g. productivity, sales growth or employment growth), *INNOi* is a vector including innovation outputs measures for both process and product innovation, HD_i is a dummy variable of high-tech industry, $INNOiHD_i$ is an interaction term representing a firm with *INNOi* belonging to high-tech industries, and *Xi* is a set of firm specific variables that are hypothesized to have effect on firm performance. These proposed variables are firm size, firm age, subsidiary, employee degree, training, government financial support and exporting as mentioned in chapter 4.

The result shows that product innovation has a positive significant effect on firm growth (both employment and sales growth). The interaction terms indicate that the positive employment effect is greater for firms in the high-tech industries. The summary statistics table 5.6 shows that 62% of firms in high-tech industries engaged in product innovation while 57% of them engaged in process innovation. Compare to firms in low-tech industries, which remains the same percentage of firms with process innovation but only 48% of firms have product innovation. Although higher percentage of firms in high-tech industries with product innovation but the average of a firm’s innovation success in high-tech industries is only slight higher (about 4%) than the one’s in low-tech industries.

It may be that the product innovation in high-tech industries needs the longer term to bring the effect on sales, so the innovation success in high-tech industries is not much higher than the one in low-tech industries. Moreover, product innovation success does not influence significantly on any firm performance which shows that the growth and productivity of Taiwanese manufacturing firms didn't rely heavily on their innovative products, regardless of the type of industry. Another interesting point is that a firm with process innovation in high-tech industries also causes a non-significant negative effect on employment growth while all firms (in both high-tech and low-tech industries) with process innovation actually has positive significant impact. Compared to high-tech industries, low-tech industries are characterized by more process innovation so it may be the reason high- tech industries did not benefit on its employment growth by doing innovation process. Furthermore, by innovating manufacturing process in high-tech industries, the demand of labor may reduce much more than the increase of R&D employee. Therefore, it causes the negative employment growth.

Table 5.11 Performance estimations_ high-tech industry effect

Variables	Product innovation decision indicators		
	Employment growth	**Sales growth**	**Productivity**
Constant	-0.167 (0.081)	8.881 (5.526)	157077 (100381.6)
Innovation activities			
Product innovation	0.099** (0.046)	3.515* (2.121)	32604.22 (34511.81)
Process innovation	0.105** (0.047)	-3.297 (3.166)	-57346.75 (50101.29)
Innovation*High-tech industry			
Product inno_ HD	0.207* (0.106)	-2.626 (1.668)	-2794.23 (28805.19)
Process inno_ HD	-0.020 (0.123)	3.446 (3.359)	2877.26 (58526.2)
High- tech industry	-0.073 (0.104)	-3.156 (2.235)	18615.22 (49935.18)
Resource indicators			
Employment	-0.0004** (0.0002)	-0.001*** (0.0005)	-44.784*** (13.246)
Employment-squared	6.77×10^{-08}*** (2.34×10^{-08})	2.61×10^{-07}*** (9.89×10^{-08})	0.002*** (0.0008)
Firm age	-0.062 (0.068)	7.317 (7.948)	17472.73 (59110.71)
Subsidiary	0.388* (0.211)	-1.365 (0.967)	-39210.98** (15838.91)
Capacity indicators			
Employee degree	0.0006 (0.0005)	-0.056 (0.041)	-511.530 (693.270)
Employee training	0.027 (0.048)	-1.194 (2.081)	-13508.66 (28284.74)
Government financial support	-0.046 (0.070)	-0.754 (1.705)	-11997.79 (33176.07)
Export	-0.014 (0.047)	-2.346 (1.777)	-60673.3 (37305.63)
Observations	1492	1492	1492

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1.
Firm age: A firm was established after 1st January 2004. 0: established more than 3 years; 1: establish less than 3 years.

Table 5.11 (Cont.) Performance estimations_ high-tech industry effect

Variables	Product innovation success indicator		
	Employment growth	**Sales growth**	**Productivity**
Constant	-0.214 (0.142)	14.687* (8.632)	306742.1 (233299.3)
Innovation activities			
Product innovation	0.0004 (0.001)	0.014 (0.043)	-1979.939 (1638.231)
Process innovation	0.151** (0.062)	-4.918 (4.212)	-50223.63 (57494.04)
Innovation*High-tech industry			
Product inno_ HD	-0.003 (0.002)	-0.008 (0.044)	2041.002 (1817.049)
Process inno_ HD	0.002 (0.160)	5.359 (4.522)	-24127.28 (65700.14)
High- tech industry	0.266 (0.207)	-5.350 (3.985)	-73047.47 (157034.2)
Resource indicators			
Employment	-0.0004* (0.0002)	-0.001** (0.0007)	-104.301*** (34.862)
Employment-squared	6.80×10^{-08}*(4.05×10^{-08})	3.34×10^{-07} (2.05×10^{-07})	0.021*** (0.008)
Firm age	-0.111 (0.093)	10.923 (1.462)	34866.59 (81021.47)
Subsidiary	0.552* (0.291)	-2.118 (1.462)	-50189.81** (23219.88)
Capacity indicators			
Employee degree	0.001** (0.0006)	-0.083 (0.060)	-618.283 (1002.491)
Employee training	0.051 (0.073)	-1.328 (3.147)	-2648.419 (49944.89)
Government financial support	0.0008 (0.097)	-1.503 (2.737)	-28943.66 (48429.22)
Export	0.014 (0.063)	-4.100 (2.800)	-70310.25 (50427.93)
Observations	1027	1027	1027

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1.
Firm age: A firm was established after 1st January 2004. 0: established more than 3 years; 1: establish less than 3 years.

5.4.2 The comparison on the IVC of high-tech and low-tech firms

In this section, the IVC estimation is again carried out, but it bases on a split between high- and low-tech firms, rather than industries.

5.4.2.1 Knowledge sourcing

The same equation as eq. 5.1 is carried here to demonstrate the knowledge sourcing activities of high-tech and low-tech firms. The equation is shown as the below.

$$KS^{*}_{ji} \equiv \beta' KS_{ki} + \gamma'_0 RI_{ji} + \gamma'_1 CI_{ji} + \gamma'_2 GFS_{ji} + \gamma'_3 EX_{ji} + \varepsilon_{ji}, \quad j,k \equiv 1,7$$

$$KS_{ji} = 1 \text{ if } KS^{*}_{ji} > 0; \; KS_{ji} = 0 \text{ otherwise,} \qquad \text{(Eq. 5.4)}$$

First of all, the result predicts undertaking of internal R&D perfectly as shown in table 5.12. This model is not able to evaluate the probability of other knowledge sourcing activities affecting on internal R&D in high-tech firms. The reason is that all high-tech firms are with R&D intensity equal to or over 3.5% and it means they are all engaged in internal R&D. It may also be one of the reasons that there is no significant effect of internal R&D on other knowledge sourcing activities.

As what have been demonstrated in the previous sections for all manufacturing firms, high-tech industries and low-tech industries, the relationship between knowledge sourcing activities of high- tech firms are complementary. However, a different result is found in low-tech firms. Most knowledge sourcing activities appear in complementary relationship but there is substitute relationship between internal R&D and forward knowledge when being low-tech firms. This supports Schmidt (2010) and Love and Roper (2001)'s argument that there is substitutability between internal R&D and external knowledge, but only on customers' knowledge because it still shows strong complementary relationship between internal R&D and other external knowledge such as external R&D and competitors' knowledge.

Moreover, another interesting point to raise here is most knowledge resources such as internal R&D, customers' knowledge, suppliers' knowledge and other sources are complementary with the linkage to competitors for low-tech firms, but only the linkage to suppliers in high-tech firms leads to engage with competitors. It shows that it helps to derive knowledge from competitors if low-tech firms also derive knowledge from others such as internal R&D, customers, suppliers or other sources.

In addition to the effect from other knowledge resources, other factors like firm resources and capabilities, government financial support and exporting proposed in the previous chapter also have a certain impact on these knowledge sourcing behaviours. Overall, these other determinants affect on knowledge sourcing activities quite differently between high-tech and low-tech firms except the below two points. Firstly, both supplier linkages are affected significantly by Government financial support with the negative relationship. It may be the reason that suppliers' knowledge is more about new materials/components and the financial support may causes firms engage on their own discovery on new materials/components. Secondly, firms over three years are more likely to derive knowledge from competitors. It shows no matter whether they are high-tech or low-tech firms, young firms are less inclined to connect with their competitors. Young high-tech firms are also markedly less likely to connect with public knowledge sources and more likely to connect with other knowledge sources than older high-tech firms (Ganotakis and Love 2010): these age effects are notably absent for low-tech firms.

5.4.2.2 Innovation activities

The same equation as eq 5.2 is adopted here to evaluate the innovation activities for high- tech and low- tech firms. However, the variable HD (high-tech industry) is replaced by HF (high-tech firm) to analyse the effect of high-tech firms on the innovation activities and the equation is shown as the below.

$$I_i = \phi_0' KS_{ki} + \phi_1 HF_i + \phi_2 KS_{ki} HF_i + \phi_3' RI_i + \phi_4' CI_i + \phi_5 GFS_i + \phi_6 EX_i + \varepsilon_i \quad \text{(Eq 5.5)}$$

Where *Ii* is an innovation output indicator (*k*=1,…,7), that indicates the alternative knowledge sources identified earlier, *HF* is a dummy variable of high-tech firm, $KS_{ki}HF_i$ represents the i^{th} high-tech firm with KS_k, ε is the error term and other variables are defined as in the previous section.

The result in table 5.14 first indicates that being a high-tech firm does not significantly directly affect on weather if a firm introduces product or process innovation. This result compared to the result in previous section 5.4.1 (A firm being in high-tech industries reduces the probability of the engagement in product innovation.) shows that a firm's decision to engage in product innovation depends more on the nature of products rather than the nature of firms (R&D intensive).

Although being a high-tech firm does not directly affect on innovation decision, it influences some knowledge sourcing activities and other factors on innovation. The results of the interaction terms show that being a high-tech firm with internal R&D strongly affects the process innovation decision. It may be because more than half (61.3%) of observed high-tech firms produce products for international branded companies (Original Equipment Manufacturer, OEM[21]), the investment of internal R&D is more likely used for innovating manufacturing process to increase or improve production. Compare to the result in the previous section which firms with internal R&D in high-tech industries are more likely to engage in product innovation. The classification of high-tech industries in this research is based on the definition of high-tech from Taiwanese Government, and it is classified by not only R&D intensity but the type of products. Therefore, the firms in these industries may not have R&D intensity over 3.5% but the products they produced belong to high- tech referred by the Government. It shows the comparison on high-tech and low- tech significantly differentiates the analysis at the industry-level and the firm-level.

[21] Original Equipment Manufacturers (OEM) are firms manufacture products or components ordered by a company and retailed under that company's brand name.

