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From the Triple Helix Model (THM) to an Actor Flow Model (AFM)

Two Case Studies on the Co-Creative Evolutionary Relationship Between Universities, Industry, the Government, and a Research Institute in Taiwan

Huang, Chia-Pin

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Chia-Pin John Huang

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I can do all things through Him who strengthens me (Philippians 4:13).

Summary of Research Topic

Title:

From the Triple Helix Model (THM) to an Actor Flow Model (AFM):

Two case studies on the co-creative evolutionary relationship between universities, industry, the government, and a research institute in Taiwan

Abstract:

The need for collaboration among different institutional actors including, universities, industry and governments, in national innovation systems, has been championed by the creators of the Triple Helix Model (e.g., Etzkowitz and Leydesdorff, 1995). However, these authors played down the importance of research institutes in these interactions during the evolution of innovation. Moreover, although under the THM it is accepted that there are flows of resources between actors, this has yet to be comprehensively conceptualised. To address these issues, in this research the THM is extended to a model that not only includes the role of research institutes, but also allows for examination of the energy flows during successful innovations, involving: human, knowledge, money and physical resources, entitled the Actor Flow Model (AFM).

Further, central to this concept of 'flow', an evolutionary perspective of inclusionality (Huang, 2010) is posited as a possible enhancement of the innovative process. This is a new evolutionary perspective conceived by Rayner (2006, 2010), a micro-biologist, who found that the evolution of the mycelia and other natural phenomena are not driven solely by competition, as Darwinists forecast, but by the facilitation of dynamic energy flows and their mutual influencing relationships across space. That is, central to this aspect of the thesis is the notion of interdependency between parties in

the innovatory process.

This model is then applied to case studies of two inventions in Taiwan that involved collaboration between the four aforementioned actors to show how its constructs offer an improvement on the THM, regarding its explanatory power for successful innovations. The two focal inventions originate from different technological fields: biomedical and optoelectronics.

A further element that this thesis shows is that the language used needs to change in order to generate an inclusional and transformational journey. The language used in this narrative changes with the development of my epistemology.

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Chapter 1 Introduction

1.1 Introduction

Today's universities are facing substantial pressures, both in terms of accountability in relation to government public funding and demands from society at large. They are expected not only to provide education and conduct scientific research, but increasingly the aforementioned stakeholders are requiring them to play an active role in economic development, in what has been called "the third mission" (Etzkowitz et al., 2000; Laredo, 2007; Readings, 1996) or the "second academic revolution" (Etzkowitz, 2003). Furthermore, with public funding for universities in many countries no longer growing and even declining in some cases, as a result of austerity programmes meted out in response to economic recession, they have to find new ways to create new resources to support themselves as well justifying continued governmental support. In sum, universities are increasingly recognising that they need to engage more with the external environment, if they are to continue to flourish during the next century. In response to such demands new missions have emerged in the sector, which scholars have variously termed: academic capitalism, the entrepreneurial university, and academic entrepreneurship.

1.2 Academic capitalism, the entrepreneurial university, and academic entrepreneurship

The term academic capitalism originated from Slaughter and Leslie (1997; 2001; 2004), when they observed market or market like behaviour in some faculties of universities in the: United States, Australia, the UK and Canada, involving such activities as: profit making, filing for patents, licensing, industry-university collaboration, spin-offs, new curricula and so on. Given this behaviour resembling that of capitalists in markets aimed at generating revenues and competing with others, Slaughter and Leslie (ibid) called the phenomenon “academic capitalism”. However, in most of these cases the main motivation for collaborating with industry has been so as to increase research funding for university based projects rather than for gaining profit (Shinn and Lamy, 2006). Similarly, after carrying out a multiple case-study of five universities in: England, the Netherlands, Scotland, Sweden and Finland, Clark (1998a; 1998b; 2001) coined the phrase “entrepreneurial universities” (Clark 1998b, p.5), where demand from outside has driven them to change their physical facilities, faculties and even their curricula. In addition, they have also adopted new strategies for enlarging the student body, such as long distance learning and new structures, e.g. cross-discipline research centres. These efforts are aimed at developing an entrepreneurial culture to supplement public funding.

Lastly, with respect to academic entrepreneurship, Franzoni and Lissoni (2009) and Shane (2004) have suggested that certain start-ups based in universities are more viable than licensing academic patents to existent firms. This is because even if a university has a scientifically proven concept, the tacit knowledge and know how is not going to come purely by transferring the idea to industry for licensing and hence, academics are required for the product development stage. That is, in such cases academic ventures are a better alternative than commercializing the invention (Audretsch and Stephan, 1999; Thursby et al., 2001; Thursby and Thursby, 2001) and Shane (2004) have argued that in a few exceptional situations a start-up may be the only viable option for commercializing the subjective knowledge of the researcher, which is especially so when the technology transfer involves tacitness and a strong scientific knowledge base (Lowe, 2006). Moreover, Zucker and his associates (1999) elicited that the particular technological field has a bearing on whether academics are central to a firm's innovative activities, citing that bio-tech companies are more successful if they involve academic researchers on their scientific boards or as stakeholders. No matter whether it is called academic capitalism, entrepreneurial university, or academic entrepreneurship, all carry the same message: universities have to be more entrepreneurial and/or innovative as well as working collaboratively with the other sectors of society.

