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**Public sector R&D and innovation in an emerging country: An  
analysis of knowledge flow between public and private sectors in the  
Thai National System of Innovation**

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Doctor of Philosophy

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“True Success is not in the learning, but in its application to the benefit of mankind”.

His Royal Highness Prince Mahidol of Songkla

## Abstract

This thesis explores Thailand's efforts to pursue greater competitiveness in global markets by enhancing the effectiveness of its National System of Innovation. The concept of national system of innovation (NSI) has been employed widely to study and describe the development of science, technology and innovation in a national context. NSI studies seek to explain systematic differences between national economies in their innovation performance in terms of the flow of knowledge among actors/players and the impacts of institutions and factors on their relationships or interactions. The concept was formally introduced into Thai policies in 2001 and it was adopted widely by the organisations directed to build up a strong national innovation system. However, the Thai innovation system has been identified by previous studies as a weak and fragmented system. This study investigates the current situation of the Thai NSI by exploring the relationships and the patterns of knowledge flows among actors in the Thai innovation system; heavily focusing on exploitation of public sector research.

A comparative study was undertaken of innovations arising as a result of initiatives arising through the Thai NSI policy. Eighteen case studies were undertaken including 6 that were seen as successful and 12 failures. The study was carried out using in-depth interviews with relevant staff in both public and private sectors together with secondary analysis of science and technology policy implementation in Thailand. The interviews show that there are still many problems hindering the attempt to build up an effective relationship between the public and private sectors; many of them fail to construct R&D collaboration and to conduct technology transfer. The influential factors are analysed and identified from the cases. Those found repeatedly among successes, but largely absent in the failure cases include technological readiness, R&D capability, good management skills, and positive attitude towards R&D while some external factors are found specific to the individual case. Some of them can be contingent factors for particular features of the case resulting in diversity among the cases especially successful ones.

The analysis of science and technology policy implementation is also integrated to explore the case studies in order to investigate the impact of those policies on the pattern of the Thai innovation system. Particularly, the policy that has been implemented after the introduction of the NSI concept which was intended to fix the linear model of innovation in Thailand. However, the analysis from this research demonstrates that there is a shortcoming in the

adoption of the NSI policy in Thailand as it still follows the 'linear plus' model of innovation (Tait and Williams, 1999) revolving around promoting knowledge flows from research. The development of ST&I is embedded in the advanced science (most in the public sector) not for building up the competitive firms. The centre of development is not on firm capability development to create learning economies but on a science push model.

To summarise from the empirical findings, the concept of NSI adopted in Thailand is used as a tool to briefly analyse the big picture of science and technology development at the national level and to identify the problems facing the country. However, this concept alone is not enough to stimulate a country's innovation process. The NSI concept has been understood in two broad ways: the Science, Technology and Innovation (STI) mode and the Doing, Using and Interacting (DUI) mode. In Thailand the former has prevailed. Secondly, the concept itself is too broad and vague to be used as the main guideline for building up innovative capacity; it only tells what should be done not how to do it. The NSI helps Thailand to initiate change in its ST&I development process although greater attention should be given to the DUI mode. However, the process requires other frameworks to support and translate the NSI concept into the level of action plans. As a result this research suggests that the factors that determine the success of technology/knowledge transfer are not only from the policy level but also other factors from the bottom up level such as social factors determining the relationships among actors.

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## Glossary and List of Abbreviations

BD	Business development unit
BIOTEC	National Center for Genetic Engineering and Biotechnology
BOI	The Office of the Board of Investment
FDI	Foreign direct investment
IP	Intellectual property
IPR	Intellectual property rights
MOST	Ministry of Science and Technology
MTEC	National Metal and Materials Technology Center
NANOTEC	National Nanotechnology Center
NECTEC	National Electronics and Computer Technology Center
NESDB	The National Economic and Social Development Board
NIA	National Innovation Agency
NIC	Newly industrialised country
NIE	Newly industrialised economy
NRCT	National Research Council of Thailand
NSI	National system and innovation
NSTDA	The National Science and Technology Development Agency
OECD	Organisation for Economic Co-operation and Development
PRO	Public research organisation
PRI	Public research institute
RSI	Regional system of innovation
RTO	Research and Technology Organisation
SSI	Sectoral system of innovation
S&T	Science and technology
ST&I	Science, technology and innovation
STI	The National Science Technology and Innovation Policy Office
TLO	Technology licensing office
TNC	Transnational corporation
TSP	Thailand Science Park

## Chapter1 Introduction

Science, technology and innovation (ST&I) development has been identified as a key factor enhancing national competitiveness. Therefore, many countries are trying to develop new technologies in order to improve their competitiveness in the global market. Thailand is one such example, as indicated by the policies set out in its National Science Technology and Innovation Act 2008. The Act makes it clear that ST&I is considered an important factor for improving society and enhancing the nation's competitiveness. However, Thailand is a follower nation struggling to adapt to the new technologies from developed countries and thus far its efforts have not allowed the development of ST&I to progress as quickly and efficiently as was expected.

Thailand has changed from an agricultural country based on utilising abundant natural resources and simple production processes to an industrialised country using machinery for manufacturing. As with other countries seeking to industrialise, Thailand needs to develop ST&I capabilities to adopt new production processes. However, Thailand is different from countries in the developed world, it has moved to industrialisation by taking a role as a production base and supplier for other big industrialised countries such as Japan and the US. Due to the large amount of foreign direct investment (FDI) and multinational companies (MNC), Thailand has enjoyed rapid GDP growth since the 1980s. During 1986-1991, Thailand was considered as one of the world fastest growing economies (Dixon, 1999). In 2010, it still maintained its economic performance as one of the fastest growing economies in Asia, and the fastest growing economy in South East Asia (CBI website, the Netherlands). It was ranked as the world's second largest producer of pickup trucks behind the US and the world's second largest hard disk drive (HDD) producer behind Singapore (Berger and Diez, 2008).

This may suggest that Thailand can enjoy impressive GDP growth from its export-based economy and that there are few problems facing Thailand's economy. However, being the production base for industrialised countries may do little to help Thailand nurture the progress of its ST&I development. Previous research on the Thai innovation system (Intarakumnerd et al. 2002, 1452) has noted that *“similar to the east Asian NIEs, the GDP growth of Thailand has been remarkably impressive,...moving towards an economy that relies heavily on production and export of industrial products, especially those classified as*

*differentiated and science-based ones*". However, the same research also suggested that unlike others Asian newly industrialised economies (NIEs), the development of the Thai innovation system provides only weak and fragmented support for the uptake of technology by industry and that *"there is a mismatch between level of economic structural development and development level of NIS"* in Thailand (p.1452).

Why does Thailand need ST&I development if it is enjoying impressive economic growth from the export-based economy? There are two main reasons. Firstly, Thailand cannot rely on cheap labour and abundant natural resources forever; it has to move to a further step of development to be more economically sustainable. Several studies (eg Brimble and Doner, 2007; The Report Thailand 2011) suggest that Thailand is losing its advantage point on cheap labour to other Asian countries and that it needs technological capability to become more competitive in the global market. Secondly, there are some niche requirements specific to Thai society, especially in the areas of public health and agriculture, that could be addressed by targeted ST&I. In particular, there are problems in public health, with many diseases that are neglected by the big pharmaceutical firms in developed countries exacerbated by the inability of the majority of people in the developing world to afford advanced medical treatment. Similarly, there are problems in the agricultural industry that are specific to the local context, and that need to be fixed by indigenous approaches.

To enhance its technological capability, Thailand needs to deal with the problems in its ST&I development. According to Intarakumnerd et al (2002), the Thai innovation system is not as well developed as in other NIEs. This negative assessment of the Thai innovation systems begs a number of questions. What happened to Thailand's ST&I development situation? Why cannot progress be made in its ST&I and innovation in order to enhance its competitiveness? How to move further and get away from its current problematic situation?

Previous studies (Chantramonklasri, 1994; Intarakumnerd et al., 2002; Chairatana, 2006; Yungsuksathaporn, 2005; Rattanawaraha, 2013) investigating the pattern of ST&I development in Thailand suggest that Thailand has relied heavily on the science push model (linear model of innovation) in which advanced ST&I knowledge is created and embedded in the public sector (universities and public research institutes) rather than in the private sector (firms and industries). Furthermore, the linkage between public and private sector is relatively limited.

To get away from its problematic linear model of innovation, the concept of national system of innovation (NSI) has been applied to the framework of ST&I policy making process in Thailand. The NSI concept has been employed widely to study and describe the development of ST&I and innovation in a national context. It is focused on the investigation of the flows of knowledge among actors/players and the impacts of institutions on their relationship or interactions. This systematic approach is developed against the linear model of innovation. The concept of innovation system was officially adopted in the government ST&I five-year Plan, 2001-2006 (Intarakumnerd and Chaminade, 2007). Later on, the ten-year Science and Technology Strategic Plan (2004-2013) places the concept of national innovation system and industrial cluster at its heart

Previous studies of the Thai National System of Innovation (NSI) indicated that there are several problems obstructing the flow of knowledge in the system. For example, Schiller (2006) points to the relationship between public and private sectors, particularly the university-industry linkage, as the weak point in the Thai NSI. According to the previous studies identify ST&I development in Thailand as it based on a science push model when knowledge is created and embedded in the public sector. The problem of public-private relationship pointed out by Schiller (2006) becomes the main concern to this issue since it is preventing the process of knowledge flow in the national innovation system.

A 2011 pilot study for this thesis investigated the relationship between public and private sector by using the in-depth interviews and questionnaires (Prachomrat, 2011). Although there were some successful cases of technology transfer and efficient public-private relationships, this preliminary research supported the conclusion of previous studies in identifying problems in the public-private relationship in the Thai NSI.

This thesis is based on further investigation of the Thai innovation system, particularly as regards the public-private relationship. This research is conducted based on two questions: 'What is the pattern of relationships between the public and private sectors in the Thai innovation system?' and 'How has it become like that?' The aim of this research is to investigate more deeply the particular problems and the factors which determine the pattern of relationships between public and private sectors in the Thai NSI, as well as to critically address the value of the NSI approach to emerging nations such as Thailand. Since Thailand adopted the NSI framework into its ST&I policy, this research explores whether the NSI framework can change the innovation model in Thailand from the linear model to the

systemic model or not. In addition, an analysis of ST&I implementation from the past to present is conducted in order to investigate the results of those policies on ST&I development in Thailand. Particularly, the policies implemented after the adoption of the NSI concept in 2001.

This study is carried out using in-depth interviews with people responsible for conducting and supporting STI in Thailand in both the public and private sectors. The data has been analysed to understand the current situation of public-private relations in the Thai innovation system. Eighteen case studies were constructed from the data analysis. Each case describes the process of knowledge/technology transfer from public to private sector and how the knowledge from the laboratory was translated into a product in the market. The cases show different patterns of knowledge flow and relationship among actors in the Thai innovation system. One third of them are considered as successful cases while the rest are identified as failures. Many factors influencing the pattern of the relationship are identified. There are some co-factors repeatedly found among successful cases while the failure cases are lacking them. Lastly, the Thai ST&I policy have been analysed to describe its development over many years and to demonstrate the impact of the implemented policies on the pattern of the Thai innovation system through the case studies. Therefore, the case studies are analysed together with the ST&I policy implementation in order to investigate the effect of those policies on the ST&I development situation in Thailand.

Chapter 2 reviews the relevant literature and develops the conceptual framework of the thesis. The first subtopic focuses on innovation systems, with particular emphasis on the national system of innovation (NSI) concept. The next subtopic is the exploitation of public research and describes the channels for bringing knowledge created in the public sector to utilisation. The third topic deals with the Triple Helix model and demonstrates another approach to public-private relations that emphasises the dominant role of universities. This chapter concludes by the knowledge/technology transfer process as a tool to encourage flow of knowledge in the innovation system.

Chapter 3 provides general information about the Thai economy and a brief history of ST&I development in Thailand. This chapter also presents the previous research conducted by many scholars investigating the Thai innovation system and the problems facing ST&I development in Thailand.

Chapter 4 describes the analytical frameworks and methodology of the research.

Chapter 5 focuses on the development of ST&I policy in Thailand. This chapter refers back to the first national economic development plan in 1961 up to present plan. In addition, some important ST&I policies are analysed together with the national plan to see the policy trend that shapes the current situation of ST&I development in Thailand.

Chapter 6 presents the empirical findings of the case studies of technology transfer. The chapter presents these cases of public-private collaboration with both successful cases and failure cases.

Chapter 7 provides additional information about the Thai innovation system based on the perspectives of key actors. It gives a reflection on the state of the Thai innovation system by other actors in addition to the actors involved in chapter 6, followed by data analysis.

Chapter 8 concludes the thesis with a discussion of the research findings and conclusions. This part also includes some policy recommendations for the further policy making process in Thailand.



## Chapter 2 Literature Reviews

### 2.1 Conceptual Framework of Innovation Systems

Innovation plays a vital role in economic growth and can be linked to the competitiveness and wealth creation of the country. Friedrich List (1856) is acknowledged as the first scholar to discuss the importance of innovation and knowledge as drivers of differential economic performance among countries (Kastelle et al, 2009). List also criticised classical economists for neglecting the importance of science, technology and skills in national growth (Freeman and Soete, 1997). The key claim, as put by Cantwell (2005, 561), is that “*competitiveness derives from the creation of the locally differentiated capabilities needed to sustain growth in an internationally competitive selection environment. Such capabilities are created through innovation*”. Similarly, Freeman (1987, 1) notes the contribution of Schumpeter and argues that “*technical and related social innovations are the main source of dynamism and instability in the world economy and that technological capability is the main source of the competitive strength of firms and nations*”.

Porter’s influential 1990 study examined patterns of national competitive success in 10 countries. He argued that national prosperity “*is created, not inherited. It does not grow out of a country’s natural endowments, its labor pool, its interest rates, or its currency’s value, as classical economics insists*”. Instead, he argued, a nation’s competitiveness “*depends on the capacity of its industry to innovate and upgrade*” (Porter, 1990, 73).

Innovation can cover a wide variety of activities. For example, one of the most important scholars who clarified the importance of innovation for economic growth was the Austrian American economist, Joseph Schumpeter. He initiated the idea of the evolutionary concept in economic systems and the notion of creative destruction (Anderson, 2011) (Later on evolutionary theory<sup>1</sup> was formally set out by Nelson and Winter in 1982). Schumpeter also saw innovation as central to the role of business cycles in capitalist development: “*The key*

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<sup>1</sup> The evolutionary theory borrows the basic idea from biology ‘natural selection’ from Darwin’s thinking. Nelson and Winter (1982, 10) explain the natural selection as “Market environments provide a definition of success for business firms, and that definition is very closely related to their ability to survive and grow. Patterns of differential survival and growth in a population of firms can produce change in economic aggregates characterizing that population, even if the corresponding characteristics of individual firms are constant”.

*process in economic change is the introduction of innovations, and the central innovator is the entrepreneur” (Oser and Blanchfield, 1975, 415).*

Additionally, it was Schumpeter who classified innovation into five different types including *new products, new methods of production, new sources of supply, the exploitation of new markets, and new ways to organize business” (Fagerberg, 2005, 6-7).*

Tidd et al. (2005, 10) talk about the four P’s of innovation including:

- *product innovation*--- change in the things (products/services) which an organisation offers;
- *process innovation*--- change 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 organisation does.

However, in the view of Freeman and Soete (1997), innovation is not only important for enhancing the prosperity of a nation, but also enables changes to people’s quality of life. In other words, innovation is not only concerned with the economic growth aspect but also with the social aspect. Moreover, there are other criteria to identify and conceptualise innovation. Edquist (2000, 11) has mentioned different concepts of innovation given by different groups of scholars. As he put it “*Innovation as conceived by Nelson and Rosenberg (1993) is narrow in the sense that it is restricted to technical innovations”* (process and product innovation are included). He compared this with the definition given by Schumpeter in which the innovation concept includes other aspects such as the organisation or market.

Another approach used to differentiate types of innovation is radical and incremental innovation. Dewar and Dutton (1986, 1422-1423) argue that: “*Radical and incremental describe different types of technological process innovations. Radical innovations are fundamental changes that represent revolutionary changes in technology.*” They also identify the incremental innovations by referring to Munson and Pelz’s work in 1979 as “*incremental innovations are minor improvements or simple adjustments in current technology*”.

The other point to make about innovation is the importance of the extent to which the innovation is used or what is typically called *diffusion*. Cooke (2003, 4) sets out a three stage process, including invention, innovation and diffusion: “*Invention is the stage of the production of new knowledge, innovation is the stage of the first application of the existing knowledge within production, and diffusion in this model means the broad use of new technologies*”. Freeman and Soete (1997, 301) also emphasised the importance of the diffusion process, noting that “*during the 1950s and 1960s the evidence accumulated that the rate of technical change and of economic growth depended more on efficient diffusion than on being first in the world with radical innovations and as much on social innovations as on technical innovations*”.

Although it is important not to lose sight of both process and service innovation, particular attention has been given to the role of invention in stimulating innovation. Freeman and Soete describe the relationship between invention and innovation thus: “*An invention is an idea, a sketch or model for a new or improved device, product, process or system...An innovation in the economic sense is accompanied only with the first commercial transaction involving the new product, process, system or device, although the word is used to describe the whole process. Of course, further inventions often take place during the innovation process and still more inventions and innovations may be made during the diffusion process*”(Freeman and Soete, 1997, 6).

Since the term innovation was introduced as one of the factors that influence economic growth and competitiveness, understanding of the innovation process has changed. At one stage the innovation process was perceived as a simple linear model initiated in the laboratory and delivered to a producer and then users. The model has since been changed to a more complex understanding. Rothwell (1992, 221-222) summarises the different generations of conceptualisation of the innovation process as follows:

- First generation: the idea of what is often called the ‘technology push’ model was developed during the 1950s, the innovation process was seen as “*beginning with scientific discovery, passing through industrial R&D, engineering and manufacturing activities and ending with a marketable new product or process. Here the marketplace was a passive receptacle for the fruits of R&D*” (p.221).
- Second generation: During the mid- to late-1960s new empirical results emphasised more the role of the marketplace and user needs and a new linear model called ‘market pull’ or ‘need pull’ emerged. “*In this case innovations are deemed to arise*

*as the result of a perceived and sometimes clearly articulated customer need, resulting in closely focused R&D activity leading to a stream of new products onto the market. Here R&D has a merely reactive role in the process” (p.221-222).*

- Third generation: During the 1970s the linear models became regarded as being oversimplified, as a new ‘*coupling model*’ emerged, “*a more general process of coupling between science, technology and the marketplace...However, it must be acknowledged that at a more aggregated (industry-wide) level, the relative importance of technology-push and need-pull might vary considerably during different phases in the industry cycle*” (p.222).
- Fourth generation: In the mid-1980s, the next generation of innovation model called the ‘*interactive model*’ was proposed. It “*marked a shift from perceptions of innovation as a strictly sequential process to innovation perceived as a largely parallel process*” (p.221).
- Fifth generation: The latest model, emerging in the 1990s, was called the ‘*systems integration and networking model*’. According to this model “*innovation is becoming faster; it increasingly involves inter-company networking; and it employs a new electronic toolkit (expert systems and simulation modelling)*” (p.221).

## **The System of Innovation (SI) Concept**

According to Fagerberg and Sapprasert (2011) the study of innovation before 1990s had a major focus on innovation at the firm and/or industry level. Then during the late 1980s and early 1990s the innovation literature shifted towards work focussing on the interdependencies between actors, organisations, and institutions influencing the innovation process while continuing to stress the importance of firm and industry. Their work was more holistic in its approach and much more focused on policy.

Edquist (1997) describes the emergence of technological innovation as an extremely complex process; it involves the emergence and diffusion of knowledge elements and also the translation of these elements into new products and production processes. The diffusion process was explained by Freeman (1987, 1) as: “*not one of passive copying and acceptance but of learning by doing and learning by using and of further improvement in new products and processes*”.

The System of Innovation approach emerged as a way to understand the processes involved in innovation. As Edquist (1997, 2) puts it *“If we want to describe, understand, explain – and perhaps influence- processes of innovation, we must take all important factors shaping and influencing innovations into account. The system of innovation approach- in its various forms – is designed to do this.”* Similarly, Gault and Earl (2006, 222) argue that *“innovation is complex and does not submit to a reductionist and linear analysis”*, and therefore the study of innovation has to be carried out as a system. Kastle et al. (2012, 4) specify that *“Innovation systems are themselves adaptive systems composed of complex structures of complex populations”*.

Chaminade and Edquist (2006, 141-142) summarise the definition of the SI from Ingelstam in 2002 (in Swedish): *“(a) a system consists of two kind of constituents: components and relations among them, (b) a function that is performing or achieving something, (c) it must be possible to discriminate between the system and the rest of the world; that is, it must be possible to identify the boundaries of the system”*. They also describe how the SI concept has origins in the evolutionary economics approach, different from the neoclassical economic approach, in that it *“shifts the focus from actions at the level of individual and isolated units within the economy (firms, consumers) towards that of the collective underpinnings of innovation”* (Chaminade and Edquist, 2006, 144).

The problem with neoclassical theory, as stated by Intarakumnerd and Chaminade (2011, 243) is that it *“assumed that all economic agents can maximize their profits because they have perfect information about the different options available to them. Knowledge is equal to information, i.e. it is codified, generic, and it is accessible and easily adaptable to the firm’s specific conditions”*. Instead, the SI concept draws on evolutionary economics.

Edquist and McKelvey (2000, xi) describe system of innovation (SI) theory as *“the study of innovations as an endogenous part of economy, and in fact, as an important determinant behind economic change”*. The system of innovation consists of the actors, networks and institutions (Carlsson and Stankiewicz, 1991; Bergek et al., 2008) which contribute to function of the generation, diffusion and utilisation of the knowledge (Galli and Teubal, 1997; Bergek et al., 2008). Kastle et al. (2009) argue that the system does not simply determine what its embedded agents can or cannot do; instead agents themselves have the ability to adopt and generate new innovation rules in order to change the system. Lundvall (1985, 29) describes the role of agents in the innovation system as: *“In the economy, some*

*key institutions are involved in different types of innovative activities. The vertical division of labor between institutions is far from clear-cut, but certain types of activities are predominating in each type of institution”.*

The origin of the innovation system approach has been mainly influenced by the evolutionary theories together with interactive learning theories (Edquist, 1997). The concept of system of innovation has been categorised and focused on different levels of analysis including the nation, the region, the industrial sector, and the technology (Lundvall, 1998, Carlsson et al., 2002). These different systems contain innovating agents which tend to be similar across and within systems. However, they are likely to act in the different ways which eventually differentiate the system. (Kastelle et al, 2009) Scholars have conceptualised innovations at different levels including national, regional and sectoral.

### **Regional system of innovation (RSI)**

This concept has been defined by Cooke and Morgan as: *“Regions which possess the full panoply of innovation organizations set in an institutional milieu, where systemic linkage and interactive communication among the innovation actors is normal, approach the designation of regional innovation systems”* (Cooke and Morgan, 1998, 71; Niosi, 2000, 17).

Additionally, Cooke (2006, 3) held that: *“Regions that have constructed advantage by supporting innovative enterprise can act as meaningful communities of economic interest, can define genuine flows of economic activities and can take advantage of true linkages and synergies among economic actors”*. However, the RSI concept has been criticised by many scholars involved in the innovation system approach especially from the NSI's scholars who believe that the national level is more important than the regional one.

On the other hand, Cook (2003, 1) mentions Porter's idea about the concept of industrial cluster to support the RSI approach as *“... in the United States' competitive lead in innovation was predicated on the existence of regional and local innovation systems based on clusters. This has been shown to be particularly true in new-economy sectors...”* He also states that since the millennium began, the government in many countries chose to start promoting regional innovation and cluster-building policies in order to boost national competitiveness. This can be seen in many countries such as Germany and the UK who are beginning to establish their industrial clusters and regional industrial parks.

The most important evidence supporting Cook's assertion indicated by Kastelle et al (2009) is the comparative study conducted by Saxenian in 1994 who compared the innovation system at Silicon Valley in California and Route 128 in Massachusetts. Saxenian's study concludes that Silicon Valley has more flexible regional networks and technical dynamic than Route 128 which built up the industrial system on separate and self-sufficient individual firms. As a result, Silicon Valley becomes more capable in learning and adaptation compare to Route 128 (Saxenian, 1994, 161). The result from this study demonstrates significant differences in innovation systems within a nation.

### **Sectoral system of innovation (SSI)**

The approach has been defined by Breschi and Malerba as *“that system (group) of firms active in developing and making a sector's products and in generating and utilizing a sector's technologies; such a system of firms is related in two different ways: through processes of interaction and cooperation in artefact-technology development and through processes of competition and selection in innovative and market activities”*. (Breschi and Malerba, 1997, 131 and Geels, F.W., 2004, 898) In addition, Malerba (2002, 248) also proposes that *“a sectoral system of innovation and production is a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products”*.

Malerba (2004, 1-2) summarises the three main factors affecting innovation in a sector as follows:

- *“Knowledge and technologies: sector can be characterised by a specific knowledge base, technologies and inputs.*
- *Actors and networks: a sector consists of heterogeneous agents that are organisations or individuals.*
- *Institutions: agents' cognition actions and interaction are shaped by institutions”*.

The taxonomy of sectoral innovation was developed by Pavitt in 1984 using sources of innovation and the appropriability mechanisms which are different among sectors as criteria. These are categorised as described below (Malerba, 2004, 13):

- *“Supplier-dominated sectors (textile, services) new technologies embodied in new components and equipment, diffusion through learning by doing.*

- *Scale-incentive sectors (automobile, steel) source of innovation are both from internal and external, appropriability is through secrecy and patents.*
- *Specialized suppliers sectors (equipment producers) innovation focused on performance improvement, reliability and customisation.*
- *Science-based sectors (pharmaceuticals, electronics) characterized by high rate of product and process innovations, internal R&D and research done in the public sector, appropriability ranging from patents to lead times, learning curves to secrecy”.*

Similarly, some nations, especially in Europe, have chosen to focus on the role played by particular industrial sectors (Kastelle et al, 2009). Particular industrial sectors are seen to be drivers of innovation, but with their own distinctive features that require tailored policies (see Breschi and Malerba, 1997; Malerba (2002) and Geels, 2004).

### **Technological systems**

The definition of this approach was proposed by Carlsson and Stankiewicz (1991, 111) as “*a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion and utilization of technology. Technological systems are defined in terms of knowledge/competence flows rather than flows of ordinary goods and services. They consist of dynamic knowledge and competence networks*”. However, Carlsson (1995, 3) states that “*the concept of technological system seems to have been first used by Thomas Hughes (1983) in his study of the electrification of Western society during period 1880-1930.*”

The technological system approach put forward by Carlsson and Stankiewicz (1991, 93) is different from other systems as it “*defined in terms of knowledge/competence flows rather than flows of ordinary goods and services*”. Thus Carlsson (1997, 4) sees an advantage of this approach that it disaggregates innovation processes that may be obscured by a national level approach: “*In contrast to national innovation systems, there are many (or at least several) technological systems in each country, and national borders do not necessarily form the boundaries of the system*”.

Carlsson (1997) also explains three types of network involving market and non-market interaction in technological systems including; buyer-supplier (input-output) relationships,

problem-solving networks, and informal network (including overlapping between these networks).

#### *National vs Regional vs Sectoral vs Technological System of Innovation*

When it comes to a comparison among different systems of innovation, there are some similarities and differences among the systems and also advantages and disadvantages in application of each system.

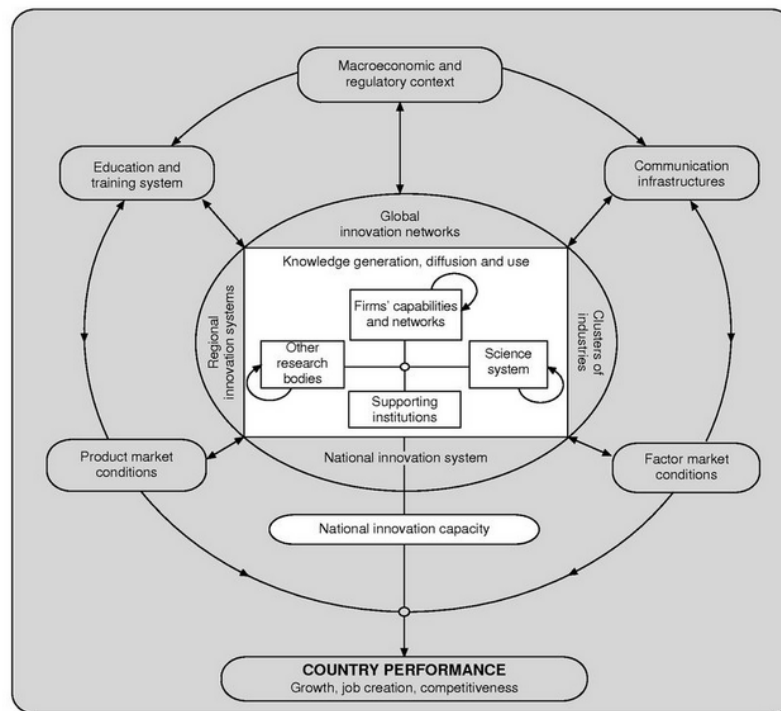
Lundvall (2010, 319) explains the differences among these IS approaches as the RSI is the one that shares similar characteristics of NSI. *“It uses the fact that some knowledge is local and tacit to explain that innovation systems are localised”*. He also explains the different perspectives that the other two (SSI and technological system) applied to their core concept. As he puts it: *“The analysis of technological systems has been especially useful in analysing how new technologies emerge. The sectoral system approach is unique among the different approaches in not defining as analytical object a vertically integrated system”*.

Schrepf et al. (2013, 10) analyse the application of different innovation systems including NSI, RSI, SSI and TSI. As they put it for the NSI concept, after it has been developed for more than two decades it *“still remains ‘under-theorized’ in terms of a lack of common definitions and terminologies”* (this point will be emphasised more in the section of NSI framework). In case of RSI, Schrepf et al. (2013, 15) argue that the concept demonstrates the *“idea that there is no single one-size-fits-all policy. Policy instruments should always be context-specific...”*. However, the study points out the criticism on the policy implemented for the RSI as there are *“the risk of normative thinking and the danger of overestimating the capability of innovation policies”* (p.16). Another criticism on the RSI that this study has mentioned was made by Hess (2004 and Grabher (2006) about *“a danger of over-territorialisation a tendency to neglect the importance of non-local links (to other regional systems, to the national and the global systems)”* (p.12). For the SSI, as the system boundaries relies on existing products in the system; therefore, when the new product emerges, it might cause the problem to the system. Furthermore, this study points out the weakness of SSI and TSI as the knowledge and learning perspective in these approaches are *“biased towards technological learning, whereas social learning is usually not sufficient considered”* (p.19).

In principle, analysis at various levels has benefits. As Lundvall et al. (2009, 8) put it: “*We see a complementary role for analyses at different levels of aggregation and it is important to note that the analysis of sectoral and regional innovation systems bring in a meso level that can mediate between the micro and macro dynamics*”. There are some who criticise the focus on the national level of analysis, arguing that “*there is therefore no a priori reason ... that the national level should be privileged*” (Sharif, 2006, 756). Cooke et al. (1997, 479) for example object to the idea “*that a ‘national’ picture can simply be built up from adding together regional profiles*”.

Meuer et al. (2015, 890) suggest that the innovation system research needs to consider the co-existence of different research systems and develop more understanding on integrated innovation systems. In doing so, it allows “*researchers to identify points of inter-sections between innovation systems, to specify similarities and differences in the innovative capabilities of co-existing innovation systems, and to determine the function of individual innovation systems in a broader innovation system*”.

However, for the purposes of this study the main focus will be on the National System of Innovation (NSI) concept because Thailand, along with many other emerging countries, has adopted the concept as an integral part of its national innovation policy framework. It also is implicit, if not explicit, in many of the policies promulgated by organisations such as the Organization for Economic Co-operation and Development (OECD) as evidenced by Figure 1.



**Figure 1 Actors and linkages in the innovation system**

Source: OECD, 1999, p.23

Why National System of Innovation?

Chris Freeman, a pioneer of this concept, defines NSI as: “*The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies*” (Freeman, 1987, 1). Another important scholar is B-A Lundvall, who defines NSI as “*an open, evolving and complex system that encompasses relationships within and between organizations, institutions and socio-economic structures which determine the rate and direction of innovation and competence-building emanating from processes of science-based and experience-based learning*” (Lundvall et al., 2009, 6).

The national system of innovation (NSI) approach, which was pioneered by Chris Freeman in 1987 to analyse the post-war Japanese economy (Mowery and Oxley, 1995), has been used widely to illustrate the contribution of S&T to a country’s development and competitiveness. However, Freeman himself referred back to Friedrich List as the first one who expressed the idea of national system of innovation. As he puts it “*the idea actually goes back at least to Friedrich List's conception of "The National System of Political*

*Economy' (1841), which might just as well have been called 'The National System of Innovation' (Freeman, 1995, 5).*

The NSI approach is especially important, not just because it has been an influential conceptual framework, but even more so because it has been widely adopted as a policy prescription. Works such as Porter's 1990 book *The Competitive Advantage of Nations* popularised this approach with a clear message: "*Competitive advantage is created and sustained through a highly localized process. Differences in national values, culture, economic structures, institutions, and histories all contribute to competitive success*" (Porter 1990, 73). Influential organisations such as the OECD took the NSI concept to constitute prescriptive guidance for how countries should improve their economic performance: "*For policy-makers, an understanding of the national innovation system can help identify leverage points for enhancing innovative performance and overall competitiveness*" (OECD, 1997, 7). As Guinet from the science and technology policy division at the OECD put it, the NSI approach "*helps identify certain key linkages between the subject you are dealing with and other broader subjects. And this is very important from an analytical perspective and from policy perspective*" (Interview in Sharif, 2006, 758). Lundvall (1998, 413) argued that it is difficult to understand the system of globalisation if we do not understand what happens at national levels.

The essential argument of the NSI approach is, as Intarakumnerd and Lecler (2010, 1) put it, that "*a country's competitiveness and ability to catch up rely very much on its embedded 'national' characteristics or so-called 'national system of innovation'*". An example of how this happens can be seen in the different ways that industrial exploitation of carbon fibre occurred in three different countries - the UK, USA, and Japan (Spinardi, 2002). In this case, national differences in financial systems and defence funding clearly played major roles. Patel and Pavitt (1994, 78) found similar factors at work in their study: "*Differences amongst countries in the resources devoted to such deliberate learning – or "technological accumulation" – have led to international technological gaps which in turn, have led to international differences in economic performance*".

As Freeman (1995, 21) puts it "*nation states, national economies and national systems of innovation are still essential domains of economic and political analysis, despite some shifts to upper and nether regions*". Similarly, Arocena and Sutz (2000, 56) emphasise the importance of investigating innovation systems at the national level: "*Even if globalization*

*heavily affects many—if not all —of these issues and the overall climate for innovation at country level, there is always room for ‘national influences’ that can take the form of public policies—at macro, meso or micro level—and can also be the outcome of distributed initiatives coming from the most diverse social actors”.*

Although an advocate of the sectoral approach, Malerba (2002) notes the importance of “institutions”, whereby norms, routines, rules, laws, standards, and so on are most significant at the national level. Additionally, Malerba (2004, 3) points to the importance of relationships between national institutions and the sectoral level, including the role of “*national institutions such as patent system, IPR and regulations*”.

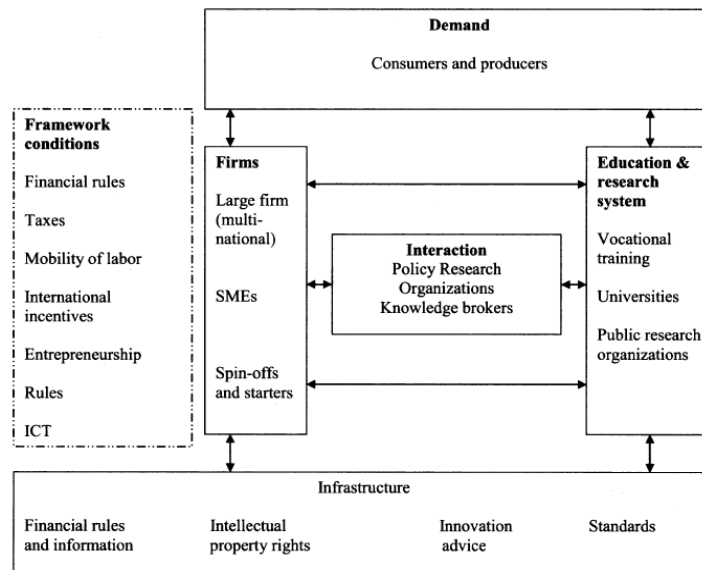
Furthermore, Niosi et al. (1993) also describe additional factors that make the ‘national’ important including: markets and natural resources determinants, informal user-producer interactions, technically-based interdependencies, and politically driven linkages and determinants. Those who favour the NSI approach thus argue that “*...the ‘national’ domain better accommodates the policy dimension concept*” and they further argue that “*even though regional, sectoral, or technological systems often transcend a country’s borders, national characteristics and frameworks always have a role to play in shaping the system in question (regardless of the delimiting criterion employed)*” (Sharif, 2006, 756) .

#### *Components of National Systems of Innovation*

According to the NSI approach, economic competitiveness can be enhanced through policies that facilitate innovation. As Godin (2007, 5) puts it: “*The National Innovation System framework suggests that the research system’s ultimate goal is innovation and that the system is part of a larger system composed of sectors like government, university and industry and their environment*”. Similarly, Intarakumnerd (2011, 11) describes an NIS as “*an interactive system of existing actors, including private and public firms (both large and small), universities, government agencies and others, that aim to produce, diffuse and utilise knowledge within national border*”.

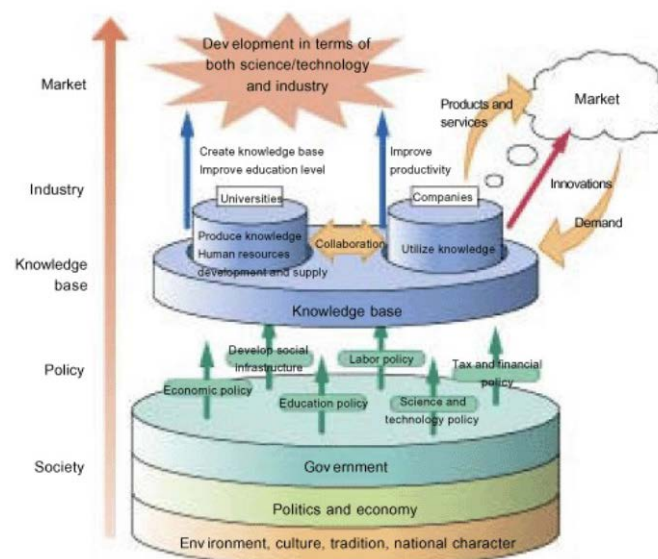
However, the concept goes beyond these obvious actors to include ‘institutions’ (Edquist and Hommen, 2008, 9): “*Sets of common habits, norms, routines, established practices, rules or laws that regulate the relations and interactions between individuals, groups and organizations. They are the rules of the game*”.

The components and their relationships involved in the NSI concept have been portrayed in various schema (see for example Figure 2 and 3).



**Figure 2 The benchmark NIS model**

Source: Bemer et al. (2001) in Groenewegen and van der Steen (2006)



**Figure 3 Conceptual of National Innovation System**

Source: [www.mext.go.jp/b\\_menu/hakusho/html/hpag200201/hpag200201\\_2\\_006.html](http://www.mext.go.jp/b_menu/hakusho/html/hpag200201/hpag200201_2_006.html)

Soete (2009, see also Schrempf et al., 2013) describes five main characteristic features of NSI as (1) particular role of the sources of Innovation, (2) Institutions (and organisations) including market and non-market institutions, (3) Interactive learning focuses on continuous learning in order to adopt to changes, (4) Interaction which includes interactions among actors and coordinated by institutions, (5) Social capital which most emphasises on trust among the actors.

#### Measurement of NSI performance

It is difficult to measure the performance of a national system of innovation (NSI) since such systems are complex and varied (Patel and Pavitt, 1994). However, according to the OECD the performance of an NSI can be measured and evaluated by assessing the knowledge or information flows amongst the key actors of government, university/public research institute, and the private sector (OECD, 1997; Milford, 2000). The criteria for measuring the effectiveness of an NSI proposed by the 1997 OECD document hinge on the pattern of knowledge flows in the system, and have been investigated using four criteria as follows:

Firstly, joint industry activities involving collaboration activities among firms can create a pattern of horizontal knowledge flows. The knowledge is exchanged between firms within the same industry or across industries. These activities can generate new innovations, which are useful and beneficial for industries because of the knowledge specialisation in each sector.

Secondly, the public/private interactions involve patterns of knowledge flow in a vertical direction. The importance of linkages between these two institutions leaves the NSI system open to a potential bottleneck, where mismatches in knowledge levels leads to wasted and sometimes unused technologies. In other words, while the universities or public research institutes are focusing on creating new scientific knowledge or new advances in technologies to fulfil basic research goals, the private sectors are seeking new knowledge to apply or improve their businesses, including creating new products.

The diffusion of technology is the third pattern of knowledge flow. According to Coombs et.al. (1987, 120-121): *“The diffusion of innovations not only spreads throughout the economy the increasing productivity and other benefits resulting from the innovations, but*

*also conveys information about their performance both to potential adopters and to manufacturers of innovations*". In this process, new innovations can be created during an ongoing diffusion process, as depicted by the feedback loop model. In the past, innovation processes had been taken as a linear model which always starts from S&T development and delivered to the producer or manufacturer to develop a new product. However, a more recent concept of technology diffusion, the feedback loop model has been used to describe the process, which demonstrates that the knowledge flows can be created in many ways.

Lastly personnel mobility, which is related to human resource flows within the system. The mobility of skilled people can create flows of knowledge and technological exchanges across institutions. When people move from public sector to industry or vice versa, they carry knowledge with them and it can lead to a knowledge exchange across sectors. The knowledge that people carry with them when they move is often termed 'tacit knowledge'. This kind of knowledge *"is a key flow in national innovation systems ... Personnel interactions, whether on a formal or informal basis, are an important channel of knowledge transfer within industry and between the public and private sectors"* (OECD, 1997, 18).

### **Different NSI Concepts and Policy-making**

There is a vast literature that has been written on the NSI approach, with different conceptual emphasis, and different implications for policy implementation. Two main approaches from Europe and America can be identified as particularly influential factors in Thai policy-making as discussed in the next chapter of this thesis.

The first approach is part of the US science and technology tradition. According to Lundvall (1998), who has researched the two different NSI approaches, the US science and technology tradition tends to regard the NSI concept as an aspect of the national science system and national technology policies. This view is supported by Edquist and McKelvey (2000, xv) who refer to Nelson's works on innovation systems by noting that *"most of Nelson's book contributions...emphasize the importance of development (and sometimes diffusion) of technological and scientific knowledge"*. This view rests on what Nelson and Rosenberg (1993, 3) identified as *"a strong belief that the technological capabilities of a nation's firms are a key source of their competitive prowess, with a belief that these capabilities are in a sense national, and can be built by national action"*.

The alternative approach comes in the NSI conceptualisation of Freeman and the Aalborg group (Lundvall and colleagues), amongst others, and focuses on the importance of routine-based learning by doing, using and interacting, and not just on research activity related to S&T. Thus Edquist and McKelvey (2000, p.xv) note that Lundvall puts “*more emphasis on the structure of production. He argues that user-producer relations play a particularly important role, although he also emphasizes how the national context influences firms’ ability and willingness to engage in such relations*”. They also highlight that the prevailing economic structure and institutional set up are at the core of NSI analysis. As Lundvall (2010, 318) puts it, “*a double focus is needed where attention is given not only to the science infrastructure, but also to institutions/organizations that support competence building in labor markets, education and working life*”.

Kastelle et al. (2009) argue that these two different approaches focus on different aspects of innovation. The first one (Nelson and others) focuses on the institutions supporting innovation, looking at proxy measures of research such as patents, education levels and research output. While the alternative approach emphasises the relationships between firms and other organisations, focussing on the cooperation and trust at firm/network level and links to the national level.

Lundvall et al. (2009, 2) have defined the two different perspectives on the NSI concept as the narrow and broad definition: “*a narrow one, equalling innovation to science and technology, and broader one encompassing learning, innovation and competence-building at different levels of aggregation*”. The narrow perspective fits with earlier analyses of the US national science system and technology policies in which it was convenient to map the indicators of national performance and specialisation with innovation and R&D effort. On the other hand, “*the broader definition of innovation systems includes social institutions, macroeconomic regulation, financial systems, education and communication infrastructures and market conditions as this have a major impact on innovation*” (Gu and Lundvall, 2006, 293).

This distinction has significance for policy advice for a developing country. The narrow view of the NSI concept, which can be termed the STI (Science-Technology-Innovation) approach, focuses on innovation based upon R&D efforts. While the broader definition, which is termed as DUI (Doing, Using and Interacting), is learning focused, especially with regard to tacit and localised knowledge (Jensen et al, 2007 in Lundvall et al., 2009).

Lundvall et al. (2009) also argue that in a less-developed country there is an ‘innovation paradox’: the investment and progress in science is not matched by innovation outcomes and economic performance. This ‘innovation paradox’ cannot be explained by the narrow definition of NSI. Furthermore, (Lundvall, 2007, 3) argues that: “*Without a broad definition of the national innovation system encompassing individual, organizational and inter-organizational learning, it is impossible to establish the link from innovation to economic growth*”.

### **NSI as conceptual framework or policy prescription**

The NSI approach is used by some as a policy framework to construct ST&I policy at different levels (regional, national). Others see it more as a conceptual and analytical tool to study innovation in order to analyse the ST&I development process and to identify problems, which may then lead to prescriptive guidance for policy-makers. As Lundvall (2010, 320) puts it: “*The innovation system concept may be regarded as practical tool for designing innovation policy. But it might also be seen as a synthesis of analytical results produced by scholars working on innovation*”. Similarly, Feinson (2003, 14) notes that the NSI concept is perceived by economists and policy makers “*as having great potential both as a source of understanding of the roots and primary causes of the gulf in economic development, as well as a powerful conceptual framework that can produce policies and institutions capable of bridging that gulf*”.

Adopting the NSI concept for use in the policy making process has been criticised by many scholars who argue that it is inappropriate as a tool. Teixeira (2014, 182) summarises some problems and criticisms from many scholars with regard to the adoption of the NSI concept as it is still subject to a narrow approach in terms of concepts and policy practice. In particular, it is difficult to implement since it lacks operational guidelines and lacks of appropriate measurement tools and guidelines for use in in developing regions or countries.

Additionally, Edquist (2005) points out the NSI approach suffers from conceptual diffuseness. The terms involved in this concept have been used by many scholars in different ways. Moreover, he states that the NSI is not considered as a formal theory and so it “*should be labelled an approach or conceptual framework rather than theory*” (Edquist, 1997 in Edquist 2005, 186). Cooke (2003, 6) makes a similar critique: “*The systems approach, as has been said earlier, only provides an analytical framework, and is not itself a*

*substantive theory*". However, Lundvall (2007, 18) has rejected these critiques, arguing that: "Using the perspective helps to see, understand and control phenomena that could not be seen, understood or controlled without using this (or a similar) concept. In this sense it does what theory is expected to do: it helps to organize and focus the analysis, it helps to foresee what is going to happen, it helps to explain what has happened and it helps to give basis for rational action".

Furthermore, Ludvall (2007, 31) argues that: "We use this concept as a focusing device in order to better understand how innovation affects economic development at the national level. Within this broad view many factors contribute to innovation and it might be seen as a problem that almost all aspects of society need to be brought in to explain the actual pattern of innovation".

The more important issue for this thesis, however, is the way in which the NSI approach has been operationalised in practice through policy measures. NSI has been widely adopted by many countries and organisations all over the world, but because of ambiguity with the conceptual underpinnings of the approach and diffuseness of definitional terms, there are many ways in which NSI framework is adopted by different institutes. Lundvall (2007) thus sees "distortion" in the way that the two approaches of the NSI concept - the STI (narrow) and DUI (broad) – have been confused, since most of the adoption process take only the narrow approach.

An important aspect of this distortion is the role of international organisations such as the OECD and the EC in promulgating the narrow NSI approach because it is more readily amenable to quantifiable indicators (Eparvier, 2005; Lundvall, 2007). As (Lundvall *ibid*, p.22) notes: "it is much easier to develop quantitative analysis of R&D and patents, than it is to measure organizational forms and outcomes of organizational learning". Further criticism on this issue is also made by Lundvall (2009, 3-4) with regard to other approaches such as the triple-helix model and Mode2 knowledge production approach: "...these approaches contribute to the distortion. These perspectives capture processes linking science and technology to innovation...we refer to this as STI learning".

Balzat and Hanusch (2004, 197) summarise the overview on the NSI research as it was adopted into three main categories which are "policy-oriented studies that frequently combine the NIS approach with the terminology of corporate benchmarking, contributions to

*the formalization of the concept of NIS through descriptive or analytical models, and NIS studies of countries beyond the group of highly industrialized economies”.*

### **National innovation system in developing countries**

Although the NSI approach has attracted widespread interest, its adoption and application as policy has been particularly focussed on the less developed countries. As Feinson (2003, 18) puts it *“successful economic and industrial development is intimately linked to a nation’s capacity to acquire, absorb and disseminate modern technologies. Whereas in developed economies the innovation system serves the role of maintaining or improving an already established level of competitiveness and growth, developing countries are faced with the task of ‘catching-up’”*. The process of catching up is the main point of the NSI in the developing countries but the difficulty is how to do so.

Arocena and Sutz (2000, 55) investigated the adoption of the NSI approach in less developed countries (the South) and noted that most empirical research that contributed to the NSI concept was from the developed world (the North): *“However, its applicability is not confined to those countries. In fact the NSI approach can be useful for studying the specifics of innovation processes and policies in the South, as well, and can draw attention to similarities and differences from those in the North”*. In the same study, Arocena and Sutz raise the concern that the NSI concept emerged as a descriptive tool to understand what happened in the ‘North’ (which in this case includes Japan!) but has then been put forward as a prescriptive tool for guiding innovation policy in the South. In other words, it emerged in the North as an ex-post concept but became an ex-ante concept in the South. They also suggest that the concept of NSI is inherently political: *“NSI describes situations in which conflict is present: NSI are not socially neutral: its configurations affect unequally different social groups”* (Arocena and Sutz, 2003, 5-6).

Altenburg (2009, 33) compares the innovation systems in developing countries to a member of the OECD countries and suggests that innovation systems in less developed nations are different in many ways: *“They need to cater for different needs; they build on institutional frameworks that tend to be much less formalised, and rules that are less enforceable; and the key agents as well as the incentives that determine their behaviour tend to be very distinct”*.

Gu (1999), using the NSI label descriptively rather than conceptually, the following characteristics are typical of developing countries:

1. *“NIS in developing countries are less developed by order, in terms of institutional composition, the sophistication of scientific and technological activities, and linkages between organizational units”* (p.43).
2. *“NIS in developing countries are development sub-phase or development-level specific. This is a natural derivation from the heterogeneous historical transition in which institutional structure and the ability of an economy in raising productivity gains from modern sources change over time”* (p.44).
3. *“Extraordinary ‘enhanced learning’ is the key for a successful catching up which requires and is supported by a rapid development of their NIS”* (p.45).
4. *“The role of market in promoting learning and generating change needs to receive special attention”* (p.46).
5. *“For developing countries, learning to innovate is more closely related to capital investment”* (p.47).

According to Intarakumnerd (2006, 100), the number of studies on the NSI in developing countries is still small compared to developed nations. Most countries that have been investigated in terms of their NSI are Korea, Singapore, and Taiwan. As he puts it *“Little is known about the innovation, entrepreneurs, dynamics and changes in a less successful developing country where its innovation system can be characterised as weak and fragmented”*.

This PhD thesis is one of the studies contributing to the NSI work in developing countries. This study aims to investigate how the NSI approach is being implemented in Thailand and what impact the NSI approach has on ST&I development process in Thailand.



## 2.2 Exploitation of Public Research, the Triple Helix Concept, and Technology Transfer

This section brings other concepts and approaches related to the public-private relationship together with the NSI approach for consideration. The concepts include the exploitation of public research when knowledge is created and embedded in the public sector, how it will be utilised and through which channels that knowledge will be transferred to the private sector. Then the concept of the Triple Helix model is briefly described. Since it is not the main analytical framework in this thesis, this concept is examined to explain another analytical view of public-private relations, particularly the university-industry-government. The last topic in this section concerns the process of technology transfer as it is the main practice of bringing knowledge from one actor to another in the innovation system or making knowledge/technology flows from public to private sector (or vice versa). This section of the literature review provides more analytical tools to investigate empirical data presented in the next chapter.

### Exploitation of public research

Public sector research is central to the science-push view of innovation. It is almost taken for granted that research done in universities or government research laboratories could (and certainly should) lead to useful and economically valuable innovation. As the Science, Business Innovation Board, AISBL (2012) put it: *“When companies and universities work in tandem to push the frontiers of knowledge, they become a powerful engine for innovation and economic growth”*.

According to the Fact Sheet produced by the European IPR Helpdesk in 2014 (p.1), public research is defined as *“the activity carried out by publicly funded research centres. These can be considered institutions, universities, enterprises, whose activity is primarily funded with public resources, and that here are referred to as public research organizations (PROs)”*. Such ‘public research’ is conducted by universities or other publicly-funded research organisations. Although the focus in this thesis is on technology transfer, it is worth noting that university teaching and experience gained in public research organisations provide another important channel for the transfer of knowledge as people move from education or work in the public sector to jobs in the private sector. As indicated in a document produced by The Innovation Policy Platform (IPP) (undated, 1) *“perhaps the*

*major contribution to innovation from public sector research comes from the person-embodied knowledge and skills it nurtures”.*

#### *Why PROs perform R&D activities?*

In the past, public research organisations (PROs) were seen as the main knowledge generators which produced advanced knowledge to provide new technologies to a firm. According to Belinko et al. (2004, 2) PROs perform R&D *“to develop and maintain their core competencies, to broadly disseminate knowledge, to provide policy support, to support the private sector, [and] to launch commercial ventures”*. Funded by public money, PROs respond to the public needs. For example, the US situation was described by the Office of Technology Assessment, USA (1994, 3): *“the Federal Government funds nearly half of R&D performed in the United States, largely to meet public objectives such as national defense, space exploration, improved health, greater food production, and energy conservation”*. In developed countries, PROs operate mainly to target societal requirements not adequately addressed by private industry, but in many developing countries the PROs are seen as central to the development of national R&D capability.

Public research is normally seen as the creator of advanced knowledge and the provider of that new knowledge. As Mazzoleni and Nelson (2007, 1512) put it: *“Universities and public labs have contributed to the development of technological capabilities in different forms across countries and economic sectors”*. However, the indisputable evidence that public sector research has contributed to innovation, sometimes through break-through inventions, has led to an ‘heroic’ narrative of technology transfer. Often known as the ‘linear model’ this sees basic research (mostly in form of science) conducted in the public organisations producing results that can then be transferred to the industry and applied or commercialised in the form of a new technology.

One important misunderstanding is that technology is an applied science which contributes to the linear model of innovation in the utilisation of public research. It is true that some technologies can be created from applying scientific knowledge to produce it but it is not necessary to be that way. As Barnes (1982, 168) puts it: *“Technology and science could both survive as forms of institutionalized activity independently of the other, but they are in fact enmeshed in a symbiotic relationship.”* Some technologies were created and used without any supporting scientific knowledge. This is confirmed by Rosenberg (1982, 143) as he puts

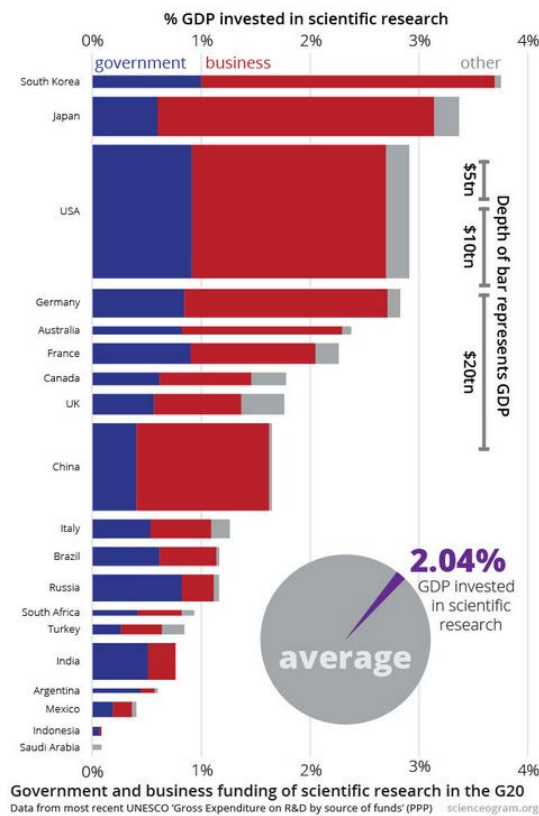
it: *“Technological knowledge was long acquired and accumulated in crude empirical ways, with no reliance upon science. Scientific knowledge, of course, would have vastly accelerated the acquisition of such knowledge, but historically, vast amounts of technological knowledge were collected and exploited, and this trend continues today”*.

In addition, not only science can contribute to the process of technology development but technology also does the same on scientific progress as MacKenzie and Wajcman (1999, 9) put it *“it is mistaken to see the connection between them as one in which technology is one-sidedly dependent on science. Technology has arguably contributed as much to science as vice versa -...”* As Dosi et al. (2006, 1451-1452) note that *“..., technological innovations have sometimes preceded science in that practical inventions came about before the scientific understanding of why they worked...”*

As mentioned above about the misunderstanding of science and technology, it creates a concept of linear model, as it is started from basic research (mostly in form of science) conducted in the public organisations then sent to the industry to be applied or commercialised (develop a new technology).

The problem for the innovation process is that the linear model rarely works in reality. As Cohen et al. (2002, 4) put it: *“there is broad consensus that while the linear model may capture key aspects of the innovation process in some settings, its applicability is limited”*.

As a reaction to the limitations of the linear model approach it has been suggested that better results can be obtained by an approach involving a feedback loop where the public and private sectors create relationships as a network in order to keep informing each other. This idea is supported by Cohen et al. (2002) who suggest *“a more interactive relationship where public research sometimes leads the development of new technologies, and sometimes focuses on problems posed by prior developments or buyer feedback”* (Cohen et al, 2002, 1).



**Figure 4 Government and business funding of scientific research in the G20**

Source: The Conversation

<https://theconversation.com/infographic-how-much-does-the-world-spend-on-science-14069>

Governments spend large sums of money on public research (see Figure 4) and so it is important to find ways to maximise the benefits to innovation and national well-being. From the data shown in Figure 4, although the percentage of public investment in S&T is smaller than private investment in most countries, the value of investment is still concerned with a large amount of money. Particularly, the first three largest R&D investors including USA, China, and Japan with less than 1% of GDP invested by the government is bigger than the total GERD in some countries when considered the value of their GDP. Furthermore, in some countries like India and Russia, the percentage of investment from government is bigger than from the business. It can be seen that there is a large amount of money put into the public research. Undoubtedly there should be a large number of public research results to come out from those investments.

Concomitantly, attempting to exploit public research can benefit the public organisations themselves, as indicated by European IPR Helpdesk (2014, 2) as follows:

- *“Generate additional revenues for PROs;*
- *Promote open innovation;*

- *Increase access to and sharing of research data and publications;*
- *Engender possibilities for collaboration in research and teaching;*
- *Raise the PRO profile and get publicity;*
- *Broaden the job market for students”.*

The Fact Sheet (2014, 4-7) also analyses two types of channel to exploit public research through industry. The first one is *commercialization channels* which are categorised into five main activities including:

- *“Assignment—the ownership of IP is permanently transferred from one party (the assignor) to another party (the assignee). Consequently, the assignee becomes the new owner of the IPR.*
- *License—a license agreement is a contract under which the holder of IP (licensor) grants permission for the use of the intangible asset concerned to another person (licensee), within the limits set by the provisions of the contract.*
- *Joint venture—a type of collaborative commercialisation. It is a situation where scientists and private companies jointly commit resources and research efforts to projects; research activities are carried out jointly and may be co-funded.*
- *Spin-off—a separate company usually established to bring IP, in this case resulting from public funding, onto the market.*
- *Consultancy—it comprises contract research and/or faculty consulting. The first channel consists of a research commissioned by a private company to pursue a solution to a problem of interest. In the case of contract research, the results generated by the PRO should be owned by the private-sector party.”*

Secondly, the *knowledge transfer channels* which are identified based on the flow of knowledge created by PROs and cannot be completely separated from the commercialisation channels. These channels can be listed as:

- *“Publishing—Publication is deemed to be the most suitable means of knowledge dissemination for PROs as it permits the fastest and open diffusion of research results.*
- *Conferencing and networking—Alongside publications, professional conferences, informal relations, casual contact and conversations are among the channels ranked as most important by industry for the flow of knowledge between private and public sectors.*

- *Consortium agreements*—When a public-private partnership for conducting a R&D project is created, the parties usually sign a so-called consortium agreement.
- *Personnel mobility*—can be executed through personnel exchanges, employment, students' secondment and placement or collaborative research,
- *Standards*—A standard is a document, established by consensus and approved by a recognised body, which provides for common rules, guidelines or characteristics for activities or their results and having the purpose of achieving an optimum degree of order in a given context” (p.8-10).

In order to produce good knowledge and make it potential useful for industry, the public knowledge producers need good preparation. The Innovation Policy Platform (IPP)'s document (p.1-2) proposes some important factors that affect the ability of universities and PRIs to contribute to innovation:

- *“the requisite capabilities and resources to perform useful research including hard R&D infrastructures and soft organisational capabilities for managing and exploiting their research activities.*
- *the demand for the knowledge they produce.*
- *the knowledge transfer infrastructures to facilitate and accelerate the commercial exploitation of public sector research.*
- *Scientists and engineers work under certain norms and incentive conditions that can also influence the types of research related activities they engage in.*
- *For exploitation through the spin-off channel, access to start-up finance is an important factor.*
- *Public policy intervention”.*

### **Technology transfer process**

Zhao and Reisman (1992, 19) suggest that: *“TT involves more than just technological or engineering dimensions. With improved understanding of the multidimensional facets and the multidisciplinary views of TT, engineering and technology managers and/or policy makers can better formulate strategy so as to transfer technology more effectively”.*

Gibson and Smilor (1991, 290) have propose a ranking of technology transfer in terms of three levels of involvement:

- *“Technology development (Level I) is the most fundamental level. Here the transfer process can be largely passive through such means as research*

reports, journal articles, and computer tapes. A second, more involved level of technology transfer,

- Technology acceptance (Level II), includes the responsibility of making certain that the technology is made available to a receptor(s) that can understand and potentially use the technology.
- Technology application (Level III), includes the profitable use of the technology in the marketplace as well as other applications such as intra-firm processes”.