Table 5.12 Knowledge sourcing_ high-tech firm

Variables	Internal R&D	External R&D	Forward knowledge	Backward knowledge	Horizontal knowledge	Public knowledge	Other knowledge
Knowledge sources							
Internal R&D	-	-0.419 (0.268)	0.026 (0.224)	0.259 (0.250)	0.132 (0.283)	-0.198 (0.179)	0.183 (0.312)
External R&D	-	-	0.074 (0.052)	0.034 (0.067)	0.073 (0.066)	0.109 (0.075)	-0.097 (0.085)
Forward knowledge	-	0.066 (0.045)	-	0.035 (0.065)	0.021 (0.064)	-0.050 (0.065)	0.242*** (0.067)
Backward knowledge	-	0.008 (0.050)	0.021 (0.053)	-	0.254*** (0.058)	0.069 (0.064)	0.164** (0.065)
Horizontal knowledge	-	0.049 (0.044)	0.015 (0.049)	0.237*** (0.056)	-	-0.031 (0.062)	0.082 (0.064)
Public knowledge	-	0.082 (0.058)	-0.059 (0.058)	0.071 (0.071)	-0.028 (0.071)	-	0.583 (0.045)
Other knowledge	-	-0.091 (0.063)	0.209*** (0.060)	0.171** (0.071)	0.050 (0.073)	0.577*** (0.046)	-
Resource indicators							
Employment	-	-0.0002 (0.0002)	-0.0001 (0.0003)	-0.00006 (0.0006)	0.0002 (0.0002)	-0.00003 (0.0002)	0.00005 (0.0002)
Employment-squared	-	1.86×10^{-08} (0.000)	1.61×10^{-07} (0.000)	6.95×10^{-07} (0.000)	-7.39×10^{-08} (0.000)	7.71×10^{-08} (0.000)	-5.12×10^{-08}
Firm age	-	0.011 (0.088)	-0.052 (0.094)	0.100 (0.101)	-0.175* (0.099)	-0.285*** (0.059)	0.236*** (0.075)
Subsidiary	-	0.079 (0.079)	0.028 (0.075)	-0.159* (0.094)	0.019 (0.092)	0.062 (0.099)	0.026 (0.098)
Capability indicators							
Employee degree	-	0.0009 (0.0007)	-0.0006 (0.0008)	0.001 (0.001)	0.0006 (0.0009)	-0.00008 (0.001)	0.003** (0.001)
Employee training	-	0.142*** (0.045)	-0.080 (0.052)	0.007 (0.066)	-0.030 (0.064)	0.102 (0.066)	0.128* (0.072)
Government financial support	-	0.041 (0.052)	-0.064 (0.055)	-0.261*** (0.059)	0.063 (0.068)	0.129** (0.062)	-0.017 (0.073)
Export	-	0.003 (0.051)	-0.035 (0.053)	-0.075 (0.065)	0.049 (0.064)	0.006 (0.068)	0.008 (0.071)
Observations	-	362	356	365	365	365	365
Log likelihood	-	-178.273	-195.441	-198.533	-232.350	-160.152	-146.869

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1. All the figures in the table are marginal effects generated from probit models. All models include industry dummies. Firm age: A firm was established after 1st January 2004. 0: established more than 3 years; 1: establish less than 3 years.

Table 5.13 Knowledge sourcing_ low-tech firm

Variables	Internal R&D	External R&D	Forward knowledge	Backward knowledge	Horizontal knowledge	Public knowledge	Other knowledge
Knowledge sources							
Internal R&D	-	0.189*** (0.034)	-0.061* (0.034)	0.064 (0.042)	0.083** (0.042)	0.045 (0.049)	0.041 (0.042)
External R&D	0.114*** (0.022)	-	0.033 (0.029)	-0.002 (0.033)	0.022 (0.034)	0.063 (0.039)	-0.008 (0.034)
Forward knowledge	-0.037 (0.024)	0.037 (0.033)	-	0.034 (0.035)	0.138*** (0.037)	0.026 (0.043)	0.034 (0.036)
Backward knowledge	0.037 (0.027)	0.006 (0.034)	0.025 (0.032)	-	0.259*** (0.034)	0.083* (0.042)	0.141*** (0.036)
Horizontal knowledge	0.046* (0.025)	0.018 (0.032)	0.115*** (0.031)	0.236*** (0.031)	-	0.005 (0.040)	0.084** (0.034)
Public knowledge	0.024 (0.028)	0.054 (0.037)	0.030 (0.035)	0.070* (0.038)	0.009 (0.040)	-	0.538*** (0.026)
Other knowledge	0.025 (0.031)	0.002 (0.041)	0.020 (0.038)	0.162*** (0.041)	0.105** (0.043)	0.622*** (0.025)	-
Resource indicators							
Employment	0.0004*** (0.0001)	-0.00003 (0.00006)	0.00009 (0.00006)	0.00002 (0.00007)	0.0002** (0.00007)	0.0001 (0.0001)	-0.00004 (0.0001)
Employment-squared	$-6.28x10^{-08}$*** (0.000)	$7.39x10^{-09}$ (0.000)	$-2.11x10^{-08}$ (0.000)	$-4.51x10^{-09}$ (0.000)	$-3.39x10^{-08}$** (0.000)	$-3.00x10^{-08}$* (0.000)	$2.44ex10^{-08}$ (0.000)
Firm age	0.082** (0.032)	0.105 (0.068)	0.093* (0.049)	0.026 (0.062)	-0.148** (0.068)	0.103 (0.079)	-0.119 (0.075)
Subsidiary	0.013 (0.035)	-0.088** (0.039)	-0.038 (0.041)	0.013 (0.044)	-0.013 (0.045)	0.031 (0.052)	-0.038 (0.045)
Capability indicators							
Employee degree	-0.0004 (0.0004)	0.0009* (0.0006)	-0.0007 (0.0005)	0.0003 (0.0006)	0.0005 (0.0006)	0.0009 (0.0007)	-0.0008 (0.0006)
Employee training	0.219*** (0.036)	0.002 (0.039)	0.089** (0.038)	0.038 (0.039)	0.047 (0.040)	-0.069 (0.049)	0.030 (0.043)
Government financial support	-0.026 (0.025)	0.047 (0.031)	0.021 (0.030)	-0.091*** (0.032)	0.014 (0.034)	0.053 (0.039)	-0.128*** (0.031)
Export	0.068** (0.028)	0.029 (0.033)	0.081** (0.033)	0.056 (0.035)	0.002 (0.037)	0.064 (0.043)	-0.003 (0.035)
Observations	1065	1065	1061	1065	1065	1061	1065
Log likelihood	-451.781	-646.445	-587.807	-584.678	-639.371	-505.967	-429.656

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1. All the figures in the table are marginal effects generated from probit models. All models include industry dummies. Firm age: A firm was established after 1st January 2004. 0: established more than 3 years; 1: establish less than 3 years

High-tech firms with external R&D have a significant negative effect on product innovation success while the linkages to customers and universities are more likely to increase the percentage of innovation success: the customer effect is very marked here and it shows the tight connection between customer sourcing and market demand. The period of data we derived may be not long enough to see the effect of external R&D on the innovative products to sales but the university and customer knowledge are more direct affect on the sales for high- tech firms. Supplier knowledge influences significantly on product innovation decision and the explanation can be that more than half of high-tech firms are acting as ODM (Original Design Manufacturer)[22]. However, customer linkages do not significant affect on product innovation. It is not surprising because ODM companies design and manufacture products to their customers, so customers only receive the result of product innovation. These ODM companies may derive some market knowledge from their customers, but mainly depend on knowledge from others such as suppliers and public organizations. Knowledge derived from exhibitions or industrial associations can also increase the probability of the decision to product innovation if being a high-tech firm.

The above results show that high-tech and low-tech firms with clear boundary of R&D intensity do have significant different knowledge sourcing strategies to innovation activities.

[22] An original design manufacturer (ODM) is a firm which designs and manufactures specific products but eventually branded by another firm for sale.

Table 5.14 Innovation production_ high-tech firm effect

Variables	Product innovation: decision	Product innovation: success	Process innovation: decision
Knowledge sourcing			
Internal R&D (0/1)	0.134*** (0.040)	6.172 (3.939)	0.016 (0.040)
External R&D (0/1)	0.045 (0.032)	4.642 (2.850)	0.061* (0.032)
Forward (0/1)	-0.009 (0.034)	-6.162* (3.143)	-0.028 (0.034)
Backward (0/1)	-0.037 (0.034)	-2.360 (3.114)	0.044 (0.035)
Horizontal (0/1)	0.029 (0.033)	-2.898 (2.967)	-0.009 (0.033)
Public (0/1)	0.008 (0.038)	-7.428** (3.315)	0.051 (0.037)
Others (0/1)	-0.037 (0.040)	7.384** (3.514)	-0.065 (0.040)
KS*High-tech firm			
InterRD*HF (0/1)	-0.307 (0.301)	6.132 (12.861)	0.341* (0.187)
ExterRD*HF (0/1)	0.035 (0.071)	-10.081* (6.061)	-0.094 (0.074)
Forward*HF (0/1)	-0.078 (0.073)	9.935* (5.951)	0.075 (0.066)
Backward*HF (0/1)	0.123** (0.059)	8.986 (5.725)	-0.072 (0.068)
Horizontal*HF (0/1)	-0.020 (0.064)	-3.443 (5.551)	-0.044 (0.064)
Public*HF (0/1)	-0.149* (0.080)	10.863* (6.554)	0.015 (0.074)
Others*HF (0/1)	0.159** (0.067)	-6.524 (6.697)	-0.068 (0.080)
Resource indicators			
Employment	0.0002*** (0.00007)	-0.003 (0.005)	0.00005 (0.00006)
Employment-sq	$-2.58x10^{-08}$* (0.000)	$-2.34x10^{-07}$ (0.000)	$6.16x10^{-09}$ (0.000)
Firm age (0/1)	0.053 (0.051)	-0.587 (4.780)	-0.018 (0.055)
Subsidiary	-0.008 (0.039)	0.385 (3.262)	-0.019 (0.039)
Capability indicators			
Employee degree	0.003*** (0.0005)	0.047 (0.043)	-0.0003 (0.0005)
Employee training	0.066** (0.033)	1.039 (3.081)	-0.020 (0.033)
Government financial support	0.002 (0.029)	1.406 (2.545)	0.032 (0.029)
Export	0.024 (0.030)	6.179** (2.742)	-0.012 (0.030)
High- tech firm (0/1)	0.268 (0.239)	-16.136 (13.28)	-0.336 (0.250)
Observations	1430	979	1430
Log likelihood	-888.564	-4265.8525	-948.2795

Note: Standard errors in parentheses; *** p<0.01, **p<0.05, *p<0.1. All the figures in the table are marginal effects generated from Probit/Tobit models.
Firm age: A firm was established after 1st January 2004. 0: established more than 3 years; 1: establish less than 3 years.

5.4.2.3 Innovation outputs- value added

Follow the same concept mentioned in the previous section, the same equation as eq 5.3 is adopted in this section but with the variable of *HF* instead of *HD* to analyse the effect of high-tech firm on firm performance, and also its influence on the relationship between innovation and firm performance. The equation is listed as the below.

$$BPERF_i = \lambda_0 + \lambda_1 INNO_i + \lambda_2 HFi + \lambda_3 INNO_i HF_i + \lambda_4 X_i + \tau_i \qquad \text{(Eq. 5.6)}$$

Where *BPERFi* is an indicator of business performance (e.g. productivity, sales growth or employment growth), *INNOi* is a vector including innovation outputs measures for both product and process innovation, HF_i is a dummy variable of high-tech firm, $INNOiHF_i$ represents high-tech firms with *INNOi*, and *Xi* is a set of specific variables that are hypothesized to have effect on firm performance. These proposed variables are firm size, firm age, subsidiary, employee degree, training, government financial support and exporting which are mentioned in chapter 4.

The result in table 5.15 shows that being high-tech firms significant affects productivity. It means that the average value of products produced by high-tech firms is more than low-tech firms while being the same size. However, process innovation affect negatively on productivity if being a high- tech firm and it may be the reason that the process innovation of high-tech firms takes longer term to reflect the return of value.

Being a high- tech firm does not directly influence employment growth, nor does it affect the impact of product and process innovation on employment growth. Product or process innovation decision has a significant impact on employment growth but being a high-tech firm has no additional effect. Furthermore, being a high-tech firm also causes the effect of product innovation success on employment growth becomes positive from negative although it is non-significant. This may be because the observations of high-tech firms do not need to increase more employees to engage on product or process innovation, but more employees are needed if being more percentages of innovative products within their sales.