1.3 Universities in the knowledge society and the triple helix

The increasing role of knowledge economics in today's high technology environment puts universities in a potentially strong position to exploit opportunities, as knowledge creation is central to their operations. In particular, they are being encouraged to deliver more applied oriented knowledge to solve problems in the real world, being referred to as mode two, in contrast to mode one knowledge, which is about creating knowledge purely for academic interest (Gibbons, 1994). To assist this adaptation regulations have been introduced (e.g., the Bayh-Dole Act in 1980 in the US), which allow universities to commercialize their government funding research and development by licensing and creating spin-offs.

The experience of MIT in the US has shown how higher education institutions can play a key role in regional economic development through innovative collaborations with government and industry (Nelson, 1993). This notion could be extended to the national level by governments creating networks that link those involved in such projects and passing laws that facilitate the operationalisation of their outcomes (Lundvall, 1992). Amongst the researchers studying national systems of innovation (NSI), Leydesdorff and his associates (Leydesdorff and Etzkowitz, 1996; 1998) have been advancing the triple helix model as an effective strategy for integrated university-industry-government collaboration that can contribute to better economic development. In particular, Etzkowitz (1994) drew on the experiences of some outstanding American universities, such as MIT as mentioned above, to support the contention that such collaboration provides an effective path to innovation. Later he and Leydesdorff (Etzkowitz and Leydesdorff, 1995; Leydesdorff, 2000) claimed that the triple-helix is a co-evolutionary model, which fulfills the predictions of natural selection.

Nonetheless, the triple-helix model fails to explain the development trajectory of newly emerging industrialized countries in East Asia, such as South Korea and Taiwan, where universities have been playing a rather limited role in the initial development of industries. For example, the establishment of the semiconductor industry and its related knowledge acquisition, both in Korea and Taiwan, was brought about by a collaboration between industry and a research institute that received assistance from the government (Chang and Hsu, 1998; Kim, 1997), whereas the universities' roles in these two nations were confined to delivering the underpinning knowledge for engineering the semiconductors. In sum, although in these cases three actors were involved in the innovation, they were not the same as those identified in the triple helix model and hence it fails to provide comprehensive explanatory power for these two contexts in their chosen road for developing an NIS. Therefore, in this thesis, this researcher will modify the THM model by introducing other actors involved in innovations.

1.4 Evolutionary models suffer from problematic Darwinism

Another implicit issue related to the triple helix and most other developmental models is it that they accept the basic tenets of Darwin's evolution theory. In particular in this regard, the NSI proposed by Nelson and Winter (Nelson and Winter, 1982; Nelson and Winter, 2002) drew on evolutionary economic theory which in turn was founded on Darwinian thought. That is, they applied 20th century advances in genetics to argue that organizational routines are equivalent to the genes in the human body, as a basis for improving understanding of economic evolution. More specifically, from their perspective organizational routines include the way organizations sense the environment, perceive opportunities, respond to external stimuli, renew themselves and even acquire new routines. Further, the performance of an organisation is correspondingly thought to be largely determined by the effectiveness with which it acquires organizational routine variation, internally or externally and executes it to compete with other organizations. Consequently, under this lens the rule is the fittest survive as put forward by Darwin in his theory of natural selection. However, the effectiveness of Darwin's evolution theory has been widely challenged by some biologists and ecologists. For instance, Eldredge and Gould (1972) showed that climate change during the last ice age did not lead to a macro-evolutionary change as Darwin's theory would predict. Furthermore, Kauffman (1993) summarized eight criticisms of Darwinism and Neo-Darwinism, including the weakness of the circular and distructive concept of natural selection. Therefore, it is posited that new theory needs to be developed that takes into account positive aspects of interactions between parties involved in innovatory activities.