#### Determinants of effectiveness of technology transfer

Bozeman (2000, 637-644) identifies the determinants that affect the process of technology as follows;

- *“Characteristics of the transfer agent*
- *Characteristics of the transfer media*
- *Characteristics of the transfer object*
- *Characteristics of the demand environment*
- *Characteristics of the transfer recipient”*

Additionally, Gibson and Smilor (1991, 287) suggest more determinants affect the process of technology transfer including *“four variables: communication interactivity, cultural and geographical distance, technology equivocally, and personal motivation-are central to technology transfer processes within and between organizations”*.

Grant and Gregory (1997, 149) explore the issue of 'tacitness' embedded in the firm that influence the technology transfer process as they put it: *“the ability of a firm to transmit its technology is considered to be a function of not only the knowledge accumulated through using the technology, but also the form in which this knowledge has accumulated”*.

Jolly and Creighton (1977, 82-84) explore the factors that contribute the movement of knowledge from source to receiver and explain them as follows:

- Method of Information Documentation.

- The Distribution System, *“this is the physical channel through which technology flows...”*
- Formal Organisation of the user, *“the determination of an attitude to accept or reject change by a formal organization”*.
- Selection process for projects (user’s contribution)
- Capacity of the Receiver, *“the capacity of the user to utilize new and/or innovative ideas”*.
- Informal Linkers in the receiving organisation.
- Credibility as viewed by the Receiver, it *“is an assessment of the reliability of the information as perceived by the receiver”*.
- Perceived Reward to the Receiver.
- Willingness to be helped

#### Barriers to Technology Transfer

Jung (1980, 20-23) suggests the barriers to technology transfer including *“Communication difficulties due to different languages, potential mistrust due to the uncertainty about the mutual environments, organisational barriers, geographical barriers and limited receiver capacity”*.

In addition, Ehrlich (1985, 20-22) proposes the barriers which impede the success of technology transfer as *“(1) organizational structures which inhibit the flow of communication between different groups; (2) the technology imposing specialized knowledge on the people who work with it; and, (3) the individuals themselves who have cultural biases which inhibit communication with people from different professional and experiential background”*. Finally, she makes a conclusion in her research by suggesting a different view to look at the process of technology transfer from *“a sequential set of operations that begins with research and ends with a product”* to a partnership and communication process (p.23).

#### **Knowledge/technology flows from public to private sector**

According to Arvanitis et al. (2008, 1866) *“knowledge and technology transfer between academic institutions and the business sector is understood as any activities aimed at*

*transferring knowledge or technology that may help either the company or the academic institute – depending on the direction of transfer – to further pursue its activities”*. Lerch et al. (2010, 6) suggest that the process of technology transfer between PROs and companies involves different types of relationship. As they put it: *“These may include in the case of involvement of financial resources third party financed research, licensing, spin-off companies and the hiring of students, graduates, and researchers and in the case of absence of financial resources publications, presentations, informal exchange, other spill-overs and serendipity”*.

To utilise or exploit the technology created in the public sector requires the process of technology transfer to deliver technology to the user. But the process itself is not simple or easy to execute since it requires many actors and complicated networks to be involved in this process. As Large and Belinko (1995,67) put it: *“The attempt to transfer a technology from a publicly funded laboratory to a profit-oriented manufacturer can be a lengthy and complex process, involving several organizations and several key individuals within each organization”*.

The mechanism of technology transfer can be conducted in various ways; however, in this thesis, the main focus will be on the movement of technology from the public to private sector, as examined in case studies (chapter 6). There are many previous studies from scholars interested in the process of technology transfer between public and private sector. Underlying this research is the idea, as Faulkner (1992, 1) put it, that *“prosperity is thus seen as lying in our ability to foster collaboration between academic and industrial R&D, and to enhance the ‘transfer’ of new technologies from public to private sectors”*. Faulkner and Senker (1995, 1) point out the different goals of the public and private laboratory as *“industrial lab(s) are primarily concerned with the production of innovations, to sustain or improve the market performance of their companies, whilst academic lab(s) are primarily concerned with the production of knowledge...”*. This shows the difficulty of the collaboration of those two sectors. From Faulkner’s research, the study has been conducted using interviews with 66 researchers in 35 companies in different fields which are biotechnology (12 researchers), ceramics (29 researchers) and parallel computing (25 researchers). Faulkner and Senker (1995) identify a number of key factors influencing the strength and character of industry and public sector research (PSR) linkages as follows:

- *Industry sector factors*: the character of new product development, the size of the firm.
- *PSR – related factors*: the availability of expertise in PSR, public context and the role of PSR as a key user.
- *Technology – related factors*: general factor of the technology, age and dynamism of the field.
- *Firm – level factors*: existing knowledge base, propensity to linkage.

Faulkner and Senker (1993, 11) also make the significant point that technology transfer follows different patterns in different sectors: “*in biotechnology or pharmaceutical where innovation is strongly knowledge–led following the classic linear model...by contrast, innovation in both ceramics and computing is more ‘circular’ in nature involving strong feedback between technology users and suppliers in the development of new products so that other companies are likely to make the greater contribution to external STI [scientific and technological inputs]*”.

Additionally, Large and Belinko (1995, 81-82) propose seven propositions that are required to facilitate the successful technology from public to private sector as follows:

- “*A complete team of key organizations, which may be situation-dependent.*”
- *A complete set of key individuals, or "linchpins," within each organization, which may be situation-dependent.*
- *The sequence of soliciting organizations and individuals can affect the likelihood of success.*
- *The stage of commercialization in which organizations and individuals are solicited can affect the likelihood of success.*
- *Every linchpin must be totally committed to the success of the transfer.*
- *A potential linchpin's level of commitment to the transfer team is a function of his/her perceptions of: (1) the prior linchpins' credibility, (2) the prior members' commitment, and (3) a set of personal benefits comprising incentives and rewards.*
- *The team of linchpins should remain intact until the commercial launch is successfully achieved or the project is suspended”.*

On the other hand, Pertuzé et al. (2010, 85-90) suggest seven guidelines for the firm side to enhance the chance for success in industry-university collaboration. The guidelines do not

guarantee the success of but help firms to steer around the pitfalls. The seven keys to collaboration success can be described as follow:

- *“Define the Project’s Strategic Context as Part of the Selection Process; Indus-try-university collaborations must be aligned with the company’s research and development strategy and address a tangible need of the company”*.
- *Select Boundary-Spanning Project Managers; the boundary spanner is responsible for facilitating knowledge exchange from external sources and knowledge dissemination within the organisation.*
- *Share with the university research team the vision of how the collaboration can help the company; this is about trust building between firm and university researcher, and firm can make decision to disclose firm’s strategy and future plan to the researcher.*
- *Invest in long-term relationships; the study suggests that the presence of previous relationship is positively correlated with the outcome of the subsequent collaboration.*
- *Establish strong communication linkage with the university team; a regular communication such as site visit, telephone, video conference, or short-term personnel exchange can enhance the success of collaboration.*
- *Build broad awareness of the project within the company; all involved staff should be informed about the collaboration and they can prepare for further adoption of new knowledge/technology created from the collaboration.*
- *Support the work internally both during the contract and after, until the research can be exploited; the collaboration does not completely succeed after the research contract ends but after it is fully utilised and creates the impact for the firm, so the project manager has to continue support it and make sure the firm achieves the full benefit.*

### **Case studies for success and failure in innovation and technology transfer**

There are two studies that attempted to compare successes and failures in innovation: SAPPHO (Scientific Activity Predictor from Patterns with Heuristic Origins) from SPRU, University of Sussex and FIP (Falk Innovation Project) from the Falk Institute for Economic Research in Jerusalem.

#### SAPPHO Project

*“Project SAPPHO was designed as a systematic attempt to discover differences between successful and unsuccessful innovations. The technique employed is one of paired*

*comparison, where a successful innovation is compared with an unsuccessful innovation, any difference between the two being noted” (Rothwell et al., 1974, 259). The SAPPHO project was conducted in two phases, the first phase comprised 29 pairs including 17 pairs in chemical processes and 12 pairs in scientific instruments. In the second phase a new total of 43 pairs was included: 22 in chemical processes and 21 in scientific instruments. The result from SAPPHO supports the hypotheses for explaining innovative success that are listed below (Rothwell et al., 1974, 277-289):*

- *“Attention to market explanation and the importance of need satisfaction.*
- *Key individual explanation of innovative success, particularly with regard to the ‘business innovator’*
- *Strong R & D explanation of successful industrial innovation.*
- *Communication explanation*
- *Scale explanation*
- *Planning and management techniques explanation*
- *Qualified scientists/engineers explanation*
- *Other hypotheses tested: Lead time explanation, Familiarity explanation, Basic research explanation”.*

The conclusion from the SAPPHO project suggests that the most important factors linked to success *“are those relating to the importance of need satisfaction” (p.289).*

Rothwell et al. (1974, 259-260) also summarise five variables from SAPPHO that distinguish success from failures as follow;

- *“Successful innovators were seen to have a much better understanding of user needs.*
- *Successful innovators paid more attention to marketing and publicity.*
- *Successful innovators performed their development work more efficiently than failures but not necessary more quickly.*
- *Successful innovators made more use of outside technology and scientific advice, not necessarily in general but in the specific area concerned.*
- *The responsible individuals behind the successful innovations were usually more senior and had greater authority than their counterparts in unsuccessful projects”.*

### FIP

Teubal et al. (1976, 355) explain the aim of FIP: *“The purpose of our project is to develop a framework for performance in innovation of science-based industry. Such a framework*

would enable us to define optimum strategies for science-based firms and optimum patterns of government support to science-based industry.” The project studied 23 R&D programmes in the Israeli Biomedical Electronics Sector; 5 of them are categorised as successes while 18 are considered as failures. The project “*identifies a small set of variables which are correlated with the innovation performance of R & D programme*” in the selected industry (p.354).

FIP resembles the SAPPHO project as they share similar units of analysis and also the classification of success cases and failures. However, Teubal et al (1976, 356-357) suggest the differences between these two projects are as follows:

- The FIP “is not based on pairs - there are cases of more than one failed R & D program corresponding to a particular innovation and in several cases there is no successful program at all”.
- In FIP, “the areas or markets associated with the failed programs are not necessarily related to the areas or markets of the successful ones”.
- In SAPPHO, a search is made for variables which differentiate success from failure. These variables do not include market or area characteristics. In FIP, they search for variables which are correlated with performance, and they may include area or market characteristics”.

Teubal et al. (1976, 357) conclude that: “*It follows that our methodology is more appropriate than SAPPHO’s for studying a country’s comparative advantage in different areas or markets of science-based industry. SAPPHO’s methodology is, on the other hand, more adequate than ours for analysing the relative importance for performance of other variables related to firm behaviour*”. They also describe the key variables identified in the project which correlate with the performance of R&D programmes (Teubal et al., 1976):

- *Exogenous (R&D program) variables*: “Market determinateness, Product acceptance, Type of competition, Extent of competition, R & D threshold, Marketing threshold, Market size, Rate of growth of market, Intensity of spectrum effects, Product life” (p.360-361).
- *Endogenous (area) variables*: “Innovation profile: functions and price, Dominant factor in undertaking the programs, Technological uncertainty, Spectrum of products offered by firm, Degree of offensiveness, Synergy in R & D with other programs, Synergy in marketing with other programs, Marketing channel” (p.361).

- *Firm variables*: “Firm size, Firm growth, Number of years in biomedical electronics, Previous line of activity, Structure of organisation of biomedical electronics” (p.361)
- *Other variables*: “Origin of idea” (p.361).

From the results of FIP, it was concluded that: “*The central variables are market determinateness (an area characteristic) and the innovation profile (an attribute of R & D programs). The nature of the idea leading to R & D programs, the type of competition prevailing in the industry and the notion of product acceptance all complement the main explanation given by these two variables*” (Teubal et al., 1976, 377).

These two projects were compared and analysed by Mowery and Rosenberg (1982, 221) who suggested that: “*The success criterion thus deals more with commercial diffusion than with the innovation process per se*”.

#### Case studies for technology transfer

Larsson et al. (2006) present the paper names *Technology Transfer: Why some succeed and some don't* in TT'06 conference using the case studies from technology transfer cases conducted by the Software Engineering Institute, Carnegie Mellon University, large firms, and small firms. The Software Engineering Institute involves with three different stages of technology development and transfer including *create*: basic research and technology development, *apply*: large scale technology prototype and field test cooperating with the industry, and *amplify*: technology transferred and disseminated to the industry. The paper deals with the obstacles and problems facing technology transfer process in this institute. Many questions have been asked including which point the transfer should start? At which point the industry should be involved? What are the factors influencing the success of technology transfer process from the university to industry? This paper uses the different case studies to find out the answers. The case studies are divided into two main groups: successful examples, and a failure case.

Success cases, there are five cases within three different categories including

1. *Research to large product company*. There are two cases categorised in this group: success1 and success2
  - Success1 involves with a prototype of robot automation that was executed by a research unit at a large product company. The technology transfer process is from the research unit to the product company. The paper identifies several success factors for the case including continuous communication with the receiving party,

someone championing the technology, clear interest in the technology, and feeling part of the transfer.

- Success2 deals with tool development and software maintenance aiming for improving internal efficiency in the company. The research was conducted by the company research unit and transferred to the product company. The success factors are identified as follows: a willingness to help and respond to the customer or user from the technology provider, encouragements from the technology receiver and their contribution to the research project lead to a positive working climate and brought success to the project.

2. *University to large product company: success3 and success4*

- Success3 attempted to transfer a tool developed in the university to a product development company. This case demonstrates how to bring a theory embedded in the tool into a practical use in the industry. The transfer process becomes successful because one member of the research team works as a consultant in the product company. The case also has a senior specialist to evaluate an application and value of technology before it was transferred to the company.
- Success4 is about transferring the analysis tool for complex system to the product development company. The researcher working in this project used to work in the development project for this system before, therefore, he has a thorough understanding of the system and also a strong network of contacts. This factor was vital to the success of the case.

From success3 and success4, the common key factors are identified as a strong technology receiver, technology provider's ability to respond to the user need by translating theory to a tool in a practical use, and a mutual trust between technology provider and receiver.

3. *University to small product company: success5*

- Success5 is the case of Spin-off Company from the university. The case deals with a novel debugging technology developed in the university. The researcher involved in this project has an entrepreneurial mind-set and also creates contacts with the potential customers since he was a researcher in the university. Moreover, the university was active in supporting spin-off activity. The technology was evaluated by the existing industrial company who becomes a potential customer later. The key

success factors for this case are the entrepreneurial skill of the researcher and the network between the researcher and the customers.

#### Failure case

The case involves two steps of technology transfer: from the university to the company research unit, and from the research unit to the product company. The transferred technology is a very high standard real-time analysis. The development of technology was very complex and difficult. The stake holders involved with the project have meetings regularly and the have been working very closely. The job rotation scheme between units was deployed to facilitate the technology transfer. However, after three years, the attempt to do a technology transfer failed. The main reason for this is because the technology is very complex and the receiver lacks of ability to adopt it. Another reason is that *“the perceived value of the tool was less than the cost of assigning developers to the cause, i.e. the business case was not strong enough to pursue the product company”* (p.26).

From this research, Larsson et al. (2006) summarise the important factors influencing the success of technology transfer process as follow;

1. A strong receiver who genuinely needs a technology
2. A transferred technology should be ease of deployment or ease-of-use
3. Minimising the effort for adopting or taking ownership of transferred technology
4. An efficiency communication and collaboration between transferor and receiver
5. Mutual trust between two side
6. Expert and management commitment in the receiver side
7. Receiver's competence to maintain and utilise the technology
8. Timing

The research points out that for the failure case, although there are many success factors taking place in the case, it can still be a failure *“due to the reasons not clearly envisioned”* (p.26). Moreover, this research suggests that *“the success is dependent on several important factors, including the maturity of the technology, receiver's expectations, and commitment from receiver. Moreover, successful technology transfer is also a matter of timing. The research must be in a mature enough state and the results from a transferor must fit in the receiver's culture and business situation”* (p.23).

### *Influential factors for technology transfer process*

From the cases mentioned above, several factors can influence the probability of success when conducting technology transfer or innovation. Many previous studies also suggest that certain factors can have both negative impact and positive impact on the process of technology transfer. Many of which have been pointed out earlier in this section. Some interesting influential factors are listed below:

- Technology readiness and capability. The technology capability and maturity are the important factors that determine the success of the technology transfer as the technology is the first factor that needs to be ready in this process. This factor is pointed out by Larsson et al. (2006) and other scholars including Heslop et al. (2001, 369). As they put it: “*Successful technology transfer begins with the identification of appropriate candidate technologies for transfer*”. Their research aim was to create a tool to assess technology readiness by constructing the model named The Cloverleaf Model. The model considers four main factors to calculate and score an individual technology before making a decision for technology transfer including market readiness, technology readiness, commercial readiness, and management readiness. Technology readiness is categorised into different levels. The Technology Readiness Level (TRL) was initiated by NASA in earlier 1980s with 7 levels of technology readiness then it has been changed to 9 levels<sup>2</sup>. Later on, several organisations including U.S. Department of Defense (DoD), the European Space Agency (ESA), and the European Commission (EC). Each organisation defines TRL in different ways depending on their application. The European Commission (EC)<sup>3</sup> has a broader definition of the TRL that can be applied to the general technology as follow.

- TRL 1– basic principles observed
- TRL 2– technology concept formulated
- TRL 3– experimental proof of concept
- TRL 4– technology validated in lab

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<sup>2</sup> [http://www.nasa.gov/topics/aeronautics/features/trl\\_demystified.html](http://www.nasa.gov/topics/aeronautics/features/trl_demystified.html)

<sup>3</sup> [http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014\\_2015/annexes/h2020-wp1415-annex-g-trl\\_en.pdf](http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf)

- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
  - TRL 6– technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
  - TRL 7– system prototype demonstration in operational environment
  - TRL 8– system complete and qualified
  - TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)
- Receiver’s capability. Cohen and Levinthal (1990, 128) suggest that “*the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities. We label this capability a firm's absorptive capacity and suggest that it is largely a function of the firm's level of prior related knowledge*”. Even if the public side is able to provide an excellent technology to the firm, if the firm lacks the capability to adopt it, the technology transfer will not be successful. Without background knowledge and an appropriate production facility in the firm, the technology transfer process cannot be completed. Faulkner and Senker (1995) identify the existing knowledge base in a firm as one of the influential factors determining public and private collaboration. Similarly, Faulkner and Senker (1995) point out the firm’s existing background knowledge as one of the main factors determining the public-private relationship in technology transfer.
  - Trust and attitude. From the success cases in Larsson et al. (2006), mutual trust is one of the main factors that make the cases become successful. “*Trust is a type of expectation that alleviates the fear that one's exchange partner will act opportunistically*” (Bradach and Eccles, 1989, 104). Trust should be concerned with two sides of a relationship. A good relationship should be led by a mutual trust between two parties. Another factors relating to this issue is the attitude. Lerch et al. (2010, 4) explain the problem for public-private technology transfer having different ideas and attitude on conducting R&D: “*One of the main reasons for this observation is the fear of losing know-how from joint research activities, as scientist from academia are primarily eager to publish their findings, whereas the private sector partners are looking forward to secure their competitive advantage in terms of profiting from first-mover advantages*”. Similarly, Faulkner and Senker (1995, 1)

argue that: “*industrial lab(s) are primarily concerned with the production of innovations, to sustain or improve the market performance of their companies, whilst academic lab(s) are primarily concerned with the production of knowledge*”.

Different attitudes lead to different way of performing R&D activity and sometimes to the different ultimate goals between technology provider and receiver. Furthermore, having different attitudes between two sides potentially impedes a mutual trust in technology transfer.

- Timing. This is one of the factors mentioned in Larsson et al. (2006). It is not very clear about when the perfect time is to do a technology transfer and when it is the best time for the technology receiver to get involved in the process. Allain et al. (2011, 1) argue that “*the buyer of an idea should take over development at the stage at which he has an efficiency advantage*”. Furthermore, they also suggest that “*any other timing increases the cost of innovating and might lead to the innovation being abandoned. The innovation rate thus crucially depends on the timing of technology transfer*” (p.2). Therefore, the timing for conducting technology transfer depends on the specific context and situation in each case.
- Effective communication and collaboration between transferor and receiver. These are other factors specified by Larsson et al. (2006) as key factors involved in technology transfer. Gibson and Smilor (1991, 287) explain that “*four variables: communication interactivity, cultural and geographical distance, technology equivocally, and personal motivation-are central to technology transfer processes within and between organizations*”. Similarly, Malik (2002, 433) suggests that a factor helping the process of technology transfer “*is ‘good listening and communication skills’, which seems an obvious criteria, but can often be overlooked or not considered to be highly relevant*”. This issue includes building up networking among the players in technology transfer process. As suggested by the OECD (1997, 18) to be successful in adopting new technology and become an innovative firm requires “*the ability to access outside knowledge and to link into knowledge networks, including informal contacts, user-supplier relations and technical co-operation*”.
- Technology field. This factor determines the pattern and difficulty of doing a technology transfer as noted earlier by Faulkner and Senker (1995): *technology – related factors*: general factor of the technology, age and dynamism of the field. Likewise, Faulkner and Senker (1994, 688) describe the key differences among the

three industrial sectors of pharmaceuticals, ceramics, and computing as follows: “*In the pharmaceutical industry innovation is probably closer to the classic ‘linear model’ than in any other sector... By contrast, innovation in both the ceramics and computing sectors is more ‘circular’ in nature, involving strong feedback between technology users and suppliers in the development of new products; in ceramics, production and RD&D are also particularly close*”. To emphasise on the impact of technology on the process of technology transfer, biotechnology or life science related technologies are very unique and different from other types of technologies as it is imposed by strong regulations and rules. McMillan et al. (2000, 1) study the role of public research on innovation using biotechnology as the main technology field. Their research suggests that “*the biotechnology industry depends on public science much more heavily than other industries. In addition, we found that biotechnology companies rely on public science for very basic scientific research*”.

Tait (2007) describes the role of the regulatory body in life science innovation system as the barrier for bringing new products to the market because of the lengthy, expensive and complex set of regulatory requirements. Moreover, it is a factor that aids MNCs in preventing new small firms from entering the sector since the incumbents have accumulated more skill and knowledge dealing with the regulation. Firms doing business in this field of technology should be aware of this issue and prepare for it. At the same time, the regulator should keep abreast of new technological knowledge in order to offer appropriate regulation.

On the other hand, in some fields of technology, regulation might create more opportunity for the firm to launch its new technology. For example, environmental regulation that prohibits the use of some old technologies that cause environmental problems or pollution creates a market for new replacement technologies. As can be seen from the case of Automated Firm in chapter 6, a firm can benefit from new environmental regulation launched by the government. Hall and Khan (2003, 12) suggest that: “*Environmental regulations directly affect adoption because in many industries regulations will either prohibit or require the use of certain technology or production methods*”.

- Bridging organisation. This factor has become very important as the process of technology transfer needs an intermediary in facilitating and strengthening the relationship between two parties involved in the process particularly the public-private relationship. As Intarakumnerd and Chaoroenporn (2013, 112) put it:

*“Intermediaries have been recognized by innovation scholars and policy-makers as critical actors with the potential to at least ‘partially’ solve market and systemic failures in innovation systems”*. The intermediary can take different forms including research technology organisations (RTOs), industrial and trade associations, professional associations, and private foundations.

#### Technology Licensing Office (TLO)

The Technology Licensing Office (TLO), which may also be known as the Technology Transfer Office (TTO) or the Office of Technology Licensing (OTL), etc is the unit established under universities, PRIs or private firms responsible for managing, protecting and promoting IPR under its organisation. *“It generally may range from an interdisciplinary team of people with legal, scientific, licensing and commercial expertise to a single individual that is capable of leveraging the necessary support from external experts”* (Nezu et al., 2007, 44). Anderson et al. (2007) state that there are many stakeholders involved in the technology transfer process including academic researchers, technology transfer offices, and private industry. TLOs among others, are considered by many as the key players determining the success of the process. Besides the role of IPR manager, TLO can play another important role as Debackere and Veugelers (2005, 325) suggest that *“in addition, a TTO can be instrumental in reducing the critical asymmetry of information problem typically encountered in the scientific knowledge market”*. Therefore TLO can act as a bridging unit or the intermediary that communicates and creates relationships concerned with IPR management between the organisation and outside. The TLO plays an important role in public research exploitation especially in the process of public-private technology transfer.

However, as a vital player, TLO itself sometimes becomes a burden obstructing the process of technology transfer. In many organisations, most of TLO’s staffs are from Law schools or Business schools, not many of them are scientists or engineers. Therefore the communications between laboratory and TLO in many cases may not go well. Gross and Allen (2003, 59) identify a problem that happens in the relationship between TLO and the researcher under federal labs: *“In building an effective teaming approach, often a critical gap exists between the government scientist and the laboratory technology transfer office”*. Since the researchers think as scientists, they focus on the research and how to publish their discovery and sometimes overlook the importance of knowledge utilisation. On the other hand, in many cases TLO’s staffs do not take part in the initiation of R&D project

development, so they miss some important parts of the project or sometimes they do not have a clear idea how to bring that research into application. The most important thing for the process of technology transfer is the communication both among units within the same organisation and with people from outside.

In universities or PRIs, the TLO is also their marketing unit which tries to commercialise or utilise public research conducted under those public organisations. To sell something, the marketing unit should know the benefit of those goods; therefore, to make TLO's staff understand the benefit of the research from the beginning, it is a good practice for the researcher to think about research application carefully. Another burden that TLO can cause during the negotiation of technology transfer is that they try to maximise benefit for the organisation in form of licensing fee. This might prohibit the firm from the utilisation of public research since they cannot afford the fee. Moreover, licensing technology from the public organisation can give more risk to the firm since many of them are just a basic research or a prototype. Hence, the TLO under public organisation needs to act differently from the TLO under the private firm where technology commercialisation becomes their core business.

Making decisions for technology transfer in the public organisation is more difficult than having it done by the firm. This is because the public organisation is using public funds to support their activity, thus, they have to be concerned about other issues beside commercialisation. As Belinko et al. (2004, 1) put it "*Unlike the private sector which is mainly motivated by economic factors, PROs are driven by both social and economic objectives making the selection of the most appropriate technology transfer pathway a daunting task*".

#### Intellectual property right (IPR)

There is a question concerning the role of the IPR and whether it helps to create more innovation or not. Followed by another question; can it be used to facilitate the exploitation of public research? Falvey and Foster (2006) explain the benefit of IPR protection on the development of innovation, as strong protection of IPR allows innovators to share their works and it encourages long term-growth of innovation. The IPR protection assures inventors that their discovery will be protected by law so they can disclose it to the public and it also gives temporary power of monopoly to the inventor. If every inventor tries to hide the new knowledge or technology because they are afraid of imitation, the innovation

process will be dragged down. Similarly, Chabchoub and Niosi (2006, 113) state that *“For firms in science-based industries, intellectual property (IP) is a key element of their assets. It is thus essential for firms to be able to ensure the mastering and the protection of this asset”*.

The study of Colyvas et al. (2002) aims to find out how to bring university inventions into practice by investigating 11 cases of invention produced in the university and the way they were applied. The study suggests the role of IPR as: *“intellectual property rights are likely to be most important for embryonic inventions, and unimportant for inventions that are useful to industry off the shelf”* (Colyvas et al, 2002, 67). It can be seen clearly in this case that the firm needs some assurance before making risky investments in an embryonic invention which needs more development stages compared to ready-to-use inventions. Falvey and Foster (2006, 1) state that *“IPRs encourage innovation by granting successful inventors temporary monopoly power over their innovations. The consequent monopoly profits provide the return on successful investment in R&D”*. Many firms intending to license embryonic inventions from PROs require exclusive licensing in order to maintain a monopoly position.

However, the same study conducted by Falvey and Foster (2006, vii) suggests a negative impact of a strong IPR on innovation. As they put it: *“excessive IPR protection is likely to lead to an inadequate dissemination of new knowledge, which in itself could slow growth to the extent that access to existing technology is necessary to induce further innovation”*. Therefore, to implement IP laws and IPR policy that takes into account these positive and negative impacts.

#### *Incubator and Science Park*

Another way to build up public-private relationship is through industrial incubators and Science Parks. It has become a new approach for many countries to try to bring firms together with universities and/or PRIs in the same location: *“A Science park is a real estate development scheme designed to give high technology firms (new or established) easy access to R&D infrastructure. Science parks are therefore located on university campuses or in close vicinity to universities”* (Stankiewicz, 1986, 67). Science Parks can facilitate the public private relationship in various ways. Being at the same location stimulates relationships among them in many directions both between firm and university, or between different firms. According to the United Kingdom Science Park Association (UKSPA, 1999), Science parks are designed to have three fundamental characteristics: *“1) to foster the formation and growth of innovative firms 2) provide an environment which enables large companies to*

*develop relationships with small, innovative firms 3) promote formal and operational links with 'centers of knowledge creation', such as universities, higher education institutes and research institutions"* (Siegel et al. 2003, 178).

According to UNESCO, the world's first Science Park was Silicon Valley established in the USA in the early 1950s, and formerly known as Stanford University Science Park since it was founded by Stanford University. The second one was Sophia Antipolis established in France in the 1960s after the concept of the Science Park was brought to Europe. The third Science Park was Tsukuba Science City established in the early 1970s in Japan, the first Science Park in Asia. Later on, the concept of Science Park has been disseminated to many regions as a tool to build up the cooperation among university, firm and government.

Another concept which normally brought together with Science Park is the Technology Business Incubator. It *"is an economic platform designed to help start-up companies by providing them with the necessary resources and support that they need to evolve and grow into more mature business. The main goal is to generate successful businesses that will leave the programme financially viable and freestanding"* (UNESCO-WTA Initiatives 2006-2010, 4).

The combination of Science Park and Technology Incubation is an appropriate way to facilitate the exploitation of public research. The knowledge flow can be initiated from the relationship between the university and firms located in the same Science Park; the relationship varies in different patterns including collaborative research, consulting project or contract research. In addition, besides the cooperation in R&D projects, the firm can have access to R&D facilities and infrastructure set up in the university's laboratories. Concurrently, the university staff can learn and absorb entrepreneurial skills from firms. The result can be fruitful as the university staffs are able to initiate new business or start-up companies.

Alternatively, even while many of them might not be interested in starting their own business, they can learn how to think as a private firm and understand the needs of industry more clearly when they initiate the next R&D project. In the case of start-up companies, initiated either by university staff or people from outside who see the opportunity provided by starting up a technological firm, the Technology Business Incubator can provide aid at the starting point. Being incubated under the Business Incubator and located in Science Park, the

start-up firms can enjoy the benefit in many ways. As start-up firms, they can get a financial support in form of the seed money to start the business. In some Incubators, they provide the central R&D infrastructure for their incubatees to conduct R&D activities or the facilities are provided by the university or PRIs located at the same Science Park. This is related to the mature firms doing business in the Science Park where the start-ups firms can learn from them or in some cases; they initiate the collaborative project together.

Massey et al. (1992) studied the characteristics and formation of science parks in the UK including the relation between their scientific and technological content, social structure and meaning, and spatial distribution and form. They characterise the formation of science parks as it stems from scientific research in the academic laboratories and science parks become the channel linking scientific research to commerce which is seen as a 'linear model'. The model assumes that basic research started on the academic side will be developed and applied, and then transferred to the producer and finally diffused to the market. Their overall conclusion was that *"the level of science and technology on science parks falls considerably below the claims of much of the rhetoric. The numbers of scientists-turned-entrepreneur are relatively few, the predominance of small companies is very greatly exaggerated"* (p.250).

However, this contrasted with the situation and the role of Science Parks in Taiwan. In Taiwan, Science Parks are seen to have played a vital role in helping the country become another NIC in Asia, following South Korea, Singapore and Hong Kong. So (2006) describes the economic growth in Taiwan as it moved to become a hi-tech industrial country relying on the development of the semi-conductor industry. The development was supported by the government through a state-led catch-up strategy which the Taiwanese government used to overcome the crisis in the mid-1970s (the setback of withdrawal from the United Nations, the oil crisis, and the fast growth of the electronics industry in South Korea and Hong Kong). Taiwan's Hsinchu Science Park (HSP) was found in 1980 as the earliest and most significant science park in Taiwan and also one of the earliest science parks in Asia. So (2006, 67) describes the link between HSP and the development of the semiconductor industry in Taiwan as: *"The semiconductor industry is the mainstay of Taiwan's high-tech industry; HSP is the cradle of the semiconductor industry. The growth of the industry cannot help being associated with the establishment of HSP. Most semiconductor corporations or plants in Taiwan were set up in the science park at the outset and then extended their production networks across the island"*.

*Start-up and Spin-off firms*

Nezu et al. (2007, 41) state that the spin-off process is considered as an important avenue for the university to commercialise new technology “*particularly when the nature of the technology is such that no current player in a particular market would be willing to take the risk of taking a given invention to market*”. The terms start-up and spin-off are the channels for formation of a new company to create another business opportunity. These two types of firm are similar but not the same. Koster (2004, 3) clarifies the difference between these two using the resource-based theory as “*the resource-based theory allows for the idea that new firm can be partly regarded as rearrangement of existing resources or assets. Spin-offs can be seen as new entities managing existing resources originating from a mother company, whereas the resources of individual start-ups originate from elsewhere*”. Additionally, Hamano (2011) identifies the differences between the two types of firm in the case of public research exploitation (channel for knowledge transfer from university) as the spin-off firm is created, financed, technology-owned, and managed by the university while the start-up firm is created, financed and managed outside the university but with the technology licensed or transferred by the university. Consequently, start-ups and the spin-offs can be distinguished by using the source of their supporting resources.

**Table 1 Qualitative advantages and disadvantages of a start-up versus a spin-off**

Start-up		Spin-off	
<b>Plus</b> Retention of full upside	<b>Minus</b> No company track record	<b>Plus</b> Preassembled team	<b>Minus</b> Heavy royalties due
Brand new project	Money limitations	Experience	Precontracted options, limiting upside
Full patent life	Troubleshooting, planning, and operations limitations	Faster to operational status	Second choice project
Versatility	Lack of visibility	Time and money preinvestments	Residual patent life
	Time lag to milestone delivery	Good visibility and positioning	Limited potential of third-party partnering
	Absolute reliance on one or very few initial projects	Established networks	
		Established and /or additional projects to tap into	
		Attraction of parents to potential partners	

Source: Persidis and De Rubertis (2000, 570)

In Table 1 Persidis and De Rubertis (2000) summarise some advantages and disadvantages of the different forms of new firm formation. This study was conducted using business models in biotechnology comparing two types of firm. It concludes that the spin-off firm

grows and achieves its goal faster than the start-up one while the latter may offer more return to the investor together with more risk in doing business. Therefore, it is not possible to decide which form of the company is better; the decision should be made by considering each case in turn. In terms of their benefit for public research exploitation, both of them are a useful tool for transferring the knowledge from the public organisation to the industry.

#### *Drawbacks from attempting to exploit public research*

University researchers are typically orientated towards basic research and publication while ignoring the applications of that research or the need to patent. To change this behaviour, there must be a compensation for them. One of the well-known policies launched for this purpose was the American 1980 Bayh-Dole Act, which increased university patenting and licensing activity (Colyvas et al, 2000). This Act “*permits a university, small business, or non-profit institution using federal funds for research to produce an invention to retain the title on any patent issued for such inventions*” (Rhines, 2005, 2). In the same paper, Rhines describes how the Bayh-Dole Act had great impact on the IPR system and the patenting of public research produced by universities (see also Cohen et al., 2002). However, Rhines also notes that the Act could also cause some negative impacts on the relationship between universities, government and industry.

In some countries, university promotion criteria have been to the number of patents and level of collaboration with the private sector. However, there are some potential drawbacks that could result. Chiesa and Piccaluga (2000, 330-331) define some negative impacts from the strong attention towards exploitation:

- “*...if every researcher wished to do things that can be sold, and since things that can be sold are often those which are immediately ready and ‘packed’, basic research could be severely impoverished,...*”
- *...some researchers may be concerned about the fact that getting involved in commercial objectives may prevent the publication of scientific papers, thus removing a source of recognition, prestige and career advancement for them.*
- *Disparities might emerge within universities between those researchers/departments with research results that can be sold and those without them.*
- *The ethical issue regarding these questions is delicate and sometimes it is argued that direct exploitation is not compatible with the university mission.*

- *The absence of specific competencies as well as complementary assets in universities for commercialization activities also plays a role”.*

These are only some parts of the problem of trying to exploit public research through the commercialisation channel. Encouraging public researchers to benefit from utilising their research raises a potential dilemma. A focus on individual profit, where every piece of knowledge can potentially create money, may lead to secrecy, sometimes even with their colleagues. This tends to destroy the S&T development atmosphere based on sharing knowledge and inhibit further development of research. Another problem concerns the conflict between being public research and commercialised asset. This is linked to the ethical issue that Chiesa and Piccaluga (2000) mention above, as public research funded by public money should not belong to one individual but to the public.

However, to exploit those research results most of them should be in the hands of private firms who can make it useful for industry. Some of them might be used as public goods or it can be transferred to the user through the knowledge transfer channel as mentioned in the European IPR Helpdesk Fact Sheet (2014). However the latter channel might not create the obvious benefit as the former does. There are some advantages and disadvantages from using both channels so it is a responsibility for people concerned with decision making process to choose the most appropriate way.

## Triple Helix Model

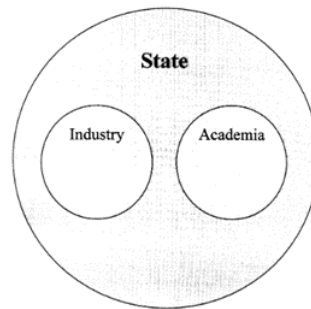
Regarding the exploitation of the public research approach, another model that can be used to demonstrate the public-private relationship is the 'triple helix model'. According to Leydesdorff and Etzkowitz (1996), this model was initiated from the concept of knowledge-based economics. The model was created by looking at transformation of knowledge into the marketplace through two processes of differentiation: the functional differentiation between sciences and markets, and the institutional separation between private and public control. As they put it: "*The Triple Helix model takes the traditional forms of institutional differentiation among universities, industries, and government as its starting point*" (Leydesdorff and Etzkowitz, 1996, 280).

From the beginning, the model aimed to emphasise the role of the university in innovation process to enhance knowledge-based society. It thus differs from the concept of national innovation system which puts the role of firm at the centre, and the Triangle model of Sabato that focuses on the state role (Etzkowitz and Leydesdorff, 2000, 109). The conventional role of the university was limited to a two-role model: teaching and researching. To move to a three-role model which adds one more role focusing on a direct relation with society, becomes controversial in deciding what is the appropriate function for the third role of the university (Sutz, 1997). Additionally, Ranga and Etzkowitz (2013, 238) summarise the characteristic of the Triple Helix as: "*The Triple Helix thesis is that the potential for innovation and economic development in a Knowledge Society lies in a more prominent role for the university and in the hybridization of elements from university, industry and government to generate new institutional and social formats for the production, transfer and application of knowledge*".

Similarly, Saad and Zawdie (2011, 1) explain the triple helix as an interactive model between the three principle institutional spheres in an economy including the university, industry, and government which puts the central role on the university: "*and the leading role university assumes in this relationship to ensure that the knowledge it produces is useful enough to be widely shared and applied, ultimately translating into regional and, indeed, national development*".

The triple helix model has evolved as explained by Etzkowitz and Leydesdorff (2000, 111) and can be categorised into three patterns. Firstly, the Triple Helix I (Figure 5) in which the

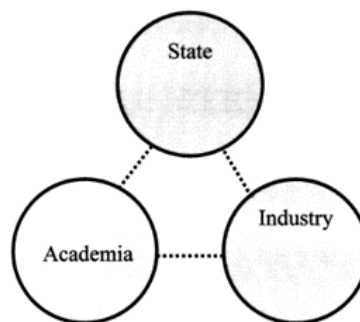
nation state encompasses academia and industry and directs the relations between them. This model can be seen in countries where the government plays a strong role in the innovation system.



**Figure 5 An etatistic model of university-industry-government relations**

Source: Etzkowitz and Leydesdorff, 2000, p.111

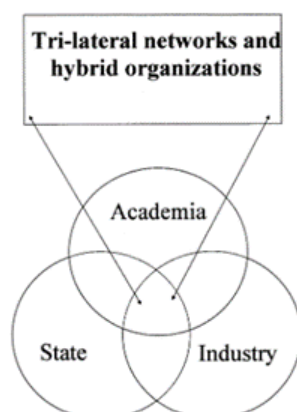
In the second model, the institutional spheres are separated with strong borders dividing them and highly circumscribed relations among the spheres. This model identifies the role of each sphere individually and each plays its own role. The model is demonstrated in the Figure 6



**Figure 6 A 'laissez-faire' model of university-industry-government relations**

Source: Etzkowitz and Leydesdorff, 2000, p.111

Thirdly, the Triple Helix III (Figure 7) generates a knowledge infrastructure from overlapping institutional spheres, with each taking the role of the other and with hybrid organisations emerging at the interfaces.

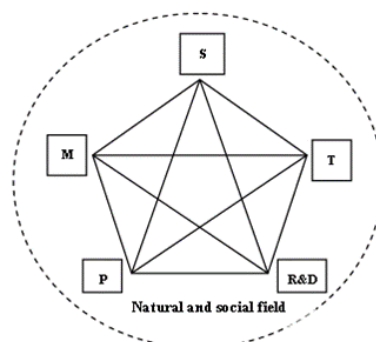


**Figure 7 The Triple Helix model of university-industry-government relations**

Source: Etzkowitz and Leydesdorff, 2000, p.111

According to the Triple Helix Research Group, Stanford University (2015): *“The Entrepreneurial University is a central concept to the Triple Helix. It takes a pro-active stance in putting knowledge to use and in creating new knowledge. It operates according to an interactive rather than a linear model of innovation. As firms raise their technological level, they engage in higher levels of training and knowledge sharing”*. This links back to the model of Triple Helix III where the spheres do not play an individual role but instead perform overlapping roles. The university extends its role from teaching and researching to the role of entrepreneur that brings the knowledge directly to the user or customer. As Etzkowitz (2008, 9) puts it: *“Going beyond traditional missions, universities were the source of venture capital and incubation movements that were enhanced by the support of industry and government”*. However, he also emphasises that while taking the role of others, the institutional spheres need to maintain their primary role and distinct identity. For example, when the university takes on some business and governance function, it needs to carry on the mission of socialisation of youth and dissemination of knowledge. Etzkowitz and Zhou (2007, 2) describe the key elements of the entrepreneurial university model as comprising *“a research base with commercial potential, a tradition of generating start-ups, an entrepreneurial ethos on campus, policies for defining ownership of intellectual property, sharing profits and regulating conflicts of interest and participation in regional innovation strategy”*.

Etzkowitz (2008) raises another issue with the Triple Helix model as a non-linear model of innovation. As mentioned earlier by the Triple Helix Research Group, Stanford University as the model operates as an interactive model rather than linear model, Etzkowitz (2008, 24) suggests the same idea by proposing the netlike pentagonal model which can be seen in Figure 8 . This model suggests that innovation may begin from different starting points among science, engineering, R&D, production, and marketing activity.



**Figure 8 Non-linear and netlike pentagonal model of technological innovation**

Source: Etzkowitz, 2008, p.24

### *Application of the Triple Helix model*

Jerome (2011, 9) states that: “*The potential offered by triple helix collaboration is significant. New pattern of cross-cutting partnering and commercialisation have arisen in industry consortia, university-industry arrangements and hybrid public-private organisations that reflect prototypes for blending resources*”. The model was widely adopted in many countries, as Cai (2014, 1) puts it: “*it has been commonly used as a normative framework among researchers for understanding interactions between key actors in innovation systems. It has also become a common strategy of many governments in developing innovation policies*”. Additionally, the data provided in the book: *Theory and practice of the triple helix system in developing countries: Issues and challenges*, presented the experiences and perspectives on application of the triple helix from academics, policymakers, and practitioners from fifteen countries. Most countries included in the book are considered as developing countries, and they show the same pattern of institutional players’ interactions as it is differentiated and essentially dysfunctional. The institutions are characterised by widespread fragmentation and rigidities (Saad and Zawdie, 2011).

### *Triple Helix vs National System of Innovation*

As mentioned earlier, by focusing on the university, the triple helix model is different from the NSI approach that puts the firm at the centre of the concept. Leydesdorf and Zawdie (2010, 798) compare the triple helix to the innovation system approach as it has neo-corporatist overtones and it emphasises collaboration at the local, regional, and national level. As they put it: “*Unlike the a priori choice for national level, the triple helix model can be appreciated at various levels of geographical integration*”. However, later in 2013, Ranga and Etzkowitz (p.237) described the concept of Triple Helix systems as “*an analytical tool that synthesizes the key features of university–industry–government (Triple Helix) interactions into an ‘innovation system’ format, defined according to systems theory as a set of components, relationships and functions*”. The new concept categorises the components of the Triple Helix into three groups including a) R&D and non-R&D innovators; (b) ‘single-sphere’ and ‘multi-sphere’ (hybrid) institutions; and (c) individual and institutional innovators. Furthermore, the relationships among the components are divided into five categories: technology transfer; collaboration and conflict moderation; collaborative leadership; substitution; and networking. Integrating the systemic approach to the Triple helix model helps the model to identify blockage and gaps in the interaction among Triple Helix actors.

### *Criticisms of the triple helix model*

One critique made by many scholars of the triple helix model is that it neglects the national context. For example, Shinn (2002, 610) states that the triple helix's institutional spheres all function in a national setting. *“Even scientific disciplines and specialties operate differently in different national institutions, and this is also true for business”*. He also suggests that from this point, the concept of the NSI still accounts for much of science/industry/government dealings. Cai (2014) summarises other comments on the triple helix from several scholars as follows: it overlooks other social settings, and that it hardly provides appropriate rationales to explain empirical cases, especially in different national and cultural contexts. Cai (2014, 2) also suggests that: *“This implies that the Triple Helix model has not been fully developed to take into account the context effect”*. From the same study, Cai further investigates the implementation of the triple helix framework in China. Since the triple helix was developed in the context of western countries; therefore, this study attempts to investigate how a country like China has adopted this framework. The study reveals that *“although Chinese economic reforms have changed the policy environment in a direction that may facilitate the implementation of the Triple Helix model in China, some institutional logics at work may shape its development in a different way as seen in the West”* (p.15). There are some institutional logics and characteristics deeply rooted in the Chinese traditions and political system.

Similarly, Ludvall (2010, 318) makes another comment on the triple helix approach as it *“focuses on science and the role of universities innovation”*, and it contributes to the distortion of NSI approach adoption as it leans towards the narrow concept of the NSI approach (STI mode). Moreover, he emphasises that: *“To bring innovations, including science-based innovations, to the market organisational learning, industrial networks as well as employee participation and competence building are more important than ever”* (ibid). In other words, he emphasises the DUI mode of the NSI approach.

Additionally, another criticism raised by different scholars is the problem of each taking role of each other. In the Triple Helix III model, each institutional sphere is taking the role of each other, particularly the university which moves from knowledge producer to entrepreneurial university by taking the role of firm. Tuunainen (2002) investigated a case study of a Spin-off Company in plant-biotechnology. The study applied two schemes: the Mode-2 thesis and the Triple-Helix model, to explore the case. From this research, Tuunainen suggests that both Mode-2 thesis and the Triple-Helix model failed to give enough attention to the problems and contradictions when the university research is

commercialised. The problems were categorised into three groups including: “1) *the ownership of intellectual property rights, 2) the industrial collaboration and the difficulties of transferring the research results to the market, and 3) the failed attempt of creating a hybrid community between the research group and the spin-off company*” (Tuunainen, 2002, 36).

## Other Sources of Technology transfer

Both the NSI and Triple Helix approaches view public sector research as a key generator of new knowledge that can benefit innovation in the wider economy. Whether one takes a simplistic linear model view or a more complex interactional one, a central aspect of these concepts is that a nation can develop its innovative capacity by funding basic research. However, such an analysis overlooks an important source of new technology, especially for developing countries, in the form of Foreign Direct Investment (FDI) and the operations of Transnational Corporations (TNCs).

For example, Coe et al, (1997, 136) note that: “*FDI can involve technology transfer which is able to be a very potent source of learning, the benefits of which can spread within an industry and across sectors as a result of labour mobility*”. Singh (2004, 218) states that empirical studies conducted to examine the impact of foreign investment on international technology diffusion report mixed results. Some studies show positive results while others show negative ones. However, Singh indicated that “*the impact of foreign direct investment on productivity is stronger and more robust for advanced countries than it is for less developed ones*”.

Investopedia (2015) defines the foreign direct investment as “*An investment made by a company or entity based in one country, into a company or entity based in another country. Foreign direct investments differ substantially from indirect investments such as portfolio flows,... Entities making direct investments typically have a significant degree of influence and control over the company into which the investment is made*”.

Graham and Krugman (1993, 21) suggest that “*Foreign direct investment is, in essence, the creation or expansion of firms that operate across national boundaries*”. Since 1980, foreign direct investment (FDI) grew very fast and became “*a major form of international capital transfer*” (Froot, 1993, 1). Graham and Krugman (1993, 24) suggest the factors supporting

the long-term growth of the TNCs and their influence on the world economy include “*increasing integration of world markets, growing similarity of national markets, improved communication and control technology, and growing symmetry in the international generation of technology*”. The potential value of TNCs, as Cantwell (1991, 34) notes, is that the “*involvement of foreign MNCs in research in centres of innovation have a direct effect on broadening the scope of local technological capability, and an indirect effect through its competitive stimulus encouraging other firms to extend their local research programmes*”.

Berger and Diez (2008, 1049-1050) summarise the patterns of the linkage between TNCs and local firms from several previous studies (Hirschman, 1958; Dicken, 2003; Altenburg, 2000), the patterns are suggested as follows:

- *Backward linkages*: TNC procures inputs and services from domestic sources
- *Forward linkages*: TNC-affiliates sell to domestic customers, thereby inducing knowledge transfer
- *Competitive effect*: Often TNCs enter domestic markets and compete with local firms
- *Demonstration effect*: TNC-affiliates are shop windows for the domestic firms
- *Effects on human capital formation*: Affiliates link up with domestic research and education organisations
- *Diffusion of knowledge via minds*: TNCs tend to have advanced technology and modern management practices”.



## Chapter 3 History and background of ST&I development in Thailand

This section describes the history and background of ST&I development in Thailand. After setting out background information about Thailand, I describe the history of how measures to support Thailand's ST&I were started and developed. Additionally, regarding the previous section on the NSI concept, this part describes how Thailand adopted the concept to its policy making process. Furthermore, previous studies on the use of the NSI concept and its adoption in Thailand are presented here.

### History and background of Thailand

#### *General information about the Thai economy*

Thailand is identified as a developing country by its level of S&T advancement. An authoritative study by the International Monetary Fund in 1991 noted that: "*Thailand was well advanced in its transition from an agricultural to an industrial and service-based economy*" (Robinson et. al, 1991, 4). By this time Thailand was considered one of the second generation of the newly industrialised economies (NIEs) in Asia. During 1986 – 1991, it was rated as one of the fastest growing economies in the world (Dixon, 1999). By this time, as Dixon (1999) notes, Thailand had become known as the fifth tiger of Asia. Additionally, it was categorised by the World Bank in 1993 to be in the highly performing Asian economies group. Dixon (1999, 1) also suggests that Thailand has a distinctive economic characteristic compared to other Asian countries, in part because of its history. Thailand has not been colonised for more than 200 years (the last time was more than 250 years ago from Myanmar), and has never been colonised by any western country. Therefore, the way Thailand entered the global market was different from others in the same region. As Dixon (1999, 2) notes, foreign direct investment (FDI) and transnational corporations (TNCs) play a more important role in Thailand's economic growth, Thailand has less state intervention compared to countries like Singapore, Taiwan, and Korea, and lastly the government facilitates the role of FDI in the country.

According to Visudtibhan and Yip (1998, 203), economic development policies in Thailand have changed over time in the following way: "*The industrialisation process was largely characterised by an import substitution policy in the 1960s, an import promotion policy in*

*1970s, a foreign direct investment promotion policy in 1980s, and a trade liberalisation policy in 1990s”.*

Since Thailand has shifted from an agriculture dominated country to newly industrialised country (NIC), the GDP contribution from the agricultural sector has decreased while the industrial sector and service sector continuously increase their contribution to GDP. For the first time in 1985 manufacturing took a larger share of the GDP (Visudtibhan and Yip, 1998, 204). Thailand was considered one of the fastest growing economies in Asia, and the fastest growing economy in South East Asia (CBI website, the Netherlands). It was ranked as the world’s second largest producer of pickup trucks behind the US and the world’s second largest hard disk drive (HDD) producer behind Singapore (Berger and Diez, 2008, 1057). However, unlike many NICs in Asia, the growth of Thailand’s industrial sector mainly depends on the TNCs and FDI.

Although, Thailand has moved from agriculture-based to be a more industrial-based economy, its technological capability has not greatly increased. Intarakumnerd (2005, 89) argues that the distribution of Thai manufactured exports by technological categories in 1990s shows that *“those categorised as science-based exports might be only assembled locally, while their technologically sophisticated and high-value-added components are imported”*.

As mentioned earlier, Thailand has enjoyed impressive economic growth since the 1980s until the economic crisis came in 1997. At that time, Thailand realised the problems hidden underneath the surface of impressive progression. As Visudtibhan and Yip (1998, 203) put it, *“Thailand has had one of the fastest growth rates of the Asian tigers. Its financial and economic crisis beginning in 1997 suggests that Thailand’s rulers now have this tiger by the tail!”*. Traisorat (1998, 23-24) argues that the financial crisis in 1997 stemmed from *“the existence of unsound macroeconomic policies and imbalances, and chronically unsafe and unsound banking and finance sectors”*. The crisis was aggravated by other internal and external factors such as political instability, slowdown of export growth, and speculative attacks. Although after the crisis in 1997, Thailand managed to bring back its impressive GDP growth, the lesson from the crisis reminds Thailand to be aware of the problems that might be caused by another crisis in the future. Regarding this economic crisis, Visudtibhan and Yip (1998, 219) suggest that *“The ability of Thailand to sustain its economic growth and to play a more vital role in the globalisation process of MNCs depends very much on how*

*Thailand develops its human resources and increases its ability to absorb high-value-added technology”.*

In the past Thailand’s economy relied on natural resources, cheap labour, good macroeconomic policy and strong infrastructure, but circumstances have changed with the rise of new competitors with lower wage producers and more demands from buyers. As Brimble and Doner (2007, 1021) state: “*Thailand’s needs for technological competences have become more pressing as the country loses its cheap labour advantage and confronts new competitive pressures*”. Therefore, some improvement in technical capability is considered essential for maintaining the country’s economic competitiveness. Thailand is trying to improve its ST&I development with the expectation in turn of increasing its competitiveness in the global market.

According to The Report Thailand 2011 (196): “*Thailand tries to foster a creative economy, with a focus on innovation in sectors that will move it up the global value chain*”. This report also supports Brimble and Doner’s argument that the country cannot only rely on cheap manufacturing for exports anymore, but it should invest in its human capacity to become a centre for higher value-added production.

According to the World Bank website, Thailand is classified as an upper middle income country. Thailand’s GDP in 2013 had a value of \$387.3 billion and the data for GDP per capita income was \$5,779 with population of 67.01 million. With regard to GDP composition by sector, the service sector contributes the highest proportion at 44.2%, followed by the industrial sector at 43.6% and the agricultural sector at 12.1% (2013 estimate).<sup>4</sup> Additionally, the details of Thai natural resources, agricultural products and its main industries are described as follows:

*Natural resources:* Tin, rubber, natural gas, tungsten, tantalum, timber, lead, fish, gypsum, lignite, fluorite.

*Agriculture:* Products--rice, tapioca, rubber, corn, sugarcane, coconuts, soybeans.

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<sup>4</sup> The Global finance website: <https://www.gfmag.com/global-data/country-data/thailand-gdp-country-report> accessed 20 June 2015

### *Main industries:*

Automobiles and Automotive parts (11%), Financial Services (9%), Electric appliances and components (8%), Tourism (6%), cement, auto manufacturing, heavy and light industries, appliances, computers and parts, furniture, plastics, textiles and garments, agricultural processing, beverages, tobacco.

### *Human resources*

According to The Report Thailand 2011 (199) Thailand has just 6.76 research staff per 10,000 people, and ranks 57th in the quality of math and science education by the World Economic foundation's global competitiveness index. The Report Thailand 2011 (199) also provides the result from a Thai firm survey carried out by the World Bank in 2010, which indicated that half of responding firms stated that their staff lacked English fluency and IT, numerical and innovation skills. The responding firms also pointed out that the lack of trained researchers and financing were the most important factors obstructing them from innovation growth and investment.

The major cause of the lack of human resources in Thai R&D development is blamed on the Thai educational system. According to Durongkaverroj (in The Report Thailand 2011, 199) "*currently only 30% of student graduations each year are in science*". Likewise Siriruchatapong (in The Report Thailand 2011, 199) emphasises that "*there is a mismatch between university graduate's skills and the needs of the private sector [...] curricula change slowly and there is a lack of specialized vocational training*".

### *Science, Technology and Innovation in Thailand*

The history of S&T development in Thailand goes back many centuries; however, western S&T was first promoted in the period of King Rama III (1824-1851) by sending Thai students to study S&T abroad (Sungkapinyo, undated). In 1956, the government established the National Research Council of Thailand (NRCT) to fund public sector research (including universities) in wide-ranging areas, from basic science to social science. Then in 1963 the Thailand Institute of Scientific and Technological Research (TISTR) was established, originally as the Applied Scientific Research Corporation of Thailand. It was set up as the main publicly-funded institute to carry out specialised scientific and technological activity (Chantramonklasri, 1994).

In 1979 the Ministry of Science and Technology (MOST) was established with roles and objectives to formulate national policies, implement S&T policies and bring about national stability and the most socio-economic benefits possible. S&T development was first referred to in the fifth National and Economic and Social Development plan (1982-1986) (Chairatana, 2006). By the seventh plan (1992-1996), the Thai government had begun to develop Thai research institutes and promote higher education in the S&T development sector. In 1985, the Science and Technology Development Board (STDB) was established to enhance S&T capability in Thailand.

In 1991 the National Science and Technology development agency (NSTDA) was founded under the Ministry of Science and Technology by the special National Science and Technology Development Act, 1991. The three national centres: the National Center for Genetic Engineering and Biotechnology (BIOTEC), the National Metal and Materials Technology Center (MTEC), and the National Electronics and Computer Technology Center (NECTEC) were included under NSTDA. As of 2003, the National Center of Nanotechnology (NANOTEC) was added to the list. These organisations are now the modern S&T organisations of Thailand where hundreds of Thai graduate students return to work as researchers after studying abroad. It should also be noted here that NSTDA works together with other S&T organisations, including universities, as partners and funding agencies.

The National Innovation Agency (NIA) was established by the Ministry of Science and Technology in 2003. Since its inception up to September 1, 2009, NIA operated as an autonomous agency, under the supervision and policy guidance of the National Innovation Board, but outside the normal framework of the civil service and state enterprise. From September 2, 2009 onwards, NIA was restructured and became a public organisation, while remaining under the umbrella of the Ministry of Science and Technology. (MOST website, 2013)

In 2008, the National Science Technology and Innovation Policy Office (STI) was established under the National Science Technology and Innovation Act. The STI is “considered significant in providing support to the government in terms of science, technology and innovation policy formulation, coordination, as well as policy promotion. The office is committed to assist the country in moving towards knowledge-based economy

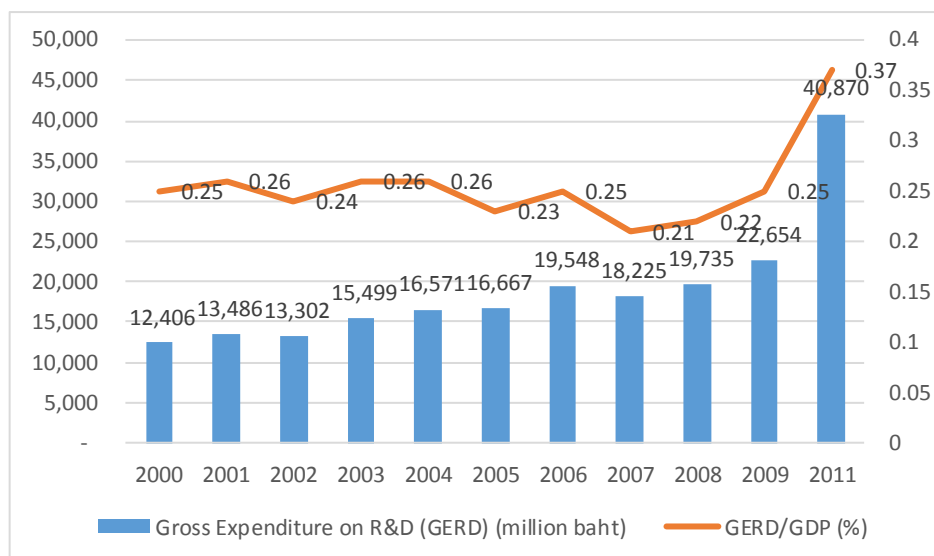
in order to promote the country's capacity and strength. The science technology and innovation strategic plan and policy recommendations provided to the government by the office are expected to improve the country's competitiveness and enhance socio-economic sustainability" (MOST website, 2013).

#### *R&D investment*

Chantramonklasri (1994, 26) indicates that the problem with *"the development of science and technology in Thailand has been viewed as nothing much more than an under-investment in R&D. Policies and measures have mainly emphasized developing public sector R&D capability, policy concern has usually been about how to increase the total level of government funding for public sector R&D"*. However, presently there are some differences regarding the targeted sources of investment which have shifted from the public sector to the private sector.