Table 5.15 Performance estimations_ high-tech firm effect

Variables	Product innovation decision indicators		
	Employment growth	**Sales growth**	**Productivity**
Constant	-0.214** (0.086)	8.459 (5.132)	133900.4** (67845.77)
Innovation activities			
Product innovation	0.171*** (0.039)	2.122 (1.552)	13835.57 (17157.45)
Process innovation	0.092** (0.037)	-2.218 (1.908)	-11147.84 (15343.84)
Innovation High-tech firm			
Product inno_ HF	0.203 (0.207)	0.392 (1.374)	50639.57 (39331.5)
Process inno_ HF	0.067 (0.264)	3.056 (2.312)	-187230.2* (101837.3)
High-tech firms	-0.066 (0.210)	-2.749 (1.950)	163230.8* (93166.51)
Resource indicators			
Employment	-0.0003** (0.0002)	-0.003*** (0.001)	-86.552*** (29.963)
Employment-squared	$5.89x10^{-08}$** ($2.98x10^{-08}$)	$5.63x10^{-07}$** ($2.51x10^{-07}$)	0.017** (0.007)
Firm age	-0.057 (0.072)	7.367 (8.122)	11396.57 (60088.12)
Subsidiary	0.409* (0.227)	-1.377 (0.997)	-34049.7*** (12744.27)
Capacity indicators			
Employee degree	0.0006 (0.0005)	-0.059 (0.042)	-666.480 (776.096)
Employee training	0.036 (0.064)	-1.491 (2.203)	4449.893 (32902.76)
Government financial support	-0.063 (0.076)	-0.524 (1.737)	-24330.22 (37681.7)
Export	-0.006 (0.055)	-2.677 (1.988)	-56979.16 (40349.99)
Observations	1430	1430	1430

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1.
Firm age: A firm was established after 1st January 2004. 0: established more than 3 years; 1: establish less than 3 years.

Table 5.15 (Cont.) Performance estimations_ high-tech firm effect

Variables	**Product innovation success indicator**		
	Employment growth	**Sales growth**	**Productivity**
Constant	-0.115 (0.155)	13.314 (8.191)	162649.7* (92580.31)
Innovation activities			
Product innovation	-0.001* (0.0009)	0.012 (0.024)	-141.031 (304.663)
Process innovation	0.167*** (0.048)	-3.087 (2.498)	-13579.06 (17948.01)
Innovation high-tech firm			
Product inno_ HF	0.002 (0.002)	-0.037 (0.027)	-2578.374 (3392.616)
Process inno_ HF	-0.021 (0.307)	4.432 (3.183)	-193857.7** (98423.22)
High-tech firms	0.026 (0.324)	-0.858 (2.888)	359097.5 (300452.6)
Resource indicators			
Employment	-0.0004* (0.0002)	-0.003** (0.001)	-84.935*** (32.005)
Employment-squared	$6.28\text{x}10^{-08}$* ($3.62\text{x}10^{-08}$)	$5.61\text{x}10^{-07}$* ($3.13\text{x}10^{-07}$)	0.017** (0.007)
Firm age	-0.127 (0.100)	11.303 (11.556)	43011.62 (79534.22)
Subsidiary	0.584* (0.314)	-2.408 (1.579)	-44869.33** (20096.03)
Capacity indicators			
Employee degree	0.001* (0.0007)	-0.088 (0.060)	-730.469 (1084.381)
Employee training	0.081 (0.102)	-1.689 (3.295)	21000.81 (60402.4)
Government financial support	-0.035 (0.107)	-1.259 (2.769)	-39520.73 (51954.25)
Export	0.029 (0.073)	-4.637 (3.084)	-69397.53 (56954.17)
Observations	979	979	979

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1.
Firm age: A firm was established after 1st January 2004. 0: established more than 3 years; 1: establish less than 3 years.

5.5 Conclusion

This chapter clarifies that there is difference to define high-tech/ low-tech sector as a high-tech/ low-tech industry or a high-tech/ low-tech firm sector. Furthermore, it shows the importance of innovation activities in low-tech sector. Therefore, there are two key points in this chapter. Firstly, one is to demonstrate there is discrepancy to evaluate high-tech and low-tech sectors at the firm-level and industry-level. Secondly, another one is to use the lens of the IVC to compare the difference between high-tech sector and low-tech sector from knowledge sourcing through innovation indicators to firm growth and productivity.

The first point is demonstrated in table 5.5 showing the distribution of high-tech and low-tech firms within high-tech and low-tech industries. More than 75 percentages of firms in high-tech industries are not qualified as high- tech firms while as many as 30 percentages of firms in low-tech industries are high-tech firms. Furthermore, the analyses of innovation value chain (see table 5.8 to 5.15) also demonstrate the different results caused because of the evaluation at the firm-level and the industry-level. The above results all show that the discrepancy exist between high-tech/ low-tech industry sectors and high-tech/ low-tech firm sectors.

The second point of this chapter is concluded by three parts of the innovation value chain which are knowledge sourcing patterns, innovation activities and innovation outputs to firm performance. The knowledge sourcing model is evaluated individually on each sector. There is complementary relationship between all knowledge sourcing behaviours within the sectors of high-tech industries, low-tech industries and high-tech firms. However, it shows that the substitute relationship exists between internal R&D and customer knowledge (external knowledge) in low-tech firms. The second part shows that firms in high- tech industries compared to firms in low- tech industries engage less in product innovation. Moreover, internal R&D, supplier and competitor knowledge are more likely for firms in high-tech industries to decide to engage in product innovation while less process innovation is engaged if there is a linkage to customer knowledge. However, the different results are found if comparing high-tech and low-tech at the firm-level. Internal R&D actually increases the probability of firms' engagement in process innovation instead of product innovation if they are high- tech firms. It is also highlighted that customer and public knowledge can lead to target markets more successfully for high-tech firms' innovative products.

The last part of innovation value chain connects to firm performance. It is less able to differentiate the distinct result between high-tech and low-tech sectors due to the uncertainty of innovation performance. The result shows that firms being in high-tech or low-tech industries do not affect directly firm growth or productivity. However, firms with product innovation have positive significant effects on employment growth especially if being in high-tech industries. It shows that Taiwanese manufacturing firms' employment growth is affected by the gain in market share (due to innovation) particularly in the sector, high-tech industries. Moreover, the productivity is likely higher if being a high-tech firm. It shows that overall the value of products produced by high-tech firms per unit is more comparing to the ones by low-tech firms.

Crucially, the analysis of this chapter shows that when estimating the IVC the definition of 'high-tech sector' and 'low-tech sector' matters a great deal. Specifically:

1. There are significant differences in the IVC between high- and low-tech sectors, however these are defined.

2. How you define ‘sector’ matters i.e. the nature of the high-tech and low-tech differences varies depending on whether the technology definition is carried out at the industry-level or the firm-level.

General speaking, innovative firms are in more uncertain environment of the success, especially firms in highly innovative sectors are always unsure about the performance in future. Because there is no assurance of the innovation, they may either apply innovation successfully (or with a good luck/opportunity) to commercial end or waste the whole investment if they mistake a decision/strategy. The worse situation can be that they lose their market share due to the threat from their strong rivals with superior resources and capabilities (Coad and Rao 2008). Because of this reason, the result of the effect of innovation on performance for high-tech firms (with higher R&D intensity) is less able to conclude especially the period of dataset is only from 2004 to 2006 and it is cross-sectional data. Therefore, the causal inference between dependent and independent variables can not be interpreted fully. It will need a long- term research with panel data to do the further analysis.

Chapter 6 The determinants of export performance

6.1 Introduction

This chapter estimates the relationship between innovation and exporting while allowing for other determinants of export performance. The earlier analyses of chapters 4 and 5 indicate that being an exporter is positively linked to innovation performance. Therefore, this chapter will consider this relationship in more detail, focusing on the innovation-exporting relationship and other factors affecting exporting. First, the conceptual framework is modelled based on the joint views of neo-endowment theory and neo-technology theory. Furthermore, it incorporates the concept of internationalisation process with the effect of IP protection strategies and international knowledge linkages to expand the extent of exporting performance and its determinants. Secondly, the data adopted to estimate the framework are introduced with the summary descriptive statistics, and the method of modelling is explained. Third, the empirical analysis is shown to highlight the determinants of Taiwanese exporters and their export performance, and especially the relationship between innovation and exporting behaviours. Some other important determinants are also highlighted in the empirical analysis, especially the linkage to international customers also enhances firms' propensity to export.

6.2 Conceptual framework

In previous research, the framework of export performance's determinants is basically explored based on new-endowment based and neo-technology based theory. This study incorporates the concept of internationalisation process to expand the extent of a firm's exporting study. Therefore, a firm's exporting performance will be examined by two indicators: (1) dummy exporting (i.e. whether a firm engages in exporting activities) and (2) export intensity (i.e. the number of foreign markets a firm exports goods).

6.2.1 Neo-endowment based theory and neo-technology based theory

According to the literature review on neo-endowment based and neo- technology based theory, here highlights again the summary concepts which are going to construct the model of export's determinants.

The traditional neo-endowment based theory argues that a firm either has a natural monopoly of a particular factor or is located in a particular region where there is abundant in a particular factor. To comprise more organizational characteristics such as human capital and firm resources, the concept of the model becomes similar to the resource based view on a firm's competitiveness (Roper et al., 2006). Therefore, the exporting performance's determinants viewed from the perspective of resource base consider those productive resources which cause a firm's competitive advantages in export markets. The neo-technology based theory suggests that advanced technology enables a firm to produce superior products to compete in domestic and global markets. The new technology can be from intra- or inter-firm innovation activities or sourced by regional or national innovation system. Based on the joint perspectives of the neo-endowment and neo-technology models, some factors can be proposed to cause effects on export performance such as innovation, firm size indicated by employee number, firm age, being part of a group, employee qualifications and skills and employee training.

6.2.1.1 Innovation

As indicated in the previous chapters, innovation is critical in enhancing performance. This is equally true of international performance especially the first-mover advantage of an innovator can enhance a firm's internationalisation to expand the extent of geographic markets (McNaughton, 2003). To enhance international competitiveness and be able to maintain the market position, there are some studies showing the evidence of R&D's significant role on export performance (Roper et al., 2006). Some other studies measure the effect of innovation directly on export performance. Wakelin (1998) groups her sample into innovators and non-innovators and show the different effects of the determinants of export between these two groups. However, the dummy variable of being an innovative firm significantly decreases the probability of exporting, while there is an insignificant positive effect on the propensity of exporting. Ganotakis and Love (2011) further specifically focus on product innovation measured by dummy innovation and innovation success (the ratio of innovative products to total sales) to estimate the effects of product innovation on exporting. In their studies of UK new technology based firms, both product innovation indicators are found to affect positively on the probability to export while there is no significant effect on exporting intensity (the ratio of international sales to total sales). The same result of product innovation measured as a dummy variable was found in Roper and Love (2002)'s study of UK and German manufacturing firms. We therefore anticipate a positive relationship between innovation outputs and export performance.

6.2.1.2 Firm size and age

> Wagner (1995: 33) states *"…the importance of firm size for direct exports follows from economies of scale in production, a more fully utilization of (specialized) executives, the opportunity to raise financing at lower cost, benefits from bulk purchasing, own marketing department plus own sales force, and a high capacity for taking risks (e.g. development of new products) due to internal diversification."*

The general belief considers a larger firm has more resources in general and has more strength to act as an exporter to compete in foreign markets. However, there are still some debates about the actual influence of firm size on exporting. Lefebvre and

Lefebvre (2001) argue that firm size could cause an effect at the first stage of internationalisation but not thereafter i.e. large size may help a firm overcome the initial barrier to becoming an exporter, but may not improve export performance once this initial entry into international markets is made. This appears logical, if size is regarded as an attribute which might help overcome some of the sunk costs of exporting, which can only be overcome by larger and more efficient enterprises.