1.5 Natural inclusionality brings energy flows as the focus to evolutionary theory

In response to the above identified need for a new approach to understanding innovation, in this research a recent new perspective on evolution, that of natural inclusionality is adopted in favour of Darwinian theory as an extension of the triple helix model. The concept of natural inclusionality or inclusionality was promoted by Rayner (Rayner, 1997, 2006a, 2010, 2011; Rayner et al., 1999) after he investigated the evolution of mycelia and struggled to find a theory to explain their development and he concluded that energy seeking, retention and management are key driving forces behind evolution. He suggested that natural inclusionality is " a new .. understanding of evolutionary process,… … as *the co-creative, fluid dynamic transformation of all through all in receptive spatial context*, allows all form to be understood as *flow*-form, distinctive but dynamically continuous, not singularly discrete" (Rayner, 2011, p.161). Consequently, he proposed that energy flow is central to the evolutionary process in that the development and decay of species is determined by the abundance or deficiency of the energy available. In addition, he highlighted the fact that the boundaries between entities are fluid rather than fixed. Therefore, this perspective offers a new avenue for innovation studies away from the conventional one regarding boundary management issues and even the more recent Darwinian evolutionary approach. In this study, the concept of energy flow from inclusionality is adopted. Moreover, Forrester's (1961) concept of resource flow in his industrial dynamic model is drawn upon to investigate the directional movement of human resources, knowledge, money, material and physical flows between actors involved in innovative collaborations.

In sum, the aim of this thesis is to extend the THM approach to include additional potential actors in the study of innovations as well as devising a system for analysing the dynamic flow of resources between partners involved in such activities, from invention through to commercialisation. The devised model is to be tested through case study analysis of successful innovations. Moreover, as will be explained in chapter 3, a validation process through three lenses, i.e. triangulation, peer debrief, and audit trial (Creswell, and Mille, 2000; Lincoln and Guba, 1985), is also adopted to verify the case study as well as the analysis. In particular, two validation meetings are held to serve as two sessions of an audit trial.

1.6 Outline of this research

This thesis is arranged as follows. In chapter 2 there is a literature review, which covers the micro and macro aspects of innovation theory. This is followed by consideration of the relevance of evolutionary theory to economic contexts, which leads to consideration of the biological concept of natural inclusionality as a possible improvement on extant theory. In chapter 3, drawing on the inclusionality perspective a framework for probing innovatory activity is constructed and the rationale for the methods adopted is provided. In addition, aresearch questionis put forward in this chapter. Chapter 4, the first empirical chapter, presents two collaborative innovation cases in Taiwan, in particular, in terms of illustrating their evolution histories. Chapter 5 compares the effectiveness of the new framework and the THM for capturing the evolutionary trajectory of the focal innovations. The key distinction between these two approaches is borne out by the subsequent detailed energy flow analysis that is possible under the new framework, but not under the THM. In addition, the outcomes of two validation meetings are reported to strengthen the credibility of the case studies and to enhance the analysis. Chapter 6 contains further discussion on the research tool and what the implications of the outcomes from its application are for the Taiwanese national innovation system as well as for higher education institutes. Chapter 7, in line with action research, sets out the learning journey covered whilst engaging in this research.

Chapter 2 Literature Review

2.1 Introduction

This chapter is mainly devoted to consideration of the relevant theories and debate surrounding an evolutionary innovation model, the triple helix model (THM). More specifically, to begin with, a review is conducted of the various definitions of innovation and their sources. Next, owing to the THM being put forward as one example of a national system of innovation (NSI), three major strands of such systems are discussed. Subsequently, the underpinning theory of the THM is explained and some of its limitations highlighted. In order to address these limitations, the concept of natural inclusionality proposed by Alan Rayner (2004, 2010), a microbiologist, is introduced as offering a means of enrichment of this model. Central to his reasoning is the role of energy flow for growth and sustainability and as will be demonstrated this can be transferred to the field of innovation to enhance understanding of how to mobilize resources so that innovatory projects result in successful commercialization. Next, by drawing on Forrester's (1961) industrial dynamics model the nature of the appropriate resources is identified for further consideration when building the modified THM model in chapter 3.

The literature in the innovation field is quite vast, and although the focus in this chapter is on national innovation systems and the triple helix model, it is important to outline other perspectives on the matter. Regarding these, some have been concerned with explaining the mutual interactions between technology and social behaviour, e.g. Actor–Network Theory (ANT) (Latour, 1987, 1991, 2005), whilst others have sought to understand the links between socio-technical regime and multiple-level innovation (Kemp, 1994; Kemp et al., 1998; Kemp and Rotmans, 2001). Another crucial branch referred to as the techno-economic paradigm was developed by scholars, such as: Abernathy and Utterback (1978), Nelson and Winter (1977), Dosi (1982) and Freemand and Perzes (1988). They investigated the evolution of technology paradigms to shed light on the interrelationships between the: adoption of technology, scientific community, and the economic conditions. Others have considered national business systems (Whitley, 1994) in terms of the ways firms are influenced by the countries in which they are located (e.g. owing to the regulations, laws and culture) and how the technology innovation system is influenced by the specific institutional structure. However, for this research the focal interest is on the evolution of the innovation process and the dynamic interrelationships between different institutional actors (e.g. universities, industry, and government) in developing and newly developed countries, such as Taiwan. Consequently, the theories emanating from these other investigations are not considered further in this thesis.