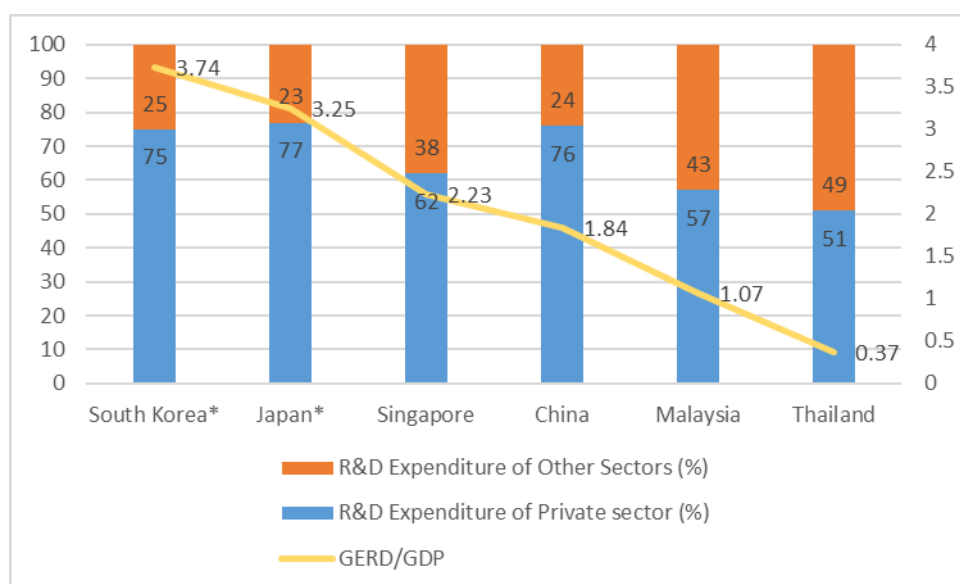
According to the data of R&D investment in The Report Thailand 2011 (196) Thai R&D investment has not grown significantly in the past decades. Combining R&D investment in the public and private sector, the range is between 0.2 and 0.25% of GDP (except in 2011 where it reaches 0.37%) which falls below the 1% average of 57 countries (IMD survey in The Report Thailand 2011). This is low when compared to other Asian countries such as Japan (3.25%), Korea (3.74%), Singapore (2.23%), China (1.84%) and Malaysia (1.07%). Additionally, in Thailand the share of R&D investment between public and private sector is opposite to others as the public sector has taken a larger share for a long period (see figure 10) up until 2011 when the private sector first took the larger share of R&D investment by 51:49 (private: public ratio).

Thailand R&D indicators



**Figure 9 Gross Expenditure on R&D in Thailand (2000-2011)**

Source: Thailand Science Technology and Innovation Profile 2014, STI (p.15)



**Figure 10 GERD/GDP and share of business expenditure on R&D in 2011 (BERD)**

Source: Thailand Science Technology and Innovation Profile 2014, STI (p.14)

\*data from 2010

**Table 2 R&D investment contribution by public and private sector (2001-2009)**

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009
<b>Public R&amp;D Investment (mil. baht)</b>	8,202	8,138	9,571	10,548	9,988	11,550	10,015	11,887	12,737
<b>Private R&amp;D Investment (mil. baht)</b>	5,284	5,164	5,928	6,023	6,679	7,998	8,210	7,278	8,174
<b>Total R&amp;D Investment (mil. baht)</b>	13,486	13,302	15,499	16,571	16,667	19,548	18,225	19,165	20,911
<b>R&amp;D/GDP (%)</b>	0.25	0.24	0.26	0.25	0.24	0.25	0.21	0.21	0.23
<b>Public/Private R&amp;D Investment</b>	61:39	61:39	62:38	63:37	60:40	59:41	55:45	62:38	60:40

<sup>5</sup>Source: Wanichkorn, K. (2013)

However, according to The Report Thailand 2011 (196), the 11<sup>th</sup> National Economic and Social Development plan has placed a high priority on raising R&D investment to 1% of GDP (100 billion bt) between 2012 and 2016. The government also aims to increase private investment up to 70%.

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<sup>5</sup> Sources: Public R&D Investments from 2001 to 2007 are collected from the national surveys on R&D expenditure and personnel by the Office of the National Research Council of Thailand; Public R&D Investments from 2008 to 2009 are collected from GFMS, the Comptroller General's Department, Ministry of Finance; Private R&D Investments from 2001 to 2008 are collected by the national surveys on Private R&D Investment by the National Science Technology and Innovation Policy Office (STI Office)

## Thailand's ranking and competitiveness

**Table 3 Thailand's ranking**

	2004	2005	2006	2007	2008	2009	2010
<b>Innovation</b>	NA	38/117	33/125	36/131	54/134	57/133	52/139
<b>Source: World Economic Forum (WEF)</b>							
<b>Science Infrastructure</b>	46/51	47/51	45/53	49/55	37/55	40/57	40/58
<b>Technology Infrastructure</b>	38/51	37/51	41/53	48/55	43/55	36/57	48/58
<b>Source: International Institute for Management Development (IMD)</b>							

Source: Bangkok post, 2011

According to the data in Table 3, Thailand had improved its competitiveness in innovation during the period of 2006 to 2007, but had started to decline since 2008 and continued to drop off up to 2010. Turning to science infrastructure there has been a stronger trend in growth, while the technology infrastructure has weakened compared to the past.

### *Local technology versus imported technology*

Why does Thailand need to conduct its own research? Is it easier and quicker to import technologies from outside? These questions have been asked several times when the local researchers try to conduct a new R&D research project both in the public and private sector. Moreover, those questions sometimes come from scholars who study the development of innovation in developing countries. They do not understand why Thailand still struggles with doing its own research to produce local technologies because it seems like some technologies are ready for commercialisation in developed countries.

In fact, Thailand does not deny using imported technology at all; indeed, the majority of implemented technologies in Thailand now are imported. As can be seen from the following table for technology balance of payment from 2001 to 2008, Thailand ran a deficit in technology balance of payment every year, and the number has been getting bigger since 2005.

**Table 4 Technology balance of payment unit 2001-2008**

Year	Technology balance of payment unit: million baht						
	Payment			Receipt			Balance of payment
	Royalty & patent licensing fee	Technical fee	Total payment	Royalty & patent licensing fee	Technical fee	Total receipt	
<b>2001</b>	36,500	83,676	120,183	393	26,705	27,098	<b>-93,085</b>
<b>2002</b>	47,424	104,640	152,067	317	25,233	25,550	<b>-126,517</b>
<b>2003</b>	52,734	95,048	147,782	313	32,247	32,560	<b>-115,222</b>
<b>2004</b>	62,628	39,665	102,293	514	15,557	16,071	<b>-86,222</b>
<b>2005</b>	67,168	60,756	127,924	681	29,176	29,857	<b>-98,067</b>
<b>2006</b>	77,695	72,560	150,255	1,756	38,738	40,494	<b>-109,761</b>
<b>2007</b>	79,050	99,454	178,504	1,872	43,943	45,815	<b>-132,689</b>
<b>2008</b>	<b>85,146</b>	<b>123,752</b>	<b>208,898</b>	<b>3,365</b>	<b>57,438</b>	<b>60,803</b>	<b>-148,095</b>

Source: STI (2011) from Bank of Thailand

Adapted from STI, 2011 (<http://www.sti.or.th/sea-eu-net/form/Thailand.pdf>)

This evidence suggests that Thailand has relied heavily on imported technology to run its economic growth and lost large amounts of money in doing so. Besides, do those imported technologies completely suit local needs? How can they be implemented and adopted? Even if Thailand continues buying technology from outside, it needs to enhance its capability in order to implement those new imported technologies.

This is another reason for stimulating a technological capability in Thailand – to enable adoption of new technologies. Most TNCs make decisions on new investment or choosing suppliers based on their production capability which is normally indicated by technological capability. As Worasinchai and Bechina (2010) suggest that infrastructure, technology development, work processes improvement, and competence/skill building of local workers are the crucial factors to attract the TNCs to invest in developing countries. Simply put, stimulating technological capability and creating local technology will help Thailand both in terms of enhancing the competitiveness of local firms and in attracting more FDI.

However, even if Thailand attracts and acquires lots of FDI and TNCs both from Western countries and Asian developed countries there is the issue of whether Thailand will gain more advanced technologies from those firms. In 2008, Berger and Diez conducted research to investigate whether the host countries in late industrialising groups benefit from TNCs using Thai industries as the case studies.

The role of TNCs has been investigated by Berger and Diez in the cases of two of the main industries in Thailand: hard disk drive (HDD) industry and automotive industry. According to Berger and Diez (2008, 1062-1066) in these sectors “*foreign firms tend to carry out R&D predominantly at their headquarters and limit their external linkages*”; “*firms in the automotive industry have only minor collaborations with universities and RTOs because of lacking of efficient scientists and tools*’ and those in HDD industry “*rarely collaborate with universities and RTOs except one large foreign firm which has a close relationship with five universities*”.

With regard to TNCs’ R&D activity, Patel and Pavitt (2000) report the same situation (drawing on earlier research conducted by Patel and Vega in 1999). This study investigated the 359 largest companies in the world that were technologically active in the 1990s. The study suggests that: “*Firms continue to perform a high proportion of their innovative activities in their home countries*” (Patel and Pavitt, 2000, 219).

However, others have claimed that TNCs can improve the innovative capability of host countries. For example, Chairatana (2006, 1066-1068) argues that:

- 1). *“TNCs are very demanding and lead to crises among supplier firms which can trigger an increase in the intensity of effort on behalf of upgrading and learning,*
- 2). *TNCs help their suppliers to develop technological capabilities, if it is in their self interest,*
- 3). *TNCs provide local firms with an opportunity to access markets,*
- 4). *TNCs improve the S&T infrastructure and the human capital basis and TNCs enrich the NIS by bringing with them or inducing the creation of new players”.*

Although, this suggests that Thailand can benefit from foreign firms in different ways including from the technology spill over, these benefits may be limited, especially if the TNCs change their host country from Thailand to others or if all of the technology IPR

remains in the hands of foreign firms. Thus, even though TNCs may bring benefits, it is considered desirable for Thailand to enhance its indigenous innovative capability and to produce its local technology. This does not imply that Thailand does not need technology from outside anymore, but it does mean that Thailand has to consider which technology has to be acquired from outside and which ones should be produced domestically.

## Adoption of NSI Concept in S&T and Innovation Development Policy in Thailand

According to Intarakumnerd et al. (2005), the Thai innovation system has been studied formally using the data collected from the Community Innovation Survey, in 1999 and 2002, conducted by NSTDA following the framework and criteria of the Frascati manual and the Oslo manual, OECD. The roles and relationships between the main actors including the government, private sector, universities and public research institutes, private bridging institutes and financial institutes have been investigated.

The first adoption of the system of innovation concept in Thailand was in 2001 as stated by Intarakumnerd and Chaminade (2007a, 197): *“the Thai government made official a new S&T five-year Plan (2001-2006) in which the system of innovation approach was officially adopted.”* The concept was at the heart of the establishment of the National Innovation Agency (NIA) was established in 2003. At that time NIA’s strategic plan was to move the Thai innovation system to become a practical innovation policy. NIA (2005, 3) indicates that: *“Innovation is an impetus for growth, therefore, it is of foremost importance for Thailand to establish a well designed National Innovation System (NIS) policy framework to provide a sound economic growth base and to inject an understanding of how various sectors might approach innovation”*.

### *Characteristics of Thai National System of Innovation Policy*

In Thailand, the importance of science, technology and innovation is recognised as central to the country’s competitive enhancement. This recognition has been stated by the government, and government support means that most scientific and technical knowledge is embedded in the public sector, including universities. Thailand has seen S&T development as a tool for

enhancing its competitiveness, as can be seen from the many policy frameworks that have been launched by the government and public organisations. More recently, in the last decade in fact, the term ‘innovation’ has been formally used as the focus of government support. This shift has been justified by Lorlowhakarn (2005, i), the director of the National Innovation Agency (NIA): “*How does an ‘innovation policy’ differ from a promotion of the role of S&T in general? A focus on innovation is important because it enables the role of S&T to be defined more clearly and centrally within overall economic and social policy context*”. According to NIA, the following terms can be defined (Yungsuksathaporn, 2005, 9):

*“**Innovation** is new things derived from the exploitation of knowledge and creativity, leading to enhancement of social and economic value”*

*“**Innovation systems** are implementation mechanisms of many agents to foster innovation”*

*“**National innovation systems** are implementation mechanisms established at national level, linking all stakeholders to foster innovation widely in the country”*

The concept of S&T and innovation in Thailand was mainly influenced by work done in European countries on the national system of innovation concept. It was only later that the idea of industrial clusters and country competitiveness was adopted from the US tradition. However, the European and US conceptual traditions were not linked until long after their introduction. Therefore, the concepts of innovation and national competitiveness were promoted and developed separately in different contexts and with different organisations taking responsibility for their development (Yungsuksathaporn, 2005). Although now the two concepts have been linked together and the Thai government is attempting to increase the contribution of S&T and innovation in the country’s competitiveness, problems in implementation have led to the NSI not working out as well as expected.

Regarding the pattern of the Thai NSI, Yungsuksathaporn (2005) argue that because of the weakness in R&D capacity of the private sector, the public side is forced to adopt national S&T and innovation development agendas. Therefore, the pattern of R&D development in Thailand has been the supply push model as opposed to the demand pull model. Thailand had to accept this model at the beginning due to the demand side being too weak to be the

leader of development. Thus, the public sector plays an important initiating role by pushing R&D development in the country.

However, this pattern should only occur in the early stages of an innovation and development system. The private sector should be developed and encouraged eventually to be the leader. According to the two different perspectives of NSI definition mentioned by Lundvall et al. in 2009, the stage of NSI development in Thailand accords to the narrow definition of NSI, or so-called Science, Technology and Innovation (STI) in the developing context. And yet Thailand is still struggling in pushing the role of R&D development led by the public sector. However, as mentioned by Yungsuksathaporn, the Thai NSI should move to the further stage which will match with the broad definition of NSI or Doing, Using and Interacting (DUI) in order to establish firm capabilities using learning processes, particularly as regards tacit and localised knowledge. The Thai firm could then move further to be a leader in the Thai NSI and the pattern of NSI will be moved from technology push model to demand pull model.

For Thailand, adopting the NSI concept is a step to move to another stage of ST&I development. However, Thailand is still in the transition period to change from the old problematic model to an efficient systematic one. Intarakumnerd (2006, 117) suggests that Thailand is in a transition period, its national system of innovation will become stronger and more coherent “*if there is a significant change in the behaviour of a key actor that can cause positive repercussions among other actors. External factors that have cross-cutting effects on all actors in the system, in different degrees, may also bring change*”. The most important challenge facing Thailand now is how to build up an effective innovation system. Regarding the NSI framework, in order to enhance an effectiveness of the innovation system, the main activity that needs to be focused is how to make knowledge flow effectively in the system.

### *Previous study of problems in the Thai NSI*

#### *Mismatch between level of economic structural development and innovation development*

Many scholars who carry out research in innovation and national development indicate that the development level of the country is linked to the development of the level of their innovation development capability. For example, Arocena and Sutz (2005, 1) note that

*“Today, when we are living the transition to the knowledge society, the economy of developed countries is solidly based on science, technology, innovation and advanced education. Developing” countries are “the rest”, those unable to use knowledge - its generation, transmission and application - as a fundamental tool for economic growth and social improvement”.* Similarly, in a paper written for the OECD Rosenberg (2004, 1) begins by noting that: *“It is taken as axiomatic that innovative activity has been the single, most important component of long-term economic growth”.*

However, this is not always the case for Thailand. Intarakumnerd et al. (2002, 1452) point out the particular characteristic of economic growth in Thailand are *“similar to the east Asian NIEs, the GDP growth of Thailand has been remarkably impressive, and the Thai economy has been moving towards an economy that relies heavily on production and export of industrial products, especially those classified as differentiated and science-based ones.”* However, their study suggests that unlike others Asian NIEs the development of the innovation system in Thailand to support industrial technology is weak and fragmented. This leads to a mismatch between economic growth level and S&T development level. This finding contradicts the claims of others, such as Gu (1999) who argues that *“there is a link between the level of economic development of a developing country and its development level of NSF”* (Intarakumnerd et al., 2002, 1452-1453).

#### Weak and Fragmented system

Previous studies conducted by Thai researchers and international scholars confirm the Thai innovation system as a weak system. The Thai innovation system is seen to suffer from the distinctive limitations of NSIs in developing countries as identified by Gu (1999, 43) who notes that they are: *“less developed by order, in terms of institutional composition, the sophistication of scientific and technological activities, and linkages between organizational units”.*

Additionally, Chaminade et al. (2013, 1478) believe that the failings of the Thai innovation stem from inadequate ‘S&T policy’ measures. As they note that the previous research conducted by many scholars (eg. Arnold et al., 2000; Bell, 2002; Intarakumnerd et al., 2002; Intarakumnerd, 2005) suggest that lacking of appropriate policies contributes to the problem of low innovative performance in Thailand compared to other Asian NIEs. They also suggest that *“The linear model of innovation and neoclassical rationales had predominately*

*influenced Science and Technology (S&T) policy formulation in Thailand for many decades before the turn of the new century...”*

Furthermore, Chulavatnatol (2005) also describes some important weaknesses in the Thai innovation system including that:

- *“Education system in Thailand does not encourage creativity, which is the key driving force of innovation. Consequently, Thais are seen as incapable of being innovative” (p.2).*
- *“Bureaucratic system is too rigid and it inhibits innovation in Thai governmental agencies” (p.2).*
- *“Research and development are performed mainly in laboratories in governmental agencies and universities while industry research center are not strong. Furthermore, the collaboration among them is weak and lacks good management” (p.10).*

In addition, Chairatana (2006) characterises linkages, successes and failures in the Thai NSI, into seven issues according to its weak and fragmented nature as follows:

- *Users-Producers Linkages* -- weak linkages, short and fragmented;
- *Co-Operation between Firms* -- lack of co-operative consortiums among firms;
- *Transnational Corporations (TNCs) and Technological Spill-Overs* -- the links for technological development between TNCs and their subsidiaries in Thailand are rather limited and trivial;
- *Industry University Links* -- lack of long-term and formal links;
- *Public Research Technology Organization (RTOs) and Industrial Firms* -- small number of linkages;
- *Leveraging of Industrial Human Resource Capacity* -- limit of policy focused on supporting skilled labour training;
- *Financial Incentives and Infrastructure* -- some obstacles obstructing firms using government fiscal and financial incentives.

Schiller (2006) focuses particularly on the linkages between actors in the Thai NSI, and argues that the weak point was actually due to a gap between the university and industry. In particular, it was the differences in the absorptive capacities of private companies and the knowledge production of universities that was failing the Thai innovation system. This is also confirmed by the OECD (2013, 273) which states that *“Limited collaborative links*

*between universities, public research organizations and the business community have compounded the weaknesses of Thailand's innovative capacity”.*

This linkage between public sector research in universities is central to the way that the NSI concept is often understood because as Intarakumnerd and Schiller (2008, 1) argue *“In the context of developing countries, universities can play an important role as an indigenous knowledge source. Fruitful university-industry linkages (UILs) help local firms to import, modify, and diffuse technology. At the same time, universities can improve their academic capabilities if they interact with the private sector”.*

Schiller (2006) also confirms the finding of previous studies of the Thai NSI as it has been less successful in upgrading technological capabilities in line with their economic performance. His study which was conducted in 2004 aimed to analyse direct mechanisms of knowledge transfer via academic services and other kinds of UIL by using a dataset of 136 UIL from interviews at five public universities in Thailand. The conclusions of this research were that *“it has shown a wide gap between absorptive capacities of private companies and knowledge production of universities. Because the university's traditional orientation focuses towards teaching, their R&D is growing more slowly overall than the commitment of the private economy in this field”* (Schiller, 2006, 88). In addition, when they cooperate with SMEs, the main obstacles that universities are faced with are low absorptive capabilities and the financial capacities of firms. Schiller's survey results demonstrated that the patterns of UIL are mostly limited to consulting and technical services.

Schiller (2006, 88-89) proposes some suggestions for solving the problem in the UIL as follows: *“SMEs in Thailand should step up their endeavours to build own technological capabilities - with assistance from government programs – so as to achieve the competence to co-operate with universities. At the same time, the content of university teaching and research should be harmonised with corporate requirements more than hitherto. [and] ... bureaucratic obstacles should be gradually abolished and incentive structures built up at the universities”.* Additionally, Schiller suggests that there should be personnel exchanges between universities and SMEs in order to build trust and learn the needs and requirements of each in research and technology.

These criticisms were echoed by the OECD (2013, 272) when it noted that: *“Linkages between Thai universities and industry are mostly limited to consulting and technical*

*services to augment the personal income of researchers*". Doner et al. (2013, 227) also confirm that: *"Even though Thailand has achieved impressive growth and diversification of its production and exports over the past half century, it is still weak in terms of industrial and technological upgrading. Weak university–industry linkages (UILs) contribute to this problem"*.

Brimble and Doner (2007, 1023) also analysed UILs in four different Thai sectors: automotive, textiles-garments, agro-industry and electronics, and found that *"across sectors, linkages between Thai educational institutions and firms (either individually or collectively) are weak"*. Furthermore, they classified the dimensions of weakness into three main categories: those linkages that tend to involve fairly low levels of technology, those that tend to be weakly institutionalised, and the few linkages that have significant benefits to both sides.

With regard to the private sector, the study showed the lack of strong interest in firms for collaborating with the public sector, and a lack of cohesion within and among sectors. The most effective Thai UILs up to now have been undertaken by large firms. Moreover, Brimble and Doner (2007, 1031) argue that even if the private sector was more eager to link up with universities, there are some challenges to working with universities. They note that *"some academics remain suspicious of the development of close links with the private sector"* and that *"finding the appropriate person to manage the interface is critical"*. In addition, *"individual researchers continue to sidestep what university regulations exist and large numbers opt for personal contacts with private companies"*. Lastly, they note that *"some of the efforts being made to develop interface initiatives have been too ambitious, resulting in long delays"*.

Brimble and Doner (2007, 1032) also describe survey results that show that only 20% of 1,000 response firms used the service of any of the Thai research technology organisations (RTOs), mostly because *"the researchers in RTOs have tended to define priorities themselves and then to develop technologies to be transferred to private firms"*. Nor are government bureaucracies considered to be doing a good job as Brimble and Doner (2007, 1033) claim that *"there are persistent weaknesses in those agencies that impact specifically on Thailand's industrial technology capabilities: supply-driven strategies and corresponding weak interaction with the private sector; overlap and lack of clearly defined functions; poorly designed financial incentives"*.

Likewise, Boonfueng (2005, 120) notes that *“despite the effort to enhance technological capacity of the country, having several government agencies undertaking similar tasks raises a redundancy concern...This may lead to the issues of conflict of interest, incompetence in policy formulation and implementation, redundancy and lack of specialization among the agencies”*. Another factor that influences the effectiveness of the Thai innovation system is political atmosphere, which affects political goals, interests and coalitions. Furthermore, Brimble and Doner (2007, 1033) explain that *“the proceeding problem is incomplete without explicit attention to the government’s understanding of the private sector’s needs and the political will to promote related institutions”*.

Weaknesses with the functioning of UILs in Thailand was also found by Intarakumnerd and Schiller (2009, 581) who claim that *“it is obvious that in general university-industry linkages in Thailand are weak. Firms do not regard university and public research institutes as important sources of information and knowledge ... most UIL projects are limited to consulting and technical services”*.

Additionally, this study suggests some important factors that determine the pattern and success of UIL including a) industrial sector: *“Knowledge demand and cooperation patterns differ significantly among the industrial sectors”* (p.569) b) scientific fields: different scientific fields differentiate pattern of UILs such as contract research, joint research, internship, and licensing. c) regional: *“all universities (in this research) have a majority of their UILs with partners in the same region”* (p.573). Another point concerning the UIL raised by this research is academic capabilities in the university. As the result from the study suggests that: *“Academic capabilities of Thai universities are not yet advanced enough to supply in-depth collaboration with high-tech industries”* (Intarakumnerd and Schiller, 2009, 583).

Intarakumnerd and Schiller (2008, 23) nicely summarise the pattern of common problems occurring in the public-private interaction:

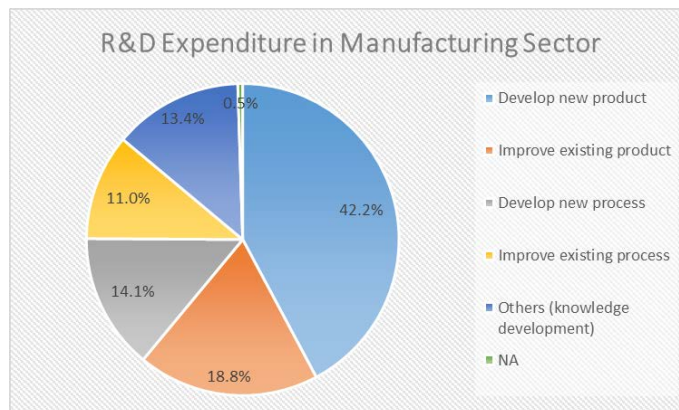
*“The fragmentation of innovation systems in developing countries often results in a regional and technological mismatch between knowledge production and needs. Excellent university departments at regional universities do not find counterparts at the regional level and have to look for partners in the economic centre or abroad. On the other hand, technologically advanced companies may not find capable university partners within a particular country.*

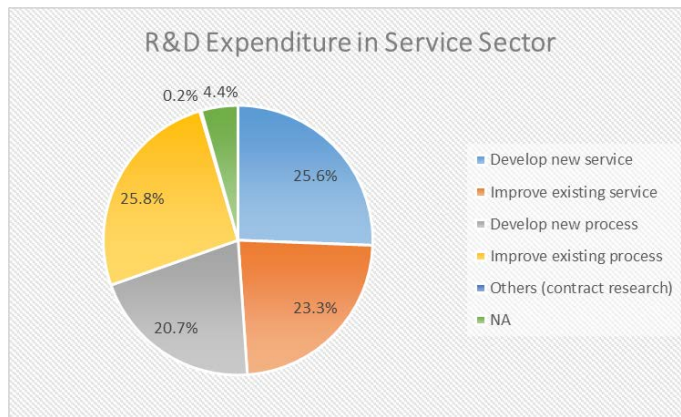
Hence, knowledge transfers with large local or foreign-owned companies often occur from companies to universities, whereas local SMEs or cooperatives are lacking basic absorptive capacities for any kind of UIL”.

#### Less innovative firms

In addition to the fragmented nature of the Thai innovation system, Chaminade et al. (2012, 1478) also point to the problem that: “Firms in Thailand have low technological capabilities... especially those in the SME group”. Likewise, Intarakumnerd and Schiller (2009, 555) state that: “The slow technological capability development of Thai firms is quite different from what characterised Japan, Korea, and Taiwan. Firms in these countries moved rather rapidly from mere imitators to innovators”.

Similar results were obtained from the Innovation Survey: Business Sector (STI, 2011) conducted by STI and NRCT in 2009 and 2010. The summary data was launched in 2011. The surveys were carried out in two business sectors including a manufacturing sector and service sector in Thailand. The research was conducted using two groups of samples in those two sectors. The first group involved 5,343 respondents and the second group was 5,519 respondents. This research aimed to explore R&D activities and innovation development in the Thai business sector including R&D expenditure invested by firms in business sector. The results from the survey in two business sectors are shown in figure 11





**Figure 11 R&D expenditure spent in different activities in manufacturing sector and service sector (2008)**

Source: Thailand's Innovation Survey: Business Sector, 2008, STI

Some interesting results of the survey can be summarised as follows:

- Innovative firm: most of the innovation budget invested by the business sector were from big firms rather than SMEs.
- Type of innovation: product/service innovations were found as dominant types of innovation activity.
- The revenue from company innovation was from existing products and services with existing markets more than new products/services with existing markets and/or new markets.
- The motivations for conducting innovation development were from customer needs, capacity building, and reduction of labour cost.
- Outputs from firm's innovation development were products/services and process innovation more than patent applications or IPR.
- There are three important factors obstructing innovation development in firms including lack of information on technology, lack of qualified personnel, and lack of information on market.

This is confirmed by Chaminade et al. (2012, 1486) who point out the main systematic problems recently occurring in non-research based firms. The problems are listed as follows:

- *“Network problems between firms and other organisations are addressed through cluster initiatives at local level (e.g., giving financial incentives), but there is very limited support for networking at the local/regional level”.*

- *“The policies are rather limited to tax incentives for training of employees and suppliers (competence building). There are no explicit policy measures promoting Thai society to be more innovative, Thai entrepreneurs to accept high a failure rate in doing innovative businesses, and Thai customers to accept innovative products or new ways of doing things”.*
- *“One of the most critical difficulties faced by the Thai firms is the lack of information on markets, funding opportunities, financial uncertainty, etc”.*

Moreover, not only lacking of technological capability but *“industrial firms tend to doubt the ability and effectiveness of universities and public technical institutes to solve practical industrial problems”* (TDRI, 1992 in Chantramonklasri, 1994, 26). This brings more severe problems to the Thai innovation system, since the firms are facing the shortage of technological knowledge and capability. This problem makes Thai firms less innovative which leads to being less competitive in the global market. For the firm who want to be ‘more innovative’, the main source of technological knowledge which most of them rely on is imported technologies.

In summary, the Thai innovation system has been described as weak and fragmented by many scholars conducted the research in the NSI studies (eg. Intarakumnerd et al., 2002 and Chairatana, 2006). Several studies reviewed in this chapter confirm the problematic pattern of the Thai innovation system as it is an inefficient system. The most critical problem emphasised by most studies is the weak relationships among actors in the innovation system particularly the public-private relationship (Chairatana, 2006; Schiller, 2006; Brimble and Doner, 2007; Intarakumnerd and Schiller, 2008; Intarakumnerd and Schiller, 2009). The problem is originated from both sides resulting in the weak relation between them. In the public side, the public organisations including universities and RTOs fail to provide appropriate knowledge to the user since many of them (in public side) lack of capability to produce advanced knowledge (Intarakumnerd and Schiller, 2009). On the other hand, the private sector as a knowledge receiver lacks of the absorptive to adopt advanced knowledge from the provider (Schiller, 2006; Chaminade et al., 2012).

Concerning the ST&I policy issue implemented in Thailand, at the beginning the policy adopted the linear model of innovation by following the science push model (ST&I knowledge created and embedded in the public sector) (Chantramonklasri, 1994). Later on in 2001, Thailand was trying to get away from the problematic linear model of innovation by

adopting the NSI concept to its policy making process (Intarakumnerd and Chaminade, 2007a).



## Research Hypotheses and Research Questions

These earlier studies have demonstrated problems that can be seen in the Thai innovation system. Each main actor of the NSI still lacks the competence to promote and develop the advancement of science, technology and innovation in order to stimulate and enhance Thailand's competitiveness. This leads to the main research question: How can Thailand improve its innovation system in order to embed S&T and innovation and in the process enhance its competitiveness? What are the problems preventing Thailand from making progress in the development and exploitation of ST&I?

These previous studies point to a weak and fragmented innovation system with problems in the knowledge flow among the actors. To fix a fragmentation in the system it is necessary to strengthen relationships among actors and to avoid a linear conception of knowledge flow. The focus of this investigation will therefore be on the relationships between firms, universities and public research institutes. In the preliminary study conducted for my master degree dissertation, the public-private relationship in the Thai innovation system was briefly investigated by using in-depth interview (with two firms) and questionnaires (36 firms in four technological fields). The result from this preliminary confirmed the conclusions of previous studies in suggesting that there is a problem in the public-private relationship in the Thai innovation system.

Consequently, in this PhD thesis a further study is carried out to explore the public-private relationship in detail. Case studies of technology transfer will be analysed to understand what factors contribute to success or failure. In addition, a detailed study of Thai innovation policy practice will enable broader examination of the way that the NSI concept has been applied in Thailand.

There are thus two main research questions addressed in this thesis:

1. What factors contribute to success (or failure) in technology transfer from the public to the private sector?
2. To what extent has the adoption of an NSI approach changed Thai innovation policy, and improved innovation?

Based on the literature review, these broad questions can be refined into more focussed hypotheses:

*Hypothesis 1:*

- 1a. The knowledge or technology produced in the public sector is inappropriate and insufficiently applied for the immediate needs of most firms.
- 1b. Thai firms lack sufficient absorptive capability to adopt new knowledge or technology.
- 1c. There are insufficient mechanisms for linking public and private sector innovation.

*Hypothesis 2:*

- 2a. Thai innovation policy based on the linear model (technology push model) constitute a limitation of the S&T development process.
- 2b. Attempts by the Thai government to overcome the linear model approach by moving to a NSI concept and strengthening the system have not been effective.

## Chapter 4 Methodology

This chapter presents the research methodology and framework for conducting the empirical study for this research. The criteria for the selection of subjects for the study, research boundaries, and research limitations are also presented here in order to provide a better understanding of this research.

### *Research Questions and Purposes*

The hypotheses about the Thai innovation system (as set out earlier in Chapter 3) are investigated through a detailed account of the development of Thai innovation policies and comparative case studies. These cases are selected from the commercialisation or utilisation by firms of research and development outputs produced from government Research Technology Organisations (RTOs) or universities. They are chosen from four different fields of technology: biotechnology, computer and electronics, material sciences, and nanotechnology. They vary in levels of success and progress of the process. In each case, similarities and differences are identified, and co-factors among cases are investigated and used to specify the factors that are influential in affecting outcomes in the utilisation of knowledge from public sector institutions by firms. This study provides new empirical evidence to address a pressing concern, and will aid the development of policy recommendation to promote the Thai innovation system.

The main issues needing to be analysed concerns the role of the NSI concept in shaping Thai innovation policy, and the factors that are influential in shaping technology transfer outcomes. First, the development of Thai innovation policy is analysed in chapter 5 with a detailed survey of policy documents over fifty years supplemented by insights from current government practitioners.

This is followed by the presentation and analysis of the case studies in chapter 6. The case studies build upon a preliminary study carried out for my MSc dissertation (Prachomrat, 2011). This preliminary investigation looked at the patterns of relationships between actors in the Thai innovation system by focusing on the university/research institute and private sector interaction. This PhD continues from these preliminary findings by seeking to specify the particular nature of the gaps between the private sector and the university/research institute, including other external factors that influence the patterns of interaction. Thus, potential solutions and ways of overcoming the gaps in interaction are uncovered.

### *Research Strategies*

This research applies two main strategies to answer the research questions. As Blaikie (2010, 18) sets out, an inductive research strategy is used to answer ‘what’ questions, in which the methodology “*starts with the collection of data and then proceeds to derive generalisations using some kind of inductive logic*”. This approach is used to address the question: ‘what is the NSI pattern in Thailand?’ Some aspects of this were answered by my preliminary study and have been addressed by other previous studies (e.g. Intarakumnerd et al., 2002; Chairattana, 2006; Brimble and Doner, 2007, Schiller, 2006). However, this thesis provides more in-depth information about the way that the NSI approach has been used in Thailand, particularly as regards the relationships among the relevant actors. Furthermore, the cases documented in this study provide comparative analysis across variables in different situations.

The deductive research strategy is applied to answer ‘why’ questions. As Blaikie (2010, 19) suggests, this approach “*adopts a very different starting-point to the Inductive strategy and is concerned with explaining some social regularity that has been discovered and which is not understood*”. This strategy is conducted by deducing one or more hypotheses from a possible explanation, or a theoretical argument, for the existence of the behaviour or social phenomenon under consideration. Then the data are collected to test the hypotheses or theories, it can either go against or support the deduced hypotheses or theory. In this study, it is attempting to answer ‘why the Thai NSI is the way that it has developed?’ Therefore, the deductive research strategy helps to find out the answer by constructing hypotheses and using data collection to test them.

### *Methods for Data Collection*

The research begins with the data collection for the literature review using information from previous studies and reports related to the problems in the Thai innovation system. At this stage, the secondary analysis was also used to analyse data from previous studies. The data are collected from many sources, mainly from the surveys or studies conducted by many governmental departments. Additionally, another type of data concerned with the NSI performance, global rankings of other countries were collected to compare among the countries in order to bench mark Thailand in the global level.

Then in-depth interviews were conducted in Thailand to obtain the specific detail of the problems that both public and private sectors have in their R&D operation. The subjects interviewed for this stage were researchers and staff, from both public and private sectors, and others involved in R&D management. At this stage, most firms used for data collection were the big firms including four Thai firms and one TNCs. Others were from public organisations, and most of them are responsible for organisation management and implementing ST&I policy in the public organisations. This round of interviews helped identify candidate case studies for the comparative study of technology transfer.

After that a second in-depth interview process was organised to collect, in detail, information from researchers and other staff, in both the industrial sectors and the public sphere. The subjects who participated in these interviews for this section comprised people from different companies and universities/public research institutes. The interviewees were selected from their collaborative research experience with the private sector, or vice versa in the case of the firm's researchers. These interviews focused on finding the detail of the process of technology transfer, problems which occurred during the collaboration, and also the solutions that they used to solve the problems (if applicable). Furthermore, additional information was obtained about organisational policies, R&D budgets and other influential factors.

The case studies of public-private interaction were selected from four technological fields in order to investigate the impediments that obstructed cooperation, or the supporting factors that facilitated their achievement. The cases were selected according to different levels of progress and success including six successful cases and twelve failure cases. The cases were identified as success or failure by the technology licensing office (TLO) responsible for the technology transfer process. The success cases were considered from the processes of technology transfer; that the technologies had been transferred completely to the firm and implemented to produce a new product or improve a production process. The commercialisation process is not the main concern in this case; however, five of the six successes have been commercialised already. These case studies are compared and contrasted with the twelve failures cases in order to find the similarities and the differences between them. Then the obstacles and support factors that influence the effectiveness of knowledge flow in the Thai NSI are identified.

Next, further in-depth interviews were conducted using subjects from the policy sector. This aimed to find out more specific detail of the policy making process and to obtain different points of view from other actors involved in the Thai innovation system. The interviewees were selected from the different policy making departments and at different levels. Additionally, another secondary analysis was carried out. The information from policies related to ST&I development issues were collected and analysed to investigate how all the policies were implemented. This part was analysed together with other empirical findings from case studies to explore the impact of policy on the public-private relationships. In total from three stages of in-depth interview, 65 interviews were carried out. All of these were recorded and subsequently transcribed, with significant sections translated into English.

#### *Timing and Sources of Data*

The whole data collection process was conducted in Thailand and completed within 2 years. Then the collected data was analysed using qualitative method (case studies) which took another six months to be finished. Therefore, this study took thirty months in total.

The participants from the public sector selected for the interviews in this study come from the National Science and Development Agency (NSTDA) -- under the Ministry of Science and Technology (MOST) as a representative of Thai public institutes -- and from the top ten R&D Thai universities, as ranked by the Office of the Higher Education Commission—and other government staff from different departments. The subjects from the private sector were selected from the list of firms in different sectors in Thailand collected by the Technology Management Centre, NSTDA. These interviewees included representatives of both large firms and small and medium enterprises (SMEs). The interviewees were selected from different sites in order to cover a variety of the NSI actors in the Thai innovation system. The four main technological fields: biotechnology, material sciences, computer, nanotechnology, and electronics and information technology, were chosen for this study. There are two reasons for choosing these four technological fields. Firstly, there are both similarities and differences in managing different fields of technology in system of innovation (as mentioned earlier in chapter 2). Secondly, these fields are the main technologies that Thailand is focusing on for its R&D development. Therefore, having different fields of technology in this research represents broader view of the NSI situation in Thailand.

The data collected for conducting case studies in this research are from the R&D projects that started after year 2001 when the NSI framework was officially adopted in the S&T policy in Thailand. Consequently, all of the case studies presented in this research were carried out under the NSI policy framework, which was launched in 2001 (details of the policy are presented in chapter 5).

**Table 5 Action Plan for Timing of Fieldwork and Analysis**

Activity/time	Year 1		Year 2		Year 3		Year 4	
	Month 1-6	Month 7-12	Month 1-6	Month 7-12	Month 1-6	Month 7-12	Month 1-6	Month 7-12
1. Data collection for the literature reviews	→							
2. 1 <sup>st</sup> round in-depth interviews		→						
3. Data collection for 2 <sup>nd</sup> analysis			→					
4. 2 <sup>nd</sup> round in-depth interviews					→			
5. in-depth interviews with the policy makers					→			
6. Data analysis		→						
7. Writing up					→			

### *Data Analysis*

There were two types of data collected for this study: data for secondary analysis, and empirical data obtained from the in-depth interviews. The qualitative data collected from the interviews shows information about the obstacles to, and support of, the R&D sphere and problems that occur in collaborative activities. The quantitative data collected from previous surveys and research was examined to investigate changes in the Thai innovation system. Once all the information was gathered, it was analysed and used to summarise the problems and gaps of relationships between the public and the private sectors in the Thai innovation system. Furthermore, it shows some evidences of the obstacles, and some key influential factors, that determine the accomplishment of the public and private interactions.

### *Discussion of the Strengths and Weaknesses of Research Design*

The information collected from the preliminary study had already suggested some answers to the question: “what is the pattern of relationships between the public and private sector in Thailand?” This then lead to the next step, which is the central purpose of this research by asking: “why and how it became like this?” To find the answer, the influential factors in each case were analysed and linked to the policy implementation determining the case. In answering the latter question we will be able to provide some potential solutions to solve the problems of interaction between public sector research and private enterprise that appear to undermine the performance of the Thai innovation system. Furthermore, it can demonstrate the impacts of the NSI framework implemented in ST&I policy making process in Thailand. Although the information that was obtained from my study is not able to be used for generalising the pattern of the relationships between public and private sector in Thailand, due to the limitation of case numbers, it can only be used to reflect some understanding of the relationships between universities/public research institutes and firms in the Thai innovation system. However, considering it together with the results of previous studies conducted by many scholars, it can be seen that the pattern of public and private sector interaction obtained from my study is similar to other previous studies. From there, this data can be used to further study the interactions between various sectors in the Thai innovation system in order to find out specific detail for the key factors that influence the system effectiveness. Thus, this research contributes more information to the subject both in terms of number and detail of the cases. Even though, this study does not aim to make a generalisation for the pattern of public-private relations in the Thai innovation system, it proposes some possible recommendations and/or useful information for policy makers to establish the appropriate policies for ST&I development in Thailand.

### Limitations and Barriers

In conducting data collection for this research, there are some limitations and barriers that arose from the researcher (myself) and the interviewees. Firstly, my status as a previous Thai government employee, eased my access to some important information collected and possessed by the public organisations. On the other hand, it prevented me from obtaining some information from interviewees, especially ones in the private sector who may have hesitated to give information, particularly when it involved negative comments about public organisations. However, most of the private firms agreed to participate in this research and were willing to give information on the public-private relation issue because they saw this research as an opportunity to communicate problems they are facing with the public sector without disclosing their identity. However, several firms that have experienced public-private R&D collaboration rejected the invitation to participate in this research for different reasons. Some had a bad experience working with the public sector and did not want to talk about it. Others had a successful story and enjoyed the output from public-private collaboration, but did not want to share their story because for confidentiality reasons. Therefore, some case studies are constructed from partial information because the private firms did not provide access.

### *Discussion on Methods and Case Selection*

The methodology used for this research comprises a mixture of secondary analysis, and in-depth interviews. In the first step of data collection the qualitative method (primarily in the form of in-depth interviews) is used as the exploratory procedure to investigate some initial information together with an analysis of previous surveys to gather quantitative data. In order to elaborate on the information obtained from the first round of interviews and secondary analysis, the explanatory procedure can be used and developed by employing in-depth interviews again, collecting from different positions in order to get a variety of opinions. Both forms of data are also used in the analysis process. Concurrently, additional qualitative data has been collected from other sources such as previous reports or studies.

By using a mixture of methods the research can benefit overall, with the “*strengths of one method offsetting weaknesses in other methods, providing more comprehensive evidence and help to answer research questions that cannot be answered using only one method*” (Blaikie, 2010, 219). However, Blaikie (2010) specifies that the disadvantages of using mixed methods is that this approach can possibly be demanding in both time and money. Mixed

methods also require a skilled researcher who has been trained in more than one research method. However, after having considered the advantages and disadvantages of mixed methods I decided that the combined use of two methods is the appropriate tool in exploring the research queries I intend to answer. Although this research inclines towards the qualitative method using in-depth interviews as the main tool of conducting the research, the quantitative data collected for the secondary analysis can help to guide a starting point of the research and also provide supportive information. To reduce the time and money consumed in doing a survey to collect the quantitative data, I decided to use data from previous surveys and research conducted by other scholars to do a secondary analysis. However, in my previous research, I had already conducted a survey to collect data from firms and it was used as the initial information for this research. Gschwend and Schimmelfennig (2007, 2) have pointed out the advantage point of using a mixture of methods in doing political science research as “*The methodological pluralism in our discipline [political science discipline] is a strength rather than a weakness*”.

In selecting methods, much thought went into deciding which data collection processes would yield the best quality and highest quantity of information. Therefore, in-depth interviews were selected to obtain qualitative data. This study required the elicitation of more detailed information on the collaborative pattern of R&D activities between the two main actors, the public and private sector, of the Thai innovation system and the problems or obstacles facing the researchers in both situations. The in-depth interview was the most appropriate method for finding out this type of qualitative information. These in-depth semi-structured interviews differ from structured ones “*by showing greater interest in the interviewee’s point of view, a flexibility and ability to adjust to the interviews flow*” (Bryman, 2004, 319).

Secondary analysis was used to analyse the data from the previous studies or reports in order to gain more information and broaden the research point of view. This method “*involves the use of existing data, collected for the purposes of a prior study, in order to pursue a research interest which is distinct from that of the original work; this may be a new research question or an alternative perspective on the original question* (Heaton, 2003, 281; see also Hinds et al., 1997) The primary data can be collected by other researchers, and by various institutions in the course of their business (Bryman, 2004). The information obtained from this method can be used to initiate and support the data collected from other empirical studies.

Additionally, Bryman (2004) suggests the advantages of conducting the secondary analysis include cost and time saving, high quality data (in most cases), opportunity for longitudinal analysis, subgroup analysis, opportunity for cross-cultural analysis, more time and data analysis, reanalysis that may offer new interpretations, and the wider obligations of the social researcher. Regarding these advantages, I decided to choose secondary analysis as one of research methods. However, I am aware of limitations of this method as well. As Bryman (2004) also pointed out the limitations of secondary analysis are a lack of familiarity with the data, complexity of data, no control over data quality, and absence of key variables.

#### *Case Selection and Number of Selected Cases*

For the criteria of case selection and the number of cases, the validity and general applicability of the cases are major concerns. However, other factors such as limitations of budget or data accessibility also have to be taken into account. The subjects in this study were selected from staff in both the public and private sectors. For the public sector, there are many types of organisations such as the universities which were selected for their R&D capabilities using the ranking of the Office of the Higher Education Commission. For the public research institutes, NSTDA is chosen for this study and other related government institutes.

There are three main reasons for choosing NSTDA as a representative of public research institutes. Firstly, there are four national centres under NSTDA doing R&D activities involved in four main industrial sectors (biotechnology, computer and electronics, material sciences and nanotechnology), while other public research institutes focus their research on specific areas. Secondly, NSTDA consists of both research units and a policy making unit, and thus it is more useful and convenient to collect data from these different perspectives. Lastly, as a former government official who worked for NSTDA, access to information is easier and more convenient for me compared to an outside researcher.

Although selecting only NSTDA as a representative of Thai public research institutes is quite limiting, and I recognise that other institutes may have different R&D activities and different management schemes, it is not possible to explore all public research institutes or universities in the Thai innovation system. Furthermore all Thai research institutes are under the same S&T policies launched by the government, so R&D activities should be conducted and managed in the same manner, and progress in the same way, with only a few minor differences in detail. This study aims to focus on the detail of the problems and find out the

key factors that determine the success of public-private interactions, so the research was designed to be narrow and focused. This led to my decision to limit the number of selected cases, which could be considered small compared to other investigations into the national innovation systems. However, after considering the criteria in selecting cases, the data collected from this research sample should represent some common problems in the relationship between the two main actors in the Thai NSI and also can provide some potential solutions and useful information for policy makers.

## Chapter 5 The Development of Thai Science, Technology and Innovation Policies

To investigate how the national systems of innovation (NSI) approach has been developed and adopted in Thailand we need to look at what Foray (2009, 1) refers to as the “*technological policies, in other words all public interventions intended to influence the intensity, composition and direction of technological innovations within a given entity (region, country or group of countries)*”. Technological policy can be used to promote innovation for supporting economic growth while playing a role in regulating innovation in areas such as health, safety, and the environment (Braun, 1994). Sweeney (2001, 1-2; see also Sweeney, 1985) suggests that investigations into the characteristics of innovation policies “*demand a systemic approach which recognises the intensive interactions between all elements of society and the strong interdependencies between technology, economy and politics*”.

Additionally, Chaminade and Edquist (2006, 144-145) suggest that diagnosis of the problems affecting innovation is key to the process of policy making: “*In order to be able to design appropriate innovation policy instruments, it is also necessary to know at least the most important causes of the problems identified. Not until they know these can policy makers know whether to influence or change organisations, or institutions, or interactions between them...Therefore, an identification of a problem should be supplemented by an analysis of its causes as a part of analytical basis for the design of innovation policy*”.

In this chapter, I describe and analysis eleven of the national master policies implemented in Thailand, beginning with the first national economic development plan launched in 1961 and concluding with the current plan of 2015. Particular attention is also paid to some specific ST&I policies that have been launched after 2001 when Thailand officially adopted the NSI concept for its ST&I policy making process. The criteria for this policy analysis is mainly to investigate the changes happening throughout the period. What are the factors that led Thailand to shift its policy from one to another?

## **6The National Economic and Social Development Plans**

The first National Economic Development Plan was established in 1961 as a five year plan aimed to develop Thailand's prosperity and well-being. However, during the first four plans, there was not much awareness of the S&T role in national development. It was not until the fifth plan in 1982 that a chapter on S&T for development was added into the plan (Chairatana, 2006 and UNESCO, undated).

A new National Economic and Social Development Plan is launched by the National Economic and Social Development Board (NESDB) every five years. The NESDB was first established in 1950 as the National Economic Council (NEC), and after restructuring in 1959, it became the Office of the National Economic Development Board (NEDB). The first plan established by NEDB was launched in 1961 as the nation's First Economic Development Plan. In 1972, the social development approach was added to the plan and it has been revised to be the National Economic and Social Development Plan as a five-year plan aimed at development for the country's prosperity and well-being. Concurrently, the NEDB became known as the National Economic and Social Development Board (NESDB).

### The First National Economic and Social Development Plan (1961-1966)

The plan aimed to maintain and expand the GDP growth rate of the country. The main activity focussed on the development of infrastructures supporting GDP growth and social well-being. The plan was categorised into sectors of development including agriculture and cooperatives, mining and other industries, transportation and communications, power, public health, education, community facilities and social welfare. The main S&T focus was in the agricultural sector and involved establishing research and experimental stations, and units for doing agricultural research and demonstration. The research aimed for high yield strains and a variety of strains that were suitable for different types of soil and environment. In this plan, the research for agriculture was not very successful because there was a lack of experts in the field and it focused too much on research only. Moreover, the farmers lacked knowledge and understanding of new technology.

### The Second National Economic and Social Development Plan (1967-1971)

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<sup>6</sup> The National Economic and Social Development Plans are produced by the National Economic and Social Development Board (NESDB) available at <http://www.nesdb.go.th/Default.aspx?tabid=62> for Thai version and <http://eng.nesdb.go.th/Default.aspx?tabid=402> for English version

This plan continued from the first plan by focusing on establishing infrastructure. In this plan the contribution of the agricultural sector to GDP decreased from 33% to 26% but still remained the most important industry in the country. The plan focused on agricultural development together with natural resources conservation and social well-being. It aimed to distribute development and economic growth to other regions of the country away from the centre. This included the establishment of Regional Agricultural Research Centres in many regions. In the industrial sector, public organisations supported industries by providing loans, consultancy, technical services and R&D services. Additionally, this plan was targeted at human resources development by increasing the number of graduates in higher education, training, and producing more teaching staff.

#### The Third National Economic and Social Development Plan (1972-1976)

This plan was launched when Thailand was facing the first economic slowdown since the first plan was introduced. Exports were stagnant due to global economic fluctuations and reductions in export commodity prices. The plan aimed to improve the productive structure in order to respond to global and local markets. In the industrial sector, the expansion of industries using local raw materials was encouraged. A strategy for reducing import goods was also introduced. In addition, the promotion of economic growth in rural areas and reduction of income disparities were also initiated. Investment in industry from the private sector was boosted by the government in order to increase the ratio of investment between private and public sectors. In social policy, family planning and birth control were promoted to control the rate of population growth.

#### The Fourth National Economic and Social Development Plan (1977-1981)

This aimed for a strategy to stimulate economic recovery after the downturn and also tried to maintain economic stability in the country. Besides the issue of economic growth, this plan had an aim of socio-economic transformation for national security. It also targeted a reduction in socio-economic disparities and the improvement of mass welfare. Policy towards the industrial sector focused on export goods including sugar, textiles, and cement. The public sector supported industries in the form of training, providing new/advanced knowledge. Additionally, the public sector created a network with South-east Asian countries that had similar industries and formed a consortium for technology transfer in order to exchange useful technologies that they could use in common. The government started to invest in some industries that needed complicated/advanced technologies, which the private firms did not want to take a risk on, or lacked the capability to build up/adopt those

technologies. The regional agricultural research centres initiated collaboration and coordinated research activities both among the research centres and with small agricultural stations over the country. In a social development approach, this plan continued with the establishment of the education system and the reduction of population growth.

#### The Fifth National Economic and Social Development Plan (1982-1986)

This was the first plan to include a separate S&T development chapter. This plan focused on awareness of using S&T for national development. In particular, this scheme emphasised the role of government in building up and strengthening public organisations devoted to S&T and promoting cooperation with foreign countries on S&T development. The plan initiated collaboration with the US in the development of three fields of technology: biotechnology, material science, and computer and electronics. Within a five-year period of the start of this plan, the three national centres for research and development had been established. The three national centres are the National Center for Genetic Engineering and Biotechnology (1983), the National Metal and Materials Technology Center (1986), and the National Electronics and Computer Technology Center (1986). This plan also aimed for increasing qualitative and quantitative S&T manpower development at middle and high skilled levels.

#### *Chapter 8 of the 5<sup>th</sup> plan: Utilisation and Development of Science and Technology*

*Chapter 8 of the 5<sup>th</sup> plan* focussed on S&T as an important factor in the production process. Its aim was to use S&T to improve the efficiency of production and utilisation of natural resources. However, at the time the industrial sector had low awareness of the importance of S&T in improving production efficiency and most technologies used in the industries were imported from abroad. Furthermore, many of them had been imported without a screening process in order to choose the most appropriate technology for industrial needs. Consequently, imported technologies came with a high cost and many attached conditions. In the agricultural sector, the application of S&T knowledge was not recognised as an important factor in the production process since people in rural areas still lacked S&T knowledge and most technologies that had been imported were not suitable to the local conditions.

Additionally, this chapter clarified more problems facing S&T development in Thailand during that period of time as follows:

- Lack of S&T basic knowledge

- Lack of skilled S&T personnel
- Lack of appropriate directions/policies
- Current research producing low standard results with no potential for application
- Lack of scientific and technological support
- Lack of efficient S&T plan to coordinate various activities and organisations.

Regarding the problems mentioned above, the plan set targets for S&T development and its application as described below:

- Supporting the application of S&T knowledge to enhance the efficiency of agricultural production and also in industrial sectors such as mining and energy. At the same time, trying to conduct R&D activities to improve production efficiency and utilising natural resources.
- The government started to screen and adapt imported technologies to suit local conditions.
- Aiming for increasing R&D ratio per GDP up to 0.5%, and encourage the private sector to spend 5% of their net profit on R&D through the existing governmental research institutes or private research institutes.
- Government cooperation with other S&T advanced countries to exchange information for technology transfer and improve the country's R&D capability. The government also provided specific training programme to the private sector to support their technological capabilities.
- The government proposed an intensive scheme for private sector and state enterprises to use more S&T in their production process.
- The government strengthened the country's S&T capability by enhancing Human Resource Development (HRD) (aimed for increasing S&T staff by 10% annually), increasing the number of research institutes, promoting the technology transfer process, and establishing a S&T information centre.
- The improvement of research management and development of the criteria to select research projects efficiently including monitoring processes and considering business impacts. Additionally, the public sector should find the right balance between basic and applied research since R&D development needs a combination and coordination between these two.
- The improvement of S&T policy formulation by establishing the Science and Technology Board with the prime minister as a chairman, and board members from

public and private sector. The board was assigned to formulate policies and operational plans consistent with the national development efforts.

#### The Sixth National Economic and Social Development Plan (1987-1991)

The plan had three main goals. Firstly, increasing the efficiency of national development regarding human resources, science and technology, national resources utilisation, and integrated systems of administration and management. Secondly, improvement of production systems and marketing, and upgrading the quality of economic factors in order to enhance the competitiveness of Thai products in the world market. Thirdly, increasing income distributions and prosperity to other regions and rural areas in order to narrow down the gap between urban and rural areas. With regard to the issue of S&T development, preceded by the fifth plan, this plan continued to promote S&T as an important factors of country development as specified in the fourth programme in the plan (the plan was categorised into 10 programmes).

#### *Programme 4 of the 6<sup>th</sup> plan: Development of Science and Technology*

In this programme of the 6<sup>th</sup> plan, the problems facing S&T development in the fifth plan were analysed and listed as follows:

- Low investment in the R&D budget: while the developed countries had an R&D budget ratio per GDP up to 2%, Thailand invested less than 0.5% of GDP. Moreover, almost all of this was invested and spent by the government. In firms, only 0.1% of their total revenue was spent for R&D activities.
- Basic research and applied research were not linked: the attempt to coordinate basic and applied research had failed since the implementation process did not work. There were very few research results that could be applied in the production process.
- Problems with importing technologies as mentioned in the fifth plan, Thai industries relied heavily on imported technologies. The Thai firms considered R&D activities as a risky and costly process, and did not want to develop their own technology, preferring to depend on imported technology. As a result, Thai firms still lacked an R&D capability. Another problem was the fees and royalties that Thailand needed to pay for those imported technologies; this had increased 14 times over the past 40 years. Furthermore, most Thai firms did not have enough knowledge to evaluate the technology or negotiate with the provider. Eventually, they ended up paying a high cost for simple technology.

- Problems with technology transfer agreements. Even though sometimes the firm could manage to get a good technology, there were some problems with the technology transfer agreement which normally included some limitation on the business activity. For example, a limitation of exporting finished products or specific export areas, a requirement for purchasing raw materials and machinery from the specific supplier, etc.
- SMEs lack of opportunity to buy advanced technology: instead with limited resources, they decided to buy a low quality technology and machine. Consequently, they produced lower quality and less competitive products. SMEs lacked the knowledge, capital and finance to develop or adapt existing technology.
- Human resources in S&T field: according to change in the Thai economic structure from an agricultural country to an industrialised country, it required more complicated technologies and a lot of qualified and capable staff. Therefore, human resources were the main tool to help the country to adopt and adapt existing advanced technology to the local context and also to develop local technology. However, the production of graduates in Thailand was more focussed on social science rather than science and technology or engineering. Moreover, most S&T staff or engineers working in the production process were lacking sufficient skill and knowledge to adopt new advanced technology.
- Lack of appropriate policy and a master plan for S&T development; there was no national policy or master plan to define a clear strategy for the country's S&T development. Furthermore, the government lacked an effective central coordinating agency and there was a problem of redundancy among the function of public S&T organisations. Additionally, the policy making process was not a unified function since most of S&T organisations had their own committees and defined their own policies.
- Problem in policy for supporting industry; the government launched many support strategies to encourage the private firms to get involved in R&D activities. However, most of them did not want to invest or conduct R&D activity. The only strategy provided by the government was a tax exemption scheme.

#### The Seventh National Economic and Social Development Plan (1992-1996)

This was the plan during which Thailand enjoyed the maximum average economic growth rate of the past 25 years. The GDP growth rate was double the expectation in the sixth plan because of export expansion, tourism, and investment. In the recovery of the global

economy, Thailand had an advantage of abundant natural resources and cheap labour to attract more investment and stimulate economic growth. However, while enjoying impressive economic growth, Thailand faced many problems from the unbalanced development including income disparity among rural and urban areas, inadequate basic infrastructures to support economic growth, and deterioration of national resources and environment. Thus, this plan was aimed to adjust the balance between the development in terms of quantity (number, economic growth rate) and quality (social well-being and equality). The plan was divided into different parts such as guidelines for maintaining economic growth with stability, guidelines for income and prosperity distribution to the regions and rural areas, guidelines for human resources, quality of life and environment, and guidelines for the development of law, state enterprises and the bureaucratic system. In this plan, science and technology development was one of the chapters under the guidelines for supporting stability of economic growth.

#### *Chapter 4 of the 7<sup>th</sup> plan: Science and Technology development*

In this chapter, successful results from the sixth plan were clarified as follows:

- Awareness raised of the importance of S&T in national development, particularly in the public sector and national administrators.
- Establishment of public S&T development institutes in three main technological areas.
- Preparation of S&T staff by increasing the manpower in S&T amongst university professors and researchers. Additionally, the government provided extensive scholarships for students in different degrees both in Thailand and abroad.

However, the problems that were facing the sixth plan continued in the seventh plan. The first one was the limited application of S&T to enhancing productivity in production processes. This meant that Industry was still relying heavily on cheap labour and natural resources which was not a sustainable situation. Secondly, since Thai industry could not produce its own technology for improvements in production processes, it depended on imported technologies which cost a lot of money and the cost was increasing every year. Moreover, the diffusion of these imported technologies was limited to the big firms while the SMEs rarely benefited. Thirdly, the problem of inadequate human resources still continued even though there were many solutions proposed in the previous plans. Lastly, existing R&D activities, basic facilities and support services for development of S&T were not enough to

absorb foreign technologies. Moreover, they were not capable of creating indigenous technological development.

This plan set the target for further S&T development as follows:

- Encourage greater application of S&T in both the agricultural sector and the industrial sector. In the agricultural sector, formulate measures for technology transfer in increasing productivity, support the application of new technologies such as genetic engineering, tissue culture, and bio-products. In the industrial sector, the government created a competitive environment by reducing the protection of domestic industry. Additionally, it supported development and technological application in specific fields for targeted industries.
- Support the distribution and diffusion of imported technologies by providing a centre to link various production units of industry. The government supported the SMEs by providing financial support for improving technology and relocating to the industrial park to exchange technological knowledge with other firms. It also provided support for foreign experts to be a consultant to enhance R&D activities.
- Improve public research institutes' capability to give assistance and support to industry and to help them to solve technological problems. At the same time, a mechanism to build up the connection between public and private sector was to be developed.
- Promote the role of the private sector in R&D by providing tax incentives, financial incentives such as soft loans and grants, and other incentive measures to stimulate R&D investment in private sector.

#### The Eighth National Economic and Social Development Plan (1997-2001)

This was the first step in adopting the new approach of development aims for the long term vision of an ideal society. All previous plans were based heavily on increasing the economic growth rate by utilising national resources and cheap labour. Thailand continued to enjoy impressive economic growth and prosperity as mentioned in the seventh plan and this carried on to the eighth plan. In parallel, the social and environmental problems facing Thailand previously continued and became more intense. Even though Thailand had been successful in accelerating its economic growth and prosperity, this did not mean that all Thai people were able to enjoy the success and improve their quality of life. Some of them were left behind and other problems were increased affecting Thai society. Therefore, this plan changed the development concept from the economic growth orientation to people-centred

development. This plan considered the economic growth as a tool to improve people's well-being.

There was also a change in the plan for science and technology development. Since the fifth plan S&T development plan was categorised as an individual chapter; however, in this plan S&T development was merged into other two topics including the development of economic competitiveness to foster human development and quality, and national resource and environmental management.