This assumption brings some research attention on focusing the investigation on the internationalisation of small and medium firms (Westhead et al., 2001). Nowadays, more small firms are found to enter international markets at much earlier stage than in the past (Reynolds, 1997). Although age is not generally found to have any correlation to internationalisation activities for small firms, it is found that there is a positive relationship between firm age and export growth once they have become international (Andersson et al., 2009) while older firms also is suggested to serve more foreign markets (McNaughton, 2003). Both firm size and firm age therefore have been used as factors to predict a firm's international activities, especially firm size has been incorporated in firm-level export model as a proxy for rich resources to cope with sunk cost when entering foreign markets, economies of scale and demand (Sterlacchini, 1999 and 2001). Most of the findings in previous studies show a positive influence of firm size on exporting performance, often with a non-linear relationship (Roper et al., 2006; Roper and Love, 2002; Sterlacchini, 1999; Wakelin, 1998; Wagner, 1995; Kumar and Siddharthan, 1994) although firm size was measured by either number of employees or total sales. Some studies with the results of an inverted U-shaped relation between firm size and export indicate the advantage of firm size only hold to a certain threshold point when coordination costs cause further expansion to be non profitable (van Dijk 2002; Wagner, 2001). Moreover, large firms are also suggested to involve in more international markets than do small firms (Beamish and Munro, 1987; Balcome, 1986; Hirsch and Baruch, 1974).

6.2.1.3 Group membership

A group-company, also called corporate group, consists of a collection of parent and subsidiary companies. These subsidiary companies function as an individual economic entity but with their parent company's control to share common resources. It is proposed that a firm connecting with others is able to derive more resources and generate better performance. Khanna and Rivkin (2001) suggest that a group-company can serve as a functional substitute to boost the profitability of its member companies via filling the institutional voids in emerging economies.

In addition, it is demonstrated by Roper and Love (2002) that being a part of group-company in UK and Germany increases exporting propensity (the ratio of international sales to total sales) because of the higher chances to access a deeper resource base. Singh (2009) also suggests a positive effect of business group affiliation on export sales. Therefore, being a subsidiary of a group-company is proposed as one of the factors which could affect positively on a firm's exporting performance. However, it is unclear from the previous literature whether being part of a group improves export propensity (i.e. helps overcome the sunk costs of exporting) or whether the effect persists into export performance once the initial entry into international markets is made. The variable being part of a group therefore is proposed as one of the export performance's determinants.

6.2.1.4 Employee qualifications and training

Employee qualifications are here measured as the percentages of employee with degree (equivalent to or higher than university degree). It is suggested that more percentages of workforce with degree leads a firm more likely to become an exporter (Ganotakis and Love, 2011) further more successful in export markets (Roper et al., 2006). The rationale for this is that such qualifications are an indicator of employee skills and possibly employee productivity, and that products embodying such skills are more likely to be attractive to foreign markets. The same argument applies to employee training that firms can enhance their competitiveness by increasing individual employee's capabilities so employee training plays an important role on export performance (Braunerhjelm, 1996). Employee training is here indicated by a dummy variable indicating whether the firm undertook employee training in the last three years.

6.2.2 IP Protection strategy

There are different ways to maintain innovative products as a firm's assets to prevent the imitation from others, such as formal IP (Intellectual property) protection and informal approach protection. IP is a term referring to a number of tangible and intangible creations/ideas recognized by law to protect someone's rights. In general, IP can be classified into four types: patens, trade marks, designs and copyrights (Intellectual Property Office, 2012). Informal approaches to IP protection include trade secrets and reinforcement of complexity in products.

IP is also a symbol of ownership and signals the uniqueness of a product. McNaughton (2003) incorporates the literature about born-global firms and hypothesises that there is relationship between the ownership of innovative knowledge/products and the number of geographic exporting markets. The argument is that, both by signalling that new products are the tangible outcome of significant new knowledge, and by providing some degree of protection from the opportunistic exploitation of third parties, IP protection helps firms expand in international markets, where the threat of opportunism is always present.

However, IP registration is not the only action a firm takes to protect its innovative products in export markets because of the variations in international laws. Some firms choose to take informal actions by increasing the complexity of products or engaging in trade secret. This is especially true of small firms, for whom patent protection is often either unavailable or ineffective. Therefore, an interest is raised here to investigate the effects both of ‘formal IP protection’ and ‘informal IP protection’ on exporting. Formal IP protection is measured as a dummy variable indicating whether a firm registers any patent or design to protect is rights by law, while informal IP protection is measured as a dummy variable indicating whether a firm engages in any trade secret or reinforces the complexity of the new product introduced.

6.2.3 International knowledge sourcing activities

In this accelerated internationalisation of 21th century, the scope of supply chain has expanded toward a worldwide level. The knowledge diffusion exists no longer just within an industry or inter-industry but between nations. It is proposed that the knowledge linkages to international organizations/objectives such as overseas branches, international supply chain partners and consultants, universities abroad and foreign governments may increase the chance to access knowledge of foreign markets and superior technology to enhance export performance. The access to international knowledge may also reduce the sunk cost of exporting, helping overcome barriers to exporting. Furthermore, from the view of internationalisation, the knowledge about one foreign market and operations could extend a firm's access to another foreign market (Johanson and Vahlne, 1977). Thus unlike the analysis of chapters 4 and 5, here we concentrate exclusively on *international* linkages which the firm possesses again measured using a series of dummy variables.

6.2.4 The framework of determinants of export performance

Based on the literature and following the discussion above, the model of determinants of export performance can be framed as the below equations:

$$X_i = \beta_0 + \beta_1 INNO_i + \beta_2 R_i + \beta_3 C_i + \beta_4 IKS_{ji} + \beta_5 P_i + \varepsilon_i \qquad j=1,7 \qquad \text{(Eq. 6.1)}$$

$$EX_i^* = \gamma D + \mu \qquad \text{(Eq. 6.2)}$$

$$EX_i = \begin{cases} 1, & if \quad EX_i^* > 0 \\ 0, & otherwise \end{cases}$$

Where *Xi* is an indicator of export performance of firm *i*, *Ri* is a set of indicators of firm *i*'s internal resources, *Ci* is a set of indicators of firm *i*'s absorptive capabilities, *IKSi* represents all the proposed international knowledge sourcing activities of firm *i*, and *Pi* is the approach of firm *i*'s protection strategy measured by formal and secrete protections, EX^*_i is a dummy exporting variable and *D* is a vector of the determinants of export performance. Product and process innovation are presented as a set of innovation activities *INNOi*. Product innovation here is measured by either dummy product innovation or innovation success which is the share of innovative products in total sales. Process innovation is measured (as previously) by a dummy variable. The coefficients of dummy product innovation and innovation success are both expected to be positive when the dependent variable export performance is measured by dummy exporting (Ganotakis and Love, 2011). The last part of *εi* represent as the error term.

In terms of the export variable X_i, the normal way of measuring export performance is in terms of the proportion of sales which is exported (e.g. Roper and Love, 2001; Ganotakis and Love, 2011). However, no such measure is available in the 2nd Taiwanese innovation survey. Instead, we employ a measure of the number of different overseas markets to which a firm exports its products. Thus we are measuring the extent of internationalisation in terms of the spread of export destinations, rather than the extent of exporting (Samiee and Walters, 1990; McNaughton, 2003)

6.3 Descriptive statistics

The data adopted to estimate the determinants of export performance is derived from the 2nd Taiwanese Innovation Survey which has been introduced in chapter 3. This section focuses on those variables which are innovation indicators, firm's resource and capability indicators, IP protection strategy indicators, the linkages to international knowledge and the measures of export performance, and table 6.1 shows the descriptive statistics being classified into product innovators with and without exporting, and non-product innovators with and without exporting. The figure as expected indicates the proportion of exporters is higher as being product innovators than non-product innovators. However, exporters have similar average (around 60 percentages) of innovative success (the percentage of innovative products over total product sales) no matter being product innovators or not. The first interesting and surprising point here is as being non-product innovators there are almost 75% of exporters engaged in process innovation. This could be explained that those exporters engaged in process innovation but not in product innovation are OEM to foreign companies, so they introduced new or significantly improved manufacturing process to produce the innovative products ordered by those foreign companies.

The second notable point here is the average of firm size, measured by employee number, is much larger as being an exporter than non-exporters in both groups of product innovators and non-product innovators. Furthermore, the result also indicates that small product innovators are less likely to become exporters than equivalent non-product innovators. [Similar relationship was found by Wakelin (1998) between firm size and innovators not only specific product innovators.] These smaller product innovators only target the domestic market but not markets abroad perhaps because they are young firms and are just expanding their business. This can be referred to the result that the group of product innovators without exporting has the most firms established less than 3 years. The relationship between product innovation and firm size of the whole sample (1806 firms) is found to be inverted U-shaped in chapter 4. This inverted U-shaped relationship is totally opposite to the result in Wakelin (1998). Therefore, the above summary of descriptive statistics using the sample means may disguise the complexity of the relationship between product innovation and firm size.

The rest of variable means are also different between product innovators and non-product innovators with or without exporting. Although some variable means are similar, the overall results show that the possible impact of product innovation on exporting performance.

Table 6.2 shows the proposed determinants of export performance with the summary statistics, and the comparison of exporters and non-exporters. As expected, the unequal means of product innovation and firm size exist between exporters and non-exporters, indicating that exporters are larger and more likely to innovate than non-exporters. Furthermore, more percentages of exporters take actions on protect their IP with 59% of firms on patents and designs and 58% of firms on secret and complex product structures. In contract, non-exporters only have 47% of firms on patents and designs and 45% of firms on secret and complex product structures. Most international knowledge linkages also have significantly different mean values between exporters and non-exporters except the linkage to foreign governments, indicating that exporters tend to be better networked internationally than non-exporters.

The descriptive statistics seem to suggest that there may be some relationship between innovation and exporting, but that other differences also exist between exporters and non-exporters which may to some extent influence the nature of the innovation-exporting relationship. We therefore move now to the multivariate estimation of the determinants of exporting and export performance.