2.1.1 What is innovation?

Schumpeter (1934) was one of the pioneers in defining innovation denoting it as being the source of 'creative destruction', which can range from new offerings (products and services) to new technology, new raw materials or components, new markets and new ways of organizing. However, the definition of innovation has been unclear (Adams et al., 2006) and when a content analysis of innovation literature was conducted by Baregheh (2009) using on-line databases and key journals, such as: Management Science, Organization Science and Administrative Science Quarterly. He discovered 60 different definitions of, with the most frequently repeated word being "new". For example in this respect:

> Innovation concerns processes of learning and discovery about new products, *new* production processes and *new* (emphasized by the author) forms of economic organization, about which, ex ante, economic actors often possess only rather unstructured beliefs on some unexploited opportunities, and which, ex post, are generally checked and selected, in non-centrally planned economies, by some competitive interactions, of whatever form, in product markets (Dosi, 1990, p. 299).

The other common words after "new" were: "product", "organization", "service", "process" , "idea", "development", "invention" and so on. Baregheh (2009) further analysed these 60 definitions using NVIVO software and classified innovation processes in terms of their: natures, stages, social entities, means, types and aims (ibid, p.1333) and subsequently summarized these into a comprehensive diagrammatical definition as shown in diagram 2.1 below.

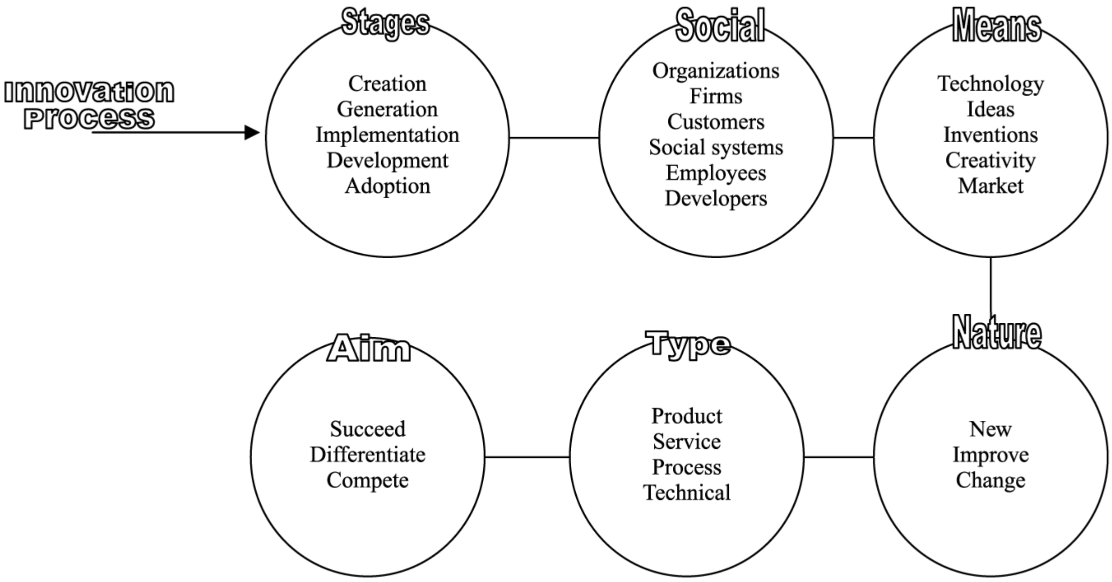

Diagram 2.1 Baregheh's diagrammatical definition of innovation

Source: Baregheh (2009, p.1333)

Not every innovation has all the above features, but regarding the top three circles, innovative activities will involve in multiple combinations of their contents. However, for the bottom three circles their contents are more likely to be mutually exclusive. That is, for example, usually only one of new, improve and change is integral to a particular innovation endeavour. Another misunderstanding of some scholars, such as Duncan, is that invention is the same as innovation (Duncan, 1972). However, most scholars agree that invention is the seed of innovation (e.g., Cooper, 1998; Drucker, 1984; Kahn et al., 2003). In other words, invention is just one part in the creation process of innovation. This perspective is found in the definitions of invention and innovation put forward four decades ago by Utterback (1971):

> An invention is an original solution resulting from the synthesis of information about a need or want and information about the technical means with which the need or want may be met… Innovation…refers to an invention which has reached market introduction in the case of a new product, or first use in a production process, in the case of a process innovation (Utterback, 1971, p.71).