In the chapter on the development for economic competitiveness, S&T was considered as an instrument for sustaining the economic growth by supporting efficient utilisation of limited production factors, and by increasing skills and knowledge in production process. The chapter set the aims for using S&T development to enhance economic competitiveness as follows:

- “To increase technology transfer by many proposed schemes, for example:
  - Promoting technological cooperation with foreign countries and foreign direct investment. Additionally, the policy targeted the import of expertise together with high-technology machinery in order to support the learning process and development of technology in the country.
  - Revising some rules and regulations to encourage and facilitate technological experts from overseas to come and work in Thailand.
  - Supporting the network building among S&T institutes and academic institutes both in Bangkok and other regions to disseminate widely the application of S&T” (p.93).
- To develop science and technology infrastructures such as:
  - Creating a foundation for indigenous technological development by fostering adequate S&T and engineering personnel.
  - Building up S&T information databases and networks related to research work, patents, and human resources in the S&T field.
  - Improving the efficiency of public testing and certification services while encouraging the private sector to invest in this area to expand the services and create a competitive environment.
- “To increase efficiency in research and technology development by:

- Supporting the development of potential technologies that play important roles in enhancing the national economic competitiveness” (p.94) which can be described as follows:
  - o Development of crops and animal breeds with high yield and high resistance to diseases and pests. Improving the process of packaging and quality control in order to increase international competitiveness.
  - o Promoting the use of information technology in order to link public and private agencies.
  - o Supporting the development of technologies concerning energy conservation, alternative energy sources, and waste management in order to promote environmental conservation.
- Encouraging R&D activities in the private sector by providing tax incentives and financial support and also improving the quality of funding in the S&T field to make it more proactive.
- Restructuring the R&D system in the public sector to become more efficient in order to support national economic competitiveness and also supporting R&D activities in the private sector.
  - o Develop a comprehensive working plan for R&D by taking the user’s requirement as a first priority, and building up a public-private network.
  - o Develop public research institutes as centres of excellence to respond to domestic needs, provide technical services and advice to the private sector, and cooperate with the private sector to establish specific research institutes responsive to particular needs.
  - o Support the collection and study of indigenous knowledge and local technological requirements by promoting regional advanced academic institutes around the country.
- Stimulating the efficiency of S&T management by creating a solid S&T plan and mechanism to coordinate and link related agencies involved in S&T development to cooperate more effectively.

The chapter on national resource and environmental management also aimed to promote the development of waste disposal technology and green technology for application in production processes. This plan was intended to minimise the negative environmental impacts from industrial/agricultural process.

### The Ninth National Economic and Social Development Plan (2002-2006)

This was the plan which first adopted the philosophy of the sufficiency economy bestowed by His Majesty the King and applied it to national development policy: “*The sufficiency economy is a philosophy that stresses the middle path as the overriding principle for appropriate conduct and way of life by the populace at all levels*” (The Ninth Plan, 1). This plan continued from the eighth plan with the approach of people-centred development and applied this in conjunction with the philosophy of the sufficiency economy. It focused on collaboration among people and also expanded participation to a wider segment of Thai people. However, during the first year implementation of the eighth plan, the economic crisis was taking place and put a lot of negative effect on Thai people’s quality of life. Then the eighth plan was revised to maintain and recover the country’s economy. To solve the economy crisis, the plan shifted to emphasise economic stabilisation, provision of social protection, change in economic structure, and improvement in managerial process and it continued to the ninth plan.

Even though the government tried to solve the economic crisis in the country and slowly succeeded through gradual GDP growth, Thailand still faced problems in some sectors, especially in the financial sector and the real estate sector. Additionally, this plan identified the weakness of Thai economic structure as it is relied heavily on imported technologies and lacked a capability to produce indigenous technology. According to the ninth plan a “*the Thai economy is still dependent on foreign technology, has a weak production base, and is unable to absorb rapid changes in external conditions. The economic environment, in general, is not conducive to local innovations or efficient transfer of technology to enhance the national development*” (p.5).

Regarding the issue of science and technology development, the ninth plan brought back handling of this topic as an individual chapter entitled ‘Economic restructuring towards balanced and sustainable development’.

#### *Chapter 8 of the 9<sup>th</sup> plan: Science and technology strengthening strategy*

This chapter of the 9<sup>th</sup> plan analyses the problems facing S&T development in Thailand which were previously identified as one of the factors that worsened the economic crisis. It was noted that the key production factors that Thailand traditionally had relied on, including cheap labour and natural resources, were losing their comparative advantage. As mentioned

above, Thai industry relied heavily on foreign technologies; moreover, it had failed to adopt and adapt those technologies appropriately. Furthermore, research work in the country had failed to respond to the users' needs in the production sector. Therefore, this plan emphasised the development and application of technology, and support for local innovation development to enhance efficient production processes and services. It also specified that the development and application of local knowledge and technologies should be supported so as to reduce dependency on foreign technologies. The plan set out two objectives as follow;

1. "To develop science and technologies as tools for increasing production efficiency, by providing support for the development and application of advanced technology, as well as innovations based on existing technologies.
2. To build up a strong foundation in science and technology within Thai society to facilitate the country's restructuring process towards a knowledge-based economy" (p.95).

The plan also set development guidelines to respond to these two objectives which can be summarised as below;

- Development and application of technology, aiming for increasing the productivity by using S&T, and also a self-reliance approach supporting development of local technology and reducing dependency on foreign technology.
  - "Support research on modifying and improving existing technologies" (p.98).
  - "Reform the research and development paradigm by consolidating existing research and development supporting funds, reforming public R&D promoting collaboration between public sector and tertiary education institutes, and stimulating multinational corporations to increase R&D activities, technology transfer and labour skill development in Thailand (p.98-99).
  - Promote innovations using different strategies; for example, encouraging the utilisation of new technologies in many areas, revising laws and intellectual property rights protection mechanisms, etc.
- "Development of human resources in science and technology; enhancing capacity, at all levels, to develop and adapt scientific knowledge and technology" (p.100).
  - Build up science-based thinking by reforming the educational system and developing new learning processes, and dispersing sources of scientific learning to all regions.
  - Increase the quantity and quality of science and technology teachers.
  - Develop the scientific and technological capability of the workforce.

- Upgrading of the development and application of information and communications technology by
  - “Developing IT infrastructure for wider and more equitable access.
  - Promoting the creation and application of information technology for various activities.
  - Expedite the development of a sufficiently large and highly competent labour force in information and communication technology.
  - Promoting the development of the information and communication technology industry” (p.102).
- Improving management of science and technology development by
  - “Enhancing efficiency and effectiveness in operation of public, or government-supported, science and technology agencies.
  - Encouraging joint ventures and collaboration among public S&T agencies, universities, and the private sector.
  - Mandating public S&T agencies to establish institutional networks in all regions.
  - Establishing mechanisms and measures to protect Thai intellectual property rights” (p.102-103).

#### The Tenth National Economic and Social Development (2007-2011)

This plan continued with the same approach initiated in the eighth plan as it aimed for people-centred development and considered economics as a tool to help people achieve greater happiness and a better quality of life. The plan also carried on with the integration of the philosophy of the sufficiency economy from the ninth plan and also emphasised the importance of the Green and Happiness Index (GHI) on the country’s development. It recognised changes caused by the globalisation that affect Thailand in many ways as follows:

- Economic groupings and changes in global financial markets are increasing inter-country flows of capital, goods, services and people.
- Leapfrog advances in technologies including communications technology, biotechnology, materials technology, and nanotechnology, present both opportunities and threats to economy and society.
- Social changes; particularly an aging society.
- Free movement of people.
- Changes in the environment and natural resources. The increase in world population has caused deterioration in the global environment and natural

resources, with effects on climate change, the incidence of natural disasters, and the spread of new communicable diseases.

The tenth plan set the targets to respond to all these challenges and to create more opportunity for Thailand to prosper. The plan looked at the state of the national economy and noted the recovery from the crisis with the average GDP growth at 5.7 percent over the period 2002-2005 and with Thailand now counted as one of middle-income countries. However, the previous problems still carried on to this plan as it was noted that *“the structural weakness of the Thai economy is its high import dependence for raw materials, components, energy, capital, and technology. As productivity is low, production relies on the resource base more than on knowledge. Wasteful usage of resources for production and consumption results in environmental problems and consequential social impacts because of the absence of appropriate preventive measures”* (The Tenth Plan, iv).

The plan also pointed out that: *“The paradigm and measurement of economic development placed a greater emphasis on economic growth rather than balance and sustainability despite the fact that ‘economic growth’ should not be in conflict with stability, balance and sustainability of long-term development”* (preamble). The plan emphasised that long-term development should be more sustainable; for instance, it requires technological independence, human development in the aspect of intellectual capacity, economic and social equality among the citizens, stability and peace in society, conservation of natural resources and the environment, and most importantly, the independence and sovereignty of the nation. Therefore, it was stated that Thailand needed to adjust its development paradigm by aiming for a more self-reliant and resilient society following the philosophy of the sufficiency economy integrated with the approach of people-centred development. However, there should be some balance between self-reliance and competitive capability in the world market, and between rural and urban society.

With regard to the issue of science and technology development in this plan, it was recombined into other topics again after it was separated and defined as an individual chapter in the ninth plan. There are three chapters in the plan related to the S&T development topic covering strategies for development of human quality and the Thai society towards a knowledge based and learning society, strategies to reform the structure of the economy for balance and sustainability, and strategies for development of biodiversity and conservation of the environment and natural resources.

*Chapter 2 of the 10<sup>th</sup> plan: Strategies for development of human quality and the Thai society towards a knowledge based and learning society*

In this chapter of the tenth plan, the S&T development related part has the aim to build up efficient manpower that can create innovation and useful knowledge by introducing many approaches such as;

- Produce more researchers in both natural science and social science to develop new knowledge in S&T development, knowledge management and administrative management.
- Improve capacity, creativity, and expertise of existing researchers to be capable to create useful knowledge for society and the market.
- Build up trust among researchers to develop research networks at both local and international levels.

The next issue in this chapter set out an intention to generate factors that facilitate systemic sciences by an emphasis on promoting learning processes in all disciplines, identifying incentive measures to encourage researchers to work to their fullest capacity, and improving the centres of excellence and creating networks among related organisations.

The last issue concerning S&T development in this chapter involved management of knowledge at the national level to increase capacity and competitiveness in the global market on the basis of self-reliance by;

- Promoting R&D in all areas to produce knowledge and technology that stimulate the capability of the country to catch up with changes, and leads to the utilisation of the knowledge to benefit society and the economy.
- Developing innovation that leads to self-reliance and reduce the import of foreign technology. Additionally, improving the intellectual property right protection system to protect the commercial use, and manage new knowledge.

*Chapter 4 of the 10<sup>th</sup> plan: strategies to reform the structure of the economy for balance and sustainability*

The chapter was targeted at adjusting the economic structure to become more balanced and sustainable by integrating the concept of sufficiency and reasonableness together with the

knowledge economy. To achieve the goal, the plan aimed to reform the domestic economic structure starting from SMEs and community enterprises and implementing the 'cluster' concept. Moreover, it aimed to build up the value chain components in the national manufacturing of products and services using the concept of knowledge and innovation base. The chapter also raised awareness of economic reforms that should cause the least problems, and avoid destruction of natural resources and environment. One of the strategies proposed for this issue was the implementation of appropriate technology that consumes less energy and natural resources, and also is environmentally friendly.

The main objectives set in this chapter can be divided into three:

- To reform the production structure towards value creation of products and services on the basis of knowledge and innovation.
- To build up a safety net and a risk management system for various sectors.
- To create fair system of business competition and investment by considering benefits of the country, along with establishing a mechanism for fair distribution of benefits from development to people in all sectors.

Some examples of the targets and strategies that were set out to respond to these objectives were:

- A quantitative target for R&D investment targeted at 0.5 percent of GDP
- Supporting the utilisation of local wisdom and knowledge to create a variety of high-value products, and generate technology for production process.
- Initiating an integrated applied research system which aims at creating innovation both from acquisition of foreign technology and integration of local wisdom to generate new unique and distinctive technology.
- Creating a road map of patent searches that firms and entrepreneurs can use to benchmark and develop technology.
- Producing more innovative entrepreneurs through a business incubator system supported by capital sources, and efficient knowledge management systems.
- Setting up public-private funds for R&D in some targeted industries, and establishing joint venture and/or technological incubator units to adopt and create new innovation.
- Conducting R&D to develop alternative and renewable energy, and reduce negative impacts on environment.

*Chapter 5 of the 10<sup>th</sup> plan: strategies for development of biodiversity and conservation of the environment and natural resources*

This chapter was concerned with natural resources and environmental management. It adopted the philosophy of the sufficiency economy as the main idea of the chapter and focused on the balance or middle path between conservation and utilisation. There are some issues that S&T development contributes to in this chapter for example;

- Promoting organic farming and sustainable agriculture by adopting utilisation of local wisdom and clean technology.
- Supporting R&D and the application of clean technology, materials technology, and nanotechnology that has potential to save resources and energy, and also reduce pollution.
- Promoting R&D that combines local wisdom with modern knowledge and supports collaboration between researchers and communities in order to respond to local needs and reduce imported technology/knowledge.
- Developing the country's capability and initiating innovations from biological resources.

The Eleventh National Economic and Social Development (2012-2016)

This plan aims to ensure that all Thai people and all segments of society have equal opportunity and access to resources, and will share the benefit from development fairly. The adoption of the philosophy of the sufficiency economy is carried on as the main thought of the plan. The economic opportunities are to be created based on knowledge, technology, innovation, and creativity while concerning an awareness of eco-friendly foundation in production and consumption which leads toward stable and sustainable development.

This plan aims to use S&T development and innovation as the main tools to drive the country's development: *"In all aspects for development, the powerhouse of the country's future development will comprise knowledge, science, technology, innovation and creativity"* (The Eleventh plan, vii). As with the previous plan, this plan deals with the topic of S&T development in a number of chapters.

*Chapter 5 of the 11<sup>th</sup> plan: Strategy for Strengthening the Agricultural Sector, Food and Energy Security*

As Thailand has the advantage of abundant natural resources, the agricultural sector is important for the Thai economy as the main source of income for most people in the country. Additionally, it is the base for increasing value added in the industrial sector. This sector has many weaknesses, especially in small-scale farming which is becoming more individualistic, with fewer cooperative activities in the community. It is also dependent on foreign markets for imported technology and products such as chemical fertilisers and pesticides which cause problems with farmer's health and the environment.

- It is essential to apply S&T development to the agricultural sector in order to improve the productivity; however, the chosen technology ought to be friendly to the environment.
- There is also a need to use S&T and innovation to promote sustainability development in the industrial sector by supporting the use of green technology.
- This plan aims to “promote local academic institutions to establish joint ventures with the private sector in conducting research” (p.62). The government will support by providing tax incentive to the farmers and firms implementing eco-friendly innovations and technologies.
- For the energy issue, the plan aims to promote research and apply the technology to increase productivity of biofuel crops.

*Chapter 6 of the 11<sup>th</sup> plan: Strategy for Restructuring the Economy toward Quality Growth and Sustainability*

This chapter addresses the challenge to the Thai economy which has been able to maintain a good average growth rate and economic stability, but with low total productivity of the industry due to limitations on the development of innovation and the absorption of foreign technology. The Thai economy has limitations especially in the area of S&T development, the quality of infrastructure services, and economic rules and regulations. These weaknesses are obstructing the Thai economy from sustainable growth and result in a lack of resilience to deal with external uncertainties.

- Economic restructuring should be emphasised by R&D, technology transfer and applications that lead to commercialisation and improve the quality of life.
- There should be efforts to encourage more linkages between large enterprises and local firms.

### Some important constraints indicated in the 11<sup>th</sup> plan

- The International Institute for Management Development (IMD) and World Economic Forum (WEF), the world competitiveness ranking organisations, indicate some weakness in S&T development in Thailand and it was written in this plan as follows:
  - Low investment in R&D
  - Inadequate S&T infrastructure
  - Lack of R&D personnel
  - Low patent registrations
  - Problem in IPRs protection
- Moreover, they also identify problems in utilisation or commercialisation of research as described below:
  - Lack of collaboration among research-related agencies
  - Ineffective mechanism linking research among government, private sector and communities
  - Inadequate risk management
  - Inequitable allocation of benefit gaining from research

### Guidelines for development in the 11<sup>th</sup> plan

From the evaluation of Thailand's past performance, the results indicate that growth and structure of Thai economy did not go in the way that could maintain its quality and sustainability. The guidelines below are proposing some comments and suggestions for improve the development system in Thailand as a whole.

- The public and private sector should cooperate to generate and improve environment for S&T development activities, and also provide appropriate infrastructure and facilities to encourage technological development and innovation.
- As mentioned previously, S&T, innovation, and creativity are major tools for driving development plans, it should be done at all levels and in all segments of society. In addition, all developments should collaborate through the cluster approach.
- Improve ST&I management by building up coordinating system among relevant agencies and providing effective systems to evaluate and follow-up the activities.

- For financial supporting issue, encourage more incentive to set up public-private partnership research funds and joint ventures.
- Emphasising application of creative thinking, intellectual property, and R&D for the development to benefit society and business.
- Concerning the policy approach, all significant issues in the plan should be integrated and implemented into other government policies, the Government Administrative Plan, specific plans and operational plans. Furthermore, it is necessary to link the issues and guidelines addressed in this plan with the community development plans, local administrative plans, and provincial cluster plans.

### **Thailand's Economic Plans – Policies for Innovation**

Over eleven plans covering more than 50 years, Thailand changed its development strategies in three main periods of time which can be categorised as:

*Phase 1:* 1<sup>st</sup> plan - 4<sup>th</sup> plan in which the government and public sector played important roles in the plan implementation. Since the 1<sup>st</sup> plan, the most important issue for country development was to build up infrastructures. The public sector took a full responsibility in creating those infrastructures concerning public health, agriculture, irrigation and flood control, communication and transportation, and human resource development. In terms of technical issue, most of technical skills and knowledge was transferred from abroad to the public organisations in form of trainings and workshops. The second plan was focused more on the economic growth and the industry contributed more to the GDP growth but still less than the agriculture. However, the plan still continued in building up important infrastructures for the country especially important infrastructures in rural areas such as roads, irrigation system, and education. Regarding the global economic crisis during the 3<sup>rd</sup> plan, Thailand has for the first time announced the policy for import substitution. The government focused on rural area development plan including education policy and implemented birth control scheme to slow down the population growth. Up until the 4<sup>th</sup> plan, the public sector still played a vital role in country development. The infrastructures including roads and highways, irrigation, education, energy management remained important for the plan. The government took a role in conducting hi-tech industries, invested in hi-valued industries or complex industries. During these 20 year period, Thailand focused on

building up its infrastructures, developing human resources, improving agriculture, and learning new technical knowledge from outside (by the public sector).

*Phase 2:* 5<sup>th</sup> plan - 7<sup>th</sup> plan in which the private sector started to take part in the country's development. In this phase, there are two main transitions that occurred in the national development plan. Firstly, from the 5<sup>th</sup> plan, the S&T development plan was created as a separate chapter of the plan as S&T development issue became more important for country development. Secondly, the private sector contributed more to this development plan. However, it was specified in the 6<sup>th</sup> plan as there was a problem in linking public and private sector to work together particularly in application of technology. Although, the private sectors started to take an important role in many industries, most implemented technologies were imported and the private sector had to pay a large amount of money for those technologies. Until the 7<sup>th</sup> plan, the government put more support in R&D development in the private sector using tax incentive scheme, soft loan, and grants. However, in this plan, many problems in S&T development were raised including lack of absorptive capability in both public and private sector to transfer foreign technologies, lack of R&D facilities and basic infrastructures, weak linkage between public and private sector in performing R&D activities and conducting technology transfer.

*Phase 3:* 8<sup>th</sup> plan – 10<sup>th</sup> plan which brought together other associate members including society and community to participate in the development process. In this phase, the national plans moved to inclusive and integrated development strategy as the government aimed to encourage every segment of society to participate in country development. Particularly, in the 9<sup>th</sup> plan when the philosophy of sufficiency economy was adopted as the main scheme of the national development plan. The plans also moved from focusing on the economic growth as the ultimate goal to deploying economics as a tool to help people in the country to achieve a better quality of life. Since problems were raised in the 7<sup>th</sup> plan concerning the issue of S&T development, the 8<sup>th</sup> plan still focused on building up S&T infrastructures and human resources. The 9<sup>th</sup> plan emphasised aimed for reducing dependency on foreign technology and encouraging the development of indigenous technologies. Furthermore, it aimed to use S&T as a key tool to increase the economic growth. This plan also tried to fix the problems found in the 7<sup>th</sup> plan by promoting a strong collaboration between public and private sector in developing R&D activities.

The 11<sup>th</sup> plan which is now being implemented as the current national plan. Sustainable development has been emphasised as the main strategy. Knowledge, technology, innovation, and creativity are the main tools for creating economic opportunity. The S&T policies were aiming to utilise R&D resources to support the three main sectors including agriculture, industry and service. The policies also aim to strengthen linkages among public organisations, private organisations, and others in order to create more innovation. In addition, the financial support scheme and incentive are emphasised to encourage a public-private partnership in conducting R&D activities.

Regarding the evaluation process and indicators, there will be a progress report after one year of the plan implementation and a half plan evaluation process. The indicators used in the evaluation process are from IMD, WEF, and national statistics for ST&I development, R&D investment, R&D personnel, and GERD. Regarding indicators for evaluating the social impact, the interviewee explains that *“at the moment, there is no clear indicator to evaluate the social impact of ST&I but we are trying to develop and push it to be used as one of our indicators”*. She also clarifies that if S&T can be used to enhance national economic growth and competitiveness, people’s well-being and quality of live will be improved and then the social impact can be achieved that way. Simply put, the economic indicators can be used to indicate social impact indirectly as economic growth is considered as the main tool to enhance societal well-being.

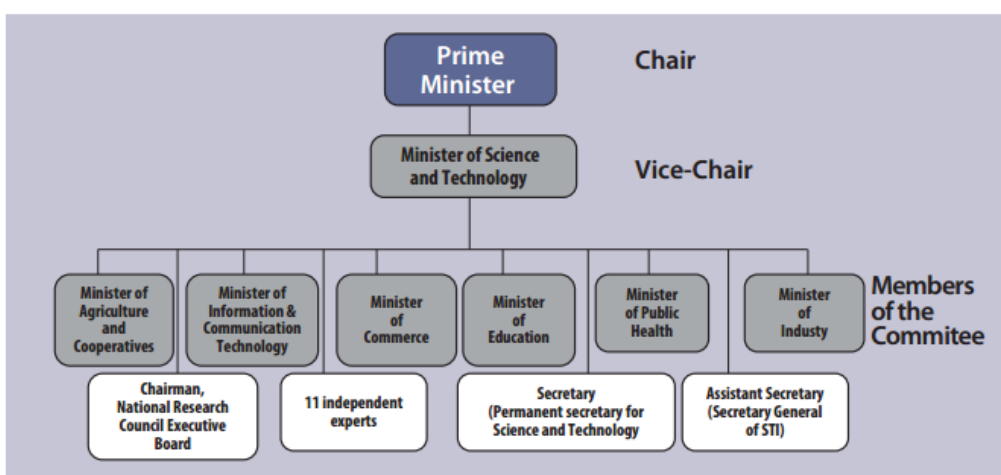
To operate the plan, all public organisations respond to the national plan by adopting the main themes of each plan and translate to their organisational action plans. Some might use the NESDB plan to construct their own strategic plans. According to the ST&I development issue, the Ministry of Science and Technology (MOST) and the Office of the National Research Council of Thailand (NRCT) take the NESDB plan to form their ST&I policies as they are described later in this chapter.

## Science, Technology and Innovation Policies

The Thai government has launched many policy frameworks promoting S&T development in Thailand in order to respond to the national plans. Thajchayapong (2005, 1), who was a Permanent Secretary of MOST at the time, stated that: “*Sets of related policies and strategies have been adopted in building up indigenous technological capabilities in order to enhance competitiveness. The government's current concern of necessity to increase the country's science and technology capability is reflected in several important policy documents*”.

In 2005, the Government Policy Statement delivered to the National Assembly focussed on five main issues<sup>7</sup>:

- “1). *to develop indigenous S&T and innovation capabilities to enhance competitiveness of industrial sectors;*
- 2). *to strengthen S&T manpower to assure sufficient supply for future demand, both quantitatively and qualitatively;*
- 3). *to induce and support development of clusters in priority sectors, including agro-industry and food, electronics, software and graphic design, automobile, healthcare, fashion, and energy;*
- 4). *to strengthen the regional economy by technologically upgrading manufacturing and service sectors in regional areas;*
- 5). *to promote development of clean technology to conserve a healthy environment*”.



**Figure 12 Thailand's National Science, Technology and Innovation Policy Committee**  
Source: UNCTAD, *Science, Technology & Innovation Policy Review Thailand 2015*

<sup>7</sup> Thajchayapong (2005): <http://www.jst.go.jp/astf/document/51pre.pdf>

Figure 12 demonstrates the structure of the National Science, Technology and Innovation Policy Committee in Thailand. Most ST&I policies are formed and approved through this committee. However, some of ST&I related plans are established under this committee such as the National Research Policy and Strategy formed by the Office of the National Research Council of Thailand.

The next section presents the three main plans related to ST&I development in Thailand. The first two plans: the National Science and Technology Strategic Plan (2004-2013) and the National Science Technology and Innovation Policy and Plan (2012 – 2021) are established under the Ministry of Science and Technology. While the third one: the Eighth National Research Policy and Strategy (2012-2016) is established by the Office of the National Research Council of Thailand and it includes other areas of research not only ST&I related issue.

#### ***<sup>8</sup>The National Science and Technology Strategic Plan (2004-2013)***

This plan was initiated as a draft of the National Science and Technology Strategic plan (2002-2007) in 2001. Later on the first plan was modified and changed to the National Science and Technology Strategic Plan (2004-2013). It was developed during the Eighth and Ninth NESDB plans, with a vision of a “strong economy with a knowledge society and better social well-being” following the main theme of these two NESDB’s plans by focusing on people-centred development and an ideal society. The plan took the aims in the S&T development chapters from the NESDB’s plans as its core strategies.

The plan was developed by the secretariat team of the National science and technology policy committee, including NSTDA, the Office of policy and strategy (under MOST), and NESDB. It is the first formal plan established to support the national strategy for S&T development in Thailand. It identified four fundamental factors for development: 1) an efficient and strong national system of innovation; 2) effective human resources; 3) a supportive atmosphere for development; 4) expertise in four main technological fields including ICT, Biotechnology, Material Technology, and Nanotechnology. The plan follows the national master plan by focusing on three targets for development: the industrial sector, community enterprise, and society.

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<sup>8</sup> The National Science and Technology Strategic Plan (2004-2013) produced by the secretariat team of the National science and technology policy committee, available in Thai at NSTDA

This plan aims to prioritise five main strategies: to develop clusters and strengthen community economy and quality of life; to develop S&T human resources (a target of 10 S&T personnel per 10,000 population); to develop S&T infrastructure and institutions; to enhance S&T public awareness and resources; and to improve the S&T management system. This framework has been used as a framework for the policy making processes in many public S&T development organisations in order to implement national policy. It adopts the concepts of national system of innovation and industrial cluster as the main fundamental factors to support development process. The national system of innovation (NIS) is defined in Thai policy as follows:

“National system of innovation is a network of institutions in the national economic system consisting of the government, private firms, universities, research institutes, financial institutes, and non-profit organisations whose activities and interactions lead to knowledge exchange, importation, adaptation, and dissemination of technology and new practices, with private firms and enterprises the main actors driving the system” (The National Science and Technology Strategic Plan, 2004-2013, 6-7) .

This plan included a World Bank study that analyses firms in the Thai innovation system. The study categorises firms into 4 different levels according to their technological capability including;

1. Labour intensive: able to use technology as it is provided without fully understanding
2. Skill intensive: able to use technology with appropriate adaptation, high technical skill, choose suitable and effective technology
3. Technology intensive: able to design, improve, and develop technology to a certain degree, but unable to create new products due to limitation of technological adaptability
4. R&D intensive: able to conduct R&D to produce new products or processes.

The study suggests that most Thai firms are classified into the first and second group. Only a few of big firms have the capability to be in the third group.

The policy also refers to the economic crisis of 1997 as one of the reasons driving Thailand to enhance its ST&I capability as Thailand’s lack of technological capability was understood to have made the crisis worse. The total factor productivity (TFP) in Thailand decreased

from 5.9% to 0.8% (1976 to 1995) which reflects the reliance of Thailand's economic base on investment and resources which are considered to be ineffective and unable to sustain growth. A lack of technological capability in the production process was identified as part of the reason for the decline in TFP.

However, the crisis had some impacts on the behaviour of Thai firms as Intarakumnerd and Schiller (2009, 555) suggest the impact of the intense competition in the global market and the economic crisis in 1997 *“to some degree, led to a change in behaviour among Thai firms. Several large conglomerates increased their in-house R&D activities rather than solely relying on off-the-shelf foreign technologies”*. This confirms the relation between the lack of R&D capability and the severity of the economic crisis.

The 2004-2013 plan also Identified several problems in S&T development in Thailand:

1. Private firms lack technological capability, and there is a lack of interaction among firms, public sector, universities, and industrial consortia. Firms rely heavily on foreign technology and are not able to produce their own technology.
2. The economy lacks S&T application in both the production process and in product development and this leads problems with product quality standardisation.
3. There is a lack of S&T personnel both in terms of quantity and quality.
4. There is inadequate S&T infrastructure and institutional structure.
5. Society lacks of awareness and understanding of the importance of S&T.
6. The management system for S&T development is inefficient and lacks an effective evaluation system.

#### ***<sup>9</sup>The National Science Technology and Innovation Policy and Plan (2012 – 2021)***

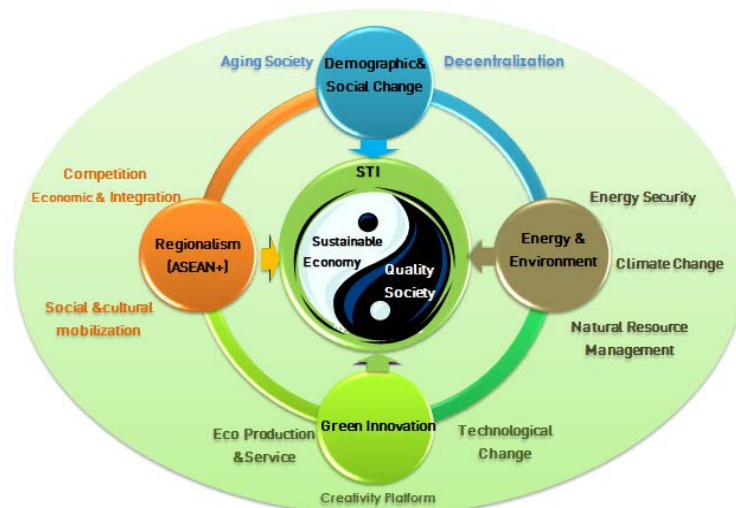
This plan is a ten-year National STI Master Plan (2012-2021) which has been approved by the Cabinet in April 2012. The National Science Technology and Innovation Policy Office (STI) under MOST as the secretary of the National Science Technology and Innovation Policy Committee (NSTIC) is the main organisation making this plan. The plan provides mechanisms to enrich Thailand's innovation system at all levels—from national to regional

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<sup>9</sup> The National Science Technology and Innovation Policy and Plan (2012 – 2021) produced by The National Science Technology and Innovation Policy Office (STI) available in Thai at STI

and local. It is developed to be in line with the 11<sup>th</sup> NESDB's plan by taking the philosophy of sufficiency economy and sustainable development to be a core of the plan. As can be seen in the Figure 13, the plan follows the main theme of the 11<sup>th</sup> national plan by continuing the people-centred approach with economic growth as the tool to support people's well-being and quality of life.

Other important issues such as environment, energy, social gaps are taken into account and then ST&I is applied to the development plan for each of them. The five main strategies proposed for this plan include strengthening society and local communities using ST&I, enhancement of economic competitiveness and flexibility in agricultural sectors, industrial sector and services, supporting the security of energy, natural resources and environment, developing and strengthening ST&I human resource, and promoting and supporting ST&I infrastructure and enabling factors.



**Figure 13 Framework for the National ST&I development plan and policy 2012-2021**

Source: The National ST&I development plan and policy 2012-2021, 2012, p.56

The plan is described more in the MOST's website which identifies knowledgeable, skilled human capital along with sufficient scientific and technological infrastructure and enabling factors as vital to the creation of a thriving innovation system. Strategies and measures are mapped out to develop these vital factors, resulting in human capital development programs—such as science education improvement through enquiry-based learning, vocational skill improvement through work-integrated learning, and enhanced university-industry-research institute collaboration via cooperative education and improved

academic/research personnel mobility—and infrastructure/enabling factor development programs—such as regional science parks, industrial technology assistance, tax incentives, and innovation financing. (MOST website, 2014)<sup>10</sup>

Concerning the implementation process for the plan, the STI is playing a central role to coordinate and support a transformation of the master plan into action plans. There will be the establishment of two action plans in response to this plan: the National action plan for science, technology and innovation I (2012-2016), and the National action plan for science, technology and innovation II (2017-2021).

### **<sup>11</sup>The Eighth National Research Policy and Strategy (2012-2016)**

The National research policy and strategy is another national policy that acts as a research guideline for research agencies and also a framework for the annual research budget allocation by the cabinet. This policy has been enacted by the Office of the National Research Council of Thailand (NRCT) for many years. The NRCT is an independent public organisation responsible for guiding research policy in all research institutions to follow. The difference between NRCT's national policy and other S&T policies is that NRCT's policies are not focusing only on the S&T research but includes social science research.

In this plan, the NRCT adopts the concept of sustainable development and the philosophy of the sufficiency economy as the main themes of the plan which comply with the NESDB's 11<sup>th</sup> national plan. The aims of the plan are to promote higher research potential and capability, develop useful knowledge bases, promote application and development of suitable and extensive bodies of knowledge, promote education and expansion of local wisdom for commercial and public utilisation, promote development of better quality of life through efficient utilisation of research resources and networks with participation from all relevant parties. The plan sets up five main strategies to achieve the mission including;

1. “Development of social development potential and capability to promote the body of knowledge that will provide a strong basis for national security through social

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<sup>10</sup> [http://www.most.go.th/eng2012/index.php?option=com\\_content&view=article&id=101:national-sti-master-plan&catid=86:book-store&Itemid=490](http://www.most.go.th/eng2012/index.php?option=com_content&view=article&id=101:national-sti-master-plan&catid=86:book-store&Itemid=490)

<sup>11</sup> The Eighth National Research Policy and Strategy (2012-2016) produced by the Office of the National Research Council of Thailand (NRCT), available in Thai at NRCT (in English for summary)

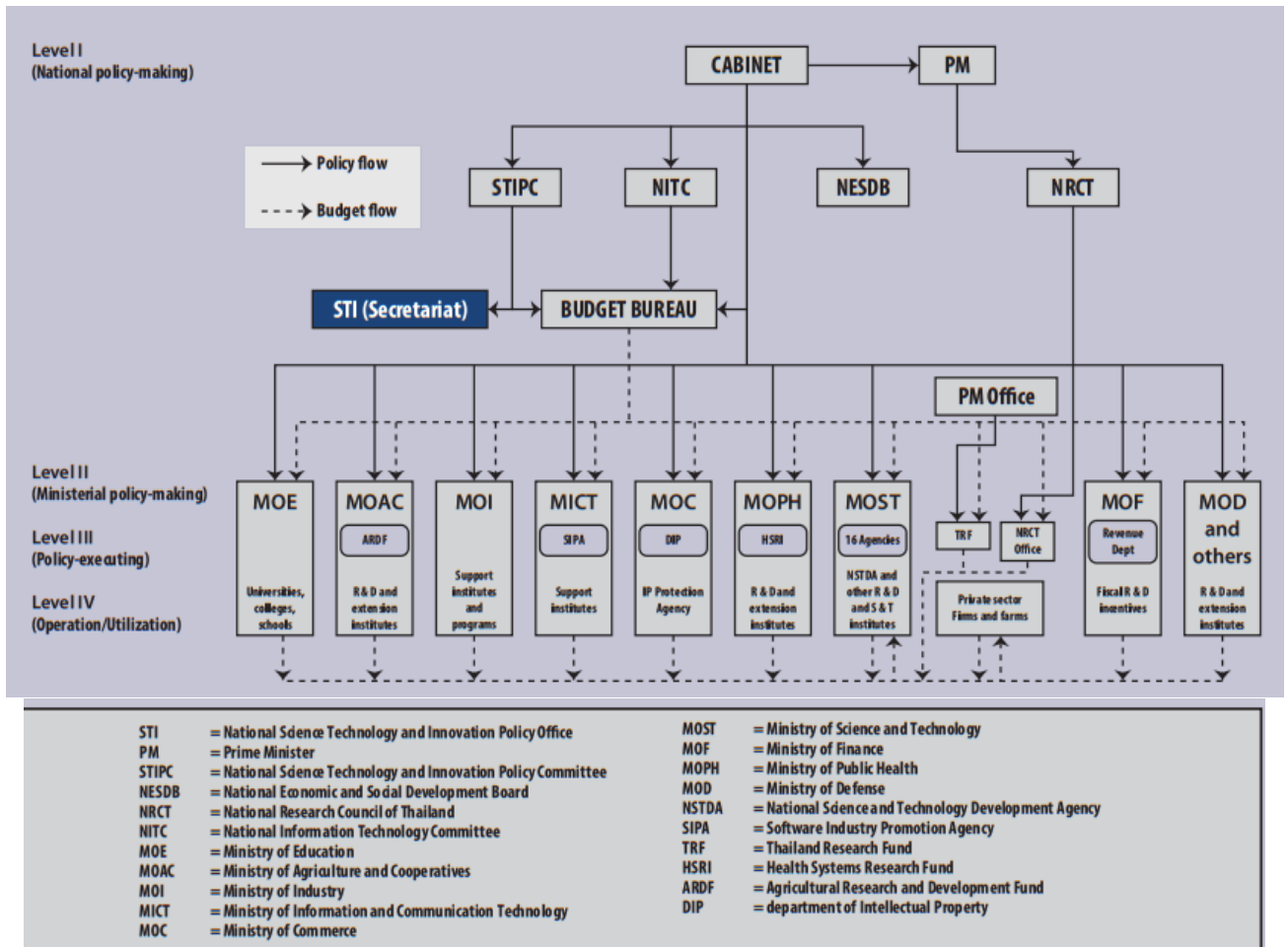
empowerment, development and advancement of the quality of life and happiness of the Thai people” (p.vi).

2. “Development of economic development potential and capability in order to promote the body of knowledge that will provide a strong basis for the development of potential and capability for a balanced and sustainable economic development based on the philosophy of economic sufficiency” (p.vi).
3. “Conservation, promotion, and development of natural resources and environmental capital to promote the body of knowledge and database for efficient and systematic management and development of the natural resource and environmental capitals through local and community participation” (p.vii).
4. “Development of innovation and research personnel potential and capability to promote the country’s competitive edge and self-reliance through the utilisation of science, technology and other forms of knowledge on a balanced and sustainable basis” (p.vii).
5. “Reform of the national research system for the management of knowledge, research findings, innovations, inventions, resources, and national wisdom towards their commercial and public utilisation through suitable strategies that will make them extensively available to the public and civil society” (p.viii).

The strategies of the plan have only small changes compared to the seventh plan; however, the first strategy has been changed from the development of economic growth in the seventh plan to social development in the eighth plan. This change corresponds with the recent NESDB’s national plan that put people-centred development as its main approach. In addition the plan has prioritised some important issues that need urgent response from research including: 1) Application of the sufficiency economy, 2) National stability and promotion of good governance, 3) Educational reform and learning creation, 4) Water resources, 5) Global warming and alternative energy, 6) Sustainable Agriculture, 7) Promotion of health, disease prevention, treatment and health rehabilitation, 8) Environmental management and development of natural resources diversity, 9) Innovative and major industrial technology, 10) Tourism management, 11) The elderly society, 12) Logistic systems, and 13) Reform of the national research system.

## Plan operation and implementation

The ST&I policies/plans are formed to respond to the national plan (NESDB plan) and they are operated and implemented by many public organisations. Figure 14 shows the different levels of policy formulation and operation. Not only the Ministry of Science and Technology that responds to the ST&I development plans but also other ministries involved in this process.



**Figure 14 Organisational structure of the science, technology and innovation policy system of Thailand**

Source: UNCTAD, Science, Technology & Innovation Policy Review Thailand 2015

**Table 6 Main public research and technology organisations**

	Budget (millions of baht)	Personnel
<b>Major science institutes (supported by the Ministry of Science and Technology)</b>		
National Science Museum	777	..
National Institute of Metrology Thailand	approx. 200 govt. funding + approx. 30 revenue (2014)	135 specialists + 65 support staff (2014)
Thailand Institute of Nuclear Technology	..	..
Hydro and Agro Informatics Institute	..	3 R&D staff, 38 support staff
National Synchrotron Light Research Institute	..	..
Thailand Centre of Excellence for Life Sciences	..	..
Geo-informatics and Space Technology Development Agency	Operating budget approx. \$20 million (govt. funding + revenue)	360 (10 R&D staff)
National Astronomical Research Institute of Thailand	178.2 (2011)	90 staff
Office of Atoms for Peace	..	..
National Innovation Agency	429 (2012)	..
Thailand Institute of Scientific and Technological Research (R&D and industrial services)	approx. 1 000 government budget + approx. 200 revenue (2013)	1 100 (800 researchers, 200 services staff)
Dept. of Science Services (testing, accreditation)	493 (2014)	..
<b>High-tech research centres (under NSTDA)</b>		
3 400 (2009)		
2 663 staff (1 784 R&D staff)		
National Center for Genetic Engineering and Biotechnology (BIOTEC)	772.7 (2012)	472 R&D staff, 98 others (2012)
National Nanotechnology Center	approx. 15 non-direct income (2011)	103 R&D staff, 51 others (2011)
National Metals and Materials Technology Center	641 govt. funding; 14.8 technological services (2013)	323 R&D staff, 186 others (2013)
National Electronics and Computer Technology Center	..	..
<b>Sector-related technology organisations</b>		
<b>Ministry of Industry</b>		
Thailand Productivity Institute	..	..
Thai-German Institute	..	..
National Food Institute	Self-financed	180 staff (50 training, 50 lab/testing, 30 data services, 50 others) (2014)
Thailand Textile Institute	..	80
Management System Certification Institute	..	..
Thailand Automotive Institute (testing services and policy advice)	Self-financed	approx. 182 staff (91 testing, 91 policy and training) (2009)
Electrical and Electronics Institute	..	..
Institute for SME Development	..	..
Iron and Steel Institute of Thailand	..	..
<b>Ministry of Agriculture</b>		
<b>Department of Agriculture</b>		
..		
Department of Rice (Bureau of Rice Research & Development, 27 Rice Research Stations)	..	..
Department of Land Development	..	..

Source: UNCTAD, Science, Technology & Innovation Policy Review Thailand 2015

Table 6 demonstrates the main public organisations responsible for research and development in Thailand. In this table also shows budget allocations and numbers of human resource in some important organisations (the information is not available in several

organisations). This table does not include the universities both public and private universities as the budget allocation in the universities is operated separately from these public organisations.

Regarding the budget allocation issue, the national budget is allocated from the Bureau of the Budget, Ministry of Finance every year. The main government bodies responsible for financing R&D in Thailand are shown in Table 7. From this table, the National Research Council of Thailand takes responsibility for a half of R&D budget in Thailand; however, this organisation is not involved only the ST&I development issue but taking other research topics in the country including social science research.

**Table 7 Main government bodies in charge of financing R&D in Thailand**

	Main responsibilities	R&D budget share (broad estimates)
<b>National Research Council of Thailand</b>	Oversees the national R&D policy, reports directly to the Prime Minister.	50 per cent
<b>Thailand Research Fund</b>	Main body in charge of non-institutional research budget and scholarships, the Talent Mobility Program and the Golden Jubilee PhD Program.	10 per cent (mostly contract funding)
<b>National Science and Technology Development Agency</b>	In charge of research institutes operating under MOST, including the four high-tech centres (Nanotec, Biotec, Mtec, Nectec).	20 per cent (mostly institutional)
<b>Agriculture Research and Development Agency</b>	Responsible for agriculture research funding and related public research structures. Allocates 30 per cent of its budget to enhance the research capacity of MOAC.	10 per cent (institutional and contract funding)
<b>Health System Research Fund</b>	In charge of health research funding and related public research structures.	5 per cent (institutional and contract funding)
<b>Office of the Higher Education Commission</b>	Responsible for research in universities	5 per cent (institutional and contract funding)

Source: UNCTAD, Science, Technology & Innovation Policy Review Thailand 2015

#### Criticisms and comments on S&T policies in Thailand

The S&T policies in Thailand have been established for more than 50 years in the form of formal plans, informal plans, individual plans, or integrated plans. The current situation of S&T development reflects the results of the policy implementation process which is considered not very impressive in terms of the progress of country development. Considering the first NESDB's plan, it was the starting point that initiated the science push model of innovation in Thailand as all research and experiment stations were initiated by the public sector. Although in the second plan public organisations started to support the private sector

by providing loans, consultancy and technical services in order to build up R&D capability on the private side, a lack of human resources was a major barrier to doing so. It was not only the private sector that lacked sufficient human resource to perform R&D activity, it was also the same in public organisations.

In the third plan and fourth plan, Thailand had to deal with its first economic crisis and focused more on socio-economic issues and social problems. It was only with the fifth plan that the S&T development topic was first placed as a separate chapter in the NESDB's plan. Although, the importance of S&T was recognised by this national plan, the focus was on imported technology and how to choose an appropriate technology to suit the local use. As many problems in S&T development were mentioned in this plan, the Thai government tried to encourage an increase in the ratio of R&D investment per GDP to 0.5% (up until now in 2015, the ratio has never exceeded 0.5%). In the sixth plan, Thailand realised the problems in linking basic research and applied research and also the weakness in the private sector in conducting R&D or adopting imported technologies. However, the following plans still continued in supporting S&T development in the public sector including universities and public research institutes. However, the lack of R&D capability and absorptive capability continued to be a problem for Thai firms adopting and utilising imported technology. The government attempted to solve this problem by encouraging public organisations to take the role of building up absorptive capability in the public sector in order to utilise advanced technology imported from outside. All these attempts made by several policies contributed to a science push model as most of knowledge and capabilities were initiated and embedded in the public sector.

The main critique of this approach is that Thailand sought to stimulate S&T development mainly by enhancing S&T capability in the public sector. As Chantramonklasri (1994, 25) notes "*STDB's [Science and Technology Development Board] main emphasis, however, in terms of both efforts and resources, was on strengthening R&D capability in universities and government agencies and on mobilizing this existing public-sector capability toward a higher level of applicability*". In addition, he divided the important features of S&T policy implementation into three main characteristics as follows (Chantramonklasri, 1994, 26-27);

- "The effort to promote science and technology development has almost exclusively focused on R&D. Behind this is the conventional wisdom which assumes that R&D is the prime-mover of a linear and sequential process of innovation—i.e., a process starting from

basic and applied research to development and engineering and eventually production and application".

- “There is a belief that as most firms in the economy are too small or backward to undertake significant R&D, such activities should be undertaken by the government. Hence, the policy perspective has been even further distorted to emphasise the development of R&D capability in the public sector with an expectation that this would generate useful outputs. Resources and efforts are directed toward establishing and strengthening R&D institutions and R&D activities outside the structure of industrial production”.
- “There has been little consideration given to utilising international technology transfer, through which most industrial firms in Thailand were established, to complement local efforts in building up technological dynamism in industry. Local technology development and international technology transfer are often treated as isolated from each other”.

Similarly, the OECD (2013, 266) notes that “*science and technology policy in Thailand has focused on research and development based on the view that private firms are ‘users’ of knowledge produced mainly by government agencies and universities*”.

Even though national level master plans (such as the NESDB’s plan) are trying to shift from a model of technology push from the public sector to the private sector, the implementation has not been very successful. As can be seen from some of the latest plans the S&T development topic has been merged to other chapters as a tool for development in each of them. The plans attempt to take the user’s need in each chapter as the main target to develop S&T but the implementation process of S&T development still relies on the public sector. The main reason for this is the lack of R&D capability and S&T infrastructures in the private sector.

The problem of policy implementation was emphasised by one of NSTDA’s policy makers. As she puts it, “making policy and implementing the policy is a different story. Even we have the STI as the main organisation to make the ST&I policy but due to the hierarchy of the public organisations, the STI does not have a full authority to enforce the policy on all responsible organisations”. Concerning the technology push model she explains that the S&T policy in Thailand has been initiated by academics, therefore it leans on the technology supply side rather than the demand side.

Regarding the adoption of the NSI approach at the policy level in order to avoid the linear model approach, the attempts at implementation are also not very successful. As Chaminade et al. (2012, 1485-1486) conclude, there is a mismatch between current implemented policies and the systematic problems observed in the Thai innovation system: *“Broadly speaking, most of the instruments currently deployed to strengthen the Thai innovation system are still mainly targeted at research-based firms, or they are likely to benefit these firms. This reflects the path-dependent nature of innovation policy making in Thailand, which traditionally focused on stimulating research (mainly outside of the firm)”*.

Thailand is trying hard to move forward in ST&I development by establishing the necessary infrastructure and promoting human resource development. However, it is still struggling with the problem of how to encourage and develop national R&D activities effectively. Intarakumnerd and Chaminade (2007b, 11-12) record how the adoption process of the NSI formally adopted in the strategic plan (2004-2012) set out measures for strengthening the national innovation system, but these were not followed through in the implementation process: *“a closer look at the instruments that are being used, still shows that while there is a gradual move in the right direction, most of the instruments still respond to the old paradigm, focusing on giving incentives to research and focusing on the public sector rather than encouraging capability building and innovation in firms”*. Additionally, Intarakumnerd and Chaminade (2007a, 209) conclude that: *“The result is a policy that although is moving in the right direction and focusing on the right problems hardly addresses the identified systemic problems in practice. System of innovation approach is like an icing on the cake which main ingredients are neoclassical economics and linear model of innovation”*.

#### Criticism of the key performance index (KPI) and indicators

The indicators and key performance index used to measure or evaluate ST&I capability in Thailand focus heavily on quantitative indicators (R&D expenditure, publication, patents, technology licensing contract) and neglect qualitative indicators of innovation. This not a problem that is unique to Thailand, as other countries are facing the same situation. Freeman and Soete (1997, 301) describe findings obtained from a comparative assessment of country performance conducted by the OECD: *“In practice they concentrated mainly on the formal R&D system and technical education...Much research on invention and innovation had amply demonstrated that many factors were important for innovative success other than R&D. However, the practical difficulties of incorporating these factors in international*

*comparisons were very great. 'League table' comparisons of R&D were much easier and more influential".*

Similarly, with regard to the NSI approach, Lundvall et al. (2009, 10) criticise the use of quantitative indicators because of their corrupting effect on the concept's key principles. As they put it *"The core of any standard study of (national) innovation systems will thus contain data on R&D efforts and patents"*. Additionally, Altenburg (2009, 34-35) suggests that *"science and technology policies should be reoriented from their current focus on R&D towards engineering capabilities; from pursuit of 'new to the world' innovations to technology diffusion; and from supporting modern urban industries to the development of innovations that improve the livelihoods of the poor"*. Additionally, he suggested that *"the main distinctive feature of developing countries is poverty"* (p.36). While improving the economic situation is central to relieving poverty, there are many social problems such as education, health, and the environment that also need addressing. Therefore the main targets for the national policy in developing countries are different from the developed nations.

This problem was acknowledged by the OECD (1997, 4) when it attempted to improve their comparative study of countries by measuring knowledge flows in innovation systems and using similar indicators: *"specific analyses will be directed to deepening the understanding of certain types of flows in national innovation systems, namely: 1) human resource flows; 2) institutional linkages; 3) industrial clusters; and 4) innovative firm behaviour"*.

### Summary

Finally, Gu (1999, 50) suggests that: *"Any piece of policy should not be regarded as fixed and universally applicable. In contrast, policy is country-specific. A workable policy runs an adaptive process in interactions with the system to which it aims to introduce a change. Adjustment over time with the operation of the system gives the possibility to the policy process to get system-fitness, that is definitely needed in the management of historical transition in economic development"*. This is the most important point for the policy as it needs to be dynamic, flexible and can evolve to catch up with the global trend.

So far, the policy implemented in Thailand particularly the national economic and social development policy shows this sort of characteristic as it has been reacted to the external changes and not become too static. For example, the policy reaction on the economic crisis in 1997, the policy makers realised the importance of innovative capability in supporting country competitiveness and tried to encourage and build up this capability in firms. However, in reality the plan does not go as it was expecting. The same thing happening

when the ST&I policy makers become aware of the drawback of science push model and attempt to implement NSI framework to the policy level. It goes back to the criticism made by Chaminade and Intarakumnerd (2007b) as it was implemented just a name of the policy not in action. This point will be elaborated more in the discussion chapter together with the data from the case studies.

## Chapter 6 Case Studies

This chapter uses empirical data obtained from the interviews to construct 18 case studies. The 65 interviews conducted for this research involved staff in the public and private sectors who are responsible for ST&I development in Thailand. Interviewee details are shown in the appendix. Unless otherwise referenced, information and quotes in this chapter come from these interviews.

The cases are categorised into 6 successful cases and 12 failure cases using criteria judged by the NSTDA's Technology Licensing Office (TLO). The criteria used to judge the success or not of the cases relate to the process of technology transfer and utilisation of transferred technology in the firm. The success of the case is not focusing on the commercialisation process of technology; however, in most of the successful cases, the products have been launched to the market and gone through the commercialisation process. Only one case is still in the process of product development in the firms but the case is considered as a special case for innovation development in Thailand as it has a potential to become a world first innovation product in the future. Therefore, the label 'success' used in this research simply means that the public sector has succeeded in completing transfer technology to the private sector and the private sector is able to utilise the transferred technology. Applying the same criteria, cases where there has been a failure to conduct technology transfer are considered to be failures. However, there is one case that was categorised as a failure even the technology has been transferred to the firm because the planned product failed to pass the requirements for regulatory approval. Another case was also considered as a failure because the technology licensing agreement was signed, but terminated later before the product had been completely developed by firm.

The cases vary across a range of technological fields, patterns of technology transfer, timings, and scales which represent different situations and patterns of public-private interaction in the Thai innovation system. In addition to the 18 case studies, others empirical findings included in this chapter provide further detail and context about the technology transfer process, based on interviews with large firms and other organisations involved in the process of ST&I development in Thailand.

## 6.1 Public-Private Collaboration: Successful Cases

This section is focused on six case studies considered as successful instances of technology transfer from the public to the private sector in Thailand. The definition of ‘*a successful case*’ in this research refers to when the firm chosen to receive the transferred technology is able to demonstrate capability and expertise in its operation. This understanding can be used to produce a new product or enhance existing products and processes. Although the definition of success used here focuses on the transfer of such technological capability, successful innovation from an economic point of view obviously depends on commercialisation further down the road.

Because the pattern of the technology transfer process can be influenced by the field of technology six different technological areas were studied, namely Material Science, Information and Communication Technology, Medical Biotechnology, Biochemical Engineering, Environmental Biotechnology, and Automation Technology. Furthermore, the cases covered a range of different technology transfer methods, including technology licensing, collaborative research, contracted research, Spin-off Company, and start-up firm.

The amount of information gathered from the public and private sector in this study is variable in each case. This was dependent on access to data.

### **Case Study 1 - *Bio-treatment Firm***

In this case, the firm and the public sector have been working together since the company was established. The research was initiated by the firm leading to collaborative research with the public sector. The technology involved in this case is biotechnology used for producing an environmental treatment agent.

#### *Private Sector*

The firm involved in this case will be called *Bio-treatment firm*. The company’s owner was in the business of trading pharmaceutical products. Then he found the opportunity from the regulation process in the standard for environmental protection; ISO14000. “I think there is room for us to play because there are not many players in this sector”, explained the firm’s owner and founder during the interview. The company decided to establish a new company

and started their business by importing environmental treatment agents from abroad. During that period, the owner took the course named 'Industrial Ecology' at Mahidol University while continuing with the business. From that course, he learned how to manage and implement biotechnology in the environmental management field. When he came back to think about his business; he thought of an opportunity to develop a product.

As he put it, "We have a business but we do not have our own product. How can we sustain our business in the long run and how can we compete in the future? We need change and differentiation." This led to the idea of doing R&D in order to develop new products for the firm. As a Small and Medium Enterprise (SME), it was difficult to set up an effective R&D unit within the firm. Therefore, they decided to contact a researcher in the public research institute. Fortunately, the owner knew a relevant researchers in person, and so they had an informal meeting to discuss the firm's needs.

### Public Sector

On the public side, the government research institute known as the National Centre for Genetic Engineering and Biotechnology (BIOTEC) is one of four national research centres under the National Science and Technology development Agency (NSTDA) of the Ministry of Science and Technology (MOST). BIOTEC was established over 30 years ago and became the first national research centre under NSTDA. It operates outside the normal framework of the civil service and state enterprises which allows BIOTEC to work more flexibly and independently from the bureaucratic system. BIOTEC's headquarters is located in Thailand Science Park (TSP).

In this case study, the BIOTEC researcher who conducted the collaborative research with the firm was working at the Excellent Centre of Waste Utilization and Management (ECoWaste). It is one of BIOTEC's specialised units located at King Mongkut's University of Technology Thonburi (KMUTT). ECoWaste is active in carrying out research programmes to improve biological waste treatment technology and has four main research groups working under this unit. The research groups include Microbiological and Biochemical Aspects, Reactor and Process Development, Computational Aids and Process Optimization, and Environmental Research and Management.

### The Collaboration Process

After several informal meetings with the firm, the BIOTEC researcher agreed to carry out collaborative research and recommended the company use the firm supporting system at NSTDA. As the researcher put it: “I think we have the potential to develop this product using our own technology. Using local bacteria in this kind of product should be more effective than imported products because when we apply this product to the local environment, the local bacteria should be better able to survive than bacteria from another environment”.

After that, the firm had contact with NSTDA as an incubatee in the Thailand Science Park (TSP). The firm moved to the incubator unit of TSP which is located in the same area as BIOTEC and other three national centres under NSTDA. Then the collaborative research was started formally and co-funded by NSTDA. After 18 months (the time period of project phase1 was 2 years), the researchers found the potential bacteria and prepared it in different formulations. These were then tested in the contaminated area to measure the effectiveness of the bacteria. This part was done by the firm and they used their previous experience with imported products to test and develop the new product. The potential product prototypes were selected, produced to a pre-pilot scale by the researcher and distributed to customers who had previously done business with the firm. From this stage, they gained useful information about the effectiveness of the new products and the proper method to apply the product in the field. Consequently, now satisfied with the result, they started to discuss the licensing agreement.

Finally, the new product was licensed to the firm and it was commercialised and introduced to the market. During this stage, the firm produced a business plan aimed at expanding the market for its new product. The response from the market to the new product was good and led to the company growing very fast. This led to another step for the growth of the firm. In the early stage of commercialisation, the product was produced in the pilot scale which was not enough when the demand was higher. Therefore, the firm needed to move to another stage, and it decided to move out from the TSP incubator unit and set up their production unit in another area. Now, the company is growing, it has moved from the local market to international markets. It has started to export its product to many countries in Asia. During the last four years, the firm and TSP have participated in many conferences and events both at national and international levels. The firm’s new product has won many prizes and gold medals as an excellent innovative product in several events. “The medals do not prove that

we will be a success in this business but it does prove that we have come in the right way”, said the firm’s owner.

Even though in this case the firm’s owner and the researcher already knew each other in person, one of the important reasons that made the firm decide to collaborate with the public sector was the specialisation and reputation of this research unit. To earn a reputation and trust, the research centre has to show its excellence in a specific research area and be able to use its research expertise to respond to user needs. The researcher explained that “We evaluate ourselves first; I mean the readiness of technologies and the team. From the product specification that the firm explained to us briefly, we think with this stage of technology that we have developed, it is not difficult for us to accomplish the goal. However, from the first place I think the key success factor of this project is not the research capability or technological readiness in the public side but the marketing process in firm”.

He also emphasised his opinion that: “I think the technology that we are going to implement is not the advanced one, it is not even the common technology but we are quite confident in our expertise. While we believed in the technology, we saw the firm’s expertise in marketing management skill. As an experienced player in trading imported products, it is easier for them to sell another product in the same market, compared to a new player in this field”. In his view, the researcher thought it was a good opportunity for both sides: “It is not easy to find a firm that is willing to invest money in R&D activity, especially a local firm in Thailand. As we know that R&D investment has a high risk, even though it can provide a high return in some cases, but few people can be brave enough to do it, particularly with the local researchers and local technology. That is why I say it is a good opportunity, especially for us to have a chance to prove the use of our technology in real life”.

#### *Other Public Support*

At the starting point of the collaborative research, there were many people from different sections in public sector involved in this process. Teaming up with the public institute researchers to do collaborative research was a good starting point, but it did not guarantee the success of the project. What other supporting factors were important?

The first one was the co-funding. Even though the firm was willing to invest its own money for the project, it was not possible for it to invest the whole amount. “It is quite risky for us as a new firm, and being an SME, to invest a large amount of money in an R&D project that we do not even know the preliminary result of yet. For me, if we have to we will find the

way to do it. However, if there is another way to reduce our risk, I will choose that way. Luckily, we do have it”, the firm’s owner said. In NSTDA, there is a function available to support R&D activities in firms called ‘co-funding/co-investment’. This function used to be run by several divisions, but is now mainly run by the Cluster and Programme Management department (CPM). This department’s main function it to act as a research programme manager supporting industrial clusters, and to provide funding. The function of CPM and other important departments supporting STI development under NSTDA will be explained in more detail in another section.

In this case, CPM got involved as a co-funding body and project manager at an early stage of the project. CPM’s staff coordinated with staff from the Technology Licensing Office (TLO) to evaluate and manage the project. This is not a formal or compulsory process but it is a process that CPM normally does when a firm gets involved in an R&D project. CPM focuses on the academic concept of the project while the TLO’s staff will help with the business idea. For this collaborative project, evaluation was carried out by peer reviewers comprised of a technical committee and an executive board meeting in order to grant the money from NSTDA and also to help the researchers steer the academic concept. Progress reports were submitted to CPM and the firm every six months and evaluated by peer reviewers and the committee to follow the progress of the research closely.

Another NSTDA function involved in this project was the business incubator unit under TSP. This function is another important supporting factor for the firm. As a newly founded SME, it needed help with the facility and location. Therefore, the incubator unit role has fulfilled this need. In this case, the incubator unit provided the rental area in TSP to the firm. By locating in TSP, the firm could use some necessary facilities available at BIOTEC and other national research centres. Furthermore, TSP has set up a research community for its incubatees and tenants to facilitate their communication with each other in order to enhance connections between the firms and to build up a research atmosphere in the TSP area. “We were trying many different strategies to make them learn from each other. We held sport events and let them join and compete. At the beginning, only a few people want to join but it is getting better nowadays. Some of them start their collaborative project between the firms without any intervention from us. It is another step of our success because our final goal is to make them move independently in the STI development”, one of TSP’s staff explained.