Table 6.1 Descriptive statistics: means (standard deviations)

Variables	994 Product innovators		812 Non-product innovators	
	734 Exporter	260 Non-exporters	453 Exporters	359 Non-exporters
Innovation indicators				
Innovation success (%)	60.255 (30.098)	54.155 (31.660)	59.475 (30.483)	62.155 (31.706)
Process innovation (0/1)	0.478 (0.500)	0.504 (0.501)	0.744 (0.437)	0.588 (0.493)
Resource indicators				
Subsidiary (0/1)	0.161 (0.368)	0.123 (0.329)	0.146 (0.353)	0.226 (0.419)
Age (0/1)	0.056 (0.230)	0.096 (0.295)	0.035 (0.185)	0.072 (0.260)
Firm size (employees)	299.165 (661.117)	134.069 (307.267)	171.521 (972.555)	90.125 (180.594)
Capability indicators				
Employee degree (%)	50.038 (25.856)	47.439 (31.813)	43.293 (27.136)	46.965 (34.186)
Employee training (0/1)	0.822 (0.383)	0.708 (0.456)	0.737 (0.441)	0.630 (0.484)
IP Protection strategy				
Patent & design (0/1)	0.621 (0.485)	0.519 (0.501)	0.547 (0.498)	0.448 (0.498)
Secret & complex (0/1)	0.601 (0.490)	0.431 (0.496)	0.545 (0.498)	0.465 (0.499)
International Linkages				
International group members	0.151 (0.359)	0.077 (0.367)	0.097 (0.296)	0.067 (0.250)
International suppliers	0.151 (0.359)	0.081 (0.273)	0.126 (0.332)	0.061 (0.240)
International customers	0.244 (0.430)	0.119 (0.325)	0.126 (0.332)	0.092 (0.289)
International competitors	0.106 (0.308)	0.088 (0.285)	0.183 (0.387)	0.019 (0.138)
International consultants	0.056 (0.230)	0.027 (0.162)	0.033 (0.179)	0.028 (0.165)
International universities	0.012 (0.110)	0.008 (0.088)	0.015 (0.123)	0
International government	0.007 (0.082)	0.008 (0.088)	0.004 (0.066)	0

Table 6.2 Summary statistics and the comparison of exporters and non-exporters

Variables	The whole sample 1806 firms			1187 Exporters			619 Non-exporters			Comparison of exporters and non-exporters
	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Two-tailed test, p-value
Innovation indicators										
Product innovation (0/1)	0.550	0.498	1806	0.618	0.486	1187	0.420	0.494	619	0.000*
Innovation success (%)	59.182	30.749	1258	60.162	30.127	833	57.261	31.880	425	0.120
Process innovation (0/1)	0.570	0.495	1806	0.580	0.494	1187	0.552	0.500	619	0.271
Resource indicators										
Subsidiary (0/1)	0.164	0.371	1806	0.155	0.362	1187	0.183	0.387	619	0.142
Age (0/1)	0.060	0.237	1806	0.048	0.214	1187	0.082	0.275	619	0.007*
Firm size (employees)	201.827	664.526	1806	250.452	796.530	1187	108.58	242.759	619	0.000*
Capability indicators										
Employee degree (%)	47.379	28.925	1684	47.486	26.538	1118	47.168	33.164	566	0.843
Employee training (0/1)	0.746	0.436	1806	0.789	0.408	1187	0.662	0.473	619	0.000*
IP Protection strategy										
Patent & design (0/1)	0.554	0.497	1806	0.593	0.491	1187	0.478	0.500	619	0.000*
Secret & complex (0/1)	0.535	0.499	1806	0.580	0.494	1187	0.451	0.498	619	0.000*
International Linkages										
International group members	0.110	0.313	1806	0.131	0.337	1187	0.071	0.257	619	0.000*
International suppliers	0.117	0.321	1806	0.142	0.349	1187	0.069	0.254	619	0.000*
International customers	0.181	0.385	1806	0.221	0.415	1187	0.103	0.305	619	0.000*
International competitors	0.081	0.273	1806	0.098	0.297	1187	0.048	0.215	619	0.0001*
International consultants	0.040	0.197	1806	0.047	0.212	1187	0.027	0.164	619	0.029*
International universities	0.010	0.099	1806	0.013	0.115	1187	0.003	0.057	619	0.012*
International government	0.005	0.070	1806	0.006	0.077	1187	0.003	0.057	619	0.403

Note: Independent sample T-test assuming unequal variances, * $p < 0.05$

6.4 Method

As indicated earlier, the export performance is measured as the number of exporting markets so count data models are appropriate to use here. The poisson regression was first tested. However, the poisson model relies on an assumption of equality between the mean and variance of the dependent variable. This restriction was found to be invalid in the present case, so negative binomial regression is chosen due to its being more appropriate in cases of over-dispersion. The alpha in negative binomial regression is significantly different from zero and it reconfirms that poisson regression is not appropriate in this case.

Next, the Vuong test is used to determine whether zero-inflated negative binomial or standard negative binomial regression is more suitable. Zero-inflated negative binomial regression (ZINB) is selected due to the bias of observations toward the value ‘zero’. This can be considered as a model with two different processes. The first process is that a firm has not exported so the outcome of export performance is zero. The second part is that a firm has engaged in exporting so the count process will be output as the number of exporting markets. Conceivably a firm may regard itself as an exporter, but may not have exported to any foreign markets in the period in question. Therefore, two parts of the zero-inflated model are formed by the first stage of binary model which logit model is used here, and the second stage of a negative binomial model to model the count process (Hausman et al., 1984). In the case of the present dataset, the ZINB model was found to be the most appropriate, and so ZINB results are reported below.

6.5 Empirical analysis

The model of determinants of export performance is estimated twice (eqs 6.1 and 6.2) with product innovation measured both as a dummy product innovation variable (i.e.

whether a firm introduced a new or significant improved product), and as innovative success, (i.e. the share of innovative products in total sales). In both cases a process innovation dummy variable is also included in the analysis. Results of the analysis are shown in Tables 6.3 and 6.4.

Results indicate that being a product innovator has no effect on inducing a firm to become an exporter, but does have a positive effect on increasing the number of international markets in which the firm exports. This effect is restricted to the innovation dummy variable (Table 6.3); innovation success has no effect on either exporting or export intensity (Table 6.4). This suggests that it is the process of being a product innovator that helps firms internationalise. However, this effect is not about overcoming the fixed costs of exporting, but rather making the firm's products more attractive to a wider range of international markets.

The surprising result with innovation is that a firm with process innovation activity is less likely to engage in exporting (Table 6.4). The reason for this is unclear, but it could be explained that the purpose of process innovation is to produce products pre-ordered by foreign customers (as being OEMs; see the explanation in section 6.3). If this is the case, it is possible that the positive effect of process innovation would be revealed in the future export performance.

Firm size is positively significant related to dummy exporting while the quadratic term is negatively significant. It shows the inverted U-shaped relationship between firm size and dummy exporting. The same significant effect of firm size on the export intensity (count of exporting markets number) exists when the product innovation is measured by innovation success. This suggests that the impact of size may be substantial and potentially long-lasting: it not only allows firms to overcome the sunk costs of becoming exporters, but also helps them to extend the range of export markets over which they can sell their produce.

The capability indicators are broadly as expected. Firms with more qualified employees (with equal or higher university degree) are more likely to enter international markets. However, the effect of employee training is on increasing the number of markets served. This appears to suggest that formal qualifications and training both have positive effects on exporting, but in rather different ways: formal qualification help firms overcome the exporting barrier, while training helps the spread of international markets served once firms become exporters. There is also evidence that using IP protection in terms of patenting or design registration has a direct effect on both exporting (table 6.4) and the number of export markets (table 6.3). Notice that this effect is additional to that of innovation discussed above: thus product innovation helps firm enter more international markets, and those that in addition use formal types of IP protection get a further boost to exporting and export 'intensity' as a result of so doing. Furthermore, informal IP protection has the same effect on export intensity once a firm becomes an exporter. This suggests that IP protection helps firms overcome barriers to exporting through knowing that their core intellectual property is less likely to be appropriated by potential competitors in foreign markets, and this effect is additional to innovation *per se*.

In terms of international knowledge linkages which are proposed to overcome the sunk cost of exporting, firms with the linkage to international customers are as expected able to increase significantly the probability to become exporters because firms may derive the knowledge regarding to the trend of foreign markets more via the linkages to international customers. The last point but also surprising is that firms with the linkage to international governments operate in a marginally lower number of exporting markets than firms without such links. The descriptive statistics in table 6.2 shows that only 0.6% of exporters with the linkage to international governments, so the explanation of this significant negative result could be that the small portion of firms with international government linkage exports some specific products to those particular countries and there are some restrictions to limit exporting countries. (see table 6.3 and 6.4)

Table 6.3 The determinants of exporting performance (Product innovation decision, 0/1)

Variables	Export (0/1)	Export intensity (count of exporting markets)
Innovation Indicators		
Product innovation (0/1)	0.061 (0.056)	1.041*** (0.281)
Process innovation (0/1)	-0.074 (0.056)	0.357 (0.267)
Resources Indicators		
Subsidiary (0/1)	-0.018 (0.070)	-0.453 (0.314)
Age (0/1)	-0.017 (0.119)	-0.493 (0.411)
Employment	0.0001*** (0.0001)	0.002 (0.002)
Employment-squared	-8.37×10^{-9}** (3.39×10^{-9})	-3.02×10^{-7} (3.95×10^{-7})
Capability Indicators		
Employee degree (%)	0.003* (0.001)	-0.011 (0.007)
Employee training (0/1)	0.062 (0.064)	0.492** (0.240)
IP Protection Strategy		
Patent & design (0/1)	0.036 (0.054)	0.491** (0.248)
Secret & complex (0/1)	-0.039 (0.059)	0.513* (0.306)
International Linkages		
International group members	-0.048 (0.073)	0.556 (0.529)
International suppliers	-0.015 (0.077)	0.618 (0.687)
International customers	0.124** (0.062)	0.061 (0.368)
International competitors	0.046 (0.095)	0.321 (0.807)
International consultants	-0.026 (0.109)	0.023 (0.670)
International universities	0.048 (0.193)	87.495 (172.765)
International government	0.349 (0.257)	-3.163** (1.468)
Observations	1684	1118
Chi-square in the poisgof	-	2506.223***
Over-dispersion parameter alpha	-	58.26***
Vuong test of ZINB vs. standard negative binomial	-	90.56***

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1. All models include industry dummies.

Table 6.4 The determinants of exporting performance (innovation success, %)

Variables	Export (0/1)	Export intensity (count of exporting markets)
Innovation Indicators		
Innovation success (%)	0.001 (0.001)	0.003 (0.004)
Process innovation (0/1)	-0.175*** (0.054)	-0.029 (0.281)
Resources Indicators		
Subsidiary (0/1)	-0.176** (0.071)	0.632 (0.548)
Age (0/1)	-0.126 (0.136)	0.404 (0.517)
Employment	0.0001 (0.0001)	0.058*** (0.012)
Employment-squared	8.6×10^{-9} (2.2×10^{-8})	-0.00001** (4.73×10^{-6})
Capability Indicators		
Employee degree (%)	0.002* (0.001)	-0.006 (0.004)
Employee training (0/1)	0.041 (0.076)	0.378 (0.289)
IP Protection Strategy		
Patent & design (0/1)	0.133** (0.060)	0.264 (0.279)
Secret & complex (0/1)	-0.008 (0.061)	0.200 (0.291)
International Linkages		
International group members	-0.004 (0.076)	0.536 (0.673)
International suppliers	0.092 (0.080)	-0.098 (0.518)
International customers	0.164** (0.065)	-0.036 (0.424)
International competitors	-0.087 (0.093)	0.661 (0.809)
International consultants	0.016 (0.119)	0.646 (1.04)
International universities	0.145 (0.222)	0.329 (1.557)
International government	0.183 (0.284)	-6.643 (50.866)
Observations	1169	782
Chi-square in the poisgof	-	1720.115***
Over-dispersion parameter alpha	-	33.19***
Vuong test of ZINB vs. standard negative binomial	-	6.04***

Note: Standard errors in parentheses; ***p<0.01, **p<0.05, *p<0.1. All models include industry dummies.

6.6 Conclusion

This chapter uses the firm-level data to explore the determinants of export performance which is based on neo-endowment and neo-technology based theories. From the view of microeconomics, export performance in previous studies has always been measured by dummy exporting and export intensity (the ratio of international sales to total sales) such as the studies by Wakelin (1998), Sterlacchini (1999), Roper and Love (2002), Roper et al. (2006) and Ganotakis and Love (2011). However, the performance of a firm's exporting can be examined by not only the exporting sales but also its degree of internationalisation. To discover the export performance in terms of geographic markets, this study incorporates the concept of internationalisation process and measures export performance by the intensity of geographic markets (the number of exporting markets).

Furthermore, the focus on the 'innovation-exporting relationship' is expanded by increasing the types of innovation used in the analysis. Previous research typically emphasizes product innovation; however, process innovation also has its crucial position to competitiveness. This study then distinguishes the determinant of innovation into product and process to discriminate the effects of different types of innovation. The econometric result indicates that product innovation has no effect on the probability of exporting while process innovation has a negative effect on being an exporter. Once a firm becomes an exporter, product innovation has its positive effect on the extent of exporting into a number of geographic markets while process innovation has no effect.