A good invention is not necessarily a good innovation. The major difference between invention and innovation resides in the fact that the latter can realize its value to the market. That is, without the successful introduction of a product to the market (or service) or the introduction of a new process to production and further successful commercialization, invention will not become innovation. Regarding this, a survey found that at least one third of the many products launched in the market during 1990 failed to achieve sustained viability (Cooper, 1994). Moreover, Dosi (1990) argued the process of innovation is a value-added process as it passes through: discovery, learning, and implementation. Extending this perspective, it becomes apparent that successful commercialization is a central element of effective innovation. In sum, innovation is about exploring new possibilities whose potential value can be realized by exploiting existing knowledge and other resource stocks (March, 1991).

McFadzean (2005) effectively drew on the above elements when he wrote:

> Innovation can be defined as a process that provides added value and a degree of novelty to the organization and its suppliers and customers through the development of new procedures, solutions, products and services as well as new methods of commercialization (Mc Fadzean et al., 2005, p.535).

Hansen and Birkinshaw (2007) put forward innovation as a value chain process which involves: generation, conversion and diffusion. Regarding the foremost, three different functions were identified: sourcing the idea from the internal project team, cross team or divisional pollination, and input from outside the organization, as shown in table 2.1.

Phases	Idea Generation			Conversion		Diffusion
Functions	In-house sourcing	Cross-pollination	External sourcing	Selection	Development	Spread of the idea

Table 2.1 Innovation value chain

Adapted from: (Hansen and Birkinshaw, 2007, p.124)

One much cited definition of innovation fitting with this view was put forward earlier by Damanpour (1996). More specifically, he introduced a holistic definition that takes into account both internal and external drivers, as follows:

> Innovation is conceived as a means of changing an organization, either as a response to changes in the external environment or as a pre-emptive action to influence the environment. Hence, innovation is here broadly defined to encompass a range of types, including new product or service, new process technology, new organization structure or administrative systems, or new plans or programmes pertaining to organization members (Damanpour,1996, p. 694).

In other words, from this it can be seen that the author views the dynamic mutual co-evolution of the organization and the environment as being at the centre of the innovation process. Moreover, unlike an invention, which can simply involve researchers, a successful innovation involves a range of different efforts aimed at changing the organizational process and environment. A typical example of an innovative activity is Edison’s light bulb, whereby although he invented it he had to acquire help from policy makers and others to establish an electricity network, some new regulations, new infrastructure to diffuse his invention as well as needing skilled marketing to ensure that it was widely adopted (Hargadon and Douglas, 2001; Israel, 1998).

These perspectives on innovation as being a process that combines invention, value creation and successful commercialization have also been supported by practitioners, such as the chairman of the Stanford Research Institute (SRI), Dr Carlson (2006). However, this somewhat neoclassical view of the process has been criticized for ignoring the social impacts of innovatory activities, i.e. the increasingly important field of social innovation and social entrepreneurship (Martin and Osberg, 2007; Mulgan et al., 2007). For example, the invention of micro-loans in form of the Grameen Bank of Bangladesh, pioneered by the Noble Peace Laureate, Muhammad Yunus, allowed the poor to start their own businesses and consequently changed their economic situation for the better (Elahi and Rahman, 2006).

Drawing on the above discussion, for this research a working definition of innovation is proposed as:

> Innovation is the process through which new and useful products, services, and/or technology are invented then with effort and energy are organised internally and externally to respond to the needs of the environment as well as shaping it, thus leading to commercialization in the market and/or sustainably creating value to society.

That is, this working definition not only includes the initial invention, the effective internal organization and external network to draw upon and exploit the energy or resources, but also contends that successful commercialization results from the evolutionary management of the innovation, organization, and the environment. Moreover, it also addresses the recently highlighted essential aspect put forward by both academics and practitioners in the field, that of social innovation (Deiglmeier and Miller, 2008; Mulgan et al., 2007).

With regards to the sources of innovation, as cited above, Hansen and Birkinshaw (2007) pointed out that good innovative ideas can originate from in-house, cross-unit or external sources. In relation to the foremost, commercialization has been widely studied by scholars (e.g. Amabile, 1998; Amabile et al., 1996; Csikszentmihalyi, 1997) and it has generally been concluded that the rate of success is determined by the level of creative thinking capabilities, expertise and the motivation of the individual and the group (Amabile, 1998). Next, well conducted cross-unit collaboration can yield fruitful sources for innovation brought about through the amalgamation of different knowledge or technologies, which result in novel synergies for the organization. One example of this is GE capital, which became one of the largest businesses in GE by forging links between its consumer business (e.g. refrigerators), which not only involved providing finance that previously had been the role of external lenders, but perhaps more importantly, meant that they were directly linked to the production side and hence, increased their knowledge of loan and mortgage, which resulted in effective connection with other business units such as the power plant and engine business (Eisenhardt and Galunic, 2000; Sethi et al., 2002).