Presently, the project is in the second phase of development. Although, the research has already been translated to the commercial product, it still needs a further development to

improve the product in the market. During phase 2 of the project, the firm is growing as mentioned above. The market is also expanding because the firm finds increasing opportunities as environmental regulation becomes stricter. Furthermore, the product has been adapted for use in different ways. “It is about the vision and experience of the firm. They know where to go and how to use it. We support them in the technical aspect while they move with their excellent business vision”, the researcher clarified.

During the past four years, the firm has faced the many changes; the important one is the market trend. “If we decided not to move into the R&D area, I cannot predict what we are going to be today. The pattern of the business has changed so much. If we do not have our new developed product we might end up in the different way. In my opinion, innovation has saved our business”, the firm’s owner said, confirming the importance of innovation. He also emphasised that “NSTDA is really helpful; many functions under NSTDA supported the success of our project.” This was also confirmed by the researcher: “I think even the TV advertisement that NSTDA did to introduce the new products is useful. It makes people from outside know what are we doing and it is easier for the firm when the product has launched to the market. They know what it is and they know that the product was developed by the Thai researchers”.

### *Case analysis*

This case can be understood as following a simple pattern of demand-pull innovation which started from the need of the firm based on what they knew they wanted. Then the researcher responded to the need using his existing technology to develop the product and the new product was launched to the market. However, when the case is analysed further, some interesting factors are found in this simple case.

Firstly, although this could be considered a normal case that has happened often in many developed countries, it is still rarely found in a developing country like Thailand. This is because the thing that normally happens in a country like Thailand is that firms, especially local SMEs, do not have much interest in innovation or R&D activity. There are many reasons underpinning this. The first one is budgetary; even though they are willing to do R&D, it is not easy to share a limited resource to an activity that they cannot predict the return from.

This leads to the second reason that makes firms not do R&D activity, the attitude of the firm’s owner or shareholders with regard to R&D activity or innovation. When the person

who has the power to make a decision does not believe in the benefit of innovation, it is difficult for the firm to move on as an innovative firm.

Lastly, it is about the experience and trust of the firm. Some firms have expected benefits from investment in R&D but then experienced an initial failure and so they do not trust in R&D anymore. Although, some firms did not experience it by themselves, they saw and learned from other firms who invested in R&D activities and failed, and it made them hesitate to do the same thing. This can be a critical problem even with large firms, as noted by a member of staff from the R&D unit of one of the large Thai firms: “We are quite big in the market of our business, maybe the top five in this country. We have our own R&D centre which is a big one but we still have the problem with the R&D activity and budget. Our executive saw many success cases from abroad but never experienced it by themselves. They do not realise that the process of R&D should have both failure and success. The only thing we need now is a one big success case as a role model. Otherwise, we will still have the problem with the R&D budget all the time since they did not see the benefit of innovation yet”.

Another factor that blocks the innovative atmosphere in Thailand is on the S&T development side. As mentioned above, not many firms in Thailand invest their money on R&D activities which means they do not have their own researchers to conduct research. So, where does the S&T knowledge come from? The answer is it comes in two ways: imported technology from abroad, and technology developed by local researchers in the public sector such as universities and public research institutes in the country.

For the imported technology, normally it is unproblematic as long as the firms have the potential to buy it. Even then, however, there can be some problems in using imported technology in the local context (which is discussed in another section discussing local technology versus imported technology). However, in this section, focusing on the problem of developing the local technology by local researchers, the typical problem that can be found in many cases is the failures of the technology’s developers to respond to the needs of the user. There are many PhD researchers working in universities and public research institutes and doing much research that they think is going to answer the needs of the industry. Unfortunately, there is only a small percentage of this research that can be delivered to the finishing line as a new product in the market. Where are the rest of them? Most of them are still sitting on the shelf in the lab. It can be seen that even where there is a strong demand and there is potential supply, it is not always the case that the supply can meet the demand as it has been expected.

The key issue therefore is to understand the differences of this case to other cases which make the demand and supply match perfectly. Why was this case a successful one? What are the different things that happen in the case? What is the key success factor?

The first difference that can be seen clearly from this case is the firm. The firm was willing to do R&D in the first place; this can be influenced by the attitude of the firm's owner. He saw an opportunity that some people might ignore. However, it is not only an attitude, it is about experience and education. The firm's owner admitted that the entrepreneur course that he took in the university was really useful. It gave him an idea about innovation and how to benefit from it. Therefore, he was ready to take a risk with R&D investment.

When we look at the S&T supply side, the BIOTEC researcher had managed to form a team instead of doing it all by himself. He evaluated the technology he already had and found that another part was required to fill a gap. Even though the project started quite well, during two years of developing the process there were many problems that the firm and researchers had to solve. The researchers learned from the specification of the previous product that the firm used to import from abroad. They took advantage from it as they knew the local bacteria should grow very well in the local environment. Additionally, the firm already had connections with the users which meant they could test developed products in many places.

There were pros and cons in this regard. It was good to have places to conduct field tests but if it went wrong, it might reduce trust in the new product. Furthermore, when benchmarking the new product with the previous one, it made them have a clear goal, but a difficult goal to reach at the same time. It is not easy to get better performance or even to be as good compared to imported products. From this case, some people might think that the owner and researcher were lucky that they could find a perfect match between the firm's demand and S&T supply from the public side. Nevertheless, it was not about luck, it was about the intention, trust and attitude of those two sides. The firm trusted in the researchers and their technology while the public side was confident in their expertise and evaluated it closely to fill the gap. Moreover, they kept going with the project even though they were facing many obstacles at the beginning.

Another key factor concerned the supporting system. As mentioned above, even though the firm was willing to do R&D, it still needed support and someone to help and share the risk. Then the firm found the next part of the puzzle which was the business incubator unit at TSP. In TSP, there are more than 60 firms located there as incubatees and tenants. This function of TSP is to help new firms who want to start up and support mature companies to start or expand their R&D unit. Many big firms in Thailand have established their R&D unit

in TSP. Some of them are located in the same building with the national centre lab so they can share some facilities with the government lab. This also applied to the Bio-treatment firm which benefited from its location in TSP. It was easy for them to have a meeting with the BIOTEC staff or even CPM or TLO in NSTDA. When it was facing problems with the project, the partner on the public side could respond faster than if the partner were located outside TSP. This is one of the supporting success factors of this project. Being together in the same area made them work closely and understand each other more clearly. Furthermore, locating in TSP can make new firms learn from the mature or bigger firms in the way they run and enjoy the benefit from their R&D activities.

During the interview with the firm's owner, he also gave a suggestion to other entrepreneurs who are eager to move to R&D activity including:

- Firstly, we should evaluate ourselves, what are we good at? What is our expertise?
- Secondly, evaluate the market; is there any room for us to play?
- Then, use the market to lead the research goal.
- Lastly, think about the open innovation, we do not have to know or be good at everything, find the right partners and work together to achieve the final goal.

Finally, he has emphasised that "for me, innovation is like fresh milk; it is fresh today but will be going bad tomorrow. So, to manage it, time is really important and also you will always need fresh milk every day which means you cannot stop doing innovation. It will be worked as a loop in your business that you will come back to innovation again and again".

This case illustrates the same pattern of the Thai innovation system described by Yungsuksathaporn (2005) in that the weakness of the private sector in R&D development in Thailand leads to reliance on the public side thus forcing the public sector to lead in performing R&D activity. As can be seen from the beginning, the Bio-treatment firm as an SME firm was willing to move to be an innovative firm but it lacked the S&T expertise to perform the R&D activity. Therefore, the researcher from the public research institute has joined in to fill the gap that the firm was facing. However, during the development process, there are several important factors influencing the success of the case which can be summarised as follow;

- The vision and attitude of firm that the owner can see the opportunity from the new business and willing to do R&D activity as the new chance to run a business.

- The expertise of the researchers and the technology readiness on the public side who can respond to the needs of the firm successfully.
- The trust and connection between public and private sector sides.
- The supporting system in the public side including co-funding, technology management and licensing, and the business incubator and TSP.
- The firm skill in marketing the new product using the previous experience of selling the imported product.

### **Case study 2 – *Medical Devices***

This case is a spin-off company from researchers at NSTDA. The main technology used in this instance is material sciences technology to produce medical devices. The research was initiated by the researchers to develop products and provide technical services and products for users in hospitals.

#### *The Firm Side:*

While in other cases the public and private sectors can be identified and distinguished clearly, in this case it is difficult to separate them since they were previously together. However, the term ‘firm’ will be used here to refer to the spin-off company after it split from the public sector. In this case study, the firm will be named ‘Medical Devices Firm’ to maintain its anonymity. As mentioned above, this firm is a spin-off company from NSTDA run by ex-NSTDA researchers. The company is a new start-up firm which was established in 2010. The firm executive was an NSTDA researcher and used to work in another company prior to working at NSTDA. Therefore, he had experience working in the private sector before running his own business.

#### *The Public Side:*

The National Metal and Materials Technology Center (MTEC) is one of four national centres under NSTDA. Similar to BIOTEC in the previous case study, MTEC was set up under the Ministry of Science and Technology (MOST) in order to promote science and technology development in Thailand and it is also located at TSP. Its main objective is to support research and development in metals and materials. MTEC has run nine research units consisting of forty labs in total. The scope of research under MTEC is diverse and seeks to cover industry needs in Thailand using material science technology.

The nine MTEC research units are Computer-Aided Technology Research Unit, Design and Engineering Research Unit, Ceramics Technology Research Unit, Polymers Research Unit, Biomedical Engineering Research Unit, Materials for Energy Research Unit, Materials Reliability Research Unit, Environment Research Unit and Materials Characterization Research Unit. MTEC has set up its main strategic plan to respond to, and support, the five main industrial clusters which can be categorised as follows;

- Materials Technology to develop automobile, electrical appliances and electronics, machinery, and parts industries.
- Materials Technology to develop agricultural and food industries.
- Materials Technology to develop the cluster of fashion industries.
- Materials Technology to develop the medical and health sector.
- Materials Technology to develop alternative energy.

#### Technology transfer and spinning-off process

The beginning of technology development was conducted in the lab under the Biomedical Engineering Research Unit. It started with the expertise of the researchers in the lab in response to the user's needs. The design technology and prototype were developed, and then moved to the service unit which started to provide technology and prototype to the user. Since the technology was developed as a medical device, it was required to satisfy many regulations to meet the standards of the medical and health sectors.

The developed technology was not a pioneering one in global terms as it has been developed and used before outside of Thailand. The technology combined computational imaging technology and material sciences. It has been used to help doctors and medical staff with bone surgery and bone transplantation. However, this form of the technology was developed locally by the Thai researchers and has been improved and made more user-friendly. Compared to the imported technology, it is cheaper and easier to access for Thai people, which is an important issue for the public health sector. There are many valuable technologies ready for the patients to use and to help them recover from illness, but they do not use those technologies because most of them are not accessible, especially to users in the developing world.

After running a service unit for some time, the researcher team was forced to move on. It is impossible for NSTDA to function as a permanent service unit for the hospitals. It had

started the service unit for the purpose of proving the new technology. When the technology had been proved and implemented in response to the user's need, it had to move outside of NSTDA. Therefore, the spin-off project was set up. "There was a company who would like to license this technology from our lab but after the negotiation process they wanted to sell it at almost the same price as the imported product. We do not want it to be that way. If it happened like that then how would the majority of Thai patients gain access to the technology? So we decided to move to the company side by ourselves", said the firm's executive.

In the process of spinning-off, TLO came forward to provide help. "We saw the opportunity in this case, it has a potential to grow up. It was a mature technology after being tested and improved under the service unit. So, they can move forward", the TLO staff explained. The spin-off process started with the evaluation of technology and assets that were previously used by the lab to provide the service. Then the company was established using the investment of the founder and shareholder, with no NSTDA co-investment in this case.

After that, the technology was transferred to the newly established firm using the criteria of technology transfer process from NSTDA. When the company was first started up, it used the customer database that had already been built up during the operation of the service unit under MTEC. "It was not easy at the beginning but luckily we experienced it before when we worked at MTEC. We know how to deal with the doctors and the medical staff. I think it is a tacit knowledge that is our vital skill", the firm's executive explained.

Although, the company was spun-off and the researcher left MTEC to start up the company, not all of the researchers in the team have moved out. Some parts of the team still continue to be MTEC researchers and this involves close collaboration between the public and private sides. The public researchers still provide raw materials for producing the product and the firm staff are using some instruments in MTEC labs for their production process. Since the firm is in the early stage, it is still using some facilities in MTEC, including the required standards that the production process has to meet. However, as the firm grows, it will have to think about having its own production line, and developing the capacity to meet the regulations. "It has been almost two years since we have started the company. It is in the early stage; even though I think we are doing quite well. Being in the public sector before moving here is really helpful. Moreover, I am quite confident in the technology because I know how it works and how to operate it very well", the firm's executive emphasised.

Furthermore, he noted the peculiarities of the medical market place: "Mostly our customer is the doctor who is responsible for the transplantation operation in the hospital. It is not easy to

convince them to use our technology if they do not know about our technology before. Another factor is the patients, it is their decision whether to use the new technology or not. This is because even our technology is cheaper than imported technology and more accessible, but we have to admit that it is still more expensive when the doctor is using this technology compared to following a manual procedure in the operation process, and the patient has to absorb that additional cost”.

This new technology is used to help the doctor during the transplantation process. Using this technology can reduce the operation time and increase the accuracy of doing transplantation for the patient. Therefore, it is a choice for the patient who can choose to be safer during the operation process. “Even though we tried to make it the most accessible for people, it still increases the cost of the operation. We, as the firm and the doctors, are trying to encourage and educate departments to add this service to the national health insurance system. Then all Thai people who need a transplantation operation can access this technology in order to improve their quality of life which is our ultimate goal”, said the firm’s executive.

### *Case analysis*

This case is completely different from the first case study and many other technology transfer cases because it involved an instance of the public sector changing its role to become private sector. This is not normal in NSTDA or other public sectors areas such as universities. It has rarely happened that Thai public researchers have left their affiliation in the public sector which normally is considered more stable and secure than in the private sector. It might be only in Thailand or some developing countries that most people believe working in the public sector is better than the private sector. However, this kind of opinion is an impediment to the formation of spin-off companies.

The spin-off process is one of the ways in which the public sector transfers its knowledge. Ndonzuau et al. (2002, 281) refer to “*one of the most promising ways to transfer research results to the market place, namely, the creation of academic spin-offs*”. In Thailand, this process has also been adopted to be one of the technology transfer processes, but it is not widely implemented due to many factors, including the perceived risk of people moving from public to private sector employment. Even though, the government is trying to encourage its public sector organisations to move further with this process, there still are a few successful cases. To analyse the problem of this topic, this case study will be used to investigate the factors that support and impede the success of such cases.

First, as mentioned earlier, the researcher's expertise is an important factor that encourages them to start their own business. They are familiar with the technology and they know how to use it to benefit the new business. Although there is a risk of moving into business, they can have confidence in their technical capabilities. This is because in this case they had experience of it before when they operated the service unit under MTEC. This can be related to the second supporting factor, the service unit. It cannot be denied that this function under NSTDA national centres is a good starting point for proving and evaluating a new technology developed under those national centres. How can we know that the new technology is efficient in a real life? The answer is testing it and using it in real conditions as much as the researcher can.

In many cases, field testing is a good way to assess a new technology, but it is not the best one. To do a field test, the researcher tries to imitate the conditions for using the technology, but this is never fully realistic. Some might argue that the technology can be delivered to the real user to test it. Certainly, if tested product is provided for free, then the user is unlikely to refuse to use it. Nevertheless, when the user has to pay for a new technology, the response will be different. Even if the technology is really effective as demonstrated by the field test, it does not guarantee the commercialisation of that technology. Many times users still hesitate to use a proven technology depending on their ability to afford it and get a return on the money they pay. Therefore, the service unit is an excellent way of demonstrating demand for a new technology.

As well as the service unit in this case, MTEC also has other service units to deliver its technology to users as is typical for Thai universities and public research institutes. In this case, the service unit proved the technology's efficiency and developed the trust in the technology from customers. It is not an easy task to gain trust from the customer, especially in the medical and public health sector. The firm's executive explained that: "To access the customer such as doctors or medical staff in the hospital is not easy, but when you are in the public sector side, it can make it easier". The researchers had a chance to introduce and prove their technology via the service unit and this was a major benefit for them in the future when they established their own business. However, there is an awareness that the service unit approach may not work for every technology. In some cases, especially for process innovations it normally works well, but for product innovation there might be some limitations because in that case the public sector cannot provide technology in the form of service unit.

The last supporting factor is the connection with MTEC. As stated before, not all of the researchers in the team left MTEC to join the spin-off firm. The rest of the team is still working in MTEC as public researchers. Furthermore, MTEC is providing some facilities to the firm to use as part of its production unit. This helps the firm to maintain its business when it is at the early stage of spin-off. Since MTEC's lab was used as a service unit before, the production process was already certified to meet the regulations. However, this can also lead to another problem for the firm in the future. When the firm becomes more established, it will eventually need to have its own production line and have to face up to satisfying the regulation certification process. However, it can learn from the past when they were a part of MTEC, and even though it is not an easy task, it will not be as difficult as it would be for a firm without this experience.

On the other hand, apart from the support factors, there are also some interesting impediments that can be learned from this case. The first one concerns the spin-off process itself. Even though it is a normal process that many public organisations adopt to transfer their technology, it still lacks a suitable supporting process that fits the needs of new entrepreneurs. In particular, there is concern that the requirements for NSTDA co-investment are too rigid. Thus, the firm's executive argued that: "Maybe, if the criteria to implement a co-investment process are more flexible, the number of spin-off firms in NSTDA might increase. In my opinion, the nature of each business is different, so the way to manage it could be different as well".

The next obstacle in this case is the regulation process for the product. Since the product is used in the medical and public health sector, it is inevitable that there are requirements stemming from a strong regulation process. Some parts of the regulation issue were solved in the service unit because the unit had to pass the standard regulation for medical device production in order to provide a service and product to the customer. However, there were some problems with document management when the technology was transferred to the firm and the documents were needed for the firm to register for certification. The firm's executive said: "It was not a big problem for us; however, I think it is an important concern for NSTDA or other public organisations who aim to do a technology transfer. The internal management and document filing are important for doing regulation certification. It should be ready to be used by the licensee. No matter how excellent the technology is, it means nothing if the firm cannot pass the standard regulation, especially in the medical and public health sector. Therefore, in every research that aims for technology licensing, the public sector should always be concerned about the regulation issue for the product or process. I do

not agree that the firm should take all responsibility in this part. It should be included since the research was started”.

Another suggestion by the firm’s executive concerns the scaling up process involved in going from research to production. As can be seen from this case, the pre pilot scale production was done by the researchers on the public side, as well as the pre-test of the product by the service unit. It made the commercialisation process of this new product easier. The researcher noted that “It can be applied to every research, the researchers should be aware about this issue when they start new research. The product should be able to scale up and be produced on an industrial scale”. This is another important issue for the technology transfer process. The problem with scaling up processes is not restricted to the field of material science; researchers from other fields are also struggling with the same problem. For example, a biotechnology researcher said: “We know how to produce good research in the lab but we do not know how to translate it to the industrial product. We have to think about the mass production process. It becomes our big problem now”. This issue of scaling up processes will be discussed in another section analysing the problem of technology transfer.

To summarise from this case study, the factors that support the success of the case and related issues that should be of concern are:

- The developed technology in this case is excellent and suitable to be commercialised.
- The function of establishing the service unit under MTEC is a key factor because it enables testing the technology with an actual customer.
- The firm’s founder and staff were the researchers in the team who developed the technology and used to be in the service unit. Therefore, they know the technology and its benefits very well.
- The technology was tested via a service unit which can develop trust and confidence in a technology from the customer. Moreover, it built up the customer database for the spin-off firm at the same time.
- Lastly, the service unit is a good model for the firm to see the success of technology. This helps overcome the problem that Thai firms normally do not want to invest in a business when they cannot predict the benefit, particularly in the case of businesses that depend on innovation.

### **Case study 3 – *Medical Biotech***

This case is focused on innovative capability of the firm as a key factor supporting success. However, the relationship between public and private sector will also be emphasised as another key success factor. The technology involved in this case is biotechnology (genetic engineering and vaccine production).

#### *Firm side*

The firm will be named *Medical Biotech* to provide anonymity. The firm was founded in 2001 and its main business is in vaccine production using biotechnology. This kind of firm might be normal in developed countries, especially in the US or EU, but it is rarely found in Thailand. The most important reason that prevents firms from entering this business is the advanced technology used in producing vaccines. This firm is owned by Thai people but positions itself as a global company since it has a network including many countries all around the world. The company was started with a business trading pharmaceuticals and after achieving success, the R&D unit was established. The firm focuses on the development of vaccines in emerging countries. Therefore, it has connections with Asian countries and many countries in Africa.

The firm's R&D unit does research to develop new vaccines and works in compliance with the international good manufacturing practice (GMP) standard for producing vaccines. In this unit, 17 PhD researchers from different countries are working together. According to the firm's leaflet: "We develop novel vaccines using the most recent technologies available, with the aim to become a centre of excellence in research and vaccine development." The main source of innovation comes from the networking of the public and private sector in R&D development. Moreover, the firm aims to build up vaccine production capacity not for only itself but also for organisations in other developing countries. This is because access to vaccines in the developing world is very difficult due to the high costs.

#### *Public Side:*

There are two public organisations involved in this case. Each of them plays a different role. NSTDA is the funding body for the research development, and Chiangmai University is where the research is carried out.

As already mentioned, NSTDA functions to both develop and support research for other R&D units. In this case NSTDA works as a supporting component for the research unit in

the university via a funding mechanism. However, in this case the research grant was previously supported by BIOTEC. In the past, the four national research units under NSTDA had their own granting function, but in 2006 the funding mechanism was recentralised to NSTDA. NSTDA does not support R&D using only the grant system, but also uses other mechanisms such as research consultancy, infrastructure provision, soft loans, co-investment, and so on which will be described further in another section.

Chiangmai University is located in the northern part of Thailand. Even though it is far from Bangkok, the capital city and centre of research in Thailand, Chiangmai University does very well in its R&D development performance. Chiangmai University has been ranked in the top five R&D universities in Thailand (Office of Higher Education Commission, undated). The higher education system in Thailand has been changed from a pure teaching system to an R&D community by encouraging university staff to conduct research in parallel with teaching activity. In order to do that, the university needs other supporting factors to encourage its staff to perform R&D activities.

Even though most universities are moving to become R&D universities, they are not focusing on the same areas of R&D. They are different in their ways of conducting the research and also in their research topics. Consequently, they become excellent in different fields of research. One of the most important factors is research funding. Without financial support they cannot conduct any potential research.

### ***Technology transfer process***

This case is different from the previous two cases in terms of project initiation. This one more closely follows the traditional Thai R&D project development pattern where the project was started as basic research in the lab (normally called the science-push linear model of innovation). Additionally, the way of conducting the technology transfer process followed the conventional pattern of public-private sector technology transfer. Thus, this represents the pattern of TT processes that was expected to happen during the last ten years in Thailand.

### ***R&D Project development***

This project was started around ten years ago by a research team in Chiangmai University and was funded by NSTDA (BIOTEC at that time). The project as a basic research was concerned with a virus that causes a severe tropical disease. For ten years this project had a

long history of development. During the development stage, NSTDA as a granting body recommend the research team to develop new vaccine candidates.

Thailand is one of the tropical countries which has been suffering from tropical diseases for a long time. Unfortunately, countering tropical diseases was not attractive enough for the big pharmaceutical companies or biotech firms to invest a large amount of R&D investment. This is because most of the countries suffering from tropical diseases are considered developing countries, which means even if there are drugs or vaccines available they might be unaffordable. Consequently, most pharmaceutical firms believe the return on investment from R&D on tropical diseases will be low compared to other diseases that will make them more profit. For that reason, tropical diseases are also known as ‘neglected diseases’.

Consequently NSTDA/BIOTEC was trying to initiate many research projects focussed on drugs for treating tropical diseases and vaccines for prevention. BIOTEC did it via both its own research activity and through funding mechanisms in order to strengthen this field of research in Thailand. Beside the link with the universities and other research institutes in Thailand, it also had international connections with universities and research institutes in many other countries. Moreover, there are some connections with the big pharmaceutical companies in developed countries to conduct joint-research. As one the countries suffering from those tropical diseases, Thailand has plenty of useful samples to aid in research on these diseases.

Furthermore, Thailand’s location in the tropical zone means access to many natural resources that provide potential bioactive compounds for developing drugs. However, despite attempting this for a few decades, sometimes through joint-research with the international firm, there were no success cases of developing drugs or vaccines for tropical diseases in Thailand. The reason for this is that tropical disease is not the central focus of the big pharmaceutical firms. They might be interested in it but they did not mobilise enough resources to produce success.

This context provides both an opportunity but also a challenge for indigenous drug development. In the new approach proposed by NSTDA, vaccine candidates were developed by the research team. Then the project moved to the most difficult stage for the vaccine development process which is testing. Even in developed countries, launching a new vaccine takes a lot of money and effort. In Thailand, there is no previous experience of performing new vaccine testing, and so this step was particularly challenging. One of the NSTDA project analysts involved with the project explained that “at that time, we could not find any expert to help us with this problem. Actually, there was a research team in another university

doing the same subject and they had collaboration with a big pharmaceutical company from the UK. However, that collaborative project has not had a positive result yet”.

### *The stage of technology transfer*

This situation provided an opportunity for the firm to step into the project. It started with the firm *Medical Biotech* being interested in this project and contacting the researcher directly. Then the researcher informed NSTDA as their grant giving body to deal with the agreement with the firm. “We have got information about the firm. They are one of a few Thai firms doing business in vaccine production. They have good potential to adopt this project and bring it to the next stage of development. They have their own R&D unit and have experience with vaccine production, even though they did not conduct a whole development process. I think they are a good choice for us”, the TLO business analyst from NSTDA explained. After finishing the negotiation process, the technology transfer agreement was signed by the three parties; university, firm and NSTDA. The vaccine candidates were sent to the firm and it planned to conduct testing in different stages.

Presently, the vaccine candidates are in phase 2 clinical trial in animals. This is being carried out in other countries since Thailand still lacks the facilities and support services to do a clinical trial in this phase. During this phase the firm and the university’s researchers are working together with NSTDA acting as the link to coordinate the project. The researcher has provided useful information and help to the firm with technical issues. This project is ongoing and still needs many further steps in order to accomplish the goal of the world’s first vaccine for this tropical disease.

### ***Case analysis***

This case study shows distinctive characteristics of the conventional technology transfer pattern. The project was started as basic research in the university lab where for the last few decades the researchers have focused on conducting basic research as their main goal. Therefore, it has resulted in having much basic research piled up in the lab. It was considered as one of the problems in Thailand’s research community for a long time.

The next phase of research development has now come. The university’s researchers have been pushed to conduct more applied research than basic research. Even though there is no clear evidence to prove it yet, it seems they are moving in the right direction since there were

positive responses from many sides including firms. At least the aim for conducting the applied research will remind the researcher to think about the user of the work before carrying on the project. However, this does not guarantee that the project is useful.

What else can be done with the basic research? Is it useless or should researchers stop doing basic research from now on? Definitely, the answer for these questions is 'no'. The research community should not stop doing basic research because it may be needed for another application. Despite the fact that many previous studies have suggested that researchers have moved to more applied research, it does not mean they should abandon basic research completely. This is because in some research communities they have been facing the reverse effect of moving too much to the applied research with consequent concern about the decrease of academic publication. Why is this important? It is because the basic research is the important supporter behind the applied research. For this topic, it will be emphasised in another section of this thesis.

The concern about shifting too much to only applied research is supported by this case study. If there was no basic research from the university lab, then the vaccine candidates could not have been developed. The basic research is not conducted only to serve the curiosity of the researcher as it is often argued. The researcher's curiosity should be based on the fact that there must be something missing in this field of research and they have to find it out in order to fill in this gap.

A key factor in the success (so far) of this case study has been the attitude of the firm. As described earlier, there are a small number of Thai companies doing business in the vaccine development field and *Medical Biotech* is one of them. "It is not easy to survive in this business, especially being a Thai company. In the last 20 years, there were 127 vaccine producing companies/institutes all around the world and most of them belonged to the public sector. Presently, there are 5 big firms left and they are multinational companies", the firm owner said. Compare to other SEA countries like Singapore, Thailand is much weaker in adopting new technology, particularly as regards biotechnology for producing drugs and vaccines. The firm's owner noted that: "In Singapore, they bought know-how from outside and encouraged foreign investors using tax privileges. Moreover, the most important thing is they have prepared their people in advance for more than 10 years to learn how to adopt new technology from outside".

To answer the question ‘Why did you decide to do a technology transfer in this project?’ the firm owner explained that: “As we position ourselves as a global company, we analysed the market at the global level and considered our facilities and resources. We positioned ourselves in the global market, analysed the customers. The important thing is differentiation, we have to prove how different we are and how we can be better. Then we found the opportunity for doing this. To me, the investment criteria, it does not mean we invest today and we will gain the benefit immediately tomorrow. The good thing I found from the vaccine development is the vaccine is used for prevention which can save many lives. A good opportunity for the business is that the vaccine is used in normal people to prevent the illness so the market is bigger than the drugs that will be used to treat ill people”.

“The reason I chose to do a technology transfer from the Thai researcher is because I believe in their capabilities. I see it as a good opportunity; we should make it become the world’s first vaccine to prevent this tropical disease.” the firm owner explained. Similarly, the TLO business analyst argued that “I think this is the challenging project for the firm. Other people might see the difficulty of producing the world’s first vaccine as an obstacle but I think for the firm it is an opportunity. Since it is the first one, it means if you can make it happen, you will get a big return”. Therefore, from this case, it can be seen clearly that the firm’s willingness to take a big risk in this kind of business is the critical factor influencing the progress of the project.

However, there are some issues that considered as problematic to the case. In particular, the firm owner’s view was critical of the role played by the public sector organisations, saying: “I have been in this business for a long time, from my experience, the public organisations did not play their role very well”. He suggested that: “The public side should realise their duty. They are not supposed to play the private role by doing the firm’s job. The public sector should be the supporter not the main player in the business. I think some of them are playing the wrong part by acting as a commander or producer and not the supporter”. Additionally, he argued that “being a supporter, [the public sector] should be the mechanism that strengthens the private sector. For example, the infrastructure such as the pilot plant in the university. It should be established to support the private sector in order to use it for gaining experience in the up-scale production not for generating benefit for the public sector”.

In addition, the firm’s owner did not think that it was sensible to demand that firms pay an upfront fee when signing a technology transfer agreement. The firm’s owner said: “When the firm decided to do a technology transfer, it realised that it has to take a lot of risk in its

business. Then it was asked to pay for the up-front fee for the public side while it does not know whether the transferred technology will make the benefit in the market or not”. This matters because a firm still needs a large amount of money to invest in product development (testing, packaging, product design etc.) and for launching a product to the market. Some firms will not be able to afford all of these processes which leads to the opportunity lost in the public sector for doing technology transfer as well. According to the firm’s manager: “I did not mean the public sector should not gain any profit from the technology transfer process. I meant to say that it will be better if they wait until the process of product commercialisation is a success and then they can enjoy the benefit of the project together with the firm”.

\*The R&D project used in this case study is an on-going project and highly competitive. Therefore, the name of disease and the vaccine will not be stated in this document.

#### **Case study 4 – *Bioactive Company***

This case shares some features with the previous case - the Medical Biotech firm. The research project was initiated in the same way as the third case study as it also stemmed from basic university research. However, this case is in the bioactive compound production field and it is in different stages of the technology transfer process.

##### *The Firm Side:*

The firm involved in this case will be named *Bioactive Company* and was founded in 2000 by a pharmacist. The businesses started with products that contain an essential oil extracted from Thai herbs. Since the firm’s owner is a pharmacist, he had enough information about the production technology to start the business. The products in the first phase of the firm were toiletries, cosmetics and pharmaceutical products containing the herbal essential oil. The firm’s competitive advantage stems from the beneficial property of the bioactive compound in the herbal essential oil. They know how to use it and have the technology to extract and produce the product. In the second phase of their business, the firm has expanded its production line and its market by transferring technology from the Department of Medical Sciences, Ministry of Public Health to produce a new product to control a disease transmitting insect. The firm has thus moved into another field of business using the same core production technology.

### The Public Side:

For this case, there are two parties on the public side involved in the research project. The first one is BIOTEC, NSTDA and the second party is the King Mongkut's Institute of Technology Ladkrabang (KMITL).

In 1995, BIOTEC, NSTDA cooperated with the Thailand Research Fund (TRF) to establish a research programme named The Biodiversity Research and Training Program (BRT). This research programme aimed to provide support and funding for research and management of biodiversity resources in Thailand. Most of the research projects under BRT were considered as basic research since it was aimed to study the diversity of bioresources in Thailand. The plan was that the results would be pooled and used to establish the bioresource diversity database to help manage and conserve bioresources. There are seven sub-programmes under the BRT: Systematics, Genetics and Ecology; Monitoring of Populations and Ecosystems; Economics, Society and Biodiversity; Information Coordination; Human Resources Development and Training in Tropical Biology; Development of Technological Proficiency for Sustainable Social and Commercial Use of Biological Resources; and Policy Development and Management of Biodiversity.

King Mongkut's Institute of Technology Ladkrabang (KMITL) was established by the King Mongkut's Institute of Technology Act, 1971 as an amalgamation of three technical colleges. KMITL is recognised as one of the most prestigious universities in Thailand. As an institute of technology, KMITL is well known for its excellence in technology and engineering, especially the capability in applying mechanical or biochemical engineering in R&D development. Subsequently, there are many research projects conducted by KMITL's researchers in this field of technology as well as collaborative projects with researchers in other universities or firms.

### R&D Project Development

The beginning of the research project in this case study originated from the BRT programme. From the seven sub-programmes under BRT, the researcher from KMITL was granted a research project to study the biodiversity of one type of pest in villages in Thailand. The first project was started in 2002 and basic research was carried out to survey the pest that causes allergic symptoms to people in that village. "It was a small project tied to the type of pest in the small scale. I never thought about the applied research at that time", the researcher said. However, after finishing the first project, the second phase was continued with a larger scale

survey. “At that time, from our data collection, we realised that the allergic symptom caused by the pest we were studying was a big problem for Thai people. We have found that more than 8 million people in Thailand are suffering from allergic symptoms because of this pest. It made us think about how to help them escape from this problem and it became our new research question”, the researcher explained.

From reviewing many previous research studies of allergic symptom problems, the researcher found that existing solutions came in form of curing, not prevention. According to the researcher: “From our survey, we found this kind of pest in many places and many of them are in the household. Even though not everyone who comes into contact with the pest will get the allergy, it is still a risk for people who are sensitive to it since we will never know who will have the symptom. Therefore, I thought if we can eliminate it from the house, it will help to protect everyone from this pest”. The researcher team proposed this idea to the BRT, and then another research project was funded. The project was aimed to find a way to control the pest in the household. “Since, the previous project found that the pest was found in the household both in the urban and countryside areas, we should find the proper method that can be used in these types of area”, said the researcher.

The project started by using bioactive compounds for killing the pest. Because it has to be used in the household, using a strong chemical might not be good for people and the environment, although there were some reports for controlling this pest using chemical compounds. The researcher explained that: “We were concerned a lot about the environmental issue and definitely about people’s health so we decided to use bioactive compounds extracted from plants”. After conducting the research, the researcher team found a positive result from their experiments which involved using a combination of bioactive compound ingredients. Then the product formulation was studied to obtain the best formula to kill the pest.

Eventually, the researcher team achieved a good product formulation and it was tested in fieldwork. The result was impressive, and it was considered as a successful applied research project for the BRT. The researcher team has filed four patents from the project. The successful project was announced through the media and it was moved to the stage of obtaining the technology license.

#### Technology transfer process

In the process of obtaining the technology license, the NSTDA technology licensing office (TLO) stepped in to help in this stage. The TLO staff responsible for this project explained

that: “We took this role because we are the granting body. I have consulted the IP department of KMITL for managing this project. They were happy to let us play as the main actor. We have agreed on the benefit sharing after the technology transfer process has been finalised”. After the announcement, there were many companies showing interest in this project. However, after being informed about the conditions for doing technology transfer, only two companies were left.

There are some criteria that TLO use for considering the choice of technology licensee, including using a first-come-first-served approach depending on involvement in the research project at the beginning, capability to transform a lab scale product to an industrial scale product, skill for commercialisation of new products, etc. These criteria were used to screen the companies and the two of them were chosen. “Why were two firms the only ones that we chose? It was quite complicated for this case”, the TLO staff explained. “From our criteria, it was mixed between them. The first one I will call them Firm 1, has come first and they have been involved in some of additional field tests. They showed good intention since the beginning while the second one, Firm2 (*Bioactive comp.*) has come later. However, Firm 2 is more capable in the production capability and marketing. Therefore, we have discussed with them and decided to transfer technology to both of them”.

Deciding to transfer technology to two companies can cause both positive and negative effects. The TLO has realised this while they made the decision. The positive thing is expanding opportunity for the technology to be disseminated by two firms. On the other hand, those two firms might become competitors and destroy each other’s opportunities. However, in this case, the expectation is that this will not happen. When both of them have acquired the technology, Firm 2 which has more production capability is likely to become a supplier for the firm1 by producing a bulk product for them. Additionally, the channels used for distributing the product to market are different.

As well as doing large scale production to supply product to the other firm, *Bioactive Company* is doing its own downstream processes at the same time. The product package was designed to be used as a spray can, so it can be used easily in the household. Then the firm has applied to certify the product with the Thai FDA which took two years to be granted. When the product was launched, the market response was fine. It did not grow quickly but it was acceptable to the firm. “As an SME firm, I am quite happy with the product. I had experiences with the commercialisation of new innovative products before, so I do not worry about it. I have a plan to expand the market to other countries who are facing the same

problem with this pest. I will start with Vietnam as the first country. I have a connection there and I just finished my business trip in Vietnam yesterday”, the firm owner explained.

After the technology licensing process, the researcher team and the firm worked together for a while. Then the researcher continued the research and found another application for the product. However, the firm did not take on this application yet since there are some disagreements between the firm and the researcher. “There are some interesting points that we need to discuss, sometimes I still feel some conflict between us. This is not anyone’s fault but this is because we are looking at different angles”, the researcher said.

### *Case analysis*

It can be seen clearly from this case that the path of technology transfer process related here followed the conventional technology transfer model. The familiar pattern in which the basic research project was started in the lab and has been moved to potential application, and eventually the product has been created and provided to the firm as a new product for commercialisation.

To analyse the success of this case, the first factor influencing the achievement in this instance is the researcher who could find the appropriate way of utilising the result from his previous study. It is the important characteristic for the scientist to have a broad vision and look at the thing from different angles. The researcher in this case was able to find a good research question from the data he had collected; moreover, he managed to get a good result which lead to the potential product. In many cases, the researchers who normally do the basic research will never cross the line to think about the applied research from their collected data even though the basic research may be useful in generating an excellent new innovation. This results in opportunities lost in the research community.

The researcher gave his analysis of the success factors of this case: “In my opinion, I think we as a team of researcher know this project very well. We were with it since it was started which made us ready for further product development. Then, we have a good connection. I did not know how to cultivate this pest but we had a team from Mahidol University helping in this issue. Besides, we have a good supporter including BRT as a granting agency, our university who always has a good policy to support our research. Finally, we have good firms to carry on our work and transform it into a commercial product”.

KMITL's policy was also considered supportive. The researcher appreciated the policy because it did not obstruct the researchers in conducting their work. Especially, when the IP issue needed to be decided, the university did not get involved in the process of negotiation between the granting body and the firm. A satisfactory mutual agreement was established between the three parties and this made the process of technology transfer easier. Furthermore, after the process of technology transfer, the disclosure fee gained from the TT process was delivered to the researchers in a proper ratio which was appreciated by the researchers. This is significant when compared to some universities that have overly rigid IP protection systems which sometimes result in the failure of technology transfer negotiation. Moreover, some universities implement policies that discourage their own researchers from doing research projects without realising what they are doing.

Another supporting factor that is important to the success of the case is the firm. The firm that became a frontrunner in this case had appropriate experience because it had previously licensed technology from another public institute. Therefore, it was familiar with the process of technology transfer. "We did the market survey before we approached the technology. We thought this new technology will become an innovation that could increase a chance for us to compete in the market", the firm owner said. Furthermore, he also explained why he chose to transfer technology from the public sector: "In my opinion, Thai researchers are capable of producing good research. Their level of academic skill is the same as researchers in world-leading research countries. So, I believe in their work and I knew how to work on our contribution". Additionally, the firm owner has emphasised the importance of finding a market for an innovative product: "As I mentioned earlier, the innovation can provide us a new opportunity. However, first of all we have to position ourselves, where are we in the market and where should we go. This is the important stage for stepping forward. To conducting a market research will tell us what is our appropriate goal".

Lastly, according to a NSTDA business analyst, the granting agency played a supporting role as an "intermediary connecting those two sides together" and "in negotiating the conditions of technology transfer." Besides these supporting factors, there are also some obstacles that can be identified from this case study. Although, it is considered as a successful case, there are a few things that could be done better to improve future cases.

These concerned the firm's experience and the firm's owner noted that: "There is a gap between lab scale and industrial scale production. Even though, we are experienced in large scale production from other production lines, we still need help from the researcher as a mentor to train us in producing new product in the industrial scale. Another point is about the

regulation certification. It took us two years to get certification for our new product. It will be better if the process does not take this long”.

#### Conclusion of the success factors

- The capability of the firm in conducting mass scale production.
- Firm's previous experience in transferring technology from the public sector.
- The creativity and research capability of the public researchers.
- An appropriate supporting policy from the university.
- Firm's attitude to the innovative product.

#### **Case study 5 – IT Firm**

The field of technology in this case is information technology (IT) which is different from the previous four cases. However, this case shares some characteristics with the second case as a spin-off firm from NSTDA.

#### The Firm Side

The firm engaged in this case will be named *IT firm* which is a spin-off company founded by researchers from the National Electronics and Computer Technology Centre (NECTEC), one of four national research centres under NSTDA. The firm was established in 2007 as a co-investment company between NECTEC researchers and the NSTDA Investment Centre (NIC). The share-holding ratio between the two partners is 49:51 (NSTDA: researchers). It was started with 0.7 million baht (~21,000 US\$) as its authorised capital. The company runs its business using information technology to service its customers. The implemented technology was started in NSTDA's NECTEC laboratory, by researchers there and then was licensed to the firm after the spin-off process.

#### The Public Side

The public organisation involved in this case is the National Electronics and Computer Technology Centre (NECTEC). Similar to the other three national centres under NSTDA, NECTEC has its own strategic plan and policy for carrying out research in the computer and electronics field. NECTEC was founded in 1986 as a project of a technology transfer centre.

Then in 1991, it was changed to become a national research centre. By 2013, there were five research units operating under NECTEC including Intelligent Informatics Research Unit, Wireless Information Security and Eco-Electronics Research Unit, Advanced Automation and Electronics Research Unit, Information Communication and Computing Research Unit, and Intelligent Devices and Systems Research unit.

NECTEC has set its vision as: “Being a core organisation collaborating with alliances in R&D of electronics and computer technologies for strengthening the sustainability of Thai industries and the sufficiency society”. In order to respond to this vision, NECTEC has contributed through research, technology transfer activities, human resource development, and policy and infrastructure development.

This case was managed by the NSTDA investment centre (NIC) which is responsible for promoting investment in science and technology through co-investing, with the ultimate goal of benefiting Thailand’s economy and society. For the process of co-investment, the applicant has to submit a project proposal to NIC including a five-year business plan. Then the proposal will be evaluated and considered by several board meetings. If the proposed project is granted, the joint venture will be set up and the co-investment budget will be put in the form of a shareholding. However, the ratio of the co-investment must not be over 49 percent in order to maintain the company as a private firm and not a public enterprise which must conform to different regulations. By 2013, NIC had formed nine joint ventures in various fields of technology. In terms of joint ventures, NIC can invest in either a Spin-off Company or other firms that are pioneering S&T development.

#### *The development of the research project*

The research project involved in this case was initiated by a researcher team from the NECTEC research lab. The project uses information technology to develop a new system providing a service to internet users. The system works as a tool that gives web statistics service to websites in Thailand. Initially, this service was provided as a free trial through a unit under NECTEC. After evaluating the efficiency of the new technology from the responses of the users, the service has started to charge a fee. This service was run under NECTEC for five years.

During that period, the researchers gained experience from providing this technology to the users while they found the opportunity to start their own business. “We think it would be great if we can do this in the form of a company. Many things will be easier to operate,” the

firm founder explained. In his point of view, operating the service within a public organisation is inflexible since it is under the bureaucratic system.

Moreover, the policy shift to encourage the public research institute to gain more research budget from other sources became a point of conflict within the organisation. This topic was raised many times by the researchers and middle executive staff and caused confusion as to whether they should dedicate their work to the public good or whether they should gain the benefit from their work. This is because the way of acquiring additional budget from outside for the public research institute is mainly from the technology licensing process. This controversial problem will be discussed in detail in another section of this thesis.

After the researchers got the idea for the business, the first challenge they faced was the investment budget. This case differs from the Medical Devices Firm case, where the researchers left NSTDA to start their own business by using their own money; in this case the head researcher of the team continued his work in NSTDA and applied for the co-investment scheme from NIC. One factor in this case may be that the founder of the IT firm received a scholarship from the government to study for his Ph.D. abroad, and a condition of the scholarship was that he could not leave the public organisation for a period of time.

Consequently, NIC became involved in this project after they received an application for the co-investment project from the researcher team. “When we got their proposal, it was quite interesting for us. We knew that the project was being implemented as a service under NECTEC at that time. However, the business plan still looked unclear at that time. In order to implement a joint venture, we have to think in the business running mode. Since, we saw a good opportunity in this project; we decided to help them improve their business plan. As researchers, it was not easy for them to predict the market precisely. However, after six months the new business plan was finished”, one of NIC staff responsible for this project explained. The spin-off process took two years to finish including the process of the joint venture.

After the co-investment firm was established, the service running under NECTEC was shut down immediately. In terms of technology transfer, the technology was transferred through the researchers who moved to the firm and the server that had been used to provide the service under NECTEC was sold to the new firm. The customer database was transferred to the newly established firm and the service was maintained during the transfer process. The new business ran smoothly and has grown very fast during the last three years. The share value increased by almost ten times since the firm was started.

This phenomenon was a big success for the co-investment firm. Moreover, the firm conducted further research to propose a new service to the customer. The NIC staff explained that: “Since they are researchers, they realised about the cycle of technology. No matter how good technology is, there will be a time period for the life cycle. If they want to maintain it, the improvement or the new model is needed”. From this point of view, the *IT firm* managed to maintain its business and kept its competitiveness in order to expand the market.

### **Case analysis**

This case involves information technology which is totally different from the previous four cases in the nature of the technology transfer process. The process of conducting the research in order to obtain an efficient technology is similar to other fields of technology; however, the process of technological innovation is different. Due to the diverse nature of technological fields, they might face different problems in the development process. For example, while other fields such as biotechnology might be struggling with the up-scale process or how to train the technology licensee to adopt new technology properly, in information technology does not have to think much about such a process. The critical point in the process of technology transfer in the IT field is how to develop a proper business plan and gain the benefit from technology as quickly as possible before the competitor enters the market with the better technology.

To analyse this case closely, the question ‘what are the success factors supporting this project?’ has been asked to the firm owner and the NIC staff. From the firm side, the leader of the research team stated that: “In my opinion, public researchers should not design their own research questions. We have to think about answering the user’s need as the main goal for the research. For my team, we thought about it since we started our research. We also thought about the business model to see whether the research project will be beneficial or not. Furthermore, we planned properly how long it might take for the project and also how much does it cost for the research budget and the most importantly who is going to be our user. This is the way to benefit from the research project that we normally use”.

Finally, he also concluded that: “For me, I think for innovation it is not necessary to be new or pioneering but it should be something that people need and are ready to spend their money to use it which means it is really useful for them. Therefore, innovation should drive the business, supported with a sufficient research budget and human resources, and returning

with a useful result. I did not mean we should not do something that is really new but in order to do that it should be done in the university not in a public research institute like ours”.

It can be seen clearly from the researcher’s view that the attitude of the researcher is the important supporting factor for the success of the case. Since it was planned for the business purpose at the beginning, the research project was driven towards that goal. Even though the business goal is not always the case for every research project, at least the researcher who conducts the project should aim for the utilisation of the project rather than finishing the project first and finding the way to use it later.

This perspective was supported by the NIC staff who also identified similar success factors: “I think the first and the most important factor is the researchers themselves. They knew how to benefit from their project and also the developed technology is really efficient. Another factor is the market opportunity, there are a few competitors in the market and the technology can fit the user need very well. Furthermore, the service was implemented under NECTEC for a while which meant the researchers could learn how to improve technology to meet user requirement and also the service charge is affordable so they can expand the market and the number of customers has increased significantly. Lastly, they have a good marketing strategy. They held additional events to introduce their product including the new service to maintain customer satisfaction”.

This NIC perspective supports the idea that the researcher is the most important success factor for this case. Since the researchers had aimed to bring their research project to the market, they planned every process for that purpose and learned how to achieve that goal.

Although there are other factors that influenced the success of this case, the researchers still moved forward for their ultimate goal. Even when they had to revise their business plan for six months, they kept going with it and they had been waiting for the spin-off process for two years, and they did not give up with their plan. It took them almost ten years from the beginning of the project until now before they could experience their success. The problem that normally occurs with most researchers is they could not wait that long to achieve their goal. Additionally, there is another interesting point shown in this case that the researchers were working under the public organisation and running the service through their affiliation which made them able to wait for that long.

Although this case is considered a successful one, it does not mean that there were not any problems. Besides the period of time taken to finish the spin-off process, the researchers

have experienced other problems as well. The researcher has described the problem facing him running a spin-off company: “Now, I am still working as a public researcher for NSTDA while running the firm at the same time. As I told you before, I am under the condition of the government scholarship student which prevents me from leaving the public organisation during this period of time. Honestly, it is not convenient for me at all”. Another problem is the shareholding issue due to the policy regulating the spin-off process. The researcher was told that when he moved to the firm fully, he can buy shares at the book value cost. However, when the firm grows very fast and the share value increases rapidly like this, it means he has to buy the share in the company that he is the co-founder of at high cost, maybe ten times as much as at the beginning. “I do not think this is a fair policy to implement with the spin-off researcher”, said the researcher.

Another thing that the researcher has complained about is the way of supporting the research project under NSTDA: “We need change in the way we support our researchers to conduct the research project. We need the motivation system when we finish the project what will happen next and what will we gain from doing it. As I said, the researchers should aim for the research utilisation at the beginning but the organisation should respond in the same way”. He also recommended that the policy should encourage people to move in the same direction in order to utilise the result of the research project. This will include the indicator that is used to evaluate the performance of the researchers such as the key performance index (KPI) which should be able to indicate the capability of the researchers in order to transform their research to be a product/process in the market.

Another issue raised by the firm is the IP management issue, as he explained that it is not necessary that we have to focus on the number of patents or other IP protection tools. A high number of patents do not indicate the performance of our research commercialisation or utilisation. He also clarified that he did not mean it is not necessary for the IP protection issue but I think we are focusing on the wrong direction.

In summary, there were many interesting factors influencing the success of the technology transfer process from the public sector to the firm in this case. However, one important factor that greatly concerned the researchers but not discussed here relates to the influence of policy. This issue will be considered and analysed in detail in the next section of this thesis.

## **Case study 6 – Automation firm**

This case was selected to represent another route of technology transfer process. The firm involved in this case is classified as a start-up company established by the former NSTDA staff.

### *The Firm Side*

The chosen firm in this case (known here as the *Automation firm*) has automation and sensor technology as its main technology. The firm was founded as a start-up firm which is different from the previous two spin-off firms from NSTDA.

It was founded by the owner who used to work as an NSTDA researcher in NECTEC for six years. After he resigned from NSTDA he started his own business using the expertise and experience that he gained from working as a researcher in the public sector. He fully moved out to the private sector and did not transfer any technology from NSTDA at that time. “I started my company ten years ago. At the beginning, my company was located at the Thailand Science Park (SP) and we moved out to the present location three years ago”, the firm owner stated.

He also described that he worked as a researcher at NECTEC for several years. His responsibility is in the automation field. During that time he gained a lot of experience and learned about the market and competitors in this business field. Then, he started to think that he should do something else as a new challenge so he decided to quit the position and start his own business. As he emphasised, “from my experience, if I switch my role to be the private firm, I can do something more to improve this field of business in our country. I chose to stay in SP because I still have the connection with the NECTEC and MTEC lab; we are still working together until now even though my role has changed from the public researcher to the entrepreneur”.

The firm business was started by establishing a contract with the factory and manufacturer that required the automation system in their production process. “We did it as a contract service for the customer by designing the automation system to help them to set up the system”, the firm owner clarified. He stated that: “When I worked in the public sector, I did the same thing as my business has been run. I used to set up the automation system for the big companies and some big departments of the public sector. My job was quite difficult and could not be duplicated in each case but finally it became a routine work. That is the reason why I needed something new and challenging”.

After that the firm moved to the further stage by setting up their own R&D unit. Since they needed their specific technology and product, the R&D unit was established. Since the owner was a researcher and he had a research team with him, and the connection outside the firm including the researchers in NSTDA. Then the firm started to license technologies from the public research institutes, not only from NSTDA, but also from other public organisations and universities. Now the firm runs the business using products that have been developed by its R&D unit together with the licensed products that have been transferred from outside.

#### *The start-up company*

Apart from technology licensing, start-up and spin-off firms are the processes that universities/public research institutes normally use to implement technology transfer. However, regarding the various definitions of these two processes, the difference in the source of the implemented technology, budget investor and IP owner will be used to differentiate them in this thesis.

According to the previous definition, the firm involved in this case is categorised as the start-up firm rather than a spin-off firm since it was started outside the public organisation, and financed and managed by the private sector. Additionally, despite the firm owner having developed expertise and gained experience from being a NECTEC researcher, the core technology and main product of the firm have been developed under the firm R&D unit. This case can be compared with the case studies of the other two companies established by the former NSTDA researchers which are considered as spin-off firms.

The *IT firm* more clearly shows the characteristic of a spin-off firm since it was founded as a joint venture between NSTDA and the private sector. On the other hand, the *Medical device firm* can be categorised as a start-up firm in some aspects. However, since the technology used in this case was developed and run as a service under MTEC before; when the technology was transferred to the firm some parts of technology still attached with the MTEC and the head of the research team is still working as the MTEC researcher including the infrastructure under MTEC lab is being used to produce some parts of the product. Therefore, NSTDA has considered the Medical device firm as a spin-off firm rather than a start-up firm.

#### *The Public Side*

There are several public organisations involved in this case; most of them play a role as a technology licensor. However, the public organisation that plays the most important role as the technology licensor and the former affiliation of the firm founder is NECTEC.

As mentioned earlier in the previous case, NECTEC is a national research centre under NSTDA. NECTEC is responsible for technologies involved with computers and electronics and includes automation and sensor technology as one of its research units. Even though the five research units are run under NECTEC as the national research centre; the technologies under each research unit are diverse and different. Regarding the fifth case study described previously, the information technology is also implemented under NECTEC, but compared to other technologies it has different characteristics that lead to different ways of implementing and managing the technology. Likewise, the automation technology has a different nature and characteristics, since the design of automation systems is specific to the user and is not something that can be simply duplicated. To serve the user's needs the technology provider has to work closely with the user.

This is one important factor that pushed the researcher to move into the private sector. As a firm, it is easier to serve the user need and being the researcher makes it possible to conduct research within the firm to develop the product that responds to the specific need of the user. Simply put, working as a private company is more convenient than being on the public side when it comes to generating business with automation technology.

According to the NECTEC support role, the firm owner was encouraged to attend the training course for new entrepreneurship while he was a NECTEC researcher. The training course was organised by the department under the Ministry of Industry to promote new entrepreneurs from the public side. One of the NECTEC executives has described this approach as: "Besides the national research centre, we think NECTEC can also be an incubator for the new entrepreneur. Many of our former researchers have left NECTEC and started their own company and many of them are a success in their business. The *Automation firm* is one of those successful entrepreneurs. As researchers, they gained some useful information and experience and some of them can see the opportunity through their routine work. As the executive, we have a fully supportive policy for them to walk in that path. It is a good approach to develop and carry on our ST&I in our country".

Other public organisations involved in this case as technology licensor and supporter included BIOTEC, MTEC, National Innovation Agency (NIA) under Ministry of Science and technology; universities; Ministry of Industry; Ministry of Agricultural and Cooperatives etc.

## Case analysis

To analyse the case closely the way of running the business for this firm was described by the firm owner. After the R&D unit was set up, the firm started to develop their own product which gave them some small success. It was an analyser device which is required in many manufacturers and factories in industry. There were some imported products in the market at that time but they did not fit with the user requirement perfectly. At that time, the firm was informed by the public organisation responsible for this issue that there was going to be a strong regulation established for the environmental protection issue and that the law would be changed to be stricter in this regard. As a result, the analyser device would need to be installed in regulated factories. Understanding this situation, the firm learned about the specific needs of the user and then developed the product to serve that need. “As a local firm, some people might think it is a disadvantage but in this case being a local firm gave us an opportunity to be the first firm who heard about this new regulation”, the firm owner stated.

During the development process of the new product, the *Automation firm* was supported by several public organisations before accomplishing the goal. The first one was the Ministry of Industry, which encourages Thai entrepreneurs to compete with international firms and strengthen Thai industry. The second public organisation is the NIA under the Ministry of Science and Technology which helped the firm in the process of innovation development. Another partner was the King Mongkut's University of Technology Thonburi that helped with technical matters by co-developing a prototype sensor device. Finally, the product has been developed successfully and efficiently used.

Being a local firm sometimes gives an advantage as it is easier to track changes in the country especially with regard to regulation policy. Furthermore, working with Thai industry, the local firm can benefit from having a similar working culture and manner. Thus the firm owner noted that: “We know how the Thai manufacturers run their business. We have learned many things in the past ten years even the way of managing the supplier and how to introduce our product to the new factory. It has its own mechanism; we have to know it and manage to get into the system”.

Even though the firm owner described this product as a small success for the firm, in fact the success of this product is not small, especially when it is considered that the firm has many international competitors in the automation and sensor business. The product cost is 0.6 million baht (~20,000 US\$) per unit and the product has been sold to more than 60 Thai factories. The firm is ranked in third place in market share after the big two international firms which is quite impressive for a newly established local firm.

Another advantage that the firm gains from being a local company is in the ability to build up relationships of trust. After-sale service is important for these types of product. “We have experienced that the customer are worried about the after-sale service issue, if the device is broken what will happen if the firm who sells this product is outside the country. We as a local firm will be ready to serve our customer here in Thailand while the international firm even they have a representative in this country, they need to consult with the parent firm before giving a service”, the firm owner revealed.

Some might argue that many international firms with a business in Thailand do not have this kind of problem. This may be the case for other businesses, but it is different in automation technology. In this business field, it has a unique characteristic that the producer and the user work closely to use the technology. Moreover, the technology is quite specific to the individual user and the producer who can respond to the user needs properly will get more chances to be successful. This is an important point that gives an opportunity to the local firm to compete with the big international firm. In that respect, this type of automation technology is unlike other types of technological business such as electronics or automobile industry where the big firm can occupy the major part of the market and leave only a small part of the market for local firms.

Presently, there are a few Thai firms emerging in this field of business. However, they have run their business in different ways. “We have more local competitors during last few years but it is not a problem. I think we can be called an alliance in some regards since we can talk to each other and work together sometimes. We hold different techniques and different technology. In some applications our technology fits best but in some other works, they might need different types of technology to apply. Therefore, we manage to move together and share the market appropriately”, the firm owner described.

Apart from developing its own technology under its R&D unit, the firm also acquired new technology to develop new products via the technology licensing process. One product of technology transfer is the detection device that was developed by KMUTT and funded by the Agricultural Research Development Agency. The technology was transferred and the machine was improved to be an industrial model. The other one is the detection device that has been co-developed by the researcher from NECTEC and BIOTEC and funded by NSTDA. This product has been transferred as a prototype and the firm R&D unit developed it to be a commercial version. The product has been launched to the market but it is in the early stage, so the result of the commercialisation process is unpredictable at this time. However, the response of the user has been positive so far.

### *The supportive factors and inhibiting factors*

From this case, the most important supportive factor is the capability of the firm itself to be able to run the business in the proper way and benefit from the technology. Even though there are other factors such as the budget and other resources, it cannot be denied that many researchers had been working in the same position and experienced the same thing but they did not move to the same path as the firm owner. What is the difference between them? The only answer I could find is the personal attitude.

However, even if they have the same attitude to become entrepreneurs, it cannot guarantee the success of the case. The firm owner revealed that of the researchers who joined the new entrepreneurship training program together and moved to the private sector, only 10-20 percent of them still survive in their business. The successful entrepreneur must also know very well the core technology involved in running the business, along with other resources and access to funding. “Besides the technology we need the investment budget, a good management, business partner, connections especially technological development partner. Another important thing is we have to adapt ourselves to the situation and the new environment”, the firm owner has emphasised.

The next supportive factor is the public organisations who helped the firm to succeed. To begin with NECTEC, the former affiliation of the firm owner, implemented an appropriate policy to encourage its staff to be new entrepreneurs. Secondly, the Ministry of Industry organised the training programme to support people in the public side to move to the private side. Then the university played the role as the technology development partner with the firm. Finally, the granting agencies and the innovation supporter such as NIA helped to support the firm to develop its own technology and do the technology transfer process. It seems like every part of the public sector played a useful role in this case to help promote the success of the firm.

Finally there are some interesting points from the firm owner for doing a start-up company with the technological business.

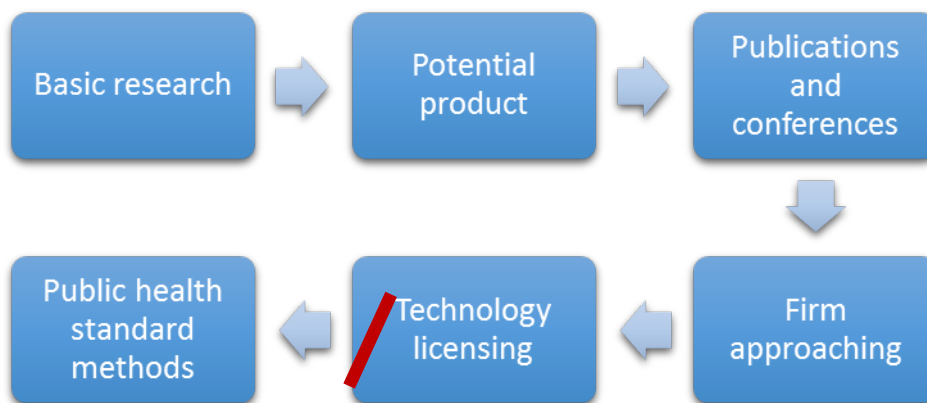
- We have to respond to the need. The market is the first thing to be considered then find the way to serve the need with our capability we have got.