The overall internal resource and capability indicators meet the expectation to have positive effects on exporting except being part of group-company. The result is opposite to UK and German companies by Roper and Love (2002). Sterlacchini (1999) demonstrates that only large firms being a part of group-company affect positively on exporting. This can be concluded that the actual effect on exporting depends on how much a subsidiary is sourced by group-company not being a subsidiary.

Formal IP protection contributes to facilitate a firm to become an exporter and further to increase the number of foreign markets. IP protection in terms of an informal approach will become a catalytic to help a firm break the barriers to foreign markets once a firm becomes an exporter. These effects arise in addition to the direct effects of innovation, suggesting that IP protection plays a role in addition to merely introducing new products. The last interesting result discovered here is that not all international knowledge linkages have positive effect on exporting and some international knowledge sourcing activities actually obstruct exporting performance. The linkage to international customers as expected increases the probability of exporting, but the linkage to foreign governments reduces the number of exporting markets to exporters.

The limitation of the study in this chapter is that there is no available data of exporting sales figure so we are not able to examine the effects of proposed exporting determinants on the exporting performance in terms of quantity sales. Furthermore, because the adopted data is cross-sectional data so this study is not able to examine the factors affecting on exporting growth. These are all the possibilities what future research can be looking into.

Chapter 7 Overall conclusions

7.1 Introduction

This final chapter provides an overall view of this thesis. First, it summarises the research by recalling the research aim and the work done in the three topics: (1) the IVC of Taiwanese manufacturing firms, (2) a comparison between high-tech sector and low-tech sector by using the lens of the IVC, and (3) innovation and export performance. Second, the key findings are highlighted to show the significance of the study. Third, we provide the theoretical and practical implications and the important contributions drawn from this study. Finally, the limitations of the study are presented and possible future research directions are suggested.

7.2 Summary of the research

The aim of this thesis is to demonstrate the process of innovation activities in Taiwanese manufacturing firms. The first chapter gives an introduction to the whole thesis and the second chapter reviews the relevant theories used to propose the research frameworks. The empirical background, Taiwan, is also introduced with its economy, industrial development, innovation activities, competitiveness and export performance. The third chapter introduces the database where we derive the secondary data and shows the summary statistics to describe the characteristics of the data adopted. There are three topics to investigate in this thesis so each topic is introduced in an individual chapter from chapter 4, 5 and 6. Each of these chapters, 4, 5 and 6, tend to answer different research questions to fill either theoretical or empirical gaps.

7.2.1 The IVC of Taiwanese manufacturing firms

The first topic aims to examine the IVC in Taiwanese manufacturing firms. The process of innovation value chain contains three stages of knowledge sourcing, innovation production and firm performance. There are seven different types of knowledge sourcing activities proposed at the beginning of the IVC. Product and process innovation are the main focus of innovation activities investigated in this study to examine the process of innovation from knowledge sourcing to the end of value added which is measured by three performance indicators, employment growth, sales growth and productivity.

1806 innovative manufacturing firms are adopted in this study for the analysis and probit model, tobit model and linear OLS regression are applied to answer the research questions.

7.2.2 A comparison of the IVC between high-tech sector and low-tech sector

The second topic aims to compare the difference of the IVC between high-tech and low-tech sectors. This part uses the lens of the IVC to investigate the comparison between high-tech and low-tech industries and the comparison between high-tech and low-tech firms. This is done first to discover if there is any difference in the IVC of high-tech and low-tech sectors. Because of the discrepancy found on the definition of high-tech and low-tech depending on whether the measurement is carried out at the industry-level or the firm-level, another comparison between high-tech and low-tech firms is investigated too.

7.2.2.1 High-tech and low-tech industries

There are 910 firm in high-tech industries and 896 firms in low-tech industries adopted here for the analysis. In the first stage of the IVC, the analysis of knowledge sourcing activities is done separately in each group, high-tech industries and low-tech industries. In subsequent stages, suitable interaction terms are used to allow for the differences between high-tech and low-tech industries.

7.2.2.2 High-tech and low-tech firms

There are 382 high-tech firms and 1119 low-tech firms adopted here for the analysis. In the first stage of the IVC, the analysis of knowledge sourcing activities is done separately in each group, high-tech firms and low-tech firms. In subsequent stages, suitable interaction terms are used to allow for the differences between high-tech and low-tech firms.

7.2.3 Innovation and export performance

The third topic aims to examine the innovation-export relationship. Because of the importance of export performance to a nation's economy, it is interesting to examine the effect of innovation on export performance especially after the investigation of the IVC. Although the effect of innovation on export performance is the main focus, other determinants are still explored to extend the extent of export performance's determinants.

Compared to previous studies which often either only measure innovation in general or specifically focus on product innovation, an additional measure of innovation, process innovation, is included in the model of export determinants.

The determinants of export propensity and performance are mainly viewed from the perspectives of neo-endowment theory/resource-based view and neo-technology theory/absorptive capacity such as firm size (number of employment), firm age, part of group member, employee qualification and training. Furthermore, knowledge derived from international sources is also measured as the determinants of export, and so is IP protection. The last determinant to be proposed is IP protection.

Within the adopted 1806 innovative firms, there are 1187 exporter and 619 non-exporters. Zero-inflated negative binomial regression (ZINB) is chosen to be the most appropriate approach to answer the research question.

7.3 Key findings of the research

As it has been mentioned, this thesis is divided into three topics to investigate the innovation in Taiwanese manufacturing firms.

In *the first topic*, the findings can be categorised in three parts, knowledge sourcing, innovation production and firm performance.

- A complementary relationship is found between internal R&D and external knowledge sources, as well as of a strong complementary relationship between all external knowledge sourcing activities such as suppliers, customers, competitors, universities, government/public research institutions and other linkages (i.e. industrial associations and exhibitions). Moreover, the usage of other knowledge linkages by a firm appears to increase the probability to engage in the sourcing activities such as suppliers, customers, competitors, universities and government research institutions.

- R&D, regardless of whether it is internal or external, still plays an important role to affect innovation but is not the only useful input resource. Furthermore, because of the complementary relationship between knowledge sourcing activities, those knowledge sources without direct effects on innovation could still have indirect influence via R&D activities.

- Product innovation plays the main role to increase a firm's growth (employment and sales) but not productivity, while process innovation has a (somewhat counterintuitive) negative effect on productivity.

- Regardless of other factors such as a firm's internal resources and capacities or government financial support, diverse effects are shown in the different stages of the IVC and most are with the normal expectation. However, government financial support is found with a surprising result that it neither encouraged firms to engage in knowledge sourcing activities nor increased innovative activities, but decreased the activities linking to backward and other knowledge.

In *the second topic*, the findings can also be categorised in three parts, knowledge sourcing, innovation production and firm performance but mainly focus on the comparison between high- tech and low- tech sectors.

- The first finding is that the discrepancy of high-tech sector and low- tech sector is found by defining 'sector' at the industry-level or the firm-level, and different characteristics are shown mostly with significant difference between high-tech and low- tech no matter whether this is measured at the industry-level or the firm-level.

The comparison of high- tech sector and low-tech sector at the industry-level:

- Firms in high-tech industries are found to be less likely to engage in product innovation.

- The same complementary relationship is found between all knowledge sourcing activities in both high-tech and low-tech industries.

- The different knowledge sourcing behaviours are found that firms in high-tech industries tend to search knowledge from suppliers and competitors to complement their internal R&D for product innovation while firms in low-tech industries are more likely to derive knowledge from customers for process innovation.

- In high-tech industries, a firm with product innovation does increase its employment growth but not other performance and neither does process innovation.

- Some significant effects of other factors are found to be different in either high-tech or low-tech industry. In high- tech industries, firm size affects negatively on the linkage to other knowledge with a U-shaped relationship, while the abnormal result found in low-tech industry is that a firm with more employee with degree reduces its engagement in internal R&D.

The comparison of high- tech sector and low-tech sector at the firm-level:

- The estimation predicts undertaking of internal R&D perfectly in high-tech firms because all high-tech firms are defined as a firm with internal R&D intensity equal to or more than 3.5%. The rest of the relationship between knowledge sourcing activities is found to be complementary. The same complementary relationship was found in low-tech firms but with a substitute relationship between internal R&D and forward knowledge.

- High-tech firms are more likely to increase the probability of product or process innovation or the percentage of innovation success if deriving knowledge from different sources accordingly. However, it reduces the percentage of innovation success if a high-tech firm engages in external R&D, and if a high-tech firm derives knowledge from public linkages it is less likely to engage in product innovation.

- Being a high-tech firm positively affects a firm's productivity but the engagement in process innovation reduces significantly a high-tech firm's productivity.

In *the third topic*, the findings are focused on the effect of product and process innovation on export performance and other factors which determine exporting.

- Product innovation is found to enhance a firm's export performance while process innovation reduces the likelihood of a firm being an exporter.

- Formal IP protection boosts a firm's likelihood of entering export markets and continues its effect to assist a firm to extend the number of geographic markets, while informal IP protection also enhance a firm's export performance once a firm enters international markets.

- International customer knowledge does increase the probability of being an exporter as expected, but the linkage to foreign government reduces the export performance measured by the number of international markets.

7.4 Contributions and implications

The contributions of this research can be divided into three parts. The first contribution is that IVC of Taiwanese manufacturing firms is the first IVC study to be carried out on non-developed countries especially in Taiwan. It also extends the extent of knowledge sourcing activities and shows the importance of other knowledge linkages such as industrial associations and exhibitions. The second contribution is that this study is one of the first studies on a comparison of the difference of the IVC between high-tech sector and low- tech sector. Especially, it also demonstrates the discrepancy of the 'high-tech sector and low-tech sector' comparison whether the investigation is at the industry-level or the firm-level. The third contribution can be referred to the use of 'the number of international markets' as one of the measures of exporting because most previous export research focus export performance on the sales of exporting goods but ignore the importance of export performance in terms of the extent of geographic foreign markets. Furthermore, some interesting determinants are explored in the model of export performance such as IP protection strategy and international knowledge linkages. The following sections detail the contributions in each topic and the implications drawn from the research.

7.4.1 The first topic: the IVC of Taiwanese manufacturing firms

This part of study provides an empirical contribution on the IVC in non-developed countries and in an advanced developing country, Taiwan in particular. It provides an understanding of the process of innovation activities from knowledge sourcing to the end of value added in an advanced developing country which its economy plays a different role in the global position from that of a developed country. Furthermore, it is also the first empirical study to be carried out for a country which is in a different geographic area from Western countries (i.e. UK, Ireland and Switzerland). The above difference in terms of economics position and geographic location provides different knowledge sourcing behaviours extended in the IVC.

In this study, other linkages to knowledge derived from industrial associations and exhibitions extend the extent of knowledge sourcing activities examined in previous IVC studies. It explores an important source where a manufacturing firm in an advanced developing country like Taiwan derives knowledge.

By adopting the IVC model to examine the process of innovation activities in Taiwanese manufacturing firms, it is discovered that the main knowledge to enhance a firm's innovation (i.e. product and process) is still derived from R&D activities which suggests that Taiwanese manufacturing firms' innovation could be developed more while increasing the effectiveness of other knowledge resources on innovation like other developed countries such as UK (Roper et al., 2008). The result also indicates that government financial support affects negatively on the linkages to backward and other knowledge and there is no significant impact of government financial support on any of innovation for a firm's growth or productivity. This provides a hint of the inefficient government financial support in the past and suggests a necessary change of financial support from Government. The overall contributions and implications drawn from this part of the study can be viewed from two perspectives of policy makers and Taiwanese innovative manufacturing firms. For policy makers, it provides a better understanding of the current effectiveness of different knowledge sources on a firm's innovation and the value added from different forms of innovation. A more effective and efficient policies can be made in the future due to the previous experience. For company managers, it provides a guideline for knowing better the effectiveness of different knowledge sources on different forms of innovation and how they lead to the end of value added.