Moreover, these types of organizational efforts can involve actors beyond the organizational boundaries, such as users and customers (Von Hippel, 1976, 1988), suppliers (Pavitt, 1984) and other companies from other industries, as external sources for innovation. Von Hippel (1976) found that 80 percent of successful innovations in the scientific instrument field involved the users being consulted during the: invention, test or prototype stages and he termed these forms as ‘user dominated’ innovations.

Similarly, Rosenberg (1982) stressed that the users' experience is crucial in developing the technology, through the process he entitled 'learning by using' and Lundvall (1988) further suggested that the interactions between producers and users represented important learning experiences when developing new products. Regarding suppliers, Schiele (2006) argued that they are often the most innovative entities, for they can be: specialist, technically competent, export-oriented, and located near to the user as well as enjoying a high trust relationship. One example of a supplier driven innovation can be seen in the Toyota hybrid car, the Prius, which would not have been possible without Panasonic's (the supplier) cooperation in helping develop the Lithium battery for these cars (Morgan and Liker, 2006).

Companies providing complementary technologies and infrastructure can also be crucial for the innovators, for they can provide the necessary infrastructure, marketing and/or enabling factors that allow for an innovation to come to fruition (Teece, 1986). For instance, again, Edison's invention of the light bulb required the setting up of an electricity network so that households could use it. That is, this great invention would have been useless if the users had had no access to a supply of electricity (Israel, 1998). In addition, universities and technology research organizations (or national laboratories), which generate new scientific knowledge, can also be important sources of innovation and their importance varies according to the field of interest (Barbro et al., 1979; Lundvall, 2007b; Mowery and Sampat, 2005). That is, in fields where innovation is driven by basic scientific research there is a heavy reliance on the inputs from universities, for example, in the biotechnology and computer science fields (Mowery et al., 2001; Zucker and Darby, 1996). With regards to this, a European Community Innovation Survey (Funda Celikel-Esser et al., 2007) of 27 EU countries elicited that 42 percent of companies in this region cooperated with other firms or institutions, of which HEIs or universities accounted for 9 percent. Moreover, many universities are providing services other than education and research, especially knowledge exploitation, by licensing technology and collaborating with the industry (Wissema, 2009). That is, nowadays they are conducting more inter-disciplinary research (Mode 2 knowledge) so as to solve the problems of the real world rather than pure scientific or academic research as previously (Etzkowitz and Leydesdorff, 2000; Gibbons, 1994).

The network study of innovation can be mainly contributed to Rothwell (1992) who reviewed the previous industrial innovation models, from 'technology push' in the 1960s, to 'needs pull' in the 1970s as well as a coupling model to meditate technology and need in the late 1970s, arriving at the new generation of the 'strategic integration and networking' perspective, which it is generally agreed represents the current prevailing innovation model (e.g. Ring and Van de Ven, 1994). With this most recent approach, it is accepted that in order to commercialize an innovation successfully, the development team needs to seek out any expertise and resources which they lack (Brown and Duguid, 2001; Freeman, 1991; Nuvolari, 2004) and to divide labour effectively across the network (Saxenian, 1991).

Birkinshaw et al. (2007) offered a taxonomy based on two dimensions to categorize four different approaches to building an innovation network. The first concerns the degree of ease there is to find a potential collaborator, and the second is the willingness of the collaborator to engage, as illustrated in the diagram below.

Building relationships with unusual partners	Moving into uncharted territory
Creating new networks in proximate areas	Seeking out new networks in distant areas

Diagram 2.2: Four different approaches to building an innovation network

Adapted from: (Birkinshaw et al., 2007, p.72)

The four different identified scenarios that innovative organizations are faced with determine their modus operandi when instigating new projects, i.e. the alternatives for which can be seen in the four boxes. Regarding these, the low hanging fruit in relation to establishing relationships with people in an adjacent field or area who are eager to cooperate with the organization are depicted in the first window on the left. Segment 2 refers to finding partners who are at a distance: geographically, institutionally, or sometimes for ethical reasons. For example, Procter & Gamble initiated a "Connect and Develop" strategy that allowed them to scout out a Japanese stain removing sponge in 2001 that they subsequently introduced to their product range as Mr Clean Magic Eraser. This initiative is also a typical 'open innovation' case, a concept that is discussed in detail in the next paragraph. In segment 3, an organization that is seldom worked with, but easy to access, can contribute valuable ideas and insights, such as a biomedical company becoming involved with doctors, nurses and patients in a hospital so as to develop more user-friendly bio-medical equipment. In this regard, Novo Nordisk launched a "Diabetes 2020" project in 2003, which led to the formation of the Oxford Healthy Alliance, comprising: themselves, doctors, nurses, patients, and government officials, with the aim of preventing or curing diabetes. Working in accordance with segment 4 it is necessary to approach those belonging to both segments 2 and 3. That is, it requires engaging with people that an organization does not usually collaborate with and is also at distance in some respect. One typical example is the public broadcasting company, the BBC, which launched a backstage programme to allow internet programmers and service developers to use the media contents in its database through its website, so as to create their own services, with the invitation to: “make your stuff out of our stuff” (ibid, p. 77).