- When we see the opportunity in the market, evaluate ourselves first. Can we compete in that market?
- The connection is important especially the partner who can develop technology together.
- The marketing research is the thing that we must do. Many of the public researchers conduct the research from the top down policy or to respond to the need of the researcher. In some cases, it just begins with the round table meeting and one or two points from the participants and conduct the research. That is not enough to be a good research question.
- Before starting the research, the researcher should see clearly who is going to be the user.
- The public researchers should find the way to speed up their research. Timing really matters in this business.
- As the private sector, we do not intend to invest in the big R in doing R&D activity even though we have our own R&D unit. We focus on the big D as the important part of development. Therefore, the public sector should be responsible for the research (R) since they have more resources and time than the private sector. Then the private sector can license the research from the public sector and continue with the development and market forecasting.

## 6.2 Public-Private Collaboration: Failure Cases

Writing about cases of failure in conducting technology transfer from the public to the private sector in Thailand is not an easy task. Even though there are lots of cases that are seen as ‘failures’ in attempting to do technology transfer, it is difficult to get detailed information from those involved. The limitation of information access is the most significant challenge in studying the cases of failure. This might be related to the cultural context as people normally avoid talking about their failures, especially in the business arena. Therefore, in this section which describes some examples of failure cases in technology transfer, there will be only some information available. Most cases are from information provided by staff from the Technology Licensing Office (TLO) who could give only names of technology, characteristics of cases, and causes of failure. None of them mentioned the name of the firm or the researchers. There was only one case that I could access information from the firm’s owner and two cases from the researchers.

### Mini Case Study 1: *Diagnostic Test Firm*



Information presented in this case was provided by one of NSTDA’s TLO staff who worked with the firm in the bio-medical field for technology licensing. It was one- sided information from the public organisation staff because the access to information from the firm side was limited.

*Private Side:* The firm involved in this case was conducting its business by producing and trading in diagnostic test kits. The firm owns a production plant that can produce products to meet the EU standards (CE standard). The core technology used to produce products was a formulation of strip tests.

Public Side: Researchers from the Immunology Unit, Chiangmai University.

This case deals with the development of a diagnostic test for an infectious disease used in hospitals. A research project was initiated by researchers from Chiangmai University and funded by BIOTEC, NSTDA. From this basic research they found some potential information to develop the diagnostic testing process. Another research project was conducted to develop the diagnostic method, and finally a prototype diagnostic test was created. The prototype was then tested with specimen samples from the hospital and showed good results for its efficiency.

The diagnostic test prototype led to the research team winning research awards from many research institutes. This provided an opportunity to promote the research to the public, including firms interested in this type of product. Next the prototype was developed further in order to be used in field tests (hospitals). At this stage, the firm called '*Diagnostic test firm*' joined in to collaborate with the researcher in the collection of data from the field tests. They obtained some impressive preliminary results. Then, the firm decided to license the technology from the researchers and stepped up commercialisation. As part of the negotiation process, the firm agreed to pay a licensing fee including the disclosure fee and royalty fee.

However, as the diagnostic test device that was intended for use with patients in hospitals, the product needed more field testing and had to pass public health criteria. Moreover, as a newly developed product, excellent testing results were required when the product was compared with the existing device in use in the hospital. There were some problems that the researcher and the firm faced during the field tests. Although the new product had many advantages over the existing kits, it did not pass public health scrutiny. It was forced to contend with some standard methods set by the public health organisation, the detail of which was not clarified by the TLO's staff.

Ultimately, the failure to meet these standards severely reduced the market size. Although the product could still be used for some cases, it did not become a new standard method that would be widely adopted in the public health system as was expected. The licensing contract has now ended and the firm did not extend the contract. This case can be considered as a success in one sense because the product was successfully licensed to the firm, but in a commercial sense it was a failure.

One important point to note in this case is timing for the firm to join in the project. The firm moved in when the product prototype was not fully developed and proven to meet standard

criteria. It saw the business potential in the product and decided to do technology licensing. Because there were not enough results from the field tests, it made this project more risky for the firm. No one could tell at that time whether the firm made the right or wrong decision.

Following another interview with one of firms in this field of technology, it became apparent that timing is one of the most important factors in determining the success of technology licensing. Sometimes, being an 'early bird' does not mean you can get the best reward in the bio-medical business. In many cases, the second player gets the best chance by learning from mistakes made by the first one. However, this is not always the case; sometimes firms experienced the reverse circumstance in that they might find it was too late in being the second one in that business because the first one took everything. As mentioned earlier, no one can tell when is the right time for the firm to jump into the project. Thus, identifying which stage is appropriate for the firm to get involved with the research project is difficult, as the answer it depends on the situation at that time and it will be varied from case by case.

In this instance, if the firm had waited until the project was complete, then the situation and condition of technology licensing would have been changed. If there was a positive result, there would be more competitors interested in the product and the cost of technology would inevitably be increased. Because the firm jumped into the project quite early, it was hard to predict the outcome. That is why there is high risk in this field of technology both from the technology itself and from the rules and regulations that comprise the social context.

### Mini-Case Study 2: *Sensor for Agriculture*



There was only minimal information about the case that the staff from NECTEC's Business Development unit (BD) could provide during the interview. However, this case suggests some interesting factors that influence the process of technology transfer.

*Private Side:* A firm doing business in agriculture machinery focusing on developing a sensor device for an agriculture controlling system.

*Public Side:* Researchers from NECTEC, NSTDA

The case centred on the development of an agricultural sensor device. NECTEC's researchers successfully developed the sensor controlling system and they met with a firm that was interested in this product.

The BD's staff began the technology transfer negotiation process and they agreed to have a technology licensing deal for this product. However, before signing the licensing agreement, the firm found a similar, but cheaper, product from a Chinese source. Even though the technology is different and the Chinese product provides less function when the firm compared the products with regard to both cost and product quality, they chose the Chinese product and terminated the previous deal.

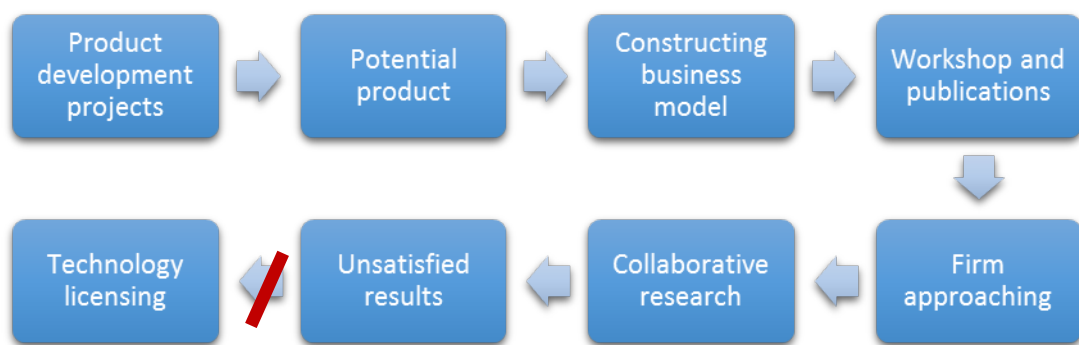
This is a common problem for Thailand today, where a product from China is cheaper, although it has less function and uses less advanced technology. This is widely perceived as a factor inhibiting the growth of innovative firms in Thailand. It cannot be denied that China's industry has cheaper labour which directly results in cheaper products. Moreover, for the technological issue, Chinese industry has a wide range of technologically capable firms. Thus, Thai firms cannot always assert that technological products from China are less advanced than Thai products. This problem might be considered normal in other industrialised countries but it is quite complicated for countries like Thailand because labour costs in this country are significantly higher than similar costs in China. Thailand's economic history relied heavily on cheaper labour but today cheap Chinese labour has removed this advantage.

The reasons why the firm chose the Chinese product are as follows:

Firstly, from their point of view, R&D activity is a cost, not an investment, so doing R&D increases the cost of a product. By choosing a finished product from China they do not have to think about product development. Secondly, the firm does not want to invest in R&D staff employment since the firm has only a small R&D unit. Although it employs many engineers to work for the firm, they are working on the production line, not in R&D.

To compete with products from competitor nations such as China, Thai firms have to develop products that can provide better quality at a reasonable price. The problem is how innovative Thai firms, or technology providers, can find the unique selling point of their products. From this case, it is clear that Thailand cannot compete with China's industry by using the strategy of cheap labour anymore. Additionally, doing market research with regard to competitor products is another activity that the firm and public sector needs to consider before initiating a new R&D project.

### Mini-Case Study 3: *Aquaculture Cultivation Device*



The detail of the project in this case was provided by TLO's staff working closely with a researcher conducting a research project in the case.

*Private Side:* The firm involved in this case is doing business in aquarium construction and exhibitions. It is considered a big player in this business and has connections with large exhibition centres as its clients.

*Public Side:* Center of Excellence for Marine Biotechnology, BIOTEC, NSTDA.

This case centred on the development of a system and device for aquaculture cultivation. Existing technology used in other countries was expensive and did not fit very well with local use. Therefore, the BIOTEC researcher started to use his knowledge and experience to develop a local technology.

Supported by funding from BIOTEC the project took four years to complete a product prototype. This technology can be used to cultivate and produce many aquaculture products varying from small algae to a multitude of marine and aquaculture life. This project was

chosen for its innovative nature and was initiated and conducted as a plan for new business development by a team of master degree students in a new entrepreneur program from Thammasat University. The student team developed the business plan for this research project. However, the student team from the business field did not understand how the business system in aquaculture works. So, in reality the proposed business plan could not be implemented properly.

After that, the researcher was contacted by an aquaculture firm that does business in aquarium construction and exhibition. The firm was interested in the system developed through this project for cultivating aquaculture animals in its aquarium. However, it was a prototype and needed further development for it to fit the user requirements. To achieve this, the firm and BIOTEC carried out collaborative research including field tests. The firm invested in materials and devices for system construction and field tests. The selected site for the tests was a real site that the firm used to provide aquarium exhibitions to customers. However, this proved problematic because of difficulty with field site access. When a problem occurred with the system and device, the researcher could not access the site immediately when there was a system failure.

Besides the difficulty of site access, the system itself was not as stable as expected. During the collaborative research, the researcher adjusted and changed the system and device many times including scaling up the system. Finally, results from the field tests were unclear. The firm decided to postpone the decision about technology transfer. At present, the researcher is improving the system to fit with the fishery industry by collecting more data with other field tests.

At present this case is neither a success nor a confirmed failure. The case highlights the challenges with transferring a technology when the potential users are not existing players in a stable socio-technical system. This also makes it hard to evaluate technology readiness and business potential. An important lesson is that knowledge of the targeted sector is critical to the development of a good business plan.

#### Mini-Case Study 4: *Electronics Device for Heavy Industry*



This information was also provided by the TLO's staff involved in the technology transfer process of the case.

*Private Side:* The firm involved in this case was in the electronic devices development industry.

*Public Side:* Researchers from MTEC and NECTEC, NSTDA.

This case concerned an electronics device development project conducted by a researcher team from MTEC and NECTEC. The main aim of the project was to develop an electronic device for heavy industry. The project consisted of two parts: a hardware part (the device) and a software part (operational software program).

The project was initiated by a firm that contacted MTEC to help it establish a new electronic device. The firm has background knowledge of constructing hardware for this type of device and it came to MTEC with a clear specification of the product. Collaboration with MTEC could help them gain get access to materials for device construction and assembly technology. This collaboration was aimed at establishing the hardware part of the device.

For the software part, MTEC researchers had collaboration with the team of NECTEC researchers who specialise in the software development process. Then the collaborative project was started. The project was funded by the firm and was considered contracted research. MTEC researchers developed the device prototype while the NECTEC researchers constructed coding as a software program to use with the developed device. During the

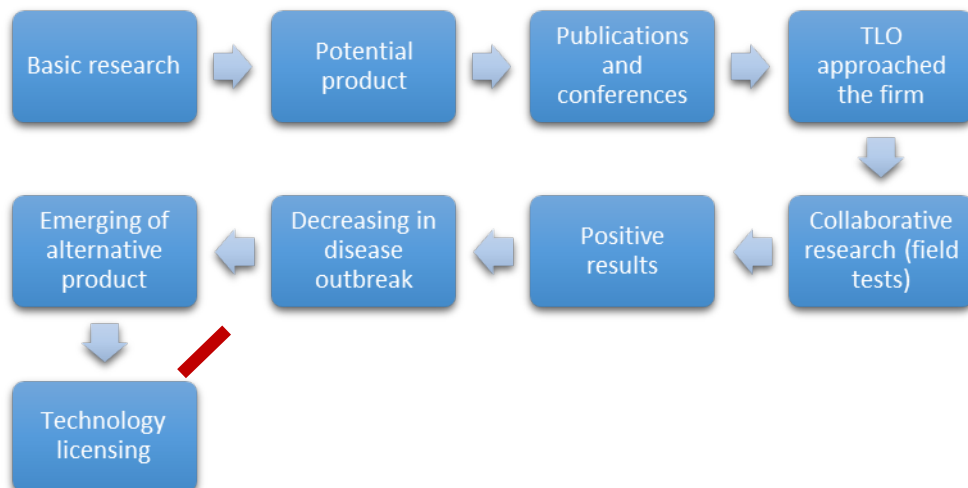
operation of collaborative research, the firm had planned a deadline for the new product launch which was determined by the project schedule.

However, the project did not work as well as expected. MTEC researchers developed the prototype but it did not meet the specification that the firm required. The main problem was the link between hardware and software which was not compatible. This problem caused the firm to lose its market opportunity to launch the new product. However, after the end of the project, the firm decided to pay for the device to keep its good relationship with MTEC even though the device needed to be improved for better efficiency.

It can be seen clearly from the case that there was a mismatch between the user's need and the technology provided. Although there was a clear product specification from the firm, it is not always the case that the public researcher can respond to it perfectly. There are still some limitations in technology capability in the public research institute. The TLO's staff gave some comments on the case as follows:

- In this case, the researcher team underestimated the difficulty of the work. They thought they could handle it with the technology they had. It made the firm lose its market opportunity.
- It is not only hardware and software that was incompatible but also, occasionally, the teams of researchers from different national research centres.

#### Mini-Case Study 5: *Bio-control Agents*



Information for this case was provided by a firm involved with the case and one of TLO's staff who worked as a case coordinator. This is the only case of failure that the firm was willing to provide information for.

*Private Side:* The firm engaged with this case was in the agriculture industry. It started its business BY trading agricultural products and fertilisers. Then it became a producer of bio-control agents using fermentation technology. The firm's first bio-control product was based on fermentation technology transferred from Mahidol University. The firm's business went well with the fermentation technology and its environmentally friendly products. Then it aimed to move to organic agriculture as a new target market.

*Public Side:* Researchers from Prince of Songkla University, one of the biggest regional Thai universities from the southern part of Thailand.

This case was about the development of a bio-product for use as a bio-control agent in rice farming. In order to reduce the use of chemical agents to control pest and plant pathogens in agriculture, bio-control has been introduced to enable organic farming. There were some imported bio-control agents in the market but they were used in different types of farming. Since the bio-control agent is quite specific to the pest or plant pathogen, it is used narrowly compared to chemical agents. However, this can be considered an advantage of using a bio-control agent because it will not affect other types of insect or microorganism which sometimes benefit the environment.

The university researchers initiated a research project for developing a bio-control agent in the university. It started with a project for screening potential bacteria to use for bio-control. The research project was funded by BIOTEC. After the potential bacteria were selected, the researcher continued with the second project to conduct a greenhouse testing process. Finally, the potential bacterial strain was selected and the researcher continued with a further project to find out about the pathogen control mechanism of the selected bacteria and with development of the formulation of the bio-control product. The researchers obtained three patents for this product. At that time, the BIOTEC's Business Development (BD) team started to find a firm or user for this product.

BIOTEC's BD contacted a firm with experience of producing bio-control products for pest control for the purpose of public health. The firm was interested in developing a new bio-control product in order to expand its market, and its expertise was relevant as the production process is quite similar for both types of bio-control product. Then BIOTEC held a meeting to negotiate with the firm and the researchers. The negotiation process went very well and

they agreed to develop the product formulation in a pilot scale production, and to carry out field tests together.

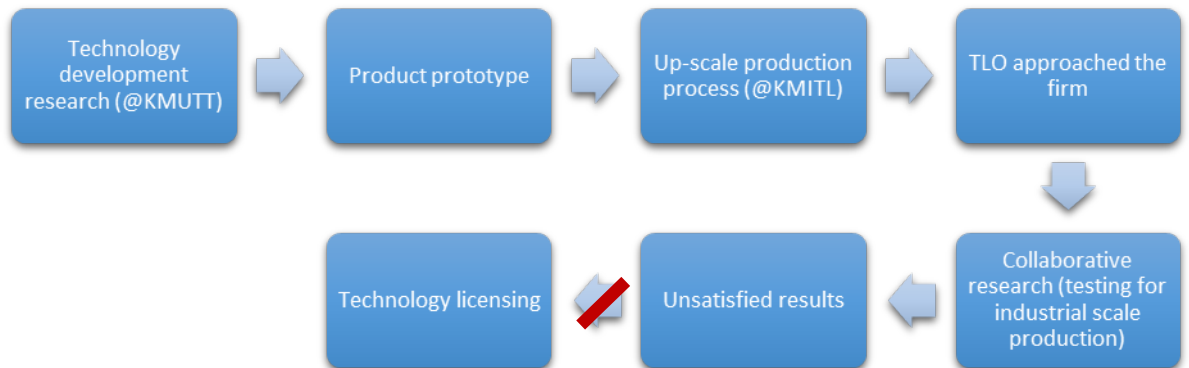
The firm helped to find sites for conducting the field tests because it had connections with farmers and some public agriculture organisations. The field sites were selected from the record of plant disease outbreaks. In addition, the firm was responsible for producing the bio-control agents used in the conduct of the field tests while BIOTEC supported with other expenses used incurred the project. The results from several field tests showed excellent efficiency of the product. The farmers who participated in the field tests were also happy with the product.

However, eventually the product was not licensed to the firm as was expected. After finishing the field tests, outbreaks of the disease decreased significantly and did not come about every year. Moreover, a new breed of disease tolerant plant was released, and so the market for this type of bio-control product became smaller. The firm decided not to carry on with technology licensing of this product even though the research project was completely successful in every stage.

This case clearly shows that even though there is a great research project that can create an excellent product and also collaborate with a good company partner, without enough user demand it cannot create a successful technology transfer case. This highlights the importance of having information about a product's need and a good market forecast, though these may not be enough if the demand for a product changes due to unforeseen circumstances.

As the TLO's staff put it, "We should be aware that when the researchers specialised in one field tries to develop and apply a product in another field, they might not have enough information to create the right research question". In this case, the researchers were specialised in microbiology and product formulation and did their job very well. However, they lacked adequate information on the outbreak statistics of the plant disease. Additionally, the launch of a new strain of plant that tolerates plant pathogens was unexpected. Ideally; therefore, such technology transfer efforts should also involve comprehensive market research that includes an awareness of replacement products and other potential market changes.

### Mini-Case Study 6: *Alternative Material for Solar Cells*



Information provided by a member of TLO's staff working in the field of material science technology who was involved in establishing collaborative research in this case.

*Private Side:* The firm involved in the case is in the stationery production business. It has some parts of its production line that can be applied to produce material for solar cell production.

*Public Side:* A team of researchers from King Mongkut's University of Technology Thonburi (KMUTT) responsible for product prototype development and researchers from King Mongkut's Institute of Technology Ladkrabang (KMITL) responsible for the pilot scale production process.

This case involved the development of material used in solar cell production. The research project was started in KMUTT to find a suitable polymer to form a new material as an alternative material for use in solar cells. There were several solar cell production plants in Thailand but all of them used imported material from abroad to produce the solar cells. When the KMUTT's researchers finished product prototype development, they did not continue with the project. After that it was transferred to KMITL to develop a scaled up production process. In this case, the researcher in the first team who developed the material had quit even though they got a good research result. Instead TLO approached a new

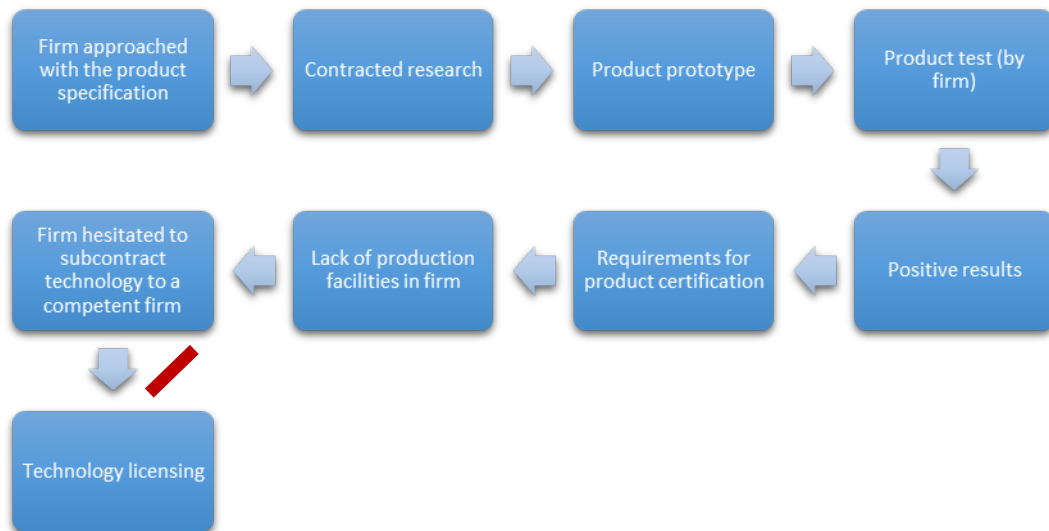
researcher team in another university (KMITL) since they were specialised in the scaling up process.

After that, TLO could approach a firm that was interested in this material. Although the firm is in a different field of business, they were interested in this material because they were using a machine in their production line that can be applied to produce this material. Then they started to do collaborative research by conducting trial production in the firm's production plant. At the same time, the firm started to do market research on the new product. Furthermore, they found some potential customers and suppliers for this new product.

After conducting a production trial, the researchers found that the production cost was not as cheap as they expected. Furthermore, the firm found out that the production cost was increased when they switched to using a machine from the main production line for the trial product. In addition, there was a regulation requiring that when a material for producing solar cells has been changed, it is necessary to apply for new certification. Finally, the Thai market for solar cells was not big enough and Chinese production plants could produce a cheaper product of almost the same quality. As a result, the firm decided to terminate this project.

Alongside these obstacles to success, another reason that heightened the risk in this case was the firm lacks of knowledge of the particular industrial sector. Since they are not in the solar cell business, they did not want to take a risk in a business in which they had no market share. In this regard there are also lessons for the role of the TLO as an intermediary, both in terms of their expertise in forecasting technology trends and in their ability to choose appropriate firms to fit with the technology and business field. As the TLO's staff admitted "We should learn from this case and use this valuable experience with our future cases."

### Mini-Case Study 7: Adhesive Plaster



This case involved nanotechnology and it was communicated by a researcher who carried out the research project for the case.

Private Side: A firm doing business in traditional Thai herbal medicine and alternative medicine development. The firm also owns a hospital that uses alternative medical therapy to treat its patients. The firm is specialised in development of traditional medicine and applies it to modern medical treatment.

Public Side: Researchers from NANOTEC, NSTDA.

The case originated from the firm's need to develop a new adhesive plaster that contains bio-active compounds extracted from Thai herbs. Bio-active compounds have been used to soothe pain from bruises for a long time but sometimes they cause an irritating effect for the user's skin. Therefore, the firm wanted researchers to use nanotechnology to develop a new formulation of those bio-active compounds in order to solve the irritation problem.

The researchers considered product specifications and agreed to carry out the project which was conducted as contracted research. The research project went well since NANOTEC was ready with lab instruments and devices. Eventually, they developed a product prototype of adhesive plaster that contained the required bio-active compounds. The prototype was tested in the hospital that the firm owns and they obtained impressive results.

Then the firm tried to register the new product with the Thai Food and Drug Administration (FDA) but as a new product using nanotechnology, it was not easy to get certification. Since

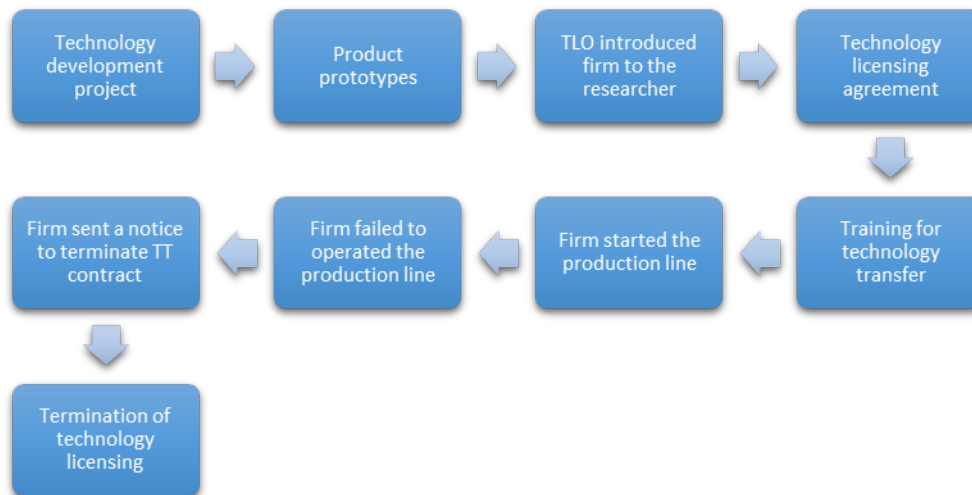
nanotechnology is new to the Thai FDA, it took time for them to gain enough data for certification. Another problem was related to the production technology itself due to the firm's lack of the production facilities that were required for nanotechnology. When the product was produced in NANOTEC's lab, it did not face any problems since the lab was fully equipped. However, when the process was to be transferred to the firm, it was difficult for it to obtain all the required equipment. Most of the production machines were expensive and high technology. This became the biggest obstacle for the firm to produce the new product.

The researchers recommended that the firm should sub-contract this production process to another firm who were capable of producing the new plasters, but the firm declined to do that because it was concerned about secrecy of the product. Finally, the firm decided to keep the intellectual property (IP) of the product but still struggled with technology utilisation.

This is a common problem that occurs with a new technology like nanotechnology. While the technology can be used perfectly by the researcher in the lab that is fully equipped with the required instruments, firms who attempt to transfer the technology often struggle with implementing the new technology. They not only lack specialised production equipment but also the background knowledge to implement the technology. Another common problem when introducing new technology is the product certification process; especially when it is implemented in the food or public health sectors. Due to many concerns about risk assessment of new technology or other involved issues, the regulating body hesitates to issue the certification when they do not get enough information. Sometimes there was no set standard to indicate how much information they need to have before making a decision. In some cases, it took too long to obtain certification and caused the firm to lose its market opportunity.

This case therefore point to two lessons for improving Thai technology transfer. First, that transferring a new technology in highly regulated fields such as healthcare would be much easier if regulatory approval could be speeded up and simplified. Second, that the private sector should be aware of investment necessary to set up production processes involving expensive equipment and associated expertise.

### Mini-Case Study 8: Dental Implant Material



This is another case where the scientist who conducted the research was willing to tell his story about collaborating with the firm.

*Private Side:* The firm engaged in the case is doing business in trading medical devices. In this case, the firm played a role as technology licensee and did not get involved while the technology was developing.

*Public Side:* Researchers from MTEC, NSTDA

The main technology used in this case is material sciences to produce an alternative material for dental implants. The research project was initiated and developed under NSTDA to find an efficient alternative material for dental implants. After the potential material prototype was developed, TLO contacted firms as potential users for this technology. At this stage, the researchers were not informed about the firm.

Then one firm was selected to license the technology and the agreement was signed on the condition of exclusive licensing in return for a five year royalty fee. At this stage of technology licensing, the researchers were responsible for teaching and transferring the production process to the firm. They gave recommendations to the firm while it was purchasing production machines and equipment. Then the firm's staff were sent to MTEC's lab to learn more technical knowledge for several months and they returned to the firm to start the new production line.

After a year, NSTDA was contacted by the firm asking for a termination of the licensing agreement. The main reason for termination was that the licensed technology could not be

applied to the industrial production process. Furthermore, the firm complained about insufficient assistance from NSTDA in solving this problem, and that MTEC's researchers did not help them to solve it. This resulted in a legal conflict (the researcher did not give any details about this part). However, eventually they found a mutual agreement and the contract was terminated. Although the researchers were blamed for the failure of the case, they only admitted that this was partly true, and did not take full responsibility. The researcher explained that: "It was too early when the firm came to us and licensed technology, it was just a prototype".

This case thus demonstrates a familiar problem with an attempt to exploit a technology that was not sufficiently ready (and with a firm unwilling to invest in bringing it to readiness), but in this case exacerbated by poor communications between the researcher and the firm. With regard to the lack of technological readiness there appeared to be failings on both sides. On the one hand, the firm should have evaluated the progress of the technology before licensing it. On the other hand, the TLO had brought the firm to the researcher when the product was only a prototype and the production line was not ready.

As with the previous case, 'readiness' was not an intrinsic property of the technology, but also depended on regulatory approval. Since this case involved the public health care system, the regulations were quite strict. The firm expected MTEC to manage this issue and also to apply for certification to meet the European production standard (CE mark), but the researchers thought it was not their responsibility. As the researcher explained: "I think we can help with everything we could contribute but we cannot take full responsibility in this issue. It should be firm who plays the main role".

This showed how poor communication was also a serious problem in this case. The researchers said that they had never been informed about the technology licensing until TLO brought the firm to them. Subsequently, it appears there was a lack of continuing contact with the firm to find out whether they were doing well with the licensed technology. At the same time, the firm complained about the lack of assistance from the researcher, though this may have been due to the firm being overly passive in its approach. As the researcher put it: "After we finished the training with the firm's staffs we never heard from them for a year and then we were informed that they wanted to terminate the contract". From this point, the researcher thought it was the firm's responsibility to ask for help when they were facing the problem. There was a gap between the firm's expectation and the researcher's perception of firm needs. The researcher emphasised that: "There was a high expectation coming from the firm. They were the investor and trader who did not have sufficient technical knowledge.

They did not understand how the technological product worked and lacked connection with other actors in the network”.

### **Mini-Case Study 9: Potential Protein for Disease Prevention in Aquaculture**



The case is the development of potential protein as a disease preventing agent in the shrimp cultivation industry. The story was told by NSTDA’s project analyst who was responsible for project funding and collaborating with the firm.

*Private Side:* The firm engaged in this case was doing business in the animal health sector. It was a subsidiary firm which has a parent firm located in France.

*Public Side:* Researchers from BIOTEC working in the centre of excellence collaborating with university.

The research project was initiated in a lab under the centre of excellence by the research team and was funded by NSTDA. It was conducted as basic research to understand the mechanism of the virus causing disease in shrimp. Incidentally, the researchers found some potential proteins that play important roles affecting the morbidity rate of shrimp’s disease. The discovery was presented in an academic conference and the researchers had the idea to develop the discovered proteins as a disease prevention agent (which is not a vaccine because it functions in different ways).

The researchers began to develop this agent by producing these proteins using the technique of recombinant proteins production. Using this technique, the researchers could produce a large amount of proteins to use in their experiments. The selected proteins were used to test for prevention efficiency by adding selected proteins into shrimp cultivation tanks (mixed

with shrimp feed) and then challenging with viral pathogens. The protein efficiency was measured by the survival rate of shrimp in the tanks. The first experiment gave an excellent result for the researchers; the selected protein could prevent shrimp disease significantly, compared to the control trial.

Then the researchers continued with their experiment by using the larger shrimp tank in the farm (it was not allowed to conduct the experiment in the real field test due to concerns of the virus leaking into the environment). The next experiment still showed a good result in preventing disease. The experiment was repeated and the protein still gave a positive result, so the researchers gained more confidence about the efficiency of the protein.

In 2010, a subsidiary firm moved to TSP as a new tenant and it began meetings with NSTDA staff to exchange research information. Information about the protein research project was given to the firm by NSTDA leading to further interest in more information from the firm. Eventually, a meeting between the firm and the research team was held by the NSTDA's staff. They agreed to engage in collaborative research for testing prevention efficiency of the protein again, but this time conducted by the firm's staff. However, in the meeting, the researchers explained that they did not know the details of how the protein interacts with the shrimp to protect it from the virus, but the firm were not interested in this point.

The collaborative project was conducted by the researcher providing recombinant protein to the firm and it was to be combined with shrimp feed before use in experiments. The formulated feed was sent back to the researcher's lab to check availability of the protein before feeding the shrimp. The test was conducted by a third party whom the firm had subcontracted to do the test. The subcontractor was specialised in doing this kind of test and used to providing testing services to many labs and firms.

The result from the collaborative research was not good; the prevention efficiency rate fluctuated. The firm continued with the second trial and it showed the same result as the first one. By 2013, they were in the third trial which showed a similar outcome to the previous experiments. The researchers were surprised about the result from the collaborative research project and tried to find mistakes in the experiment. However, after three attempts, they could not find any error to fix in the trials.

After this, the NSTDA's staff and BIOTEC's researchers had an informal meeting discussing the problem with the project. They concluded that the project needed more basic research to find out the detail of the protein prevention mechanism in order to formulate an effective protein/feed combination, or to find another effective way to feed shrimp the protein. One

hypothesis suggested by the researcher is that the difference in the results was due to the formulation process. While the researcher had used a manual method to formulate the mixture in the lab, the firm had used an industrial process to formulate the feed as a pre-mixed agent (the firm was also doing business in feed production).

This case again shows a general issue with technology transfer when promising research may not be ready for commercialisation. In particular, getting what appeared to work in the lab to also work in an industrial setting proved problematic. While the potential disease prevention effectiveness of the protein was established there was still doubt about its application. In this case, the difficulty with transferring the technology from the lab into industry could be explained by a lack of attention to the ‘tacit knowledge’ held by the researcher, which could not readily be communicated by explicit means.

#### **Mini-Case Study 10: *Biological Agent for Preventing Disease in Poultry***



This case is an ongoing project (at time of writing) and it contains some sensitive issues for the firm. It was recounted by the NSTDA’s project analyst. The selection of this case is not intended to attribute blame or take sides between the public and private sector.

*Firm Side:* The firm involved in this case is one of the big firms in Thailand. They are doing business in many fields of industry, one of them being the poultry production industry. The firm owns strong R&D units with many researchers.

*Public Side:* Researchers from BIOTEC, NSTDA

The project was started when the firm's executives made a visit to NSTDA's labs and demonstrated their intention to collaborate with NSTDA in R&D activity. The team of BIOTEC's researchers had a chance to have a meeting with the one of the firm's subsidiary operations. The firm informed them of its needs and the problems it was facing in its production lines; these problems and requirements then became research questions for the researchers. One of them was concerned a disease that was endemic in a poultry production unit. After considering their expertise and technological readiness, the BIOTEC's researchers decided to suggest a research proposal to the firm to provide the development of a biological agent to prevent, or limit, the disease. The project was proposed as a collaborative project since there were some risks that could lead to failure, and NSTDA wanted to share those risks with the firm. The firm agreed to start this research project but in the form of contracted research instead of collaborative which gave the firm the right to the project's intellectual property.

One obstacle that normally occurs with NSTDA for both contracted research and collaborative research is that there can be delays in the administrative process. This process has been the subject of complaints by firms in many cases, and even by NSTDA's researchers themselves because it causes delay in research projects. In this case, the NSTDA's coordinator staff tried to avoid this kind of problem by transferring the internal research budget to the researcher so that they could begin the research project while they were dealing with the complicated documentation process.

The researchers involved in this project were very effective, within six months they finished the first prototype of the biological substance and it was ready to deliver to the firm. The firm was informed about the progress of the project and was ready to conduct testing of the first prototype. Eventually, the prototype was delivered to the firm, even though the documentation process was not finalised and the firm had not paid for the research budget yet. The first experimental result came out quite positive but the firm needed a more effective product. Then the second prototype was delivered to the firm; this one gave a good prevention rate but had a side effect on animals.

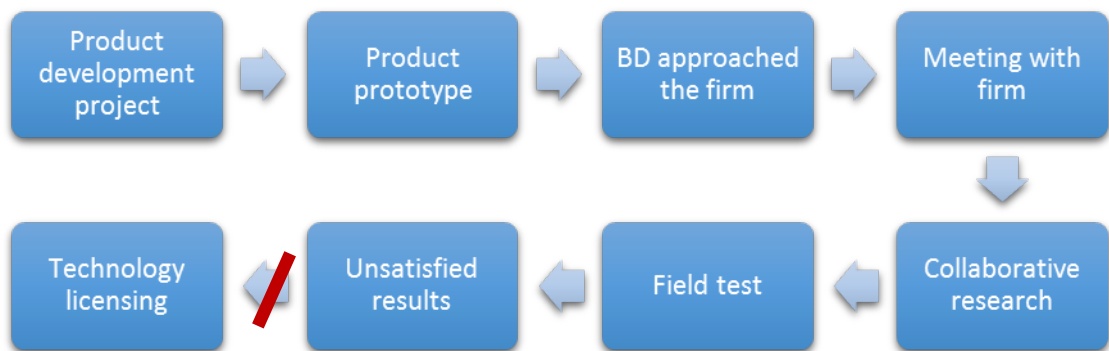
The researcher continued with the project by developing more prototypes to improve on the previous prototypes. However, there were some problems with the documentation process. It took longer than expected and this time it was delayed by the firm side, not from the public side. The project time period is 1.5 years but one year passed and the contract was not signed, and the firm did not pay any research budget to NSTDA. The coordinator tried to arrange the meeting with the firm but they avoided it. The NSTDA's project analyst said:

“There is a sign that the firm has changed their attitude on this project. It is different from the beginning when they showed a positive attitude and cooperated in every request we made”.

In this situation, the risk is with the public side because the firm had not paid any research budget but had obtained the prototypes and the results. This might be because of a change in the firm’s internal policy or because they were not satisfied with the testing result. Even though there is no conclusion for this case yet, there remains an expectation of a positive ending because the deal was initiated at the executive level with the firm and this type of big firm normally tries to maintain a good relationship with the public sector.

What this case exemplifies is the need for timely administration of research contracts. In this case, it is expected that the trust between the large firm and the public will produce a satisfactory outcome. However, in other cases the public sector’s willingness to help firms may lead them to provide firms with too much assistance in order to avoid producing a bad image of public organisation. Allowing firms extra ‘slack’ is no substitute for efficient organisation, and complicated and delayed handling of the documentation process may lead to adverse results in some cases.

**Mini-Case Study 11: Feed Additive Development in Aquaculture**



The case was an attempt to apply a research result from BIOTEC’s lab to the aquaculture industry.

Firm Side: The firm was doing business in the animal health care sector and aquaculture product development. The firm is one of TSP’s tenants.

Public Side: Researchers from BIOTEC, NSTDA

The initiative for the research project involved in this case came from a BIOTEC researcher who was aiming to produce microorganisms that collect essential fatty acid in their cells. The microorganisms were collected and screened in the lab in order to optimise the production process that they use to make fatty acid in their cells. A fermentation technique was used to produce targeted microorganisms and this was optimised in the lab and for pre-pilot scale production.

Similar to some of the other collaborative cases, this case originated from a meeting with the tenant firm in the Thailand Science Park (TSP). This research project was proposed to the firm because they are doing business in feed additive development. The firm was interested in the project and arranged a further meeting to discuss the details of the project.

The new research was initiated from the meeting as a collaborative project. The firm agreed to pay for the testing costs while NSTDA would provide the microorganisms for testing. The experiments were divided into two main parts; the first one was conducted in the fish tank and the second one in the fish farm. The agreement was settled smoothly but there was one condition that the firm's marketing department requested concerning the final price of the product. The firm insisted that the price should be based on the pre-pilot scale production cost.

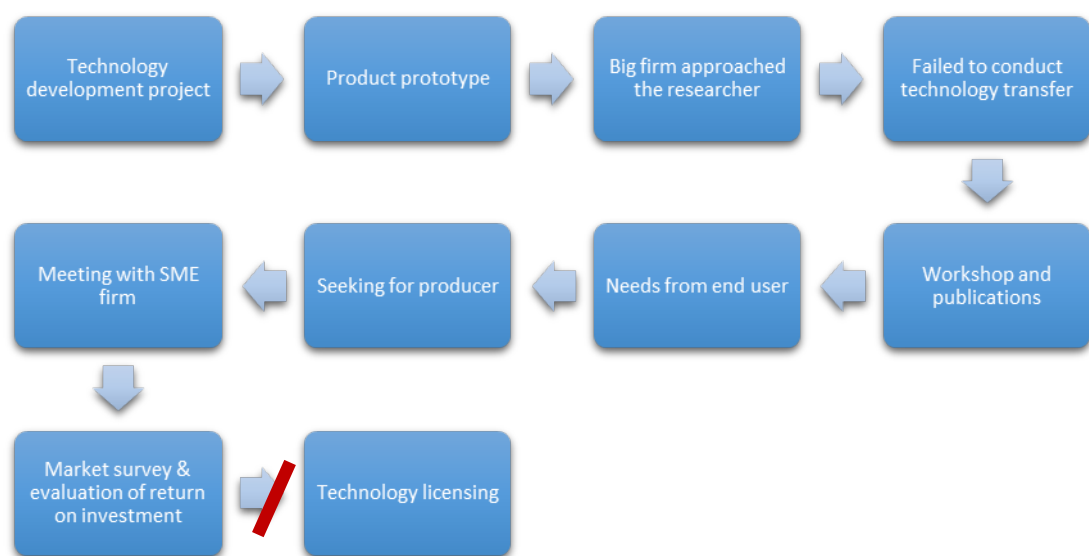
Since the price was calculated from the pre-pilot scale production, which is more expensive than industrial scale production, there was a small amount of microorganisms added in the feed additive agent when it was used to feed aquaculture animals. After that the fish samples were collected to measure the effectiveness of the feed additive. Eventually, when the result came out, it did not show a clear cut benefit when compared to the control. The researchers and firm met to discuss this, and they concluded that this was because the amount of microorganisms mixed with the feed additive was too small so it could not show its effectiveness clearly. However, the firm insisted on using the price as the main target for the project. Finally, the firm decided not to continue with the project since it did not show the expected positive result.

The major pitfall for this case was the production cost of the microorganisms. Because the firm insisted on setting the final product price based on pre-pilot results the outcome was unfavourable. This is because the production cost calculated was not to an industrial scale, which is normally much cheaper than pre-pilot scale or even a pilot scale production. The sequence of the project should have been changed by proving product efficiency first and

then if it showed a positive result, the next step would be the optimisation process to reduce the production cost.

From this case, it can be seen that in some cases the price of the final product is not always a good indicator as a target for a research project. There is a belief in the field of technology transfer in Thailand that the product has to be cheap; otherwise, the firm will not be interested in it. This is not always the case because the first important thing is to prove that the product is good and effective, and then the production cost can be managed later.

### Mini-Case Study 12: Food Processing Machine



This case involved the application of mechanical engineering technology in food processing. It shows technology readiness, but a lack of recipient.

Firm Side: The firm was an SME doing business in machinery producing industry. The firm's owner was an engineer.

Public Side: The researcher was from King Mongkut's University of Technology Thonburi, KMUTT

The research project in this case originated from the researcher's idea to apply a technology existing in the lab to the field of food processing. The research proposal was sent to BIOTEC, NSTDA to apply for funding. After considering the research proposal, NSTDA granted the research budget to KMUTT and the researcher began the project. When the project was finished, the researcher delivered the first prototype of a drying machine which

can be used to process fresh food into dried food. However, there were still some problems that needed to be fixed so the researcher applied for another grant for a second research project.

The second project was again funded by NSTDA because during the development of the first project, the researcher had demonstrated the potential use of the machine. Furthermore, there was one big firm in the food processing industry showing interest in this machine. After the second project was finished, there was a visit and a meeting with the big firm that was interested in the product. However, the big firm decided against technology transfer because its expertise was not in machine production.

Then the BIOTEC's BD staff decided to organise a workshop to promote this machine to the public. Most participants who joined the workshop were SME firms and entrepreneurs doing business in the dried food industry. They showed interest in this machine since it could help them to process their raw material quicker than the sun dried process, and it did not depend on the climate or seasonal factors (the rainy season affects the production rate of dried food). Moreover, using a machine was considered to be more hygienic.

The only problem that obstructed this project at that time was the lack of a machine producer. There were users waiting to use the machine but there was no producer who could manufacture the machine and deliver it to the end users. It was not a function of the university to produce the machine and sell it. Then the researcher tried to find a machine producer using his personal connection and finally he found one SME firm who specialised in producing such machines. The BD's staff arranged a meeting with the firm to discuss whether they wanted to do a technology transfer or not. During that time period, the firm produced some machines for the researcher in order to provide them to the end users.

Finally, the firm made the decision not to transfer this technology from the researcher. They gave a several reasons for rejecting the offer. Firstly, the market was not big enough to initiate the new business since the end users are small entrepreneurs and SMEs. Secondly, they were worried that the return from business might not cover the licensing fee. Lastly, they were concerned about product imitation. They believed that once it was launched on to the market, the machine would not be difficult to copy. Eventually, the project was stopped as a product prototype, and it has not been launched on to the industrial market. Even though there is a need from the final user, this was not enough to stimulate a producer.

From this case, it can be seen that a good technology may not always find a recipient. The available producers play a vital role in bringing a technological product to the final users,

and thus it is important to have good market research that understands the potential recipients for TT and whether they perceive that a product will provide sufficient return on any investment.

### Summary

From case studies mentioned above, there are several obvious factors obstructing the success of technology transfer process. There are also some co-factors that have been shared among the failure cases including lack of absorptive capability in firm, lack of technological readiness, inappropriate timing for the market, ineffective communication, lack of trust between firm and public organisation, and strong regulations in food and healthcare sector. The factors will be analysed together in the chapter of discussion and conclusion with the factors discovered from the successful cases.



## **Chapter7 Reflection on the state of the Thai innovation system: key actors' views**

This chapter provides additional information about the Thai innovation system based on the perspectives of other key actors. Regarding the concept of the national system of innovation (NSI) in chapter 2, the performance and interaction among the actors construct the system of innovation. To explore the NSI thoroughly, all actors influencing the system need to be investigated. Although this research is focusing on two actors: university/RTO and firm, other actors also play a role in the system. Having other perspectives on the Thai innovation system gives more complete characterisation of the system. The data were collected from interviews in addition to the interviews carried out for the 18 case studies. The actors involved include those from big local firms, multinational firms, TLOs, financial supporters, training programmes, public researchers, private researchers, policy makers, and other involved public organisations. While most firms in chapter 6 (case studies) are considered as SMEs, the firms interviewed for this chapter are big firms with all of them ranked in the top ten biggest firms in Thailand. The differences between the firms discussed in chapter 6 and those involved in this chapter are reflected in the problems they are facing in conducting innovation for their business. Furthermore, the views from the policy makers from different policy levels provide insight into why and how the policy implementation has taken the course it has. This analysis also sheds the light on how the Thai NSI situation relates to the findings of the 18 case studies.

### **7.1 Experience and expectations of big firms and related public organisations**

This section presents empirical information based primarily on interviews with big firms and the relevant public organisations involved in ST&I development processes in Thailand. The information collected from the big firms is not specific to individual cases but, rather stems from their shared experience and expectation in conducting several forms of R&D activities such as collaboration, contract research, importing technology, and in-house R&D. Another set of information presented here is collected from other supporting public organisations including the Board of Investment (BOI), financial support departments, Technology consulting unit, and RTO's executive staff.

Five big firms participated in this research, four local firms and one TNC. Each of them was interviewed separately. The firms are considered big since they are recognised as important players in their field of business, not only at the national level but also in the global market. Some of them have been ranked in the top 200 global firms. All of them have established an R&D unit to conduct their in-house R&D activity. Two of them have several R&D units according to the branches of their business. They are also experienced in conducting R&D collaboration with the public sector in many fields of technology and with different public organisations. Unlike most firms in the case studies, these big firms do not have a limitation on their R&D budget or any R&D financial support issues when conducting their research or collaborating with the public sector. They also have fewer problems with absorptive capability and are willing to take more risk if there is the potential for a high return. However, these firms have not seen great benefits from their R&D activity especially in the case of public-private collaboration. This will be elaborated below.

To keep the firms anonymous, the names of the firm and details of their business will not be presented here since the firms feel more comfortable to give the information without revealing their names.

### **The Big (local) Firms**

#### **Firm A**

This firm is considered as the top national player in its business and sits within the top five in the global market. It operates five business branches related to the core product applying different production technologies mainly relying on biotechnology and chemical engineering. The firm realises the importance of innovation by putting its core value on becoming an innovative firm and encouraging innovation creation in all firm's activities including the production, management and administrative processes, and business. The R&D unit was established as a company under the firm cooperation group. This unit works closely with the universities and RTOs, and they have collaborated in many R&D projects. Some were successful but several failed at different stages of technology development. The relationships between the firm and public R&D organisations are presented in many forms such as collaboration, contract research, and consultancy.

The interviewee in this case is an executive staff of the R&D unit. She is a researcher herself, who experienced work in the public sector before fully moving to the private firm. She sees the firm's attitude to innovation as a tool helping them to compete: "To create innovation, we need a network as we aim for 'open innovation' which we work together to build up a

working network. No one can be good at everything and we don't have to be. Just do your job and others will do theirs". The firm can be considered as one of the most innovative firms as it has successfully developed many innovative products using technology developed by its R&D unit and also from the collaborative projects with the public organisations.

The firm has also purchased some technologies from abroad, particularly when there was an urgent need. However, when they buy the technology from outside, they normally try to learn from it and develop a further step of application (not only purchase and use). From its experience, the firm's perception of the quality of technology developed by the Thai public sector and imported technology are not very different. The firm is most concerned about the speed and timing of the development process in the public sector. According to the firm's executive, most advanced technology/knowledge in Thailand belongs to the public organisations (universities and RTOs). However, she felt that many public researchers are working on their own interests and do not consider the users' need when they are initiating their research projects. Moreover, the key performance index (KPI) applied for evaluating the public researcher is not compatible with the private firm's requirements. For example, private firms do not measure academic publication as a KPI since publication does not directly help a firm to compete in the market.

Another issue of importance is human resources and funding. The most important resource that the firm still lacks is the human resource. Most firms interested in doing R&D lack experienced researchers and skilled R&D staff and this becomes a big problem since the firm cannot conduct a high-quality or advanced R&D project. As regards the funding system, the research projects funded by public money are scattered all over the place. Most of them are not connected to create a new product or process. The public organisations should think more about this, and perhaps need some roadmaps or foresight to predict the future of the country S&T development.

In terms of public support for innovation, the interviewee felt that the public sector should encourage firms to do more R&D and to be more innovative especially the SMEs. This could, for example, take the form of helping them in developing/improving products and processes or reducing production costs. Secondly, universities should be clear about their two most important roles: teaching/training/producing human resources; and conducting research to produce new knowledge. Similarly, the RTOs should perform two roles by forecasting the trend of new technology and building up core technology which responds to this trend. Although there should be research that directly responds to the industrial needs, the universities and RTOs should be careful with the ratio of basic research and applied

research. Sometimes, she thought, the policy had shifted too heavily towards supporting applied research and neglecting basic research which is the source of new knowledge. Thirdly, at the national policy level, Thailand should find its strong points and support them; for example, in the agricultural sector, it is not only agriculture, but an agro-industry that Thailand needs to aim for. As the firm's executive put it: "We need to choose what are we going to be good at and where are we going in the global market. We need to put more technology on our agricultural products in order to create value-added products then we can compete in the global market".

Finally, the firm's executive explained that the firm understands the nature of public organisations and that they worked differently compared to the firm. Some bureaucratic characteristics make them work slower than ideal. However, having a successful collaboration with the public sector should not involve an expectation that this will immediately result in finished products or processes. The firm needs time to carry on further development stages before launching the new products or applying new processes. Nor could it be expected that all projects would result in success: "Moreover, in some cases they failed to deliver good results, we still totally understand if they had reasonable explanation since it was a research we cannot expect 100 percent success. We have experienced the same thing when we conducted in-house R&D. However, we want the public organisations to keep in mind that we (the firm and public organisation) better aim for a win-win situation not one side taking advantage of the relationship. We as private firms are not their Guinea Pig that they experiment on by continuing to change schemes and implement different policies", the firm's executive emphasised.

### **Firm B**

Firm B is one of the subsidiary firms of one of the top five largest firms in Thailand. Its cooperative group ranked in the top 200 global firms. This big company owns many R&D units and employs a large number of R&D researchers. The firm's R&D is not limited by lack of financial support or human resources. It is categorised as an innovative firm fully capable of conducting R&D and creating innovative product and process. The firm's core business is based on chemical engineering technology but it has started to expand its business to other sectors, and has required different technologies to do so. Those technologies include biotechnology.

This leads to the topic that the researcher from firm B was willing to share about his experience in doing collaborative projects with the public organisations. The new policy of the firm aiming to expand its business to other sectors has led the firm to employ more researchers in the biotechnology field, but as it is not its core technology they needed help from outside to create a new product or process. According to the firm's researcher: "I was assigned to start a new project based on biotechnology. Even though I graduated in the biotechnology field I need a partner who has more experience to work with me. Then I talked to a researcher who is working in the public research institute. Actually, she was my senior in the lab when I was doing my PhD".

A collaborative project was started from this personal contact, and when the firm's researcher brought this to the company's board meeting, they all agreed to collaborate with the public organisation. The reasons for this were that the public researcher had a good reputation academically, and also that the firm trusted in the expertise of the public research institute as it specialises in biotechnology. The firm's researcher explained that: "It was a collaborative research not a contract research. So, the IPR developed under this project will be shared between firm and the RTO. Normally we prefer to do a contract research that the firm owns the IPR completely". In this case, the firm wants to learn from the public organisation so they accepted the condition of IPR sharing. Currently, this project is an on-going project in phase 2. The first phase went well but they needed more data to confirm the result so they continued with the second phase.

Additionally, the firm's researcher shared some experience of working with public organisations including RTOs and universities. "Besides this project, we also work with other public organisations. We experienced the problem when working with them which is the complexity of public organisation. We also faced this problem when we started the collaborative research in biotechnology I mentioned earlier. There are so many things to do before we can sign an agreement especially paper works", the firm's researcher explained. Other things that the firm feels uncomfortable with are the confidentiality agreement and the redundancy in functions among the public organisations which leads to more difficulty for a firm working with them. The researcher complained that: "Some of them cannot keep the promise on the time schedule and some have failed to deliver the output. Many projects we collaborated with them on did not meet our expectation at all". Lastly, he also suggests that the public organisations need more expertise to meet the firm's expectation, and that a qualified/skilled bridging organisation or intermediary is needed.

## **Firm C**

This firm specialises in life-science technology. It is ranked second place in Thailand after the biggest one in their business. This firm is a Thai firm but operates as a TNC in many Asian countries. The main business is exporting and trading. It has many subsidiary firms, one of them is its R&D centre which is spun-off from the parent firm to conduct R&D activity for other subsidiary firms. The R&D firm is quite new, being less than ten years old. However, the R&D activity has been conducted under other subsidiary firms for a long time.

The interviewee who participated in this research is part of the executive staff from the R&D firm. He was a senior researcher before being promoted to executive. He described the vision of the firm as it aims to service R&D activity to the parent firm and other subsidiaries while trying to create a big success story for itself: “The executives from our parent firm realise the importance of innovation. They have seen many success stories from abroad but never experienced it themselves. They did not know how many times those successes have failed before they became successful. We need to show them some big success cases, the ones with radical innovation”. As a big firm, the researchers are allowed to fail in their research and they still get financial support to try for the next one with the expectation of success.

The firm has experienced many collaborative projects with the public sector particularly with the RTOs. The executive’s opinion was that the public organisations do not understand the needs of the private sector. When it comes to collaboration, it normally starts with questions about how they should share the IPR and how many percent they will get if the project is successful. However, the executive felt that the emphasis should be on the public sector supporting private sector innovation, and that financial benefits would then flow back naturally. As he put it: “If we can achieve the goal, definitely the contribution will go back to the public at least in form of tax and employment (creating new jobs). We should start with building-up capability in the firm not creating the revenue in the public sector. I want them to look at the firm as a partner not a user”. Another issue he mentioned was the tendency of policy makers to adopt management concepts from abroad without taking the local context into account. Firstly, IPR management did not always work in the interests of innovation since sometimes the researcher tends to keep everything in secrecy and the result is that no one knows anything. Also the use of patenting could prevent the process of innovation when it blocks further development of the product or process. Also he confirmed the doubts of Firm A with regard to the way that public researchers are evaluated by KPIs that depend on the number of publications and patents and which do not respond to the firm’s needs.

Finally, he stated that the public organisations have not utilised their human resources appropriately and efficiently and that research should be more orientated to what is usable by the public sector. As he noted: “In many cases, I have seen the technology provided by the public researchers are not ready to go to the market yet; moreover, sometime they did not realise that the technology is not ready”.

#### **Firm D**

This firm is also one of the big top five firms in Thailand. The firm runs businesses in many sectors using different fields of technology. It is a multidisciplinary firm having large R&D units under every business sector. The firm employs many high skilled and experienced researchers, most of which have graduated from well-known universities abroad and many of them have experienced work as a researcher in public organisations. This firm is considered as a fully innovative firm aiming to apply innovation in all the firm’s activities. Most of the firm’s executives realise the importance of innovation and aim for being more innovative.

The interviewee from this firm is part of the executive staff responsible for R&D management in the firm’s central unit and she is also a researcher. As most of the firm’s activities involve innovation, especially technological innovation, the firm needs to consider how to acquire technology and what is the source of technology. The firm’s executive explained that first of all they have to decide between ‘to build’ and ‘to buy’. To build is the decision to do the research under its R&D unit, and to buy is the decision to obtain the technology from outside the firm. The sources of technology can be from abroad, from other local firms, or from the public sector. Before making a decision the firm will consider its ability to absorb technology and apply it to several business sectors. If it is urgent, it will buy finished technology from abroad but if it is not, it might consider doing a collaborative project with a partner. The firm’s partner can be its supplier, a research institute, a university (both national and international level) or other firms.

To consider working with the public sector in Thailand, the firm’s executive said they had certain criteria: “We need to evaluate their expertise and previous work before making a decision. After that normally we do the feasibility study and then we make an agreement on IPR management, timing, budget, and expected output. The speed and quality are the most important things”. She also explained the reason why the firm needs partners: “Even though we have many skilled researchers and big R&D units we realise that we are not good at everything. There will be someone out there who knows better than us in some areas”.

She also had experience working with the public sector on failure cases where the public researcher could not deliver the output that the firm was expecting. Although the firm considers many factors before starting a project, including doing a feasibility study, there are still many projects that fail to deliver a good result. “We need some reasonable explanation, it can be a technical problem or something that acceptable. If they say they do not have time to finish it or they are not capable then they should not take the job at the beginning”, the firm’s executive said. She also noted that problems that occurred when the firm was doing collaboration with the public sector included difficulty in making IPR management agreements, and delay in delivery of research outputs. Furthermore, she emphasised that the public sector does not understand the whole process of developing technological product/process that are necessary to bring something to the market. Typically, it takes more time and work after the public sector delivers the first product prototype to the firm.

Finally, she made some suggestions including establishing a translational research unit in the public sector in order to use it as the up-scaling unit to do the field test and mass production before delivering the product/process to the firm or user. She also suggested that establishing a personnel exchange programme for the public and private sector to exchange their staff would help them to learn and understand each other more. This might result in better public-private relationships.

#### **The Transnational Company (TNC)**

The parent firm of this TNC is one of the large electronics firms in Asia. Unfortunately, after having contacted the firm’s staff to have an interview, the parent firm did not allow them to talk about their R&D activity due to the issue of confidentiality. However, the firm manager gave a short interview on the phone describing their experience working with the public sector. He explained the reasons why a subsidiary firm chooses to do R&D outside their home country. Firstly, there is a tax exemption programme from The Office of the Board of Investment (BOI) provided to firms who conduct R&D activity in Thailand. Secondly, a firm will receive some financial support from the government if they perform R&D activity in Thailand. After learning about these schemes providing support for working with the Thai public sector, the firm contacted NECTEC to find a partner. This resulted in the firm working with a researcher in the NECTEC service unit. The research agreement was settled with the contracted research. The result from the research project was excellent, and the parent firm was satisfied with the output and continued with other projects.

Finally, the firm’s manager concluded that: “We are really satisfied working with NECTEC. We believe in the research capability of NECTEC researchers since we have seen from their

past performance and we still have further plans to work with them.” He emphasised that working with the public sector can fulfil gaps in the research capacity in the firm. Even though the firm already possesses its own core technology from the parent firm, it still needs other technologies to support and expand the business.

### **Research and Technology Organisations (RTOs)**

The executive staff of the RTOs provided information about the role of RTOs in the public-private relationship and the implementation of research policy in their organisations.

National Center for Genetic Engineering and Biotechnology (BIOTEC): The executive staff from BIOTEC explained that the main criteria for establishing their research policy is that it has to meet the user’s need. The users can be private firms, the community, or other public organisations. The user needs to be identified when the research project is initiated. In some big projects, the feasibility study is required before making a decision. However, there is a concern about the ratio of applied research and basic research since it is perceived that government policy has shifted too heavily towards applied research. “It is a big concern for the researcher, we need to build up the core technology before we can utilise it for application. The budget for finding the basic research should be managed appropriately”, the BIOTEC’s executive argued.

However, another BIOTEC executive staff with experience conducting collaborative projects with private firms argued that the working process with firms is improving. His view was that there are many organisations and units joining in the process to build up the network which has resulted in many successful cases. The executive claimed that “we are learning from our experience especially the success story”. Nevertheless, he suggested some improvements including better management of the translational process from research to commercialised product, resolving ethical issues (transparency and accountability), and improving the quality of research output.

National Electronics and Computer Technology Center (NECTEC): The NECTEC’s executive staff pointed out that in the electronics and automobile industries Thai firms play a role as the production base of the foreign firms. There are not many innovations created in the upstream production process but there are some innovations created in the downstream process. To make Thai firms become more innovative, experience and knowledge are needed. The technology can be imported but the local firms should own the IPR of the core technology and not just rely on foreign technology. He also argued that the individualistic culture of Thai people led Thai industry to be characterised by less network building than

elsewhere. Compared to Japan's keiretsu or Korea's chaebol, Thai culture in doing business is totally different. This is important because RTOs develop much advanced knowledge but still lack bridging organisations to link them to users, and the public researchers do not know how to bring their research to the market.