7.4.2 The second topic: a comparison of the IVC between high-tech sector and low-tech sector

This part of study first contributes to highlight the discrepancy on the definition of high-tech sector and low-tech sector by examining at the industry-level and the firm-level.

Second, this is the first innovation value chain (IVC) research studying the comparison of the IVC between high-tech sector and low-tech sector. Previous research has examined the IVC at the scale of a country such as United Kingdom (Roper et al., 2008), the focus on a specific sector like new-technology based firms (Ganotakis and Love, 2011) and comparing different countries such as Ireland and Switzerland (Roper and Arvanitis, 2009) but there has been no previous investigation of the difference between high- tech and low- tech sectors. Furthermore, the comparison between high- tech sector and low- tech sector is done twice with the investigation at the industry-level and the firm-level. The discrepancy between these two comparisons provides two different dimensions of guideline for policy makers when they develop policies to high-tech industry and low-tech industry. Innovation policies are usually set up based on industry classification. This is certainly the case for Taiwan, where the only distinction is between high-tech sector and low-tech sector. However, the results of this analysis suggest that whether high- and low-tech is defined at the industry-level or the firm-level makes a substantial difference to the nature of the IVC, and by implication may make a difference to the nature of optimal government intervention in terms of public policy. For example, one suggestion is that it might be better to set up innovation policies based on the combination of industrial classification and the actual R&D intensity level, such as dividing into high-tech firms in high-tech industries, low-tech firms in high-tech industries, high-tech firms in low-tech industries and low-tech firms in low-tech industries. Such a classification would give a much more nuanced innovation/industrial policy, based on evidence derived from this thesis.

It is the same for firm managers when they decide on a strategy of knowledge sourcing for different forms of innovation. For example, a firm with internal R&D as being in high-tech industry increase the likelihood of engaging in product innovation while being a high-tech firm is more likely to engage in process innovation. This suggests that the optimal knowledge sourcing and/or generation strategy for the individual firm may differ depending on whether they are a high- or low-tech firm *and* whether they are in a high- or low-tech industry.

7.4.3 The third topic: innovation and export performance

Although there has been a lot of research examining the effect of innovation on export performance, the effect of different forms of innovation was not estimated. It was usually in the term of general innovation or only specifically focused on product innovation. The exporting part of the thesis must be seen as an additional consideration, going beyond the IVC analysis. For example, this part of study demonstrates that process innovation actually reduces the likelihood of a firm being an exporter which suggests the effort of process innovation may not be able to be measured in a short term. Therefore, this part of study fills the gap of innovation- exporting relationship by examining innovation from different dimension.

Furthermore, most of the previous research measure export performance by export dummy variable (i.e. whether a firm is an exporter) and the sales performance on exporting goods. However, the effort of exporting is not only considered from the perspective of sales figure but also the extent of geographic areas (i.e. the number of foreign markets a firm exports its goods). Therefore, this study combines the process of internationalisation to measure export performance.

In addition, some interesting determinants such as IP protection and international knowledge sourcing activities are explored and demonstrated for the empirical contributions, and these are issues which have rarely been explored in the past, and never in the context of an economy such as Taiwan.

Combining with the results from the previous part of study, it gives policy makers a clear picture to assist Taiwanese manufacturing firms' innovation activities and to enter international markets. For example, a firm registering for patents and designs fosters a firm entering foreign markets and further extending the exporting geographic areas. Government can provide some workshops/seminars to introduce the process of registration for patents and designs and to enhance the awareness of it. For a company manager, it also provides a guideline if a firm aims to become more internationalised. For example, the result indicates that it helps a firm to expand its exporting business if a firm tries to protect its IP in some informal approaches such as to enhance the complexity of new products or to engage in some secrete business trading. Also, it shows that to connect with international customers is one of the efficient ways to enter foreign markets because it is a direct way to know the local market demand.

7.5 Limitations and future research

To meet the research aim and questions, the research frameworks were built up based on relevant literature and previous empirical works. The secondary data adopted is derived from the official national level survey to make sure the reliability and maximize the generalizability of the research findings. Furthermore, proper statistical technique and suitable econometric approaches are applied to answer proposed research questions for the purpose of this study. However, some limitations always exist due to the nature of research studies. It is then important to recognise the limitations of a study for the suggestion of possible future research. Furthermore, according to the findings from this study and the limitations which this study is not able to do, some suggestions for future research are therefore to be presented here as well.

First of all, the secondary data this study adopted is a cross-sectional data which does not interpret fully the causal inferences between independent and dependent variables. Although the additional information would help with the explanation, it is still not able to express the causality within the research. In contrast, a panel data would be preferable due to the effort of innovation which is considered as long time effectiveness and may be better to measure its value added after a few years rather than in the same period of the survey.

Second, this secondary data is conducted on the national level which is collaborated by several universities in Taiwan and funded by the Government. Therefore, the official and reliable resource enables this study to generalise or transfer the research findings. However, the utilisation of secondary data is never as perfect as the first data designed for the study because it may lack of some information required, and of course inferences have to be made. It then provides the suggestions for future research to fill those gaps.

Third, there are more work to be done in this study such as the linkage between IVC and export performance, and the comparison of the innovation-export relationship between high-tech sector and low-tech sector. For example, although the structure of the Innovation Survey questionnaire allows for some time gaps between e.g. innovation and exporting, there is always the possibility of endogenous processes between these variables that could not be fully explored in this research. Because there is a time limit of PhD learning process, these are all possible areas of future research.

Finally, as with all quantitative analysis, there are limits to how much we can learn about the process by which some of the mechanisms work. For example, while we learn that supply-chain linkages may be important in aiding innovation or what knowledge sources tend to be complementary, we know nothing about the precise mechanisms underlying these findings. If time permitted it would be interesting to conduct in-depth studies with individual innovative firms in Taiwan to learn more about the processes underlying the innovation value chain, and more about the inter-relationships between innovation, exporting and firm performance.

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Appendices

A1. All industrial codes of 1806 manufacturing innovative firms

Code 2nd TIS	**Description 2nd TIS**	**Code 2nd TIS**	**Description 2nd TIS**
6	Sand, stone and clay quarrying	25	Fabricated metal manufacturing
8	Food manufacturing	26	Electronic parts and components manufacturing
9	Beverages manufacturing	27	Computers, electronic and optic products manufacturing
10	Tobacco manufacturing	28	Electrical equipment manufacturing
11	Textiles mills	29	Machinery and equipment manufacturing
12	Wearing apparel and clothing accessories manufacturing	30	Motor vehicles and parts manufacturing
13	Leather, fur and relative products manufacturing	31	Other transport equipment manufacturing
14	Woods and bamboo products manufacturing	32	Furniture manufacturing
15	Pulp, paper and paper products manufacturing	33	Other manufacturing
16	Printing/reproduction of recorded media	34	Industrial machinery & equipment repair and installation
17	Petroleum and coal products manufacturing	35	Electricity and gas supply
18	Chemical material manufacturing	36	Water supply
19	Chemical products manufacturing	37	Wastewater (sewage) treatment
20	Medical goods manufacturing	38	Waste collection, treatment and disposal; material recovery
21	Rubber products manufacturing	39	Pollution remediation service
22	Plastic products manufacturing	41	Building construction
23	Non-metallic mineral products Manufacturing	42	Civil engineering
24	Basic metal manufacturing	43	Specialized construction

A2 2nd Taiwanese Innovation Survey

The first part is to all industries

- **Information**

1. Are you a subsidiary of a group company?

   Yes
   If yes, where is your parent company?
   Taiwan
   Mainland China
   Other countries

   If other countries, what is the country?
   What is the name of the parent company?

   No.

2. In which geographic market did your company sell goods or services during these three years 2004 to 2006? (You can choose more than one option.)

   The city/county where your company is
   Taiwan
   Mainland China
   Japan or Korea
   United State or Canada
   European countries

3. Who is your main customer? (You can choose more than one option.)

   Other subsidiary/company of the parent/group company
   Non subsidiary/company of the parent/group company (B2B)
   Government
   End customer (B2C)

4. Did your company establish after 1st January 2003?

   Yes
   No

5. Which type of business is your company? (Choose only one option)
   Manufacturing component or materials
   Assembling
   Construct customized system
   Provide package (project) service
   Provide customized service
   Provide a channel of sale or trading
   Others

- **Marketing innovation**

6. Did your company change a lot on anything below during these three years 2004 to 2006?

Marketing innovation	New approach						No new approach
	Innovation extent						
	Outward appearance/Image design	Package	Channel of sales	The way/ channel to display products	The way of payment	Advertisement/marketing	
(1) Original market, original customer, new approach of marketing							
(2) Original market, new customer, new approach of marketing							
(3) New market, original customer, new approach of marketing							
(4) New market, new customer, new approach of marketing							
(5) Others, please indicate							

If you choose no new approach in these five questions, please go directly to question 9.

7. Who developed these market innovations? (Select the most appropriate option only)

Mainly your company or group (parent) company
Your company together with other companies or institutions
Mainly other companies or institutions

8. How important were each of the following effects of your marketing innovations introduced during these three years 2004 to 2006?

Items	Degree of observed effects			
	High	Medium	Low	Not relevant
Extend the geographic area of product/service				
Increase the range of product/service (product line)				
Increase market share in the existing market				
Improve the quality of product/service (customer value)				
Improve the flexibility of production or service provision				
Change the image of product/service to customers				
Reduce the cost of sales/trading				
Increase the probability of return customers				
Others, please indicate				

- Organizational innovation

9. Has your company change anything listed as below?

Organizational innovation	Yes			Not relevant
	Extent			
	High	Medium	Low	
(1) New operation procedure in original department and original organizational structure				
(2) New business in original department and original organizational structure				
(3) New business in new department but the same organizational structure				
(4) New organizational structure and new relationship between departments, but keep the nature of departments				
(5) Strategic alliance with other companies				
(6) Strategic alliance with universities or research organizations				
(7) Change on the relationship with suppliers and customers				
(8) Merge with other companies (or merged by other companies) or establish a new company with other companies				
(9) Improve knowledge management system to make it easier to share/communicate information, knowledge and skills				
(10) Improve knowledge management system to control information, knowledge and skills sharing/communication				
(11) Others, please indicate				

10. Who developed these organizational innovations? (Select the most appropriate option only)

Mainly your company or group (parent) company
Your company together with other companies or institutions
Mainly other companies or institutions

11. How important were each of the following effects of your organizational innovations introduced during these three years 2004 to 2006?

Items	Degree of observed effects			
	High	Medium	Low	Non
Reduce time to respond to customer or supplier needs				
Improve employee satisfaction and/or reduced rates of employee turnover				
Extend the geographic area of product/service				
Extend production or service (capacity)				
Improve the flexibility of production or service provision				
Improve the capacity of production or service provision				
Improve the capability of innovation				
Reduce the labour cost of per unit output				
Reduce the risk of plagiarism or imitation				
Met regulatory requirement				
Others, please indicate				

The second part is to manufacturing industry only

- **Product (goods or service) innovation**

1. During the three years 2004 to 2006, did your company introduce (Multiple choice)

New or significantly improved products
New or significantly improved services
If no to both options, please go to question 6

2. Who developed these product innovations? (Select the most appropriate option only)

Mainly your company or group (parent) company
Your company together with other companies or institutions
Mainly other companies or institutions

3. Were any of your goods and service innovations during the three years 2002 to 2004? (You can choose more than one option)

New to market (Your company introduced a new or significantly improved goods or service into markets before your competitors.)