Another crucial development when theorizing networking is that of open innovation proposed by Chesbrough and his associates (Chesbrough, 2003b, 2003c, 2006; Christensen et al., 2005). Regarding this, Chesbrough (2003a) examined the spin-offs of Xerox’s PARC Laboratory, and found that the developers had to find complementary resources from outside of the company in order for its new innovations to be successful. Further, in an extension to this view these authors used their findings to promote a bolder model, called ‘open innovation’, where they not only advocated cooperation among different actors within a network, but also stressed the efficacy of internal organizational innovations being commercialized outside the company and external ***ideas*** being commercialized within the firm, as appropriate. As well as in industry, increasingly, universities are becoming aware of the importance of networking, in particular, by trying to create a global network of knowledge so as to be able to benefit from it (King, 2011).

National innovation systems study has spread to many countries (Carlsson, 2006), for it is crucial in the understanding of how micro actors, such as universities, can generate macro performance, such as national innovation performance. In the next section, the different concepts of national systems of innovation are explored and subsequently the triple helix model related to NSI is probed in some detail. In addition, there is consideration of the evolution of innovatory projects, with the aim of eliciting their limitations for investigating modern innovative activity.

2.2 National systems of innovation (NSI)

The concept can be traced back to the 19th century when a political economist, Friedrich List (1841), used the term national production system, arguing that Germany was underdeveloped and increasingly falling behind England, because the latter had adopted Adam Smith's 'invisible hand' free market policy that allowed the market to decide the future of domestic industry. List (ibid) suggested that the government should invest in infrastructure, knowledge acquisition and its exploitation. He also contended that the government needed to protect indigenous infant industries so they could grow sufficiently to compete with firms in England.

However, the term of "system of innovation" was firstly used in only about two decades ago by Freeman (1987, p.1). It subsequently received great attention from both scholars and practitioners at the national level (Freeman, 1987; Edquist, 1997, 2005; Fagerberg and Srholec, 2008; Freeman, 1987; Lundvall, 1992, 2007; Lundvall et al., 2010; Nelson and Rosenberg, 1993; Niosi et al., 1993; OECD, 1997; Patel and Pavitt, 1994), the regional level (e.g. Malerba and Orsenigo, 1997; Malerba, 2002), the sector level (e.g. Asheim, 1988; Braczyk et al., 1998; Cooke, 2001) and at the company level (e.g. Granstrand, 2000).

Freeman (1987) pointed out that the strong economic development of Japan could be attributed to the fact that the government worked with large domestic companies by building new institutions and mechanisms for advancing their technical innovation. That is, he highlighted "the network of institutions in the public- and private-sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987, p.1). However, innovation development is not just about technology innovation, for it also concerns: institutional arrangements, incentive mechanisms and core competences that facilitate innovatory activities in a particular country (Patel and Pavitt, 1994). Further, national economic performance relies on the performance of industries (Lundvall, 2007a) and therefore for there to be an effective NIS, there has to be robust interaction between enterprises with other knowledge infrastructure, such as universities, research organizations, and governments. In the longer term, knowledge infrastructure can co-evolve with companies to generate sustained positive economic outcomes.

2.2.1 Three Strands of National Systems of Innovation

Taking the many different perspectives on national systems of innovation into consideration, Lundvall (2010) summarized them into three different strands according to the different aspects being considered. First, drawing on Freeman's (1987) standpoint, there were those scholars like Lundvall (1983), Nelson and Rosenberg (1984) and Niosi et al. (1993) who proposed that NSI should refer to the institutional arrangements that this entails, regarding both the components and the interrelationships. Moreover, Lundvall (1992, p.2) argued that NSI refers to "the elements and relationships which interact in the production, diffusion and use of new and economically useful knowledge and are either located within or rooted inside the borders of a nation state". Nelson and Rosenberg (1993) described it as a "set of institutions whose interactions determine the innovative performance of national firms" (Nelson and Rosenberg, 1993, p.5). Providing a more detailed perspective, Niosi et al. (1993, p.212) wrote that "a national system of innovation is the system of interacting private and public firms (either large or small), universities, and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, in as much as the goal of the interaction is the development, protection, financing or regulation of new science and technology". This view focusing on the actors or components of the system and its interrelationships, was also adopted by others (e.g. Metcalfe, 1995; Patel and Pavitt, 1994). However, this definition was challenged by Edquist (2005) who argued that it contained ambiguities, such as the fact that institution could mean legal or regulatory system, whilst at the same time referring to organizations. Another criticism of this perspective is its inability to identify where the border of the NSI lies, i.e. what should be included and what should be left out (ibid). More recently, Lundvall (2007) has responded to this issue by providing some guidelines, but these are still only at the infancy stage in terms of their application.