National Nanotechnology Center (NANOTEC): According to a member of NANOTEC's executive staff: "In nanotechnology which is a new area of technology, the public sector has to be the leader to build up knowledge and infrastructure to support the private sector". NANOTEC started with an active strategy including technology road mapping and foresight, conferences, roadshows, and training. Since it is new, it takes time for the public to understand nanotechnology. Now NANOTEC follows two different strategies: developing clusters to work with industry and firms, and building up a platform technology by conducting basic research. The ratio of applied research and basic research for NANOTEC is about 60:40 while the master policy from NSTDA is 75:25. Unlike others who are concerned about IPR allocation he believes disputes can be resolved because "unlike a private firm, public organisations do not aim for the profit but for progress of the country as a whole. So, the agreement should not be so difficult".

### **The Board of Investment**

The Office of the Board of Investment (BOI) operates under the Prime Minister's Office. It aims at encouraging investment by enhancing competitiveness and investment, and facilitating business support services. One of the schemes BOI implements for enhancing the number of innovative firms offers an attractive package of tax incentives to the firms conducting R&D activities in the country. The BOI's representative interviewed for this research is the executive member of BOI, responsible for stimulating and encouraging R&D activities in firms.

Since 1990, BOI has supported several R&D stimulating projects. This was started with a big Thai firm who realised the importance of R&D activities in enhancing its competitiveness. Then other big firms joined in the programme so that now most of the big firms are participating in this scheme including many TNCs in various industries. The advantage that they can get in the form of tax incentives when they conduct R&D activity is the same whether it is a Thai firm or TNC. In the past, most TNCs did not conduct their R&D activity in a production base such as Thailand but rather did it in their home country. However, currently the trend has changed particularly for the big Japanese automobile companies. One example of a TNC starting an R&D unit in Thailand is a company that produce a pick-up truck, where the prototype was designed in the home country, but the

production process developed in Thailand. Similarly, in the hard disk drive (HDD) industry the product is only developed in the pilot scale in the home country and then the up-scale process is carried out in Thailand. During the last 10 years, Thai firms' R&D capability are getting better but still need help from outside the country. In the TNCs' R&D units, most of the staff are Thai, but training is done by the parent firm in the home country. However, this rarely leads to knowledge/or technology spill-over due to the behaviour of Thai people who work in the foreign company. They prefer to remain working for the TNC rather than moving to another firm.

Another scheme that BOI have in mind would seek to enhance relevant knowledge and skills for both public and private sectors through a personnel exchange scheme between public and private sector. Thus the BOI executive argues that: "Lacking of human resource is a big problem in stimulating R&D in private firms, particularly the local firms. On the other hand, the staff from the private firm should have a chance to work or train in the public organisation and they can exchange the knowledge both in form of technical knowledge, marketing or management skill". He also recommends that the public and private sector should work together including by importing experts from abroad to help local firms to build up their R&D capability, by providing more tax incentives to the big firms to do more R&D and disseminate technology, by establishing RTOs in the industrial estate/park, and by building up more bridging organisations or intermediaries to link public researchers and firms.

### **Bridging organisations**

Technology Licensing Office (TLO): The head of NSTDA's TLO explains that the role of the TLO in the past was to work on the technology push strategy since they took care of technologies under the national research centres. Now, NSTDA has shifted the process of technology management to three main goals: finding a research theme, building up cooperation between the researcher and the commercialisation team, and creating new research commercialisation management by establishing a network to connect TLOs in Thailand to enhance working together. Moreover, TLO helps in the decision making process for the big projects by implementing the stage-gate process to evaluate the project including the technical review and potential business review.

Business Unit (BU): This unit aims to bring the research projects developed under the national research centres to the user (market). Each of the national research centres has its

own BD unit and they work closely with the TLO. The BD holds the technology portfolio from the national research centre and is responsible for evaluating the potential of technology. Since the BD unit is embedded in the research centre it works closer to the researcher than TLO. They also take care of the service units provided under the research centres such as lab testing, technical service, and analysis and testing. The BIOTEC's BD staff clarify channels for contact with the client including walk-in customers, marketing activity (from NSTDA marketing unit), Thailand Science Park (TSP), tenants of TSP, informal connection from the researchers or promotion from the BD unit (open lab, PR). The technology licensing process under NSTDA can be processed through the TLO or BD; however, when the IPR issue is involved, TLO will join in from the beginning of the negotiation process.

A BD executive interviewed suggested that more trust in the relationship between public and private sectors is needed. The public sector should be flexible, neutral, professional and trustworthy. Furthermore, assessment of the technology transfer process using the KPI approach should not rely only on the number of licensing contracts. There are other ways to implement or transfer technology to the user, it is not necessary to do it through the licensing process.

Moreover, another BD staff member from MTEC, based on her experience working in the BD unit for more than 14 years, argued that: "The success of technology transfer process depends heavily on the attitude of both sides. From my experience, one factor that drives a firm to be more innovative is the crisis. Since they know innovation can help them to survive the crisis, when they experienced some difficulties, their attitude on R&D or innovation changed to be more positive". After the economic crisis in 1997, MTEC got more contacts from firms trying to conduct R&D activity or technology transfer from MTEC.

Lastly, NECTEC's BD staff explained that BD staff work closely with researchers, and help them to think about the user and market for their research project before it starts. She thus argues that: "Some might say BD is working on technology push model, it is true since we hold a large number of finished technology produced in the public sector but we are working on the demand pull model as well. It is actually a coupling model to match existing technology with the user need".

Industrial Technology Assistance Program (ITAP): The director of the ITAP was interviewed and provided some information about the mission of ITAP which was established to play an intermediary role bridging users' needs with experts in ST&I. It aims to build up innovative capability in private firms and acts as a channel for firms to access

appropriate ST&I knowledge and experts. The projects supported under ITAP can be consultancy, product/production process improvement, or new product/process development. Besides the research centres under NSTDA, ITAP builds up connections with the universities (national and international) and also RTOs outside of Thailand. In most of the projects dealing with advanced technology, the experts are invited from abroad to help the firm. From ITAP's experience, building up R&D capability in Thai firms requires stimulation at the beginning but after they experience the R&D activity, they learn how to manage it. Then the firms become more innovative with their cumulative experience.

### **Financial support**

Company Directed Technology Development Program (CD): The executive member of CD described the mission of CD as to stimulate R&D investment in Thai firms. It is one of the units in the Technology management centre (TMC) under NSTDA, and provides financial support to innovative firms in the form of low-interest loans. The soft loan scheme was started in 1988 to encourage firms to participate in R&D activity. Unlike the grant scheme which is more focused on R&D activity, the soft loan can include other relevant activities stimulating innovation in firms. To qualify for CD support a firm has to be Thai with a registered capital of less than 200 million baht (~6.5 million US\$). The project proposal should aim to conduct at least one of the defined activities that include developing new products, improving manufacturing processes, setting up a R&D laboratory, conducting reverse engineering, and commercialising research breakthroughs. It does not have to be a radical innovation or have strong R&D output, but must have some useful innovative activities that can help the firm be more competitive and sustainable.

Lastly the CD's executive concluded that the trend of doing R&D activity within Thai firms is improving. It has moved from lab scale R&D to product or process development and continues to commercialisation. However, the SME firm still faces the problem of accessing public financial support and lacks the ability to convince finance organisations to provide them financial support for R&D activity. He conceded that CD needs to put more effort into helping SMEs to be more innovative and competitive.

NSTDA Investment Center (NIC): The director of NIC provided information about NIC which supports co-investment mechanisms for technological businesses. It was started with the policy of encouraging researchers to spin-off and invest in their technologies. In the past, projects came from the national centres and the Cluster and Programme Management Office

(CPM). NIC has started a project known as “the NSTDA investor day” to promote research projects from NSTDA to the public, and to encourage public researchers to respond to users’ needs. The project has resulted in some successful cases, as researchers and firms that met at this event have continued their relationship working together and later established a new firm together.

## **7.2 Policy makers’ view from different policy levels**

This section presents the information from the policy makers’ perspective from the different policy levels. From the interviews, the policy makers have clarified the policy making process and the rationale of creating each policy, and also their alliances and stake holders in making the policy. As set out in chapter 5, the policies were presented in different levels including (1) the five year national master plans: The National Economic and Social Development Plans launched by the National Economic and Social Development Board (NESDB), (2) the National Science and Technology Strategic Plan (2004-2013) developed by the secretariat team of the National science and technology policy committee, including the National Science and Technology Development Agency (NSTDA), the Office of policy and strategy (under MOST), and NESDB, (3) The National Science Technology and Innovation Policy and Plan (2012 – 2021) proposed by the National Science Technology and Innovation Policy Office (STI), (4) the Eighth National Research Policy and Strategy (2012-2016) developed by the National Research Council of Thailand (NRCT).

The interviews were conducted with the policy makers from three organisations responsible for those policies presented in chapter 5. The three organisations are the National Economic and Social Development Board (NESDB), the National Science and Technology Development Agency (NSTDA), and the National Science Technology and Innovation Policy Office (STI).

### **NESDB policy maker**

The originator of the NESDB plans worked with the Office of the Permanent Secretary, Ministry of Science and Technology (MOST) and the Research council to develop policy for S&T. Since the establishment of the National Science Technology and Innovation Policy Office (STI) under the MOST in 2008, NESDB works more closely with the STI on ST&I policy. In the process of making policy for ST&I, besides the MOST and the Research

council, NESDB works with other stake holders and relevant organisations. The process consists of many small meetings and focus groups to investigate and identify the problems, then the information is sent to other meetings for brain storming both at the regional and central level.

As described in chapter 5, the S&T chapter was firstly added to the NESDB national plan in the fifth plan and then it was merged in to other chapters in the eighth plan. According to an interviewee from NESDB, the reason behind merging the S&T chapter in the eighth plan was that: *“it was the plan that focused on a people centred approach, it’s easier to merge the S&T development topic into other chapters. But S&T is still the important supporting factor for the development in other chapters”*. S&T issues are thus incorporated in to other chapters such as the chapter for restructuring the Economy toward Quality Growth and Sustainability which consider S&T as the main driving force to implement this plan.

Regarding the use of the NSI concept in NESDB’s plans, it was not written clearly into the plan. However, the NESDB is aware of this approach and uses it, along with the concepts of ‘cluster’ and ‘the triple helix’, as guidelines. The policy makers view the NSI as a broad concept that can be used to build up networks and connections among the related actors and to emphasise that national S&T should be established as a systematic development. The main organisation taking responsibility for development of NSI is the National Innovation Agency (NIA) under the MOST. Concerning the problems facing the issue of S&T development, the NESDB interviewee noted that *“the financial problem is not the only problem causing obstruction in S&T development. One of the most important problems is the managerial issue, we have limitation of management, especially the redundancy in functions among the public S&T organisations”*. In particular, there are concerns that R&D management is poor at managing the innovation required to go from scientific discoveries, inventions or lab prototype to commercialised products.

### **NSTDA policy maker**

A central element of the National Science and Technology Strategic Plan 2004-2013 plan was its adoption of the NSI concept. According to the NSTDA policymaker interviewed, this approach was adopted because *“the NSI was a well-known concept for the policy making process at that time, many international organisations including OECD use it as a framework to make their policy. One of our policy researchers also did his PhD thesis in this*

*topic*". To generate this plan (The National Science and Technology Strategic Plan (2004-2013), the team including NSTDA, the Office of policy and strategy, and NESDB worked together using the NSDB's plan as a guideline.

Since the plan adopts the NSI and cluster approach as the main concept, it focuses more on the relationship among the actors in the system including firms, universities, and others. This shifts the approach to S&T development, because in the past it relied heavily on the linear model. However, the use of NSI as a broad concept at the policy level did not make a big change at the implementation level. As she puts it, *"I'm not sure whether the NSI can create any big change or not. In my opinion, we need a strong action plan to respond to this approach"*. At the implementation level, five sub-committees were established to implement the five strategies indicated in the plan. For the cluster concept, after the plan was launched, there were many activities and structures established to respond to this approach. However, at present not many organisations continue to talk about clusters: *"In my personal opinion, it is some kind of fashion that become hit at some periods of time and it's gone. Furthermore, and understanding about the definition of the concept is varied from one to others. I think the practice of cluster and NSI are still there but people start to call it with the different name"*.

### **STI policy makers**

The data collected from interviews with the STI's policy maker team gives more information about current ST&I policy development in Thailand. Although the NSI approach is not clearly written in the STI policy and plan, the idea is carried on from the previous strategic plan (2004-2013). As one of the STI policy makers put it *"the NSI emerges automatically in each country with different context and different model. It has been there before we adopted it formally. The formal adoption of the NSI concept by NSTDA happened before the formation of STP"*. As mentioned above, the NSI approach was formally adopted in the strategic plan (2004-2013) together with the concept of cluster. During that period of time with the concept of NSI and cluster, the NESDB was working at the policy level to enhance national competitiveness, with implementation handed over to other responsible organisations such as NSTDA and the Department of Industrial Promotion in the Ministry of Industry. However, the implementation process has slowed down recently and was not developed in a sustainable way since the network and system are not very well established.

In order to build up a strong network, a network of six public organisations responsible for the country's ST&I development was initiated in 2011. The aim of this network is to link all research conducted or supported by these organisations, and to develop commercialised products or deliver them to private firms or users. Because the collaboration between public and private sectors was considered to be weak, this 10 year plan aims to build up more mechanisms to strengthen the public-private relationship. One of those mechanisms is to use the Science Park and intermediaries to bring the public and private sector together. Moreover, the aim is to promote the establishment of regional Science Parks throughout the country. Another mechanism initiated by STI and the Board of Investment (BOI) is to transform industrial parks into science based industrial parks.

Another important challenge for Thailand in ST&I development is that human resources are considered inadequate especially in the private sector. The plan targets building up the talent mobility programme in order to support ST&I personnel in the private sector by encouraging staff working in the public sector to work for a private firm. The last issue mentioned by the STI team is the regulation that hinders the public-private relationship. Concern about regulatory and legal issues has meant that public organisations hesitate to put public money into supporting R&D in private firms. This prevents firms from enjoying the benefit of public investment in ST&I development. In addition, the IPR laws are another obstacle obstructing the relationship between public and private sector. To solve this problem, STI and the Research council are trying to improve some regulations to facilitate firms' access to public investment and to enable the sharing of IPR rights from research.

Finally, the team made some comments about the ST&I development situation: "*We (Thailand) believe that innovation is a key factor for country development but we do not want to invest more because of uncertainty and risk. There are different mind sets on innovation between public and private sector, we are lacking of the triple helix tradition to build up a good public-private relationship*". The matter of money is not the biggest problem for the ST&I development since Thailand has now become a middle-income country, and it can afford the investment. The most important problem is that the country is lacking the vital factors that facilitate the process of development.

## Summary

The information in this chapter provides different perspectives on the Thai innovation system compared to the case studies. While the SME firms in the selected case studies are struggling with the financial problems or the lack of R&D infrastructures, the big firms are facing the problem of acquiring an appropriate technology or lacking a good strategy for innovation management. In case of big firm, there is different way of approaching the public sector for a collaboration compares to the SME firms in chapter 6 Most big firms consider the university/RTO as their partner that they need to exchange knowledge or technology. While the SME firms recognise those public research organisations as a knowledge provider or supporter to help them with innovation development. The big firms are more capable in adopting new technology from the public sector but it is not easier to do technology transfer since they always have more concerns with many issues. The main issue that normally obstructs big firms from technology transfer agreement is the intellectual property right. The first question they ask is who will own this technology. Many big firms prefer to buy a technology rather than pay a royalty fee or doing non-exclusive technology licensing agreement. On a contrary, the public organisations try to avoid an exclusive technology transfer because they want to share or disseminate their technology to other users as many as they can.

The big firms tend to concern with a confidentiality and competitor more than small firms. As can be seen from the case studies in chapter 6, all the successful cases are willing to share a story of their journey for becoming success while one of the big firm in this chapter who was categorised as a success in doing technology transfer with the public sector rejects to give a detail of how to do a success technology transfer because they do not want to disclose their story to the competitors. However, either big firms or SME firms see the public research organisations as an alliance for doing innovation development. They consider the public organisation as an important knowledge provider even though the big firms have optional technology providers from abroad.

Another concerning issue is about the impact of the policy on the NSI actors, when many researchers and other public staff, and also some firms are suffering from some inappropriate policies launched by the public policy making units, many policy makers do not realise the problems caused by those policies. The policy makers put a lot of efforts to make a good policy and try to make a better situation for the Thai innovation system. However, in many cases, as can be seen from the case studies and from this chapter, the solution that the policies are providing do not match with the problems that the NSI actors are facing. For

example, when the policy tries to catch up with the global trend in the ST&I policy by changing the measurement criteria and indicators or the ST&I management strategy, other actors including the public researchers or firms find it becomes a problem for them since the policy changed quickly and too often.

Another example concerns the financial support from tax exemption or tax incentive. This is because most firms that enjoy the benefit from this scheme are the big firms or the medium enterprises with R&D capability to conduct ST&I outputs. On the other hand, the small firms are facing difficulties in performing R&D activities. As the policy aims for a higher number in firm's R&D performance, the tax incentive scheme becomes one of most convenient ways to do so; however, not all firms can enjoy this benefit. Moreover, even though firms may conduct more R&D activities it does not mean they create more innovation or that they enjoy more benefit from those R&D activities. Most indicators set out by the ST&I policies are quantitative, but sometimes increasing numbers does not lead to a better situation in the innovation system.

Considering the policies set out in chapter 5, many strategies indicated in those policies are not recognised by the NSI actors participated in this chapter. Although, there are some issues that both firms, public researchers, and policy makers have a mutual agreement on it, for instance the issue of human resources. The big firms are suggesting a personnel mobility or exchange programme when the National Science Technology and Innovation Policy and Plan (2012-2021) obviously indicates this issue on the strategic plan. There might be a few cases that this strategy has been put into practice but it is not recognised broadly. This indicates a problem of putting the strategic plans into practice.

However, as can be seen from chapter 6 and this chapter, the policy has an impact on all NSI actors up to some points. Some of them are enjoying the benefits from the policy while some are suffering due to the inappropriate policy. On the other hand, different characteristics among the big firms, SME firms, public researchers, and private researchers also determines the shape of the Thai NSI. Moreover, the attitude and behaviour of support units like TLO, funding agency, BD, IP management office are very substantive in framing the NSI pattern. Taking these aspects into account gives more understanding about the current situation of the Thai NSI. Additionally, since the NSI situation cannot be solely changed by the policy level. There are many other factors that influence the situation as they were pointed out in the data analysis section.



## Data analysis

To analyse and identify the factors that determine or enable the success of the technology transfer cases, the empirical studies were conducted using in-depth interviews with people involved in S&T development in Thailand both from the public and the private side, and then 18 case studies (6 successful cases and 12 failure cases) were constructed from interview data as presented in previous chapters.

### Analysis of influential factors

To analyse the factors which determine the success or failure of the case, a comparative analysis among cases is carried out. In each case study there are some dominating factors showing their impact on the case. In some cases, one unique factor can be identified clearly as a determinant of the case (failure/success) and is specific to the case. However, in many cases, there are some factors that have been found repeatedly affecting failure or success.

Furthermore, after comparing the factors from the successful cases and failure cases, there are some interesting factors, which have been found in both types of the case, that determine it to be a success or a failure. The analysing process is begun with factor analysis from the six successful cases, and then other interesting factors are extracted from 12 failure cases. After that, some co-factors explored from each case will be analysed further to compare among similar cases that share those co-factors.

The important factors that obviously show their impact on the technology transfer process are listed as follows:

### Technological capability, readiness and appropriateness

This is one of the most important factors repeatedly found in many case studies both successful and unsuccessful. The technological capability in this case means the ability of the public researchers to produce efficient technology/knowledge that has potential for technology/knowledge transfer. Faulkner and Senker (1994, 689) mention ‘availability of relevant expertise’ in the public sector as one of factors determining the success of public-private relationship; as they put it: “*The strengths and weaknesses of the public research system in a field is a crucial limiting factor in industry-PSR linkage*”. Technology readiness is involved with the readiness level of technology as mentioned earlier in chapter 2

From all six successful cases, it can be seen that the required technology was ready, and with its performance verified, before starting the process of technology transfer. However, the timing of completed technology varied from case by case. Some technologies were finished before starting contact with the firm (research initiated in the public lab) while in other cases further innovation was carried out after the firm's contact (contracted/collaborative research initiated by firm). On the other hand, cases of failure occurred when there was a lack of technological capability on the public side. According to the TRL defined by the European Commission (EC), there are 9 levels of technology readiness. From the 18 case studies, there were different levels of technology readiness when the technologies were transferred. Most of successful cases are at least at the TRL7 (system prototype demonstration in operational environment) while the failures are varied in their TRLs. However, the higher level of technology readiness did not guarantee the success of the case. As some of the failure cases reached the TRL9 (actual system proven in operational environment) but still failed in conducting the technology transfer. An example of this would be the Diagnostic test firm and Food processing machine. This is because there are other factors influencing the success of the case. Severe problems with conducting technology transfer occurred when the public researchers overestimated their technological capabilities and attempted to transfer their technology to the firm. It is impossible to do technology transfer when there is no effective technology to transfer. It can be seen clearly in the three failure cases - Implanting material, Cultivation device, and Feed additive in aquaculture - where all of them failed through a lack of technological readiness. Moreover, some of them lacked basic knowledge to understand those technologies.

#### **Absorptive capability:**

This factor is as important for the firm's side as the technological readiness is on the public side. To transfer and adopt new technology, the firm requires absorptive capability to complete this task. Comparing the successes and failures clearly demonstrates that all firms from the successful cases have the ability to absorb knowledge/technology transferred from the public side while it is absent in many of the failure cases. From the interviews with TLO's staff and the analysts, this is the main factor limiting the success of technology transfer, not only between the public side and private firms, but also amongst the firms whether they are local, TNC, or subsidiary firms. Most attempts to conduct technology transfer failed because of an inefficient absorptive capability in the technology receiver. As mentioned earlier, the firms involved in all successful cases demonstrate their absorptive

capability in adopting the transferred technology whereas many failure cases missed this factor and failed in conducting technology transfer.

The failure cases that lack this factor are Adhesive Plaster- the firm could not adopt the transferred technology since it lacks the knowledge background and advanced machinery in nanotechnology; Alternative Material for Solar Cell- the firm did not have a business background in solar cell and also had a lack of understanding in production; Food Processing Machine- this case failed mainly because of this factor as there was no producer who had capability to both reproduce the machine and launch the product into market.

### **Attitude:**

Attitude and perspective on R&D collaboration or conducting technology transfer is important for public-private relations. Typically, the nature of the two sides is different. The public sector is usually orientated towards non-profit works while private firms look for the ways to increase their benefits. Therefore, their attitudes towards R&D activity are also different. Because of the different purposes there can be a mismatch between provided knowledge and required knowledge. Most of the big firms in the previous chapter described that they do not require academic publication for their business, but the KPI for evaluating public researchers put number of publications as the first priority.

Additionally, the positive or negative attitude towards R&D activity is also important. It can be seen clearly from every successful case that the firm involved had a positive attitude to R&D activity and believes that R&D and innovation can create a business opportunity. Therefore, they are willing to take a risk in R&D investment. However, the Bioactive Company is one success case where the firm and the university's researcher did not have the same opinion when looking at the data collected. In this case, the researchers tried to improve the new product by conducting more basic research to expand its use. However, the firm had a different opinion and did not agree on the researcher's proposal. In this case, different opinions did not fail in the attempt of technology transfer but created a small gap between the researcher and the firm. Fortunately, the TLO (intermediary) was able to fill this gap and linked them back together.

On the other hand, in many failed cases, firms did not totally believe in the advantage of doing R&D and were not ready to take a risk in doing R&D activity, as a result, many of them stepped back in the middle of the technology transfer process. Another example of the divide between firms and researchers can be seen with Sensor for agriculture, a firm that stepped back from the collaborative project when they found an alternative product which

was cheap, available, and did not need R&D activity for development. As mentioned in chapter 6, the firm involved in this case looks at R&D activity as a risky and costly activity. Two other cases are Feed Additive in aquaculture and Dental Implant Material which also failed because the firms lost their trust in the public researchers. For the latter case, other factors were involved in failure which will be discussed later.

In other respects, the public researcher's attitude to technology transfer is also important. This factor has its effect since the initial stage of research is in the public sector. The researcher's attitude influences the way they set up and shape the research. If they start with the aim of technology transfer, the research will be targeted to respond to the user's needs. If they aim for an academic purpose, the research will be steered in a different way. Furthermore, the researcher's attitude will have an impact on public and private relationships when they are doing collaborative research or technology licensing.

### **Trust building:**

Trust should concern both sides of a partnership; however, in this context, mostly this issue is focused on how the public sector can accumulate trust from the firms or, simply put, how to engender firm interest in R&D activity in the public sector. This is considered as the first priority for public researchers who are attempting to do technology transfer. In the case of the Bio-treatment firm, it is clear that the project was started from a trust in public researcher's good reputation and the researchers have proved their trustworthiness after the project was finished. On the other hand, many cases that were initiated by trust, including Electronics device for heavy industry, Potential protein for disease prevention in aquaculture, and Aquaculture cultivation device, ended in failure because the public researchers were not able to respond to the firms' needs.

However, the private side should also build up the trust from the public partner to maintain the public-private relationship. This is because sometimes when the firm did not play a fair game, it affects the attitude and reaction from the public organisation to the firm in the next partnership. This can result in stricter policies or more complicated administration process from the public sector in order to prevent potential trouble that the public-private relationship might cause them for instance the case of Biological agent for preventing disease in poultry.

Another problem concerning trust between public and private is the different purpose of doing R&D activity which sometimes makes firms avoid research collaboration. This can be linked to the different attitudes mentioned earlier, where the firm wants to keep all information secret to secure its competitive advantage, while academia is eager to publish

their new findings. This problem is not unusual when the big firms have collaborative projects with public researchers (as was mentioned by many big firms in chapter 7). Normally, the big firms do not have a problem with R&D investment therefore the public researchers are willing to work with the big firms. However, the ultimate goal of R&D investment is usually business-related while the public researchers are aiming for attaining academic reputation.

### **Networking:**

This issue can refer to both public and private sides, which does not mean only the network among the main actors in technology transfer (technology licensor-licensee), but also other involved players who perform a role in this relationship. Building up the network is a key for strengthening knowledge flows in the innovation system. The connections among actors will help to carry knowledge from one to the others. Networking can be built in many ways such as public and public network, industry consortium, or cluster. It is needed for facilitating the success of technology transfer. For example, networking among the researchers in universities or public research institutes. Since no one can be good at everything, networking can increase the possibility of success. Moreover, networking can be built through one public organisation to another, for example from the funding agency to the incubator unit or financial supporting unit. An example was the way the Bio-treatment firm became successful using a network linking the supporting public organisations. In other successful cases including two spin-off firms: Medical devices and IT firm, and the start-up firm: Automation firm, are using networks and connection from the public organisations that the firm owner/founder used to work for in expanding networks for their business.

In some cases, informal connections can play a vital role at the starting point of public-private collaboration. Then the network is built up through the informal link. One of the big firms in the previous chapter explained the reasons for doing public-private collaboration as the public organisation has strong connections with other public organisations; therefore, when firm starts a relationship with one organisation, it will bring them into contact with other ones.

### **Timing:**

It is difficult to tell when it is the perfect time to do technology transfer. In fact, no one can possibly do that since there are so many factors which affect the timing for doing technology transfer. If a firm waits until it is sure about effectiveness of a technology, then it may be too late for the marketing opportunity. On the other hand, if a firm jumps into the technology

transfer too early it may fail through lack of readiness. Therefore, this is another factor that needs to be considered carefully in doing technology transfer and it has to be done case by case. As mentioned earlier in chapter 2, Allain et al. (2011, 1) argue that “*the buyer of an idea should take over development at the stage at which he has an efficiency advantage*”. In successful cases, it can be assumed that the timing of conducting technology transfer was right. Although timing is not seen as an obvious or important factor, much of the time it leads to a case’s success. When looking at the failed cases, 8 to 12 of them started the technology transfer too early or too late.

In some cases, the firm jumped into the technology transfer agreement too early, such as the cases of the Diagnostic test firm, Dental implant material. In several cases, it was even too early to start the collaborative research between firm and the public researcher because the technology readiness level was very low. Examples include, the Potential protein for disease prevention in aquaculture, the Biological agent for preventing disease in poultry, and the feed additive in aquaculture. In some cases, including the Electronics device for heavy industry and the Bio-control agents, the researchers delayed the delivery of the transferred technology, which caused the wrong timing of the technology transfer (making it too late for the firm).

The risk of emerging of alternative products complicates such judgment and can also result in many failure cases. It is one major concerns in doing business with a technological product. In some cases, even though the researcher could produce a good technological product, when a competitor (local or foreign) launched a better or cheaper product before they could launch theirs, the firm partners might change their focus to the new product such as the case of Sensor for Agriculture. It is a normal situation for doing business in a technological field which is usually highly competitive, but the point is that the researcher should bear in mind that this situation might happen and prepare for it, and more importantly, they should be quick enough to exploit an opportunity before others.

#### **Firm’s management and marketing skills:**

This factor is very important in terms of technological product management after the process of technical knowledge transfer. The firm with good management skills has more chance to succeed in doing technology transfer. This includes the marketing skill of the firm as well. Therefore, the firm experienced in managing technological products or involved in that field of business is more likely to be successful. For example, the case of Bio-treatment firm, an experience and background in management and marketing skill of the firm play a vital role in supporting firm to be successful. This also involves market prediction and survey for the

new product as the IT firm uses experience and skill when they were working as a service unit under NECTEC to forecast a new market and customer's need. As the market is most important for the success of technological product commercialisation, this is important for either public researchers or firms. It is essential for the firms that they think about the market as the first factor for conducting their business. However, the major concern here is about the public researchers when they try to conduct research targeting technological commercialisation, as many of them do not pay sufficient (or even any) attention to the market survey process such as the case of Bio-control agents.

Another important issue related to this topic is a lack of producers for technological products. In many cases, successful product development projects have never been outside the lab in which they were created. Despite this, there were many end users outside waiting to use those potential products. However, even though there is a user need for the product, it does not always mean there is a potential technology licensee out there. In some cases such as Food processing machine, there was a strong need for the product but the firm decided not to do technology transfer because of the perceived low return on investment, even though it had already mastered the technological capability to produce that product. Another case was Adhesive plaster. Although there was a new market waiting for the product, the firm was not able to produce the product because it lacked the technological capability. Furthermore, they could not manage to get other producers to work for them. If the firm can improve its management and marketing skill, it might help to solve this problem.

#### **Effective communication:**

Communication plays a vital role in almost every relationship. Effective communication can link partners to work together successfully while a good relationship can be broken down by bad communication. The case studies showed that misunderstandings caused by a lack of effective communication among partners doing technology transfer could result in the failure of the partnership. Pertuzé et al (2010, 88) suggest that the firm should establish a strong communication linkage with the university team via regular communication means such as site visits, telephone, video conference, or short-term personnel exchange in order to enhance the success of public-private collaboration. Particularly when they are facing a problem, they should communicate with each other as soon as possible. This can be demonstrated by the case of implanting material where lack of effective communication between researchers and firm lead to the termination of the technology licensing contract. In addition, internal communications within organisations are also important, especially in the public sector which normally has a complicated structure of organisation. Another case of a gap in

communication within the organisation is the Electronics Device for heavy industry. Although the interviewee did not emphasise this issue, the communication between the researchers from the two national research centres played an important role, ultimately causing a delay in hardware and software development for transferred technology.

#### **Technological field:**

The case studies span a range of different fields of technology, covering different management processes and also different patterns of technology transfer. Comparing the two case studies in biotechnology (Medical biotech: vaccine case) and Information and communications technology (IT spin-off firm) from this research show a clear distinction between the cases. In the case of biotechnology, it took more than ten years to obtain the prototype and there is still a long way to go to get into the market, and it also follows the linear model of innovation as it was initiated as a basic research in the university and transferred to the private firm. On the other hand, the IT firm took one year to develop the product and tested it in the service unit. After the spin-off process, the product has been launched to the market and the firm has gained the benefit from the second year of the investment. However, the life cycle of the IT product is short; after a few years, the firm needs to develop a new product or at least a new version of the product to remain competitive in the market. While in the biotechnology firm, usually if the firm succeeds in introducing the product to the market, it will last much longer than other fields of technology (normally it will last at least 20 years from the patent protection).

Another case concerning this issue is Adhesive plaster which involved nanotechnology. Although the public researcher was successful in developing the product, the firm was not able to adopt a new technology to produce the product at the industrial scale. This is another problem facing the firm that deals with advanced technology. Most firms still lack the knowledge background, human resources, and machinery.

Another related factor influencing the difficulty of technology transfer is regulation, particularly when the Thai FDA get involved. The level of regulation varies from field to field. It becomes stronger when the product is concerned with food and public health issue. In some cases involved with medicine and the public health sector there is strong regulation from the responsible public organisations on emerging technological products or processes to be implemented in those fields. Products involved in the medical sector are the most difficult ones to obtain regulatory approval for because they require certification by the FDA, and this is especially challenging when the product is produced using biotechnology. This issue caused many failures in technology transfer.

As mentioned by Faulkner and Senker (1995) in chapter 2, the innovation process in biotechnology and life science related technology tends to follow the linear model of innovation more than other fields of technology. Regulation is one factor contributing to this pattern. Regulation is a foreseen process that life science related products have to pass after it comes from the lab before entering the market. It is a predictable characteristic of the innovation process in this field of technology making it look more linear than others. As can be seen from the case studies concerned with biotechnology (ending in either successes or failures), most of them were following the linear model of innovation by starting with the basic research, moving to lab scale prototype, conducting field test, collaborating with the user/ producer, and then conducting technology transfer.

The case of the Diagnostic test firm is an example that clearly failed due to regulation. This case is categorised as a failure even though the technology transfer agreement was signed and the firm launched products into the market. This is because the product was not able to enter the market that the firm intended before conducting the technology transfer. The main obstacle obstructing the product from entering the market is regulation. When the product failed to pass the public health criteria, it could not be used as the standard test method in the hospitals. It could only be used as a supportive method and still needs another standard method to confirm the result.

#### **Bridging organisation/intermediary:**

In most of cases described in this research, the staff from TLO and the NSTDA's project analyst played a vital role in creating the network and bridging the gap between the public and private side. The current situation in Thailand is that there are not many intermediaries on both the public and private side playing important roles in the innovation system, despite the fact that it is one of the important factors determining the success of knowledge transfer. Some might argue that bridging organisation is not considered as a success factor for the technology transfer because all the failures also have the TLO staff or BD staff involved in the technology transfer process. It is necessary to look at the cases more carefully for the efficiency and performance of TLO and BD staff who work for each case. Most firms involved in successful cases mentioned at least once about an important role of bridging organisation/ intermediary in their successful technology transfer.

For failed cases, some TLO or BD staff did not succeed in bridging the two sides when doing the technology transfers. An example is the case with the Dental implant material when the TLO staff initiated the technology transfer agreement before consulting the researchers causing wrong timing. Moreover, during a year after signing the agreement, the

TLO did not follow the progress of technology transfer properly until the firm terminated the agreement. In the case of Alternative materials for solar cells, the TLO contacted the firm that did not have a business in solar cell production, which was partly responsible for the failure of the case. Also, the TLO miscalculated the value of the product in the market and overlooked a cheaper product imported from China. Another failed case is the Potential protein for disease prevention in aquaculture, which was too early to bring the firm to the researchers when the R&D project was still lab-scale research. Beyond this, the researchers lacked the background knowledge to support the product development.

In addition, there are some factors that are relatively specific to the cases which can be described as follows:

*Supportive basic research:*

This issue has rarely been mentioned in previous research on technology transfer in Thailand. This might be because few of the people involved were aware of it. During the last decade, S&T policy makers have tried to encourage public researchers to move to more applied research and reduce the number of basic research projects. This was seen as desirable because many university researchers were focusing only on basic research and their academic reputation. However, moving to applied research too much and neglecting basic research can cause some drawbacks to the S&T development process. The applied research still needs strong basic knowledge to support its application.

Basic research can benefit innovation in many ways. For instance, it helps building up research skills for human resource development, as Pavitt (1991, 114) notes: “*One important function of academic research is the provision of trained research personnel, who go on to work in applied activities and take with them not just the knowledge resulting from their research, but also skills, methods, and a web of professional contacts that will help them tackle the technological problems that they later face*”. Additionally, Pavitt (1991, 114) suggests that basic research can benefit technology even through unplanned application “*where useful knowledge emerges from research undertaken purely out of curiosity, without any strategic mission or expectation of application*”.

From the case studies, two of six success cases, Medical Biotech and Bioactive Company, were initiated as basic research in the lab. These two cases become successful through unplanned application as mentioned earlier by Pavitt (1991). On the other hand, lacking basic research in creating supportive background knowledge also caused failure in

technology transfer and can be seen from the case of Potential protein for disease prevention in aquaculture and Feed additive in aquaculture.

This does not mean the policy should focus only on basic research but, rather, that it should balance the ratio of supporting of basic research and applied research properly. At least two failure cases show the obvious problem of lacking basic research to support technology application which resulted in the termination of the collaborative agreement. To solve the problem occurring during the process of technology development requires supportive background knowledge to understand the fundamentals of technology, and most background knowledge can be accumulated from basic research. From the interviews with the executive staff from the RTOs in chapter 6, many of them suggested that the policy should not neglect the importance of basic research. Furthermore, the basic research is the main avenue for generating a core technology or platform technology for further application.

*Production cost:*

This is another factor causing failure in the technology transfer process. In many cases, the researchers could develop an excellent technological product which perfectly matched with the user's need. But it failed in the technology transfer process because of a high production cost which the firm could not accept. The cases of Feed additive in aquaculture and Food processing machine are examples of this issue. The first case failed because of many factors including a lack of knowledge in managing the experiments properly. At the same time, the firm's marketing unit only focused on the production cost and overlooked the potential use of the product, as shown in the research. The latter case, there is no doubt about an efficiency or quality of the product but the cost for producing the product was too high and unacceptable for the producer. This comes back to the scale-up production process when the researcher was doing the research project. An important awareness for this topic is how to make an acceptable and reasonable production cost on an industrial scale which is linked to the firm's management skill mentioned earlier.

Besides the important factors mentioned above, there are some interesting observations that can be made from these case studies and can be summarised as follows:

- The service unit provided under public organisation is an alternative way to test and verify technology research conducted by public researchers. Two successful cases, Medical devices and IT firm, can demonstrate clearly that being a service unit under the public organisation accommodates for success in conducting technology transfer and establishing

the spin-off firm. Similarly, the start-up firm like Automation also enjoys the benefit from getting working experience in the public research institute.

- Informal connections between public researchers and firms help to create an efficient technology transfer process. The case of the Bio-treatment firm obviously confirms this notion as the research project was started from an informal connection between the firm owner and the public researcher. This is also supported by interviews with the big firms in chapter 7, as many big firms initiated its public-private relationship by using an informal connection.

- The entrepreneur course provided an efficient way to build up awareness about the importance of R&D to public researchers and firms. This can be seen from the two success cases: Bio-treatment firm and Automation firm. In the first case, the firm owner took the course to have more of an understanding of the process of innovation development and how to manage the innovation. On the contrary, in the second case, the public researcher took the course in order to learn about the business and how to become an entrepreneur by using innovation.

An analysis of case studies and influential factors is summarised and shown in table 8

**Table 8 Case study and influential factors**

Success Case	Factor											
	Technological capability and appropriateness	Absorptive capability	Attitude	Trust building	Networking	Timing	Firm's management and marketing skills	Effective communication	Technology field	Bridging organisation / intermediary	Supportive basic research	Production cost
Bio-Treatment Firm	✓	✓	✓	✓	✓	-	✓	✓	-	✓	x	-
Medical Devices	✓	✓	✓	-	✓	-	x	-	x	✓	✓	x
Medical Biotech	✓	✓	✓	✓	✓	-	✓	-	x	✓	✓	x
Bioactive Company	✓	✓	x	x	✓	✓	✓	x	-	✓	✓	✓
IT Firm	✓	✓	✓	-	✓	✓	✓	-	✓	✓	✓	-
Automation Firm	✓	✓	✓	✓	✓	-	✓	-	✓	-	✓	-

Failure Case	Factor											
	Technological capability and appropriateness	Absorptive capability	Attitude	Trust building	Networking	Timing	Firm's management and marketing skills	Effective communication	Technology field	Bridging organisation / intermediary	Supportive basic research	Production cost
Diagnostic Test Firm	✓	✓	✓	✓	x	x	x	x	x	x	✓	-
Sensor for Agriculture	✓	x	x	x	x	x	x	x	-	✓	✓	x
Aquaculture Cultivation Device	x	x	✓	✓	x	x	x	x	✓	x	x	x
Electronics Device for Heavy Industry	x	-	✓	✓	x	x	-	x	✓	x	-	-
Bio-control Agents	✓	✓	✓	✓	✓	x	-	x	✓	✓	✓	✓
Alternative Materials for Solar Cells	x	x	✓	✓	-	-	x	-	-	x	-	x
Adhesive Plaster	✓	x	x	✓	x	-	x	-	x	x	✓	x

Failure Case	Factor											
	Technological capability and appropriateness	Absorptive capability	Attitude	Trust building	Networking	Timing	Firm's management and marketing skills	Effective communication	Technology field	Bridging organisation / intermediary	Supportive basic research	Production cost
Dental Implant Material	x	x	x	x	x	x	x	x	-	x	✓	-
Potential Protein for Disease Prevention in Aquaculture	x	-	✓	✓	x	x	-	x	✓	x	x	-
Biological Agent for Preventing Disease in Poultry	x	-	x	x	x	-	x	x	✓	x	-	-
Feed Additive in Aquaculture	x	-	x	x	✓	x	x	-	✓	✓	x	x
Food Processing Machine	✓	x	x	-	x	-	x	-	✓	✓	✓	x

✓ = the factor is found and/or has positive impact on the case, x = the factor is missing and/or has negative impact on the case,

- = the factor is not found and/or does not have any impact on the case

Comparing the SAPPHO and FIP project from chapter 2 to the present study shows that some factors determining the success of innovation are found repeatedly. The response to the user's need found in the SAPPHO project is the main points which appears in the most successful cases. Additionally, work efficiency in the successes is better than in the failures, but that does not necessarily mean speed as it can be seen in some failure cases that even when some of them were the first players in the market, it did not guarantee their success in the business. Indeed some successful ones were the followers entering the market later but becoming the leaders because of their better products.

In case of FIP, the role of function and price in that study are also important to the case studies in this research. Some failures cannot compete with the price even if they have a better quality product. Technological uncertainty is the main factor causing a failure in many cases and it leads to the technological capability of the technology provider. The last factor suggested in the FIP project that relates to this research is the previous line of activity in firm. The firm's experience is vital in many successful cases, for example the Bio-treatment firm, IT firm, and Medical Biotech firm.

Regarding the case studies conducted by Larsson et al. (2006), the cases were categorised into two groups: success case and failure case the same as this study. Although, there is only one failure case, the study has analysed some interesting success factors for the technology transfer process as mentioned in chapter 2. The factors identified by Larsson et al. (2006) are similar to some factors found in this study. Those factors includes technology capability, absorptive capability, attitude, trust, management skill, and timing.

Other factors pointed out by previous studies including effective communication, impact of technology field, regulation, and regulation are also found in this study. However, the combination of the factors that determine the success or the failure of the case is varied from case to case. From the study of Larsson et al. (2006), the successful cases are driven by different factors but some factors are repeatedly found in those cases and the researchers call them the success factors. However, in the failure case, even many of those success factors are found in the case, it still failed in doing technology transfer as it has different combination of the factors. Comparing Larsson et al.'s study and this study, the similar patterns are found in both success cases and failures. In most success cases, some factors appear repeatedly among the cases while the failures miss only one or two of them but they are not the same factors that each failure is missing. Therefore, in this study I do not define any factor as the success factor for technology transfer because the success is driven by the combination of the factors and also the failure. Each case has different paths and the factors

identified above influenced their journey. In many cases only one missing factor can cause failure since the case cannot travel throughout the journey. One factor that results in failure for one case might not have a strong impact on the others if there are other factors supporting the case.

All factors that have been analysed and identified in this chapter are considered as the important factors that need to be aware of when the technology transfer is conducted.

### **Analysis of ST&I policy impact on the case studies**

In 1961, when Thailand first launched its national economic development plan, S&T was not the focus of the plan. Even though there were some attempts to do research for agriculture, they were not very successful. The main reason was a lack of experts to conduct the research (a human resource problem). In the second and third plans, Thailand aimed to build up its infrastructure and deal with the economic crisis. It was not until the fourth plan that the government started to do technology exchange with other countries in South-east Asia, and that the public sector started to invest in some industries that require advanced technology and where private firms lacked of capability. Then with the fifth plan S&T was put at the heart of policy, and became one of the chapters orientated towards national development. However, the focus was put on the public organisations to build up S&T capability and also on collaboration with foreign countries to learn about advanced technology. This can be considered as the starting point of the science push model in Thailand.

After the fifth plan, Thailand began to realise that there were many problems in S&T development. Some severe problems included a lack of human resources, low R&D budget, lack of R&D capability and knowledge in private sector, and also a lack of efficient supportive S&T policies. However, during this period of time, Thailand enjoyed impressive economic growth, with GDP growth ranking it as one of the fastest growing economies in the world. The contradiction between Thailand's economic growth and its S&T development capacity was noticed by some scholars (for example Intarakumnerd et al., 2002).

Similar problems were noted in the eighth plan (2002-2006) as Thailand relied heavily on imported technologies but lacked ability to adapt those technologies for local use. This was the time that the first Science and Technology Strategic Plan (2001-2006) was initiated (which later became The National Science and Technology Strategic Plan, 2004-2013) and it was the first time that the NSI concept was formally adopted (Intarakumnerd and Chaminade, 2007a).

One of the main goals for this plan was to achieve an efficient and strong national innovation system (as described in detail in chapter 5. Many problems impeding the S&T development in Thailand have been raised and several strategies were proposed to tackle the problems. One of them is the attempt to build public-private relationships as implemented through NSTDA's funding scheme. The preference is for research proposals that have collaboration with private firms.

Financial support is another tool that has been used to implement the plan. Although many financial support programmes have been launched a long time before the implementation of the plan, including soft loan programmes, tax incentive programmes, and co-investment programmes, they were put together as a network to facilitate public-private relations or utilisation of public research. For example, the co-investment programme implemented in the case of IT firm provided financial support which was one of the critical factors that helped the firm to become successful.

Considering the impacts of those policies on the case studies in chapter 6, all the cases are influenced by the National Science and Technology Strategic Plan (2004-2013) since the plan was initiated in 2002 by adopting NSI concept as its core strategy. However, the research strategy in Thailand has been influenced by the policies that were implemented before this period for several decades. It was started from the early national plans, when the public organisations tried to develop new technologies and adopt advanced technologies from abroad. Therefore the ST&I knowledge has been accumulated and maintained within the public sector from the early period of the national development plan. Then in the second phase, the plans aimed to encourage the private sector to take part in S&T development in the country by supporting technology transfer from public to private side. At the same time, the public organisations including universities were not interested in industrial application of S&T knowledge but the basic research and knowledge creation. By the third phase (current phase), there are more attempts in supporting public-private relationship and encouraging the private sector to contribute more on ST&I development concurrent with the adoption of the NSI plan..

Even though, the plans have been changed and shifted into three phases, the impact of the previous Plans were still present in the following phase. The pattern of science push model is a dominant characteristic of ST&I development in Thailand regardless of the plan implemented. As can be seen from the 18 case studies in this research, most of the cases were following the science push model because they were initiated in the public laboratory (university or RTO) and transferred to the private firm. There are only a few cases that were

initiated by the user's needs. However, this does not imply that the changes in the policy such as the NSI policy has no impact on the ST&I development in Thailand. The main pattern of public-private relationship is not obviously changed but the component, institutions and the relationships among actors in the innovation system has been transformed by the policy. A systematic pattern of ST&I development has been encouraged by the NSI policy as it responds to the inclusive development theme of the national development plan by bringing every part of the society into the development process. Networking and systemic working process are the main schemes of this plan.

From the case studies, there are some cases that clearly demonstrate this change. A good example is the Bio-treatment Firm. The case completely gets away from the science push model of innovation as it was initiated from the demand pull model. It clearly shows the systematic pattern of ST&I development of the case. Not only did the public researchers and the firm get involved in the process of technology transfer but other actors including a Science Park, an incubator unit, a funding agency, TLO, customers, and IP management unit also engaged to the process. At the beginning the research proposal was funded because it was a public-private collaborative project which is in line with the main scheme of the NSI plan (to encourage public-private relationship, detail in chapter 5). Then a network was initiated across public organisations and also the firm with its customers. This is what was intended by the NSI plan. That is this case became successful in conducting technology transfer and also product commercialisation.

Even though other cases did not follow the same pattern as the Bio-treatment firm, many of them were successful in their technology transfer under the NSI plan. For instance, For instance, although the Bioactive Company started as a basic research project in university and it obviously demonstrates the science push model pattern, this case still succeeded in conducting technology transfer. When the firm showed interest in the technology, the researchers received funding from the granting agency to develop products with the firm. Other actors such as TLO, BD, and the regulation body got involved in the development process. Likewise, Medical biotech is another case that has been started from merely basic research in the university. It has been developed from the science push model but later meets with the demand pull model. There is a huge demand on the vaccine product developed in this project but the technology provider (the public researchers) could not respond to the need due to many limitations. When the firm steps in to the project, the combination between a knowledge provider (public side) and vaccine producer (the firm) resulted in a success. This case also has other actors including a granting agency, TLO, a regulation body, a

clinical test unit, private researchers involved in the case. This case is different from other success cases since it has not yet become a commercialisation. However, it can still be considered as a success case because it demonstrates an efficient network among the actors in the innovation system and a collaboration to produce a potential world first vaccine.

Medical devices, an IT firm and Automation firm, established by public researchers working in public research institutes unfolded similarly. These three cases use spin-off and start-up process to do a technology transfer. However, there are still many actors involved in the process. One of the most important actors is concerned with a financial support team. To become a spin-off firm or a start-up firm, financial support plays a vital role. The cases were supported by different units including funding unit, a co-investment unit, soft loan unit, an incubator unit (seed money), and the NIA. These units are one of the actors in the innovation system that play an important role in this type of the case.

As can be seen from the case studies that the actors involved with the cases play an important role in the success of the cases. An attempt to bring those actors into the cases was initiated from the NSI plan. Although some actors were established long before the emergence of the plan, the plan gave them a guideline and framework to work together to create an innovation system. For example, the NSTDA's TLO team plays a more important role as a bridging organisation in the public and private relationship. As mentioned by the TLO's staff in the previous chapter, the TLO is trying to move from supporting a technology push model to building a network to connect innovation actors to work together. Additionally, the training and consultancy programme plays a role in stimulating firm S&T capabilities. By collaborating with experts in the university and RTO, the training programme has helped many private firms to conduct more R&D activity.

Looking at the firm side, from the interviews with executives and other members of the firm, they have noticed changes happening in the ST&I policy in the country. Some of them enjoy governmental support including the tax exemption scheme, soft loan programme or training programme. Some of the big firms have decided to do more R&D because they can benefit from the R&D support programme from the government. The SMEs found more opportunity to compete in the market by collaborating in R&D research with the public organisations (which can be seen clearly in the successful case studies, as all firms involved in the cases are considered as SMEs). Another channel that can create a new entrepreneur is the spin-off and start-up process. From the successful cases, there are two spin-off firms and one start-up firm involved with the cases.

So far, the adoption of NSI approach has created some changes in both public and private sector. Those changes included an alteration in actors' behaviour, and organisational and institutional change. The changes have been stimulated by problems identified in the Thai innovation system. However, the success of the technology transfer process in the case studies is considered as a minority compared to the failures found in this research and the data collected by the TLO. Most of the finished research conducted by universities and RTOs still have the problem of not going anywhere but onto shelves. Many attempts at trying to do technology transfer have failed at different stages, and from different causes. As can be seen from some of the failure cases, they were initiated using the same process as the successful ones but ended up with a different outcome. For example, the Bioactive Company (success) and Bio-control Agents (failure) were started as a basic research in the university, and a firm showed an interest in the product developed from the basic research. The collaborative research was initiated to test the product in the field, and both of them gave positive results. However, eventually the Bioactive Company became a success while the Bio-control Agents failed because an alternative product had been launched before the firm decided to do technology transfer.

Other cases are the Bio-treatment Firm (success) and the Biological agent for preventing disease (failure), these two cases were started from the users' need and initiated by firms. While the Bio-treatment firm became successful in its business and received many prizes for its innovative product, the firm from the Biological agent case was trying to terminate the collaboration even though the public sector provided them with full cooperation. The case studies thus demonstrate different situations and different outputs under the same policy implementation, and so there must be other factors influencing the cases besides the impact of the policy. This point will be elaborated on in the discussion chapter.



## Chapter 8 Discussion and Conclusion

Science, technology and innovation development is identified as a key factor for enhancing national competitiveness. Thailand is one of many countries trying to embrace new technologies in order to improve its competitiveness in the global market. However, as a follower in the global innovative process, Thailand is struggling to adopt new technologies from developed countries. Thus far its efforts have not allowed the development of science, technology and innovation (ST&I) to progress as quickly and efficiently as was expected. One important problem obstructing Thailand from making progress with ST&I has been a heavy reliance on the science push linear model of innovation. This results in a fragmented and weak innovation system as described in chapter 5.

Adopting the NSI concept at the policy level is one of the solutions Thailand has tried in order to get away from the linear model of innovation. It has also applied the cluster concept together with the NSI in the same policy starting in 2001. Therefore, this research aims to investigate the current situation of ST&I development in Thailand by exploring the relationship among actors in the Thai innovation system, particularly focusing on the relationship in the technology transfer process between the public and private sector. This is important because Thailand has relied heavily on the science push model in which S&T was created and embedded in public organisations such as universities and RTOs.

The issue at the heart of this thesis is whether the adoption of the NSI approach has helped Thailand to get away from the linear model of innovation, and enable progress in its ST&I development. This issue has been addressed through a detailed study of the development and implementation of Thai innovation policies and empirical case studies that are analysed to understand the key factors that influence and shape the relationships in the Thai innovation system.

There are thus two main research questions addressed in this thesis:

1. What factors contribute to success (or failure) in technology transfer from the public to the private sector?
2. To what extent has the adoption of an NSI approach changed Thai innovation policy, and improved innovation?

Based on the literature review, these broad questions were refined into more focussed hypotheses:

*Hypothesis 1:*

- 1a. The knowledge or technology produced in the public sector is inappropriate and insufficiently applied for the immediate needs of most firms.
- 1b. Thai firms lack sufficient absorptive capability to adopt new knowledge or technology.
- 1c. There are insufficient mechanisms for linking public and private sector innovation.

*Hypothesis 2:*

- 2a. Thai innovation policy based on the linear model (technology push model) constitute a limitation of the S&T development process.
- 2b. Attempts by the Thai government to overcome the linear model approach by moving to a NSI concept and strengthening the system have not been effective.

## Discussion

The cases described in the previous chapter clearly demonstrate that there are some successes in the public-private relationship for S&T development in Thailand, even though there are a small number of them compared to cases of failure. These represent successful cases of technology transfer between the public and private sector that can be used to analyse some important factors influencing the success of the cases. At the same time, all the selected case studies presented in this research build a picture of some major patterns of S&T development in Thailand. In particular, there are repeated characteristics of the cases showing the same pattern to explain why many of them ended up as failure cases.

Care must be taken in generalising that the factors involved in these cases are the determinants of the success or failure of the technology transfer process because there are some specific factors involved that influenced the outcomes of the individual cases. However, understanding the variety of factors involved provides general indicators of why some innovations succeed and others fail. It is also useful for the ST&I manager, especially the ones who manage R&D in the public sector (or even the private sector) to become aware of these factors when conducting technology transfer or R&D collaboration. Typically, the cases show that a range of conditions need to be in place for a case to become successful. Conversely, in the failure cases, lacking only one factor can result in the failure of the technology transfer process; even though other important factors may be present. Simply put, achieving success needs an appropriate combination of the key factors, whereas only a single missing factor can result in failure in a case.

Regarding the methodology used in this research, the number of cases is considered as a meso-study. This study is different from a macro study which aims to collect a large number of samples to conduct a statistical analysis seeking correlation (quantitative research), or a micro study which selects only one or two cases and investigates the case in detail (qualitative research). The meso-study I chose for this research falls between the macro study and micro study and cannot be utilised to present statistical data or to provide profound details for the individual cases. However, the meso-study approach has the benefit of providing sufficient detail across a representative range of cases thus enabling investigation of the patterns of public-private relationship found with different types of technologies transfer, different stages of development, and different fields of technology.

This research diagnoses a bundle of factors that contribute to failures and a combination of factors leading to success. Therefore, a macro approach is not very useful in this type of

study because the character of the cases cannot be generalised and the correlation cannot be calculated by statistical methods. No matter how big the number of cases, if all show different characteristics the data collected cannot be generalised. The medium size and number of cases helps this research to examine each case, and the data analysed from a single case can be utilised to compare and contrast the patterns among the cases.

This research demonstrates a diversity of outcomes, each individual case shows different patterns and different paths of the case. Even though some of them were initiated using the same approach, same technological field, or by the same organisations; the cases travelled through different paths and resulted in different outcomes. There was an uncertain process of innovation in each case. The cases went met with barriers, some managed to overcome or avoid the barriers to become successful but some failed. The factors that determine the success of the cases are contingent and specific to the individual case. Williams et al. (2005, 51-53) suggest that there is a complex interaction between technology supplier and user in the technology transfer involving learning by interacting that is “experience-based, contingent and tacit”.

They also note that: *“It is not a linear process of knowledge transfer. Instead its wider application will depend upon a creative process of knowledge translation: selecting relevant experiences and transforming them. Here the social learning perspective goes beyond the economists’ focus on linking structures (whose operation is demonstrated by the revealed cumulative performance of players in the innovation system) to address the detailed mechanisms and substance of this learning by interacting”*.

One of the major patterns of public-private relationship in technology transfer in Thailand that can be seen clearly from most of the case studies is the reliance on the linear model of S&T development. The linear model approach has resulted in focusing on the development of S&T in the public sector (universities and public research institutes) while ignoring the importance of S&T capabilities in the private sector. When the public researchers finished their research projects and failed to transfer them to the private side, they came to realise that there was a problem with this linear model. These findings thus support the first research hypothesis that questions the focus on S&T development in the public sector and sees the weak relationship between public and private sector as an inhibitor in Thailand’s S&T development.

It is not easy for Thailand to change this pattern of S&T development due to many influential factors even though there has been an attempt to change using the NSI concept which will be discussed later. The linear model approach has appeared attractive for a nation

trying to develop its S&T advancement in the public sector. In the past, this pattern of S&T development has been seen in many countries around the world (with S&T knowledge initiated and created on the public side).

One influential example is the US where technological knowledge was heavily embedded in public organisations in periods of its S&T development. In particular, this is a feature of the period that commenced after World War II and continued during the cold war. The US federal government invested heavily in R&D projects both by using research funding schemes and by conducting research in public organisations. At the beginning, the research aimed to fulfil the missions of defence, space exploration, and other statutory responsibilities, with the developed technologies then applied and commercialised. Later, the research was focused on new advanced technologies including biotechnology and computers. Then it moved to support the technology transfer process attempting to transfer developed technology to industry. A simplistic reading of this history would see a linear process whereby investment in the development process of S&T led to the US becoming a world leader in economic terms (Branscomb, 1993; The White House Council of Economic Advisers, 1995; Mazzucato, 2014).

Another interesting country that has relied heavily on the public sector to initiate its S&T development is Korea. Trying to catch up with developed countries, especially with its neighbour Japan, Korea's government implemented several policies to help its industry to compete in the global market. S&T development was started in the public sector by establishing many efficient public research institutes. Nowadays Korea has become one of the world leaders in advanced technology especially in computer, electronics, and IT (Dodgson, 2000, and Lee, 2006).

The role of the public sector in doing R&D and knowledge generation is supported by Mazzucato (2014) who sees the role of the state as more than an innovation supporter using tax exemption schemes or financial support. The state can play an equal role in creating and establishing new knowledge in the innovation system or even becomes the entrepreneur, especially in risky technological fields or industries as it has been done in countries like Japan, Korea, and the US. The more technologically advanced countries typically have more efficient private sectors that take a lead role in the ST&I development process. Although many advanced countries embrace the science push model in the public sector, most of them have strong private firms with innovative capability. All these factors in the developed countries facilitate and support an effective national innovation system.

However, many of these factors are lacking in developing countries where use of the NSI concept almost inevitably ends up involving a science push model of innovation. These developing countries are trying to catch up with the developed world and are lacking technological capability, especially in the private firms. Thus, to build up this capability, the public sector takes the lead in initiating the development process. Eventually, more capabilities are built up and embedded in the public sector and then the public sector tries to push the knowledge/technologies created in the public side to the private sector, but without the contribution of user's requirements.

One criticism of the NSI concept suggested by Arocena and Sutz (2000) is that the NSI approach in the developed countries is an ex-post concept while it becomes an ex-ante concept in the developing countries. The NSI concept was formally introduced to explain the impressive economic growth in Japan (Freeman, 1987); it did not create Japan's ST&I progress, but rather was thus described by Freeman, after the fact, as a 'national innovation system'. The concept of NSI did not contribute to the remarkable ST&I advancement at that time (though it was adopted in the S&T policy later by Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT)). The NSI was an analytical tool that Freeman used to describe how Japan became one of the world leaders using its ST&I advancement. Likewise Godin (2007, 7) explains the technological gaps among the European countries, the US and Japan after the World War II, and how the NSI concept was used to explain the gaps: "*The National Innovation System, with its emphasis on the ways institutions behave and relate to each other, offered a new rationale to explain these gaps*".

However, in developing countries, the NSI has been adopted as an ex-ante concept which means they are using the concept as a prescriptive tool to guide policy. The main advocate for this has been the OECD who have disseminated the NSI concept to other countries through its recommended scientific policy, technological policy or innovation policy. As a consequence the implementation of the NSI policy as advocated by the OECD approach has resulted in distortion of the NSI concept (Lundvall, 2007). In particular, this has led to the adoption of a version of the NSI approach in the developing countries that emphasises the science push model.

Considering Thailand's case, there are some successes perceived in the technology transfer process between public and private sector (including some documented in chapter 6). What are the factors behind the success of these cases? And, alternatively, what factors explain the failure of other attempts at technology transfer? Are there lessons that can help Thailand improve its NSI to embed S&T and innovation and so enhance its competitiveness? In

essence, can Thailand learn from its own experience and also from others who have previously succeeded in a similar situation? As mentioned earlier, there is nothing wrong with initiating the ST&I development on the public side, but the most important thing is not to fall into the trap of relying solely on the linear model of innovation.

Finally in this chapter, there is one more important issue which needs to be addressed as Thailand tries to move from the linear model to a systematic model by implementing the NSI concept. Attempting to fix some mistake caused by a linear model in S&T development, Thailand introduced S&T policies lean on NSI concept to its S&T development process. To see how effective new policies are and whether or not the NSI concept can help Thailand from the linear model problem, the final part of this chapter investigate and analyse the result of S&T policy implementation in Thailand. The analysis will bring involved policies to analyse together with the selected case studies.