Only new to your firm (Your company introduced a new or significantly improved goods or service that was available from your competitors in markets.)

4. For the goods/services provided in 2005, please give a percentage of your total turnover (Please indicate approximately percentage if there is no exact value.)

Items	Percentages
The new goods/services to markets during 2004 to 2006	%
The new goods/services to your company during 2004 to 2006	%
The significantly improved goods/service during 2004 to 2006	%
The non-changed or slight changed goods/services during 2004 to 2006 (Including the goods/services completely developed or manufactured by other companies)	%
Total turnover	100%

5. How important were each of the following effects of your product innovations introduced during these three years 2004 to 2006?

Items	Degree of observed effects			
	High	Medium	Low	Not relevant
Extend the geographic area of product/service				
Increase the range of product/service (product line)				
Increase market share in the existing market				
Improve the quality of product/service				
Improve the flexibility of production or service provision				
Improve the capacity of production or service provision				
Reduce the labour cost of per unit output				
Reduce the material & energy cost of per unit output				
Reduce the shocks of environment or human health				
Met regulatory requirement				

- **Process innovation**

6. During the three years 2004 to 2006, did your company introduce new or significantly improved process to your company?
   The method of manufacturing or producing goods or services
   Yes No
   Logistics, delivery or distribution methods for your inputs, goods or services Yes No
   Supporting activities for your processes, such as maintenance systems or operations for purchasing, accounting, or computing
   Yes No

   If no to all options, please go to question 10

7. Who developed these process innovations? (Select the most appropriate option only)

Mainly your company or group (parent) company
Your company together with other companies or institutions
Mainly other companies or institutions

8. During the three years 2004 to 2006, did your company introduce new or significantly improved process to your industry?
   The method of manufacturing or producing goods or services
   Yes No
   Logistics, delivery or distribution methods for your inputs, goods or services Yes No
   Supporting activities for your processes, such as maintenance systems or operations for purchasing, financial accounting, or computing
   Yes No

9. How important were each of the following effects of your process innovations introduced during these three years 2004 to 2006?

Items	Degree of observed effects			
	High	Medium	Low	Not relevant
Extend the geographic area of product/service				
Increase market share in the existing market				
Improve the quality of product/service				
Improve the flexibility of production or service provision				
Improve the capacity of production or service provision				
Reduce the labour cost of per unit output				
Reduce the material & energy cost of per unit output				
Reduce the shocks of environment or human health				
Met regulatory requirement				

- **Companies with no innovation activities**

10. If your company has innovation activities, please go to question 11
If your company has no innovation activity, the reason is (You can choose more than one option, please go to question 23 after this question.)

( ) According to the experience of previous innovation, there is no need of innovation
( ) According to the market, there is no need of innovation
( ) Limited by the conditions/effects of innovation activities
( ) Other effects, please indicate

- **The types of innovation**

11. Which type of innovation is more like your company's (You can choose more than one option)

1	OEM	Produce new products based on the product standards designed by customers, and the producing procedures and equipments provided by customers
2	OEM+	Produce new products based on the product standards designed by customers, but your company can improve the producing procedures and equipments
3	ODM	Collaboratively design product standards with customers; your company can improve the producing procedures and equipments to reduce the cost
4	ODM+	Design product standards and provide to customers' selections; your company can improve the producing procedures and equipments
5	OBM	Has your own brand; research and develop product standards and producing procedures; also manufacture by your own
6	OB-OEM	Has your own brand; research and develop product standards and producing procedures; but outsource to OEM
7	OB-ODM	Has your own brand; research and develop product standards; but select/outsource to ODM to design and produce
8	FastSecond	Follow the major brands in your market; reduce the cost by manufacturing process innovation; compete in the market by lower price
9	Focus	Focus on specific product standards to be competitive in small market; to avoid competing with big companies
10	Disruptive	Simplify and/or reduce the standard of products, and sell products with other distinguishing feature and lower price in non-main stream of market to avoid competing with big companies. However, devote to improve the quality of products and expect to enter the main stream of market in the future.

12. Does your company have any department as below?

To Research and develop new products or manufacturing process
Yes, please indicate the name of the department
No

To test innovative products or manufacturing process
Yes, please indicate the place
No

- **Innovation activities and expenditures (Please choose yes or no in each item)**

13. During the three years 2004 to 2006, did your company engage in the following innovation activities:

Innovation activities	Statement	Yes	No
Intramural (In-house) R&D	Creative work undertaken within your company to increase the stock of knowledge and its use to devise new and improved products and processes (include software development)	Continuously ( ) Occasionally ( )	
Extramural R&D	Same activities as above, but performed by other companies (including other companies within your group) or by public or private research organizations and purchased by your company		
Acquisition of machinery, equipment and software	Acquisition of advanced machinery, equipment and computer hardware or software to produce new or significantly improved products and processes		
Acquisition of other external knowledge	Purchase or licensing of patents and non-patented inventions, know-how, and other types of knowledge from other companies or organizations		
Employee training	Internal or external training for your personnel specifically for the development and/or introduction of new or significantly improved products and processes		
Market introduction of innovation	Activities of market introduction of your new or significantly improved goods and services, including market research and launch advertising		
Other preparation for innovation	Procedures and technical preparation to implement new or significantly improved products and processes that are not covered elsewhere		

14. Please estimate the percentages (%) of the amount of expenditure for all innovation activities to total turnover in 2006.

Also, please estimate the percentages (%) of the expenditure for each of the following innovation activity in the total amount of expenditure for all innovation activities in 2006.

Innovation activities	the percentages (%) of the expenditure for each innovation activity in the total amount of expenditure for all innovation activities
Intramural (In-house) R&D	%
Extramural R&D	%
Acquisition of machinery, equipment and software	%
Acquisition of other external knowledge	%
Employee training	%
Market introduction of innovation	%
Other preparation for innovation	%
The amount of all innovation activities	100%

- **The financial supports to innovation activities from Government**

15. During the three years 2004 to 2006, did your company receive any public financial support for innovation activities from the following levels of government? (Include financial support via tax credits or deductions, grants, subsidised loan, and loan guarantees)

Local government (City and county) Yes No
Central government (Include all departments in government) Yes No
Others Yes No

16. During the three years 2004 to 2006, how would your innovation activities work if your company did not receive any public financial support? (You can choose more than one option)

( ) Most of them would not work
( ) Would choose the innovation activities with less risk to work on
( ) Would follow the most of original plans, but reduce the budget
( ) Would follow the original plans
( ) Without the public financial support, the company would receive less external finance so we will invest more percentages of internal finance
( ) Without the public financial support, the company would still be able to receive the same external financial support from others

- **Sources of information and co-operation for innovation activities**

17. During the three years 2004 to 2006, how important to your company's innovation activities were each of the following information sources? (Please tick "not used" if no information was obtained from a source)

	Information source	Degree of importance			
Internal	Within your company or Group company	High	Medium	Low	Not used
Market sources	Suppliers of equipment, materials, services, or software				
	Clients or customers				
	Competitors or other companies in your sector				
	Consultants, commercial labs, or private R&D institutes				
Institutional sources	Universities or other higher education institutions				
	Government or public research institutes				
Other sources	Conferences, trade fairs, exhibitions				
	Scientific journals and trade/technical publications				
	Professional and industry association				
	Institutions or documents for the standards of technology and services				

18. During the three years 2004 to 2006, did your company co-operate on any of your innovation activities with other companies or institutions? (Please indicate the location and degree of importance or nil in each co-operative subjects)

Co-operative subjects	Yes										Nil
	Location							Degree of importance			
	Taiwan	Mainland China	United States	Japan	Korea	Europe	Others	High	Medium	Low	
(1) Other companies within your group company											
(2) Suppliers of equipment, materials or software											
(3) Clients or customers											
(4) Competitors											
(5) Consultants, commercial labs, or private R&D institutes											
(6) R&D department or labs in other companies in other industries											
(7) Universities or other higher education institutes											
(8) Government or public research institutes											

- **Protection of innovation**

19. During the three years 2004 to 2006, how did your company protect the results of innovation and the degree of importance? (Please indicate the degree of importance or choose nil)

Protection	Yes			Nil
	The degree of importance			
	High	Medium	Low	
(1) Apply for a new invention and a patent				
(2) Register an industrial design				
(3) Register a trademark (Although the technology is easy to be imitated, the fame is not easy to be taken)				
(4) Claim copyright				
(5) Protection of secrets				
(6) Increase the complexity of design				
(7) Introduce new products/Enter the market more quickly than competitors (The first mover advantage)				
(8) Control key materials or components				
(9) Provide complementary services or products				
(10) Keep changing/developing technology/products; leave imitators behind				
(11) Keep key technique experts				
(12) Push people to join a chain of stores; extensively authorise to occupy markets; increase market share				
(13) Others, please indicate				

20. If your company ever applied a patent, what are the reasons/purposes? Please tick the degree of importance. (Please choose the degree of importance or nil to each item)

Has your company ever applied a patent? Yes No (If you choose no, please go to 21 directly)

The purpose of apply a patent (The way of utilizing a patent)	Yes			Nil
	Degree of importance			
	High	Medium	Low	
(1) To produce specific equipments or components to avoid imitation				
(2) It is difficult to avoid imitation, but at least to delay competitors' development				
(3) To negotiate about the exchange of technique				
(4) To avoid being accused tort (Protect yourself)				
(5) To obtain customers' orders				
(6) Customer will not easily re-invoice to other competitors				
(7) To examine internal R&D employee's performance				
(8) To raise your company's fame and increase the value of shares				
(9) To appeal professionals				
(10) To licence to other companies to get money				
(11) Others, please indicate				

- **Factors hampering innovation activities or unfinished innovation activities**

21. During the three years 2004 to 2006, were any of your innovation activities or projects

Abandoned in the concept stage Yes No
Abandoned after the activity or project was begun Yes No
Seriously delayed Yes No

If you answer all no to the above three questions, please go to question 23

22. During the three years 2004 to 2006, how important were the fallowing factors for hampering your innovation activities or projects or influencing a decision not to innovate? (Please choose the degree of importance or nil to each item)

	Items	Degree of hampering			
		High	Medium	Low	Nil
Cost factors	Lack of funds within your company				
	Lack of finance and it is difficult to get from sources outside your company				
	Innovation cost is too high				
Knowledge factors	Uncertain capabilities to complete innovation activities (the risk of technique)				
	Lack of qualified personnel				
	Lack of information on technology				
	Lack of information on market				
Market factors	Difficulty in finding cooperation partners for innovation				
	Market dominated by established companies (the risk of competition)				
	Uncertain demand for innovative goods or services (the risk of demand)				
	The lack of domestic market and it is difficult to compete directly in international markets				
Other factors	Lack of measures of connection to international markets (eg. certification)				
	Lack of measures of supporting national innovation				
	Difficulty of meeting Government Laws/rules				
	Difficulty of meeting other Governments' Laws/rules (eg. EU, Mainland China, US or Japan and so on)				

- **Other information about your company**

23. What was your company turnover in 2004 and 2006? (Unit: thousand)

In 2004, TWD:
In 2006, TWD:

24. What was your company's total number of employees in Taiwan in 2004 and 2006?

In 2004, people
In 2006, people

25. In 2006, your company

(Taiwan) The ratio of employees with university degree to total employees in Taiwan %

(Mainland China) The ratio of employees with university degree to total employees in Mainland China %

If there is no other branch, please tick ( )

(Other areas) The ratio of employees with university degree to total employees in other areas %

If there is no other branch, please tick ( )