*Does the NSI concept actually help to improve the ST&I development in Thailand?*

The concept of the NSI has been widely adopted in the Southeast Asian countries since the late 1990s. The diffusion of the concept was mainly the result of graduates from SPRU, University of Sussex, from Aalborg University and from other European universities who returned to their home countries and influenced the direction of STI policy. At least six countries including Singapore, Vietnam, Malaysia, the Philippines, Indonesia, and Thailand formally adopted the NSI concept to their STI policy during that period of time. Apart from Singapore, the other countries were struggling with the conventional innovation model based on a linear model approach to innovation (Ratanawaraha, 2013, 6-7). As they were trying to get away from the old and problematic approach, they expected the NSI concept to help solve the problem.

However, after more than ten years of implementing the NSI concept into the policy making process, Thailand is still facing many problems and struggling to use ST&I to enhance its competitiveness and prosperity. Therefore, the question needs to be asked: does the adoption of the NSI concept really help Thailand to escape from its ST&I development problem? The answer is not straightforward: a simple 'yes' or 'no' will not suffice, since the NSI concept has not been implemented in an 'appropriate' way as specified in the original literatures.

According to Freeman's and Lundvall's work, along with other scholars, the concept of NSI originated from the investigation of interactions among actors, and the influence of institutions on actors' relationship in the innovation system at the national level. It was based on systematic thinking and focused on the knowledge flows among the actors within the

system by putting the firm at the centre of the system. The NSI concept emphasises the learning capability of the actors as the main tool to make the knowledge flow and utilise the knowledge. However, looking closely at the way Thailand adopted the NSI concept, it can be seen that it is far from the original concept of the NSI proposed by the pioneer scholars.

#### *Integration of NSI concept to the ST&I policy*

Thailand has adopted the NSI concept in its national policy making process since 2001. The concept has been disseminated to many public S&T related organisations, especially the ones under the MOST. In addition to NSTDA, the National Innovation Agency (NIA) which was founded in 2003, takes the concept of NSI as its core principle for the organisational operation. In 2008, the National Science Technology and Innovation Policy Office (STI) was established and, although the term NSI was not written explicitly in its core policy, its aim was to build up an effective Thai national system of innovation in order to improve the national ST&I development. The adoption of the NSI concept in Thailand was started by the integration of the concept into the S&T policy (together with the clustering concept). It has now been adopted by other related organisations as an implicit (though unnamed) goal for ST&I organisations.

In previous studies, many scholars, especially Intarakumnerd and Chaminade (2007a, 2007b and Chaminade et al., 2012), have criticised the adoption of the NSI concept, arguing that in reality, policy makers just used the NSI label, but continued the practices and implementation process as for the linear model. Intarakumnerd and Chaminade (2007a) point out that the pattern of the policy implementation after the adoption of the NSI concept still continues with the science push model. The most obvious characteristic of the policy is the reliance on pushing and supporting R&D activities in universities and RTOs or even private firms, with addressing the need for innovation capability or learning skills. This reflects the misinterpretation of the term 'innovation' when R&D is seen to be all that is necessary.

This study confirms that there has been inappropriate application of the NSI concept in Thailand. As noted in the literature review chapter, Lundvall et al. (2009, 2) categorise the NSI concept into two modes: the Science, Technology and Innovation (STI) mode, and the Doing, Using and Interacting (DUI) mode. They also criticise the adoption of STI mode only as 'distortion' of the NSI concept, as seen in the OECD's influential NSI implementation. Those who have taken the US as demonstrating an NSI approach based on the STI mode more than the DUI mode fall into the trap of the ex-post perspective. As a world leader in knowledge production in ST&I, the US NSI pattern can be dominated by the STI mode, but

the many technology-based US industries demonstrate that the US firms are able to learn and utilise the knowledge efficiently in the DUI mode too.

The lesson for Thailand is that ST&I excellence should be built up in both public and private sectors, but with more focus on the private firms to support the DUI mode. However, at the moment Thailand is focusing on creating ST&I capability in the public sector both in universities and RTOs and neglecting capability building in the private firms.

#### *Moving forward to the triple helix model not the NSI*

Some current patterns of relationship between public and private sectors in Thailand can be explained by the Triple Helix model. Particularly, in the cases where public organisations such as the university plays a leading role in process of technology transfer. In fact this triple helix model can better be used to describe some cases that show the science push pattern. This is because the knowledge/technology was initiated and then transferred from the university or RTO. Furthermore, in the case of spin-off firms, the public organisation demonstrates the entrepreneurial role instead of the firm. However, there are some limitations in implementing this model to explain public-private relations as mentioned in chapter 2, as the model neglects the national context (Shinn, 2002) and social context (Cai, 2014).

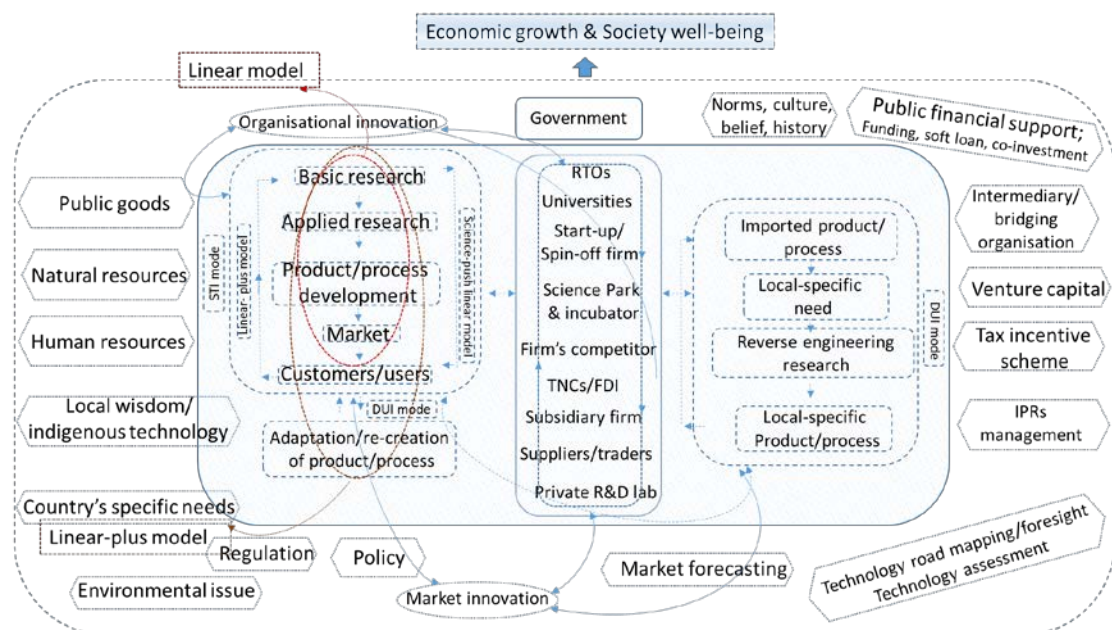
To consider this triple helix model deeply, as many cases studies can be better explained by the triple helix model rather than the NSI concept, it reflects the inappropriate way of NSI adoption. This leads to the problem mentioned earlier about the science push model. Lundvall (2010, 318) criticises the triple helix approach as it “*focuses on science and the role of universities innovation*”, and it contributes to the distortion of NSI approach adoption as it leans on the narrow concept of the NSI approach (STI mode).

#### *The linear-plus model*

Thailand’s adoption of the NSI approach was intended to bring about a shift from the linear model of innovation to a more systemic model, but what we instead is half way shift that has brought about more focus on the demand side. The result is what has been called the linear-plus model. As Tait and Williams (1999, 103) put it: “*Criticisms of the linear model have resulted in increasing attention to the market and to the process of exploitation of research, resulting in a model of innovation which could be described as ‘linear-plus’*”. This model does not change the idea of how the innovation is created which is still from science-based discovery but tries to improve the relationship among scientists, industries, and customers to make the linear model works better. Thus Tait and Williams (1999) describe how EU policy

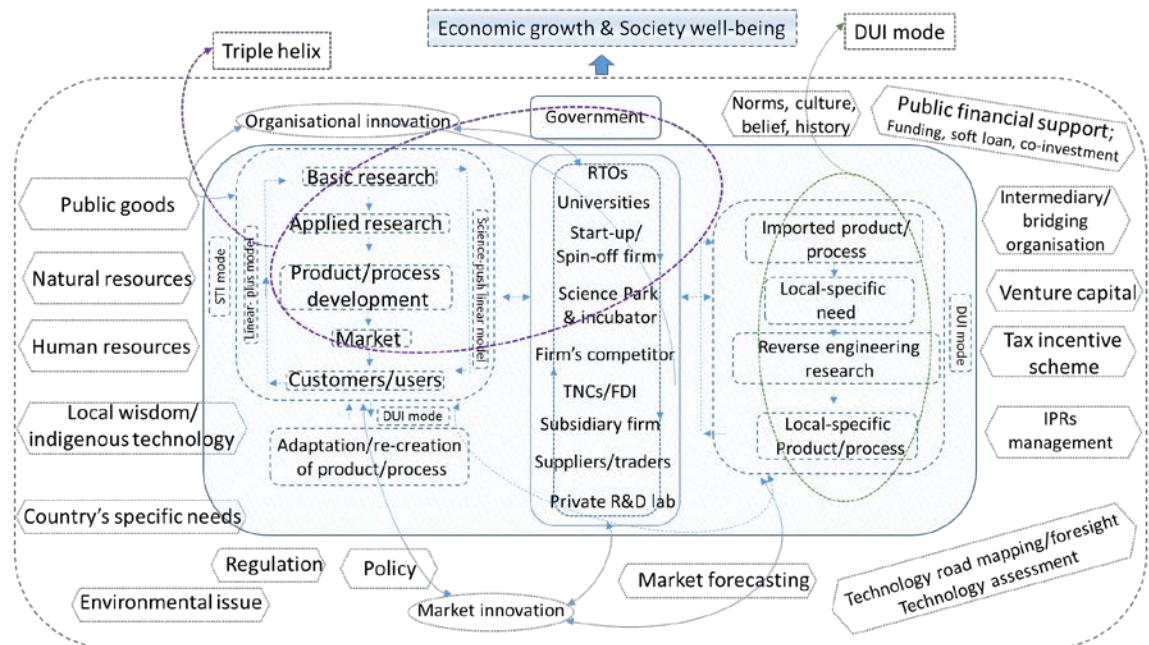
(FP5) aims to improve the impact of R&D on society and economy by reducing support in basic research and increasing applied research, and enhancing involvement of the users. A similar situation has been happening to the S&T development process in Thailand, especially in the RTOs and universities. The governmental funding agencies have shifted their policy to focus more on the applied research and to require a user contribution or collaboration with the firm in the research when applying for funding from them.

The linear-plus model is useful for the public sector for improving its old problematic linear model but it does not get rid of all the problems facing Thailand. To make it work properly, this model can be one of the mechanisms of the system of innovation. The effective system requires more than one linear model/relationship or even the linear-plus model but it needs many of them to construct the system.



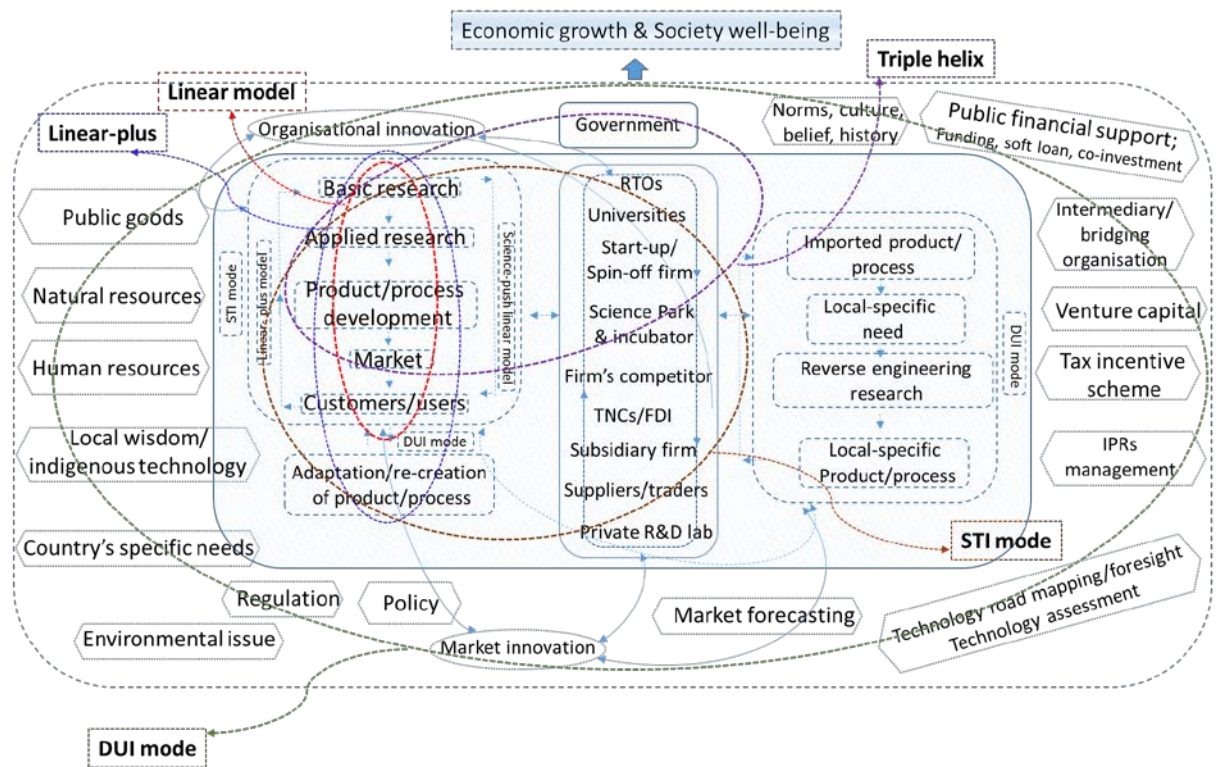
**Figure 15** Diagram shows the example of the structure of the Thai national system of innovation. The diagram in Figure 15 is one of example of the Thai national innovation system demonstrating the actors, institutions, and their relationships. The diagram is constructed from the current situation of the Thai innovation system to demonstrate possible processes and pathways of interactions among the actors and institutions involved in the system. Picking up only one part of the picture, it can be seen as the linear model, triple helix model, STI-mode, etc. As can be seen in Figure 15 if we look at the picture of the linear model which is started from the basic research to applied research, then the product/process development and finally it will be delivered or transferred to the market. This part follows the conventional linear model of innovation. However, looking at the broader scale of the picture, the linear-plus model can be spotted from this perspective when the user or

customers' needs are taken into account. Additionally, the DUI mode of the NSI concept might be seen in this process if the learning capability of the actors (can be firms, universities or RTOs) is built up.



**Figure 16 Diagram shows the example of the structure of the Thai national system of innovation**

From Figure 16 some parts of the picture have nothing to do with the science push model; such as the ones involved with the learning process or the demand-driven part. For example, the one in the green oval where reverse engineering process is involved in the model requires learning capability (learning by using or by doing) to develop new product or process. Another model that can be seen here is the triple helix model in the purple oval. This model is dominated when the university takes a leading role in the process of innovation.



**Figure 17 Diagram shows the example of the structure of the Thai national system of innovation**

Finally, the Figure 17 demonstrates a complete picture of the innovation system where all models and processes can be linked together to construct the system. The STI mode and the DUI mode are shown in the picture at different parts. Particularly, the DUI mode is needed in most process because the learning capability is a crucial factor to create an efficient system. The most important thing is not where the innovation process is started but how to make sure it flows and is utilised in the system.

*Some changes in the ST&I development process*

Ten years after the introduction of the NSI approach there are some changes found in the ST&I development process in Thailand, though not a complete transformation. The case studies demonstrate some positive changes resulting from the adoption of the NSI concept, particularly in the successful cases, most of which were influenced by the policy implemented after 2001. To get away from the linear model of innovation, the systemic model has been introduced to the ST&I policies even though it has not followed the original NSI concept set out by academics (as pointed out earlier). For example, the case of Bio-treatment firm shows how an idea initiated from the firm's side regarding the user's need led to many actors and institutions getting involved in the including RTOs, the funding agency,

TLO, the incubator unit, the Science Park, tax exemption scheme, training programme and IPRs management. This case represents the effective innovation system from the good knowledge flow between public and private sectors to the efficient interaction among actors and institutions. The public sector acted as a knowledge supporter who responded to the user's need, the incubator unit and Science Park helped to build up the firm's capability, and eventually the firm succeeded to start the new business using the R&D capability and learning capability.

The NSI contributes to the case by introducing systematic management through the master plan since many actors and institutions have been formally initiated to serve the plan. Other case studies show more of a mixture between the old linear model of innovation and the NSI model. Most of them were initiated in the public sector, some from basic research. But the basic research itself could not be directly translated to the innovation following the technology push model, it required other factors to do so. As can be seen in the failure cases, more than 80 percent of them were started in the public sector and they failed in the technology transfer process. Therefore, the rest of the successes (apart from the Bio-treatment firm) have some supporting factors that help them to be successful even though they were initiated using a science-push model.

#### *Systemic problems in the Thai NSI*

Chaminade et al. (2012) have detailed what they see as the systemic problems in the Thai NSI. Their study categorised systemic problems into 5 main types: infrastructure problems, capability problems, network problems, institutional problems, and transition or lock-in problems (Chaminade et al., 2012; see also Chaminade and Edquist, 2006). They conclude that there is a mismatch between policy instruments and the systemic problems found in the Thai NSI. The main systemic problems found in their study (focused on the firms' side) are network problems, institutional problems, and also support services problems including capability problems which are particularly found in non-research based firms.

The research in this thesis found a similar pattern of systemic problems in the failure case studies. Focusing on the firm side, most of them show capability problems since they were lacking absorptive capability. The network problems and lock-in problems were also shown in some firms. However, unlike the previous research that only focused on the firms, this research also found serious systemic problems on the public side. The most severe one is the infrastructure problem which includes universities (and RTOs in this case) who lack the capability to conduct (efficient) research. Furthermore, these problems were exacerbated by weak links between university and industry. Other problems found on the public side are

institutional problems. These are concerned with regulation. As mentioned earlier, in the food and public health fields, there is strong regulation to deal with. This regulation is important as it is established to protect people, but the criteria involved in setting the regulation and in product certification are the points of concern. The problem will arise when the knowledge in the firm (who attempts to launch a new technology based product) and regulator or certifying body is asymmetrical. Sometimes, the delay in certifying product can prevent the firm from being the leader in the market or even completely stop the firm from entering the market.

#### *Mismatch in policy implementation*

Chaminade et al. (2012) also claimed that there is a mismatch between implementation policies and the systemic problems facing the NSI, and this research found both supporting and opposing evidence for this claim. It can be seen clearly from the failure cases that there are some inappropriate policies involved with the cases. The most obvious one is the policy of supporting the research in the public sector and waiting for the firm as a 'user' to come and buy the finished technology 'off the shelf'. The case studies in this research exemplify this problem which is seen to be a chronic illness of ST&I development in Thailand. Most of the TLO staff and most firms are aware of this problem. Some might argue that this is the result of old policy practices but they cannot deny that it is deeply rooted in the system and it is not easy to change. This practice obviously shows the linear model of innovation and goes against the intention of the NSI concept. Even though it is arguable that there are some successful cases that were initiated in the same way, not many of them are clear cut since there are many other factors supporting the success of the cases.

Intarakumnerd and Chaminade (2007b, 7-8) categorise the policy instruments implemented in Thailand into two groups which relied on the neoclassical framework and system of innovation. The neoclassical group include R&D subsidies, R&D tax breaks, technology demonstrators, subsidies for production of S&T manpower (scholarships for postgraduates in sciences), and establishing government R&D institutes/centre of excellence. The second group consists of training for capacity building in firms, network programmes, facilitating access to foreign sources of technology (coupling with TNCs), business services, and strengthening user-producer interaction.

The evidences found in the case studies confirms the value of policy instruments that align with the system of innovation (the second group). However, this research is less in agreement with the group that has been categorised as a neoclassical approach. The situation might be different in other countries particularly in the developed ones but for a country like

Thailand it requires some policy instruments in this group to support its innovation system. For instance, the scholarship of postgraduates in sciences, it is the important tool to start producing knowledge in the system. The importance of efficient S&T staff in the public sector has been mentioned in many previous studies.

Finally, government R&D institutes can operate as one of the important actors in the NSI; however, they have to play an appropriate role in the system. Many criticisms have been made on the role of the RTOS in Thailand as they are not working efficiently. The capability needed in firms and in the public sector is not the same. It is not possible to strengthen the R&D capability in firms and then leave the private sector to play a sole role in the NSI with the public sector just operating as a supporter. Some parts of the system still need the role of the public side as a knowledge provider or the initiator in some fields of industry especially the risky ones as mentioned earlier.



## Conclusion

From this research, it can be argued that Thailand is in a transitional period moving from the linear model to the systemic model. Some successful outcomes can be seen in the case studies even though these are a small number compared to the failures. Although Thai innovation policy is criticised for using a narrow concept of the NSI, some of the case studies (particularly the success ones) show adoption of the DUI mode of the NSI. The firms involved in these cases needed effective learning processes to become successful in adopting the transferred technology. This can be seen obviously in the case of the IT Firm, a spin-off firm from NSTDA. As a service unit in NSTDA this firm was able to develop its competences using a learning-by-doing approach. Then when it spun out from NSTDA, the firm learned how to survive in the market and how to adapt its core technology to another application. Similar examples of DUI innovation can also be found in other successful cases, but are totally missing in most of the failures. The empirical finding from this study contributes to the NSI framework in the literature reviews as it confirms that successful use of the NSI needs two modes of operation: STI and DUI modes. In case of Thailand, the STI mode has dominated while the DUI is still missing in general. The case studies indicate that when the DUI approach is in operation, there is more likelihood of success than when there is only the STI mode.

For Thailand, use of the concept of NSI alone cannot improve the entire process of the ST&I development in Thailand, but NSI policy measures have initiated positive transformation in the process. It has been used as a tool to analyse a whole picture of the innovation system in Thailand and to identify strengths and weaknesses in the system. As pointed out by Lundvall (2010) the NSI can be either used for designing innovation policy or an analytical tool for analysing the innovation situation. Therefore, the NSI can be used to provide guidance in order to bring about solutions to the problems in the Thai innovation system. However, regarding the problems of applying the NSI approach mentioned earlier, the NSI still needs other concepts or frameworks as supporting tools to transform innovation processes in Thailand from the linear form to the systemic one. Although the NSI says what needs to be done to achieve an effective innovation system, it does not say how to make it happen in detail. It is easy to say that effective knowledge flows among the actors are needed but less obvious how to make knowledge flow more effectively. It is also clear that in different countries, different contexts and situations, different measures may be needed to execute the effective knowledge flow or stimulate the interactive learning among the NSI actors.

Furthermore, as mentioned earlier, the NSI framework alone cannot create a big impact on ST&I development in one country. Thus, to accomplish the ultimate goal of development, other concepts or frameworks are needed to support the process such as industrial cluster, regional innovation system, sectoral innovation system, technology transfer framework, and so on. Regarding the advantages and disadvantages of each concept identified in the literature review chapter, combining these concepts together helps to overcome the disadvantage points of each and to strengthen the process of ST&I development. In summary, the NSI framework cannot be used as a standalone tool to make innovation policy for a country, but it becomes useful when it is used as a guideline or a broad concept underpinning policy.

Moreover, from the results of this research, it can be seen clearly that regulation at the policy level is not enough to determine the effectiveness of the whole system. Policy measures might play a major part in influencing a nation's innovation system, but there are other factors that affect the success of knowledge/technology transfer in the system. For example, some influential factors that have been identified earlier, which policy cannot easily direct or force to happen, include trust building, effective communication, timing, and attitude. Therefore, to build up an effective innovation system, it requires more than the policy to accomplish the goal. Something that the policy maker cannot create using the policy tools but all actors involved in the process have to build it up among themselves. This is more to do with the social context among actors and how they interact with each other. It is an important issue that the policy maker or others who get involved in the process of ST&I development should bear in mind.

Thailand has done well in its economic performance until now even though it has travelled through economic crises and political changes many times. However, its ST&I development progress is not very impressive and does not efficiently contribute to economic growth. A previous study (Intarakumnerd et al., 2002) describes the mismatch between the economic performance and the level of ST&I development in Thailand. Does this imply that Thailand is able to perform well economically without using ST&I capability as the main driving factor? If so, then if Thailand can integrate ST&I into its economic growth, it will have not just better, but more sustainable, performance.

This research supports the claim that Thailand needs to build up its own ST&I capability rather than merely relying on imported knowledge. Apart from anything else, many of the case studies in chapter 6 describe innovation geared towards serving a local specific need for the country. They are not mainly created to replace imported technology or to compete with

successful foreign technology. Although some might aim to replace imported products, that is because those products failed to serve the local needs. Cases such as the Bio-treatment firm and the Bioactive Company show how using local bio-resources can be applied to solve local problems. The next step, however, is for local Thai innovation to be applied to address global markets!

### **Policy Implications/Recommendations**

The systemic problems found in the Thai innovation system can be categorised into two groups. Those in Group I can be directly addressed and improved using policy tools and include infrastructure problems, regulation, support services problems, lack of intermediary support, and lack of absorptive capability. Group II problems, however, are less amenable to such policy measures because they concern DUI mode issues such as network problems, trust building, and attitude, all of which relate to the broader social context. Although policy tools can be used to try to build up the network it is hard to create an effective or good network among the actors to produce a good knowledge flow. Policy can bring them together but cannot force them to have a good relationships or produce knowledge flows. Thus, the policy maker should bear in mind that not everything can be easily shaped by policy. As Chaminade and Edquist (2006, 146) put it: *“One point of criticism that can be expressed in relation to OECD approach is that it considers only those activities that can be directly affected by public intervention. It ignores other activities in the system that are equally important, but whose links to innovation policy instruments are not so obvious”*.

The most obvious failing in this regard has been to equate R&D input with innovative output. Although much innovation is driven by, or depends on, research-driven S&T, other forms of innovation, for example, in marketing, business practices and so on, also drive economic growth. As Fagerberg (2006, 13) notes *“it was assumed that, as long as investments in science and R&D were kept at high level, the derived economic and social benefits would ensure”*. The temptation to focus on R&D input is strengthened by the simple fact that such activity is reasonably easy to measure. Even when quantitative indicators measure outputs, these are typically proxies for innovation such as the number of publications or patents, but it is doubtful that they accurately represent innovative capability. To evaluate the national system of innovation, quantitative indicators to measure R&D inputs and outputs are not sufficient, since the system involves interactive activities among actors and institutions in the system.

From the analysis and discussion mentioned earlier, it can be seen that the implementation of the policy tool is still problematic. For example, when the policy encourages more R&D

investment, then more R&D output is expected and also more innovation. This process is thus viewed as a linear model of innovation. However, in reality things never work this way and the policy maker struggles with how to make an efficient policy for ST&I development. The DUI mode for innovation process can also be applied to the policy making process in order to make a better policy. Making policy for innovation shares a similar nature with innovation as it is unpredictable and dynamic. There are many uncertainties and unexpected situations that the policy makers need to deal with. The innovation policy should be dynamic and flexible to accommodate the learning process of the policy maker.

Finally, the last point concerning the policy making process is that there is no 'best practice' that can be generally applied to every country implementing the NSI concept. As the nature of the NSI depends on the national context, different countries demonstrate different patterns of NSI, and different problems. 'Followers' such as Thailand cannot just imitate every process conducted by the 'leaders' and become exactly the same as them. The NSI concept cannot be used as a guideline to build an action plan in policy implementation since it tells what should be achieved but does not say how to do so. As the OECD (2002, 11) put it, the NSI "*has too little operational value and is difficult to implement*", while at the same time arguing that "*the NIS approach can also provide a useful perspective to develop and implement a broad, comprehensive strategy for innovation policy*".

In summary, regarding the research questions and the hypotheses, this research has sought answers to the questions and tested the hypotheses. The first question was what factors contribute to success (or failure) in technology transfer from the public to the private sector? The answers have been presented in chapter 6, where all the factors that contribute to success or failure were analysed for the 18 cases. The influential factors included: Technological capability and readiness, Absorptive capability, Trust building, Networking, Timing, Firm's management and marketing skills, Effective communication, Technological field, Bridging organisation/intermediary.

The second question was to what extent has the adoption of an NSI approach changed Thai innovation policy, and improved innovation? The answer for this question is not clear as has been discussed earlier in this chapter. However, this research shows evidence that the NSI concept that has been integrated into Thai ST&I policies since 2001 created some positive changes in the Thai innovation system that can be seen from some successful cases, although these are considered as a minority compared to the failures.

The results from the empirical studies and other analysis showed that all the research hypotheses proposed in this research are true. For hypothesis 1, this research suggests that

ST&I development process in Thailand is overly dependent on a linear model view of innovation, in that it focuses too much on creating S&T base and not enough on industry capabilities. Public sector R&D is inappropriate and insufficiently applied for the immediate needs of most firms. There are insufficient ways of linking public and private sector innovation. Similarly, for hypothesis 2, by implementing the NSI concept in ST&I policy, Thailand has not got away from the old problematic model, and enabled progress in national ST&I development as was expected. Although there are some positive results which Thailand can learn from, Thailand needs more improvements in many aspects including the policy implementation process and the social context of the innovation process.

### **Limitations of the research and suggested further study**

This research has focussed on only one part of the Thai NSI which is the relationship between the public and private sectors and the knowledge flows between them, including the interaction with other actors and institutions in the innovation system. There were two main reasons for choosing this research focus. Firstly, as stated earlier, Thailand's ST&I development approach relied heavily on the technology push model (knowledge is created and embedded in the public sector) and therefore the process of knowledge/technology transfer is the key practice to make knowledge flow. Secondly, as a researcher working in the Ministry of Science and Technology (MOST), I have directly experienced the problems in transferring knowledge/technology among universities, RTOs, firms. As governmental staff it was also easier to have access to the information and contacts with public researchers and firms. However, I am aware that conducting the research from this perspective might cause some bias in interpretation and may have resulted in some partial information from the interviews. In this case, the official documents and formal information have been used to confirm some important data in order to make the case studies as precise as possible.

Another limitation in this research is its focus on the R&D activities and their role in public and private sector innovation. This research completely agrees on the criticism made by many scholars that R&D is not everything to say about innovation. I am aware that there are other types of innovative activity happening in the Thai innovation system but in this research I am focusing on the R&D activity because of two reasons. Firstly, as mentioned earlier I am the governmental staff working for the MOST which involved directly with S&T development and R&D activity. Secondly, the other types of innovation are difficult to measure and most of them happen in the form of incremental innovation.

Potential further research would be more investigation on the interaction and knowledge flows among firms and other actors, especially among the local firms themselves, and between local firms and TNCs, subsidiary firms and parent firms. In-depth study should be conducted to investigate the relationships among the actors and institutions. Many research questions could be asked, such as how do they build up trust among them? What changes the actors' attitudes to innovation? What is the role of public engagement in some controversial research topics and how does it shape the research direction? In some research areas or some industrial sectors, the direction of the research is shaped by societal concerns including environmental issues or cultural issues. Sometimes it is more important how the public perceives the technology than how the policy maker wants it to be. Therefore, in some cases the influential factors that determine the success of innovation system are from the bottom up level not the top down (policy) level.

In conclusion, this study presents the current NSI situation in Thailand particularly focusing on the public-private relationships through technology transfer process from 18 case studies. The result from the study suggests that in general the public-private relationship in the Thai NSI is still weak and fragmented as indicated by several previous studies. However, improvements to NSI were found in many cases, especially in success cases. The NSI policy initiated in 2002 was responsible for those improvements as it gave a guideline to involved organisations and created a new network of the NSI actors to facilitate the process of technology transfer in each case.

However, as indicated earlier in this chapter, policy is not the only aspect of creating an effect ST&I development for the country. There are other factors influencing the process. As can be seen from the failure cases, the NSI policy did not help them to be successful in technology transfer as it did for the successes. Furthermore, regarding information presented in chapter 3, all the rankings and competitiveness indices indicate that Thailand still has low level of competitiveness even after more than ten years of the NSI policy implementation. On the other hand, some might argue that the NSI policy is used as just a rhetoric gesture, and only the STI mode has been implemented in practice. As the previous studies such as Chaminade et al. (2012) and Intarakumnerd and Chaminade (2007b) suggest the NSI policy has been used only for its name and in practice the policy instruments still responds to the old paradigm: science push model of innovation.

The results from this study suggests that both claims are right to some degree. The NSI policy at some point has been used as a policy instrument to respond to the science push model (STI mode). Most cases from the case study were initiated using the STI mode

(including the success cases). However, there are some cases that later demonstrate that incorporating the DUI mode in their innovation development process lead them to success. At the same time, some failure cases followed the same policy guideline but still failed in doing technology transfer and innovation development. What is the factor that actually determines the success of the case? This is presented in the data analysis chapter in form of a combination of influencing factors and it is relevant to the individual case.

The policy plays a role in every case but it is not the only factor that determines the success in all cases. Considering the combination of the factors analysed in the data analysis section, there are several factors that the policy cannot influence or force to happen such as establishing mutual trust, influencing attitude or increasing effective communication. Therefore, the policy makers should be aware that all policies that are launched from a top down level always impact on the relationship among the actors in the innovation system. Those policies should be made carefully and they should respond to the original objectives of the policies. At the same time, an awareness should be given to the factors that come from a bottom up level as they are initiated from a social process and interaction among actors. This point concerns other responsible actors including TLO, research manager, executive staff both in public and private sector, and also the policy maker.

As it was indicated by many previous studies that Thailand has a fragmented and weak/vulnerable innovation system. However, it has the potential to improve by growing stronger and becoming more coherent:

*“if there is a significant change in the behaviour of a key actor that can cause positive repercussions among other actors. External factors that have cross-cutting effects on all actors in the system, in different degrees, may also bring change”.* (Intarakumnerd, 2006, 117)

The results of the comparative analysis of the eighteen case studies suggest that Thailand is moving to that direction. Both changes in key actors behaviour and the formation of new networks among actors of Thailand's innovation system are found in all successful cases. Although the number of failure cases outnumbers the success cases, there are positive indicators for promising developments to gain further momentum. The most important issue is to learn from insights and to apply these to increase the success rates of technology transfer projects. Consequently, this study sheds light on how effective public-private relationships can be established in order to support carrying out successful technology transfers. It intends to foreground the factors that contributed to the successful transfer of technology, and to flag those factors that impeded this process, to provide a starting point for

improved learning initiatives that can lead to higher success rates in the future. This does not mean all technology transfer cases in the future should imitate successful cases but they can be used as guidelines for newcomers. Similarly, the failure cases presented in this study also provide valuable lessons to remind others not to repeat the same mistakes.

### **Final remarks**

Concerning the policy making process in Thailand, as it can be seen from the chapter of policy analysis, the national master plan has brought the concern of the economic growth and social development into the centre of the plan. Then it has been followed by the ten-year national STI master plan to focus on the sustainable economy and quality society. This is an important movement of the policy as it does not aim to use ST&I to create only economic growth but for the better quality of the society. However, to measure the output of these goals is not easy, especially the latter one. To evaluate how the ST&I contributes to the economic growth is more general and practical since there are many indicators set up by several international organisations. Whereas in the case of quality society, there are a few indicators that can be used to indicate the output. Most of them are the qualitative indicators while in the case economic growth, it can be measured in numbers. However, many organisations at the international level are aware of this trend and try to build up effective measurement processes for the social approach. For instance, the World economic forum (WEF) implemented two more main pillars in their competitiveness ranking process including the social sustainability pillar, and the environmental sustainability pillar.

The development of ST&I cannot be only used for the economic approach but it has to be utilised and create benefits for the society. As a developing country, Thailand is trying heavily to catch up with the leader in the developed world using economic benchmarking and expecting that if it can achieve the goal it will create the prosperity and well-being for the country. This is not always the case especially when a country has disparity and a big gap of income distribution like Thailand. Even if it can achieve the goal of economic growth, it does not mean all Thai people in the country can enjoy the success. I am not saying that Thailand does not need the contribution of ST&I in its economic performance, definitely Thailand desperately needs it. But the economic growth is only one of the tools creating national prosperity and well-being. To create a real and sustainable development, it needs to look back into the fundamental structure of the society and solve the problems facing them. The development of ST&I can be one of the solutions and tools for creating sustainable development.

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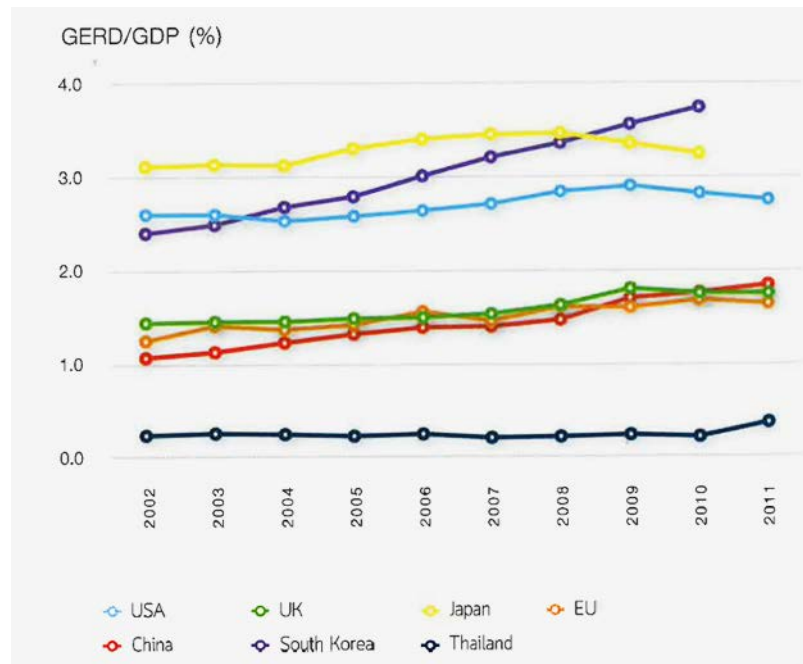
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## Appendix

### Thailand Science Technology and Innovation Profile 2014, STI

#### Gross Domestic Expenditure on R&D (GERD) to GDP (2002-2011)



Source: IMD yearbook 2013 and National Science Foundation, Science and Engineering indicators 2012 in Thailand Science Technology and Innovation Profile 2014, STI

**Global Innovation Index (GII)** co-published by Cornell University, INSEAD, and the World Intellectual Property Organization (WIPO, an agency of the United Nations, UN) provides a ranking of world economies' innovation capabilities and results.

*Innovation input sub-index* consists of 5 elements of national economy to enable innovative activities: institution, human capital and research, infrastructure, market sophistication, and business sophistication.

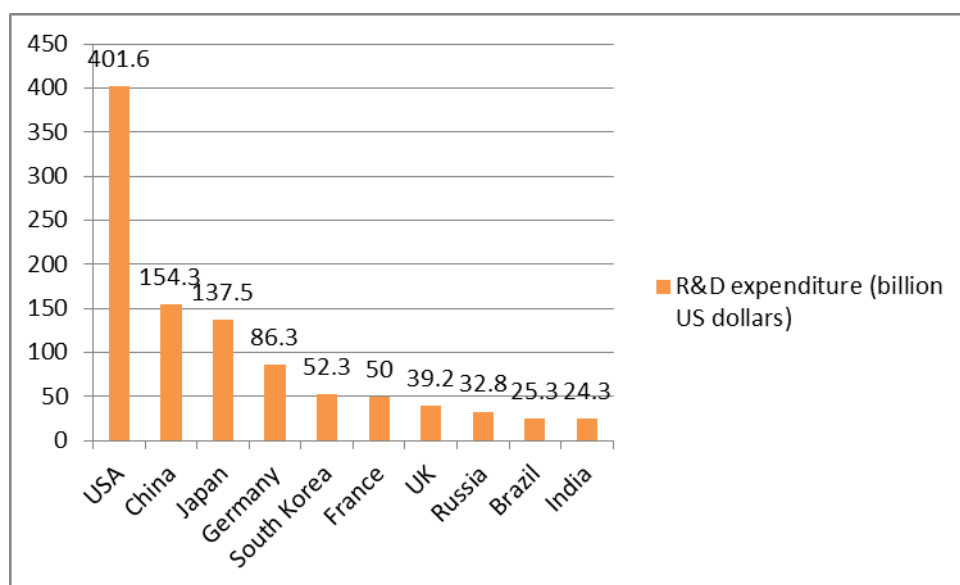
*Innovation output sub-index*; the results of innovative activities within economy: knowledge and technology outputs, creative outputs.

### Thailand's GII from 2011-2013

	2011	2012	2013
<b>Global Innovation Index (GII)</b>	48	57	57
<b>Innovation Efficiency Ratio</b>	56	61	76
<b>Innovation input sub-index</b>	48	59	57
<b>Innovation output sub-index</b>	46	56	61

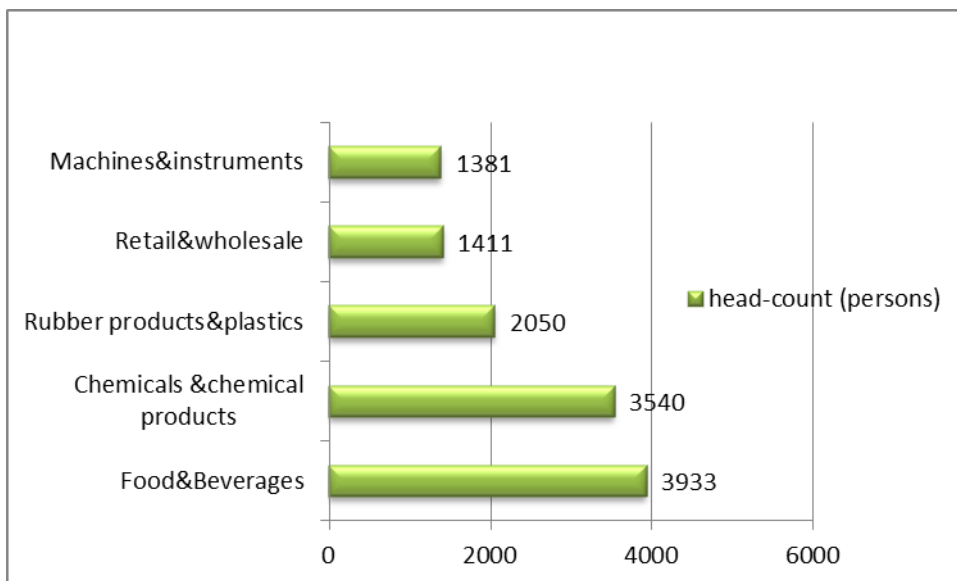
Source: Thailand Science Technology and Innovation Profile 2014, STI

### Top ten countries of R&D expenditure in 2010



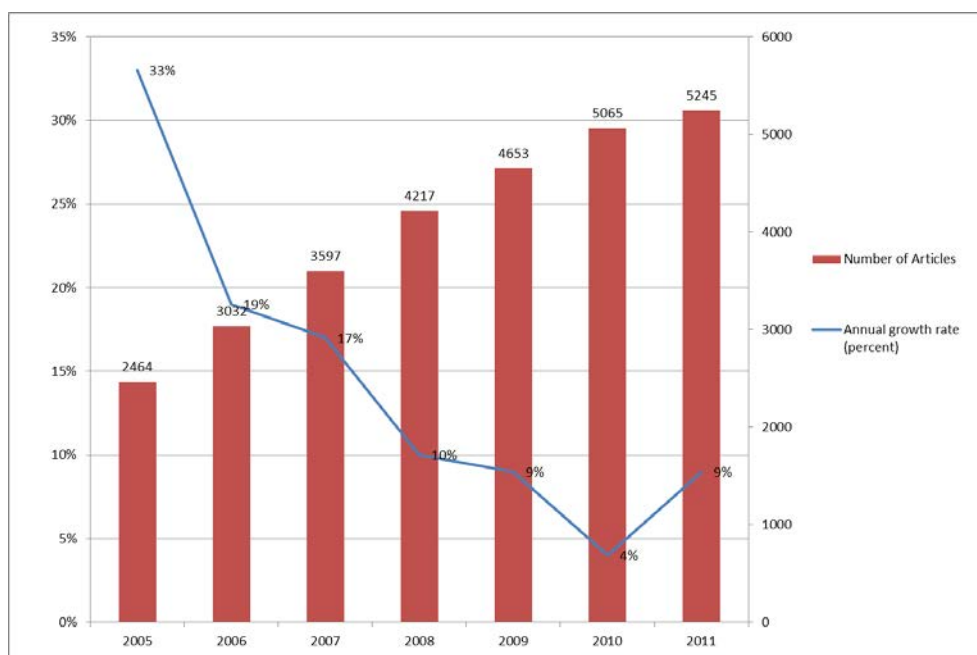
Source: UNESCO institute for statistics in Thailand Science Technology and Innovation Profile 2014, STI

### Thailand's top five industries in number of R&D personnel in 2011



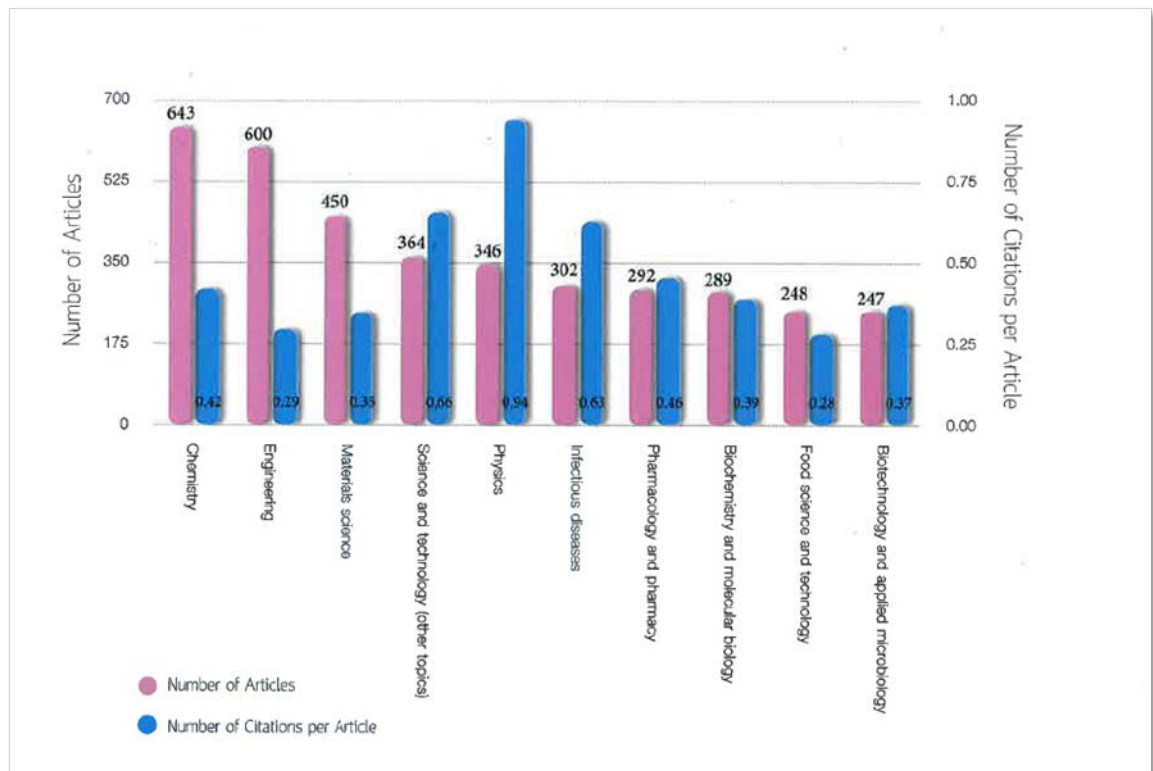
Source: Thailand Science Technology and Innovation Profile 2014, STI

### Number of publications from Thai researchers in international database (2005-2011)



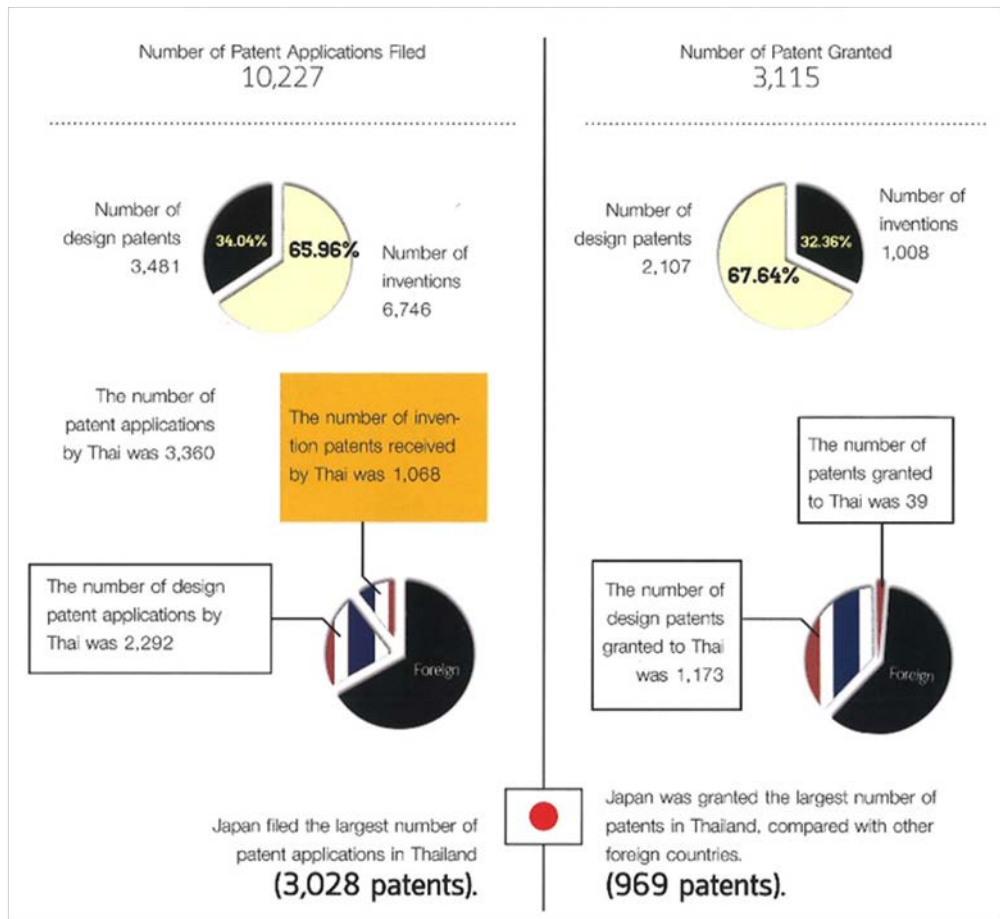
Source: Thailand Science Technology and Innovation Profile 2014, STI

### Ten subjects with highest number of publications in 2012



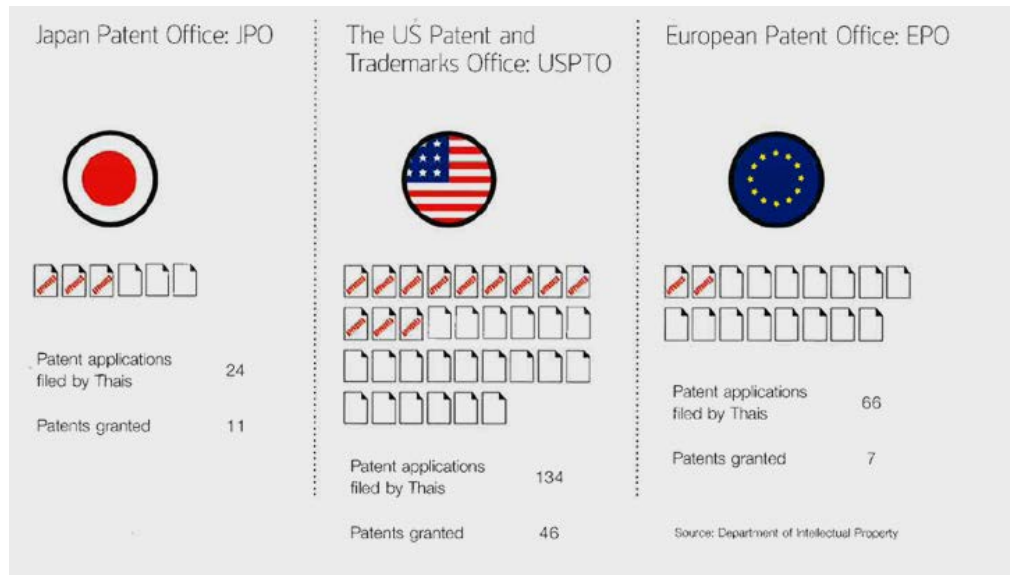
Source: Thailand Science Technology and Innovation Profile 2014, STI

## Patent Statistics in Thailand in 2012



Source: Thailand Science Technology and Innovation Profile 2014, STI

## Patents by Thais in other countries, in 2012



Source: Department of Intellectual Property in Thailand Science Technology and Innovation Profile 2014, STI

## Measurement of national competitiveness

As it has been indicated in many economic theories, the term 'innovation' is considered as one of important factors for stimulating national competitiveness. However, to enhance national competitiveness, standard criteria for measuring the level of competitiveness are needed. There are economists and international economic organisations which try to construct those criteria and apply to measure the country's competitiveness. Some of the criteria can be stated as follows:

- The World Economic Forum (WEF) regularly releases the Global Competitiveness Report every year. The country's competitiveness was measured using 12 determinants driving productivity and competitiveness. The list of 12 pillars is (WEF website, 2013):
  1. *Institutions*: Public institutions, Private institutions
  2. *Infrastructure*: Transport infrastructure, Electricity and telephony infrastructure
  3. *Macroeconomic environment*
  4. *Health and primary education*: Health, Primary education
  5. *Higher education and training*: Quantity of education, Quality of education, On-the-job training
  6. *Goods market efficiency*: Competition, Quality of demand conditions
  7. *Labour market efficiency*: Flexibility, Efficient use of talent
  8. *Financial market development*: Efficiency, Trustworthiness and confidence
  9. Technological readiness: Technological adoption, ICT use
  10. *Market size*: Domestic market size, foreign market size
  11. *Business sophistication*
  12. R&D Innovation

As the twelfth pillar, R&D Innovation has a detail for measurement as follows: Capacity for innovation, Quality of scientific research institutions, Company spending on R&D, University-industry collaboration in R&D, Government procurement of advanced technology products, Availability of scientists and engineers, PCT patent applications, and Intellectual property protection.

- International Institute for Management Development (IMD) is the international business school that launches annually the World Competitiveness Yearbook. Like the WEF, IMD

conducts the yearbook by measuring determinants influencing the country's competitiveness but different categories of the determinants. The criteria used to compute the rankings are grouped into 4 main factors divided into 20 sub-factors. (IMD website 2013)

1. *Economic Performance*: Domestic economy, International trade, International investment, Employment, Prices.
2. *Government Efficiency*: Public finance, Fiscal policy, Institutional framework, Business legislation, Societal framework.
3. *Business Efficiency*: Productivity, Labour market, Finance, Management practices, Attitudes and values.
4. *Infrastructure*: Basic infrastructure, Technological infrastructure, Scientific infrastructure, Health and environment, Education.

-The Organisation for Economic Co-operation and Development (OECD) collects data of R&D activities from its member country and some non-member country, which is launched as a yearly report. The report provides various indicators of the level and trends in total national R&D efforts. The Main Science and Technology Indicators are listed as follows (OECD, 2013):

1. Gross domestic expenditure on R&D (GERD)
2. R&D Personnel (FTE)
3. GERD by source of funds
4. GERD by performance sectors
5. Researchers (headcount)
6. Business Enterprise Expenditure on R&D (BERD)
7. Business Enterprise R&D Personnel (FTE)
8. BERD by source of funds
9. BERD performed in selected industries
10. Higher Education Expenditure on R&D (HERD)
11. Higher Education R&D Personnel (FTE)
12. Government Expenditure on R&D
13. Government R&D Personnel (FTE)
14. Government Budget Appropriations or Outlays for R&D by socio-economic objectives (GBAORD)
15. R&D Expenditure of Foreign Affiliates
16. Patents

17. Technology Balance of Payments (TBP)
18. International trade in R&D-intensive industries
19. Annex: Economic series

Having information about the measurement criteria can motivate the country to aim for enhancing those important factors influencing the development index. Although an improvement of innovation system cannot lift up the entire index, it will certainly increase some parts of the table score.

## List of research participants (interviewees)

In this study, 65 interviews were conducted for data collection. The participants are from both public organisations and private firms. The participants are listed as followed;

Private sector; Interviews with 15 companies (7 big companies, 8 SMEs) CEOs, founders and researchers (pharmaceutical, automation, medical device (material science), food and feed producers, biocontrol, bioactive compound producer, IT, software and electronics, bioenergy, vaccine producing company)

- CEO and founder; the Bio-treatment Firm
- CEO; Medical Biotech
- Founder; Bioactive Company
- Founder and researcher; IT Firm
- Founder and researcher; Medical Devices firm
- Founder and researcher; Automation firm
- Executive staff; Bio-control producer
- Researcher; Bio-control producer
- Executive staff and researcher; food and feed producer
- Researcher; chemical engineering and bioenergy firm A
- Executive staff; chemical engineering firm B
- Executive staff and researcher; R&D units, Firm D
- Firm manager; Electronics firm (TNC)
- Executive staff; Pharmaceutical firm
- Executive staff; Canned food producer

Public sector; Interviews with researchers from universities and public research institutes, experienced technology transfer and/or collaborative research with the private sector, executive staff, policy makers, analysts

- Executive staff; Board of investment (BOI), the Prime Minister's Office
- Head of Department; Tax exemption for S&T office
- Head of Department; Soft loan for S&T department
- Analyst; Soft loan for S&T department
- Executive staff; TLO, NSTDA
- Analyst; TLO, NSTDA
- Analyst; TLO, NSTDA
- Analyst; TLO, NSTDA
- Analyst; TLO, NSTDA
- Executive staff; IPR management unit, NSTDA
- Analyst; IPR management unit, NSTDA
- Analyst; Cluster and Programme management office, NSTDA
- Analyst; Cluster and Programme management office, NSTDA
- Analyst; Cluster and Programme management office, NSTDA
- Analyst; Cluster and Programme management office, NSTDA
- Analyst; Cluster and Programme management office, NSTDA
- Head of Department; NSTDA Investment Center
- Analyst; NSTDA Investment Center
- Executive staff; Industrial Technology Assistance Program (ITAP)
- Analyst; Thailand Science Park (TSP)
- Executive staff; Business Development Unit, BIOTEC
- Executive staff; Business Development Unit, MTEC
- Executive staff; Business Development Unit, NECTEC

- Analyst; Business Development Unit, NECTEC
- Analyst; Business Development Unit, NECTEC
- Executive staff; Business Development Unit, NANOTEC
- Analyst; Business Development Unit, NANOTEC
- Analyst; Business Development Unit, NANOTEC
- Executive staff and senior researcher; BIOTEC
- Executive staff and senior researcher; BIOTEC
- Executive staff and senior researcher; NECTEC
- Executive staff ; NANOTEC
- Senior R&D researcher; NANOTEC
- R&D researcher; BIOTEC
- R&D researcher; collaborative unit BIOTEC and King Mongkut's University of Technology Thonburi (KMUTT)
- R&D researcher; BIOTEC
- R&D researcher; NECTEC
- R&D researcher; NANOTEC
- R&D researcher; NANOTEC
- R&D researcher; NANOTEC and Chulalongkorn University
- R&D researcher; MTEC
- R&D researcher; MTEC
- Researcher and lecturer; King Mongkut's Institute of Technology Ladkrabang (KMITL)
- Researcher; Mahidol University

- Policy maker; Office of National Economic and Social Development Board (NESDB)
- Policy maker; NSTDA
- Executive staff; National Science Technology and Innovation Policy Office (STI)
- Executive staff; National Science Technology and Innovation Policy Office (STI)
- Policy maker; National Science Technology and Innovation Policy Office (STI)
- Policy maker; National Science Technology and Innovation Policy Office (STI)

## List of questions for interview

### For firms

1. Could you give me a brief idea about innovative/R&D activities in your point of view?
2. Do you have those kinds of activity in your organisation?
3.
  - 3.1. If so, how do you perform your R&D activities? (in-house R&D/outsource/etc.)
  - 3.2. If not, do you have any particular reason not doing R&D activity in your organisation?
4. What kind of R&D activity do you do in your organisation? Could you give me some example, if possible?
5. Have you ever contact or collaborate with public sector such as government lab unit or university?
6. If so, what is your opinion on collaboration with the public sector?
7. In your opinion, what is the critical factor that determines the success of the collaborative case?
8. What is the benefit that you can get from the collaboration with the public sector?
9. Are there any particular points/skills that the public sectors still lack of when doing the collaborative project influencing the effectiveness of public-private relationship?

### For public organisations

1. What is your idea about public and private sector in R&D collaboration?
2. Do you have any experience collaborate with the private sector? If so, what kind of activity have you done?
3. Could you tell me the story about that case, if possible?
4. In your opinion, what is the critical factor determines the success of the collaboration?
5. Do you think there are some things that firms still lack of and needed to be fulfil to complement the process of public-private relationship in R&D activity?
6. In vice versa, are there any things that the public side needs to be improved or fulfilled in order to facilitate the success of relationship?

## Consent Form

*Interview: Public sector R&D and innovation in an emerging country: An analysis of technology transfer and linkages between public and private sectors in the Thai National System of Innovation*

I am conducting this research as part of my PhD thesis in Science and Technology studies, Graduate School of Social and Political Sciences, the University of Edinburgh. I am inviting you to participate in my study. The purpose of the study is to investigate the relationships between actors in Thai NSI and identify gaps within these interactions by focusing on university/research institute and private sector interaction. This study involves doing interview and will take 60 minutes.

**Your participation is completely voluntary. You may withdraw from this study at any time without penalty.**

All information obtained in this study will be kept strictly **confidential**. All participants will be asked not to disclose anything said within the context of the discussion. All identifying information will be removed from the collected materials, and all materials will be secured so it is accessible only to the researcher. The record material and transcript will be deleted after the course marked or end. *Your name will be not disclosed in any place of the transcript and the report.*

I also understand that my words may be quoted directly. With regards to being quoted, please initial next to any of the statements that you agree with:

	I wish to review the notes, transcripts, or other data collected during the research pertaining to my participation.
	I agree that the interview may be electronically recorded.
	I agree to be quoted directly.
	I agree to be quoted directly if my name is not published (I remain anonymous).
	I agree to be quoted directly if a made-up name (pseudonym) is used.
	I agree that the researchers may publish documents that contain quotations by me.

**By signing this consent form, you are indicating that you fully understand the above information and agree to participate in this study.**

**Participant's signature** \_\_\_\_\_

**Date:** \_\_\_\_\_

**Researcher's signature:** \_\_\_\_\_

**Date:** \_\_\_\_\_