The second strand approach to the definition of national system of innovation considers it in terms of functions. That is, under this perspective the main function of a system can be deployed into different sub-functions (Edquist, 2005; Galli and Teubal, 1997; Hekkert et al., 2007), which can involve: creation, diffusion or exploitation of an innovation. More specifically, Liu and White (2001) suggested that education, research and development (R & D), implementation, end-user, and linkage.

are important activities in the innovation framework. In even greater detail, Edquist (2005) listed ten different activities in relation to innovation, including: R & D, capability accumulation, new market formation, checking for user needs, establishing or changing the organizational structure or institution, knowledge networking, funding, entrepreneurial activity, and acting as an advisory service. These functional perspectives open a new approach to understanding how an NIS can influence innovation. However, this broad brush approach fails to distinguish the relevance of each function in different contexts, i.e. in countries with quite specific institutional arrangements. Moreover, Lundvall (2010) has contended that some activities under this umbrella have been overlooked, such as the level of freedom in the labour market during innovations.

The third strand, proposed by Lundvall et al. (2010), focuses on the evolutionary process of the system, addressing both the origins and evolution of innovations as well as their economic impact. Drawing on the work of Freeman (1987), Lundvall and Edquist (1993), Patel and Pavitt (1994), and evolution theory, the author wrote "The national innovation system is an open, evolving and complex system that encompasses relationships within and between organizations, institutions and socio-economics structures, which determine the rate and direction of innovation and competence building emanating from the process of science-based and experience-based learning" (Lundvall, 2010, p.6). That is, under this lens both the institutions and the socio-economic structure in which the organizations are situated are taken into consideration. This definition also includes the two sides of knowledge management, knowledge creation to boost the innovation activities, and the ability to assimilate knowledge so as to build up competency, which is increasingly important for developing countries. In addition, this perspective stresses the need for science and technology push innovation as well as the doing, using and interaction modes (Jensen et al., 2007; Lundvall, 1988, 2007). In sum, this process approach to NIS integrates different elements in the learning economy, to describe the evolutionary process, involving: learning, competence building, organization formation and institutional change.

2.2.2Applying the NSI approach to developing and newly industrialized countries in Asia

Most NSI studies have drawn upon the experience of developed countries with sophisticated innovation systems and consequently, are often not applicable to the circumstances of economies in transition, such as many of those in: East Asia, Latin America and Eastern Europe (Adeoti, 2002; Gu, 1999; Intarakumnerd et al., 2002; Inzelt, 2004; Kitanovic, 2007; Szogs et al., 2009). However, it would be wrong to group all of these countries together, because some, such as South Korea, Taiwan and Singapore, have made great strides over the last thirty years in relation to their technical capability, skills levels and capacity to obtain, digest, use and even create new knowledge (Dahlman and Nelson, 1995) and hence, have performed well economically. One of the reasons why the afore-named countries and some former Warsaw Pact countries have been so successful is because they have built effective innovatory networks at the national level (Lundvall, 1992; Kitanovic, 2007). Lundvall (2006) has also pointed out how quite a significant number of Asian economies have successfully connected with the global economy, which is in contrast to most of those in Latin American and Africa. He put forward three possible reasons for this. First, the Asian economies have access to skilled human resources and technology capability or absorptive capacity. Second, there has been relatively uncorrupt government involvement in globalization and third, the rules of the game and institutional transition have been more readily embraced in these societies (ibid).

The recently industrialized countries, South Korea, Singapore, and Taiwan, have been termed the New Tiger Economies and because of their success scholars have been endeavouring to understand the national arrangements in science and technology (e.g. Dodgson, 2000; Lall and Teubal, 1998), learning and catch-up (e.g. Chang and Hsu, 1998; Kim, 1993, 1997) and how they have come to play crucial roles in the global market (e.g. Chen, 2002; Hobday et al., 2004; Kim, 1997a). In contrast to the Western perspective on NSI, which stresses the importance of research and development, Mathews (1999, 2001) argued that knowledge diffusion and the mechanisms for promoting this have been the major driving forces behind these tigers catching up. He (Mathews, 2002) further suggested that the resources leverage strategy that was adopted by Korean and Taiwanese firms by firstly acquiring and combining existing non-rare, transferable, imitable knowledge, which was implemented by the public agencies (research institutes) and inter-firm arrangements, had a significant impact. That is, this first learning, with the help of ICT, enabled these countries to connect to the global market. Moreover, Lundvall (2010) highlighted the fact that government interventions have been crucial for the successful transformation of these economies, for they have helped the relevant organizations to respond effectively to any changes in the institutional environment in their pursuit of a learning economy.

Lundvall (2010) has pointed out that whilst the study of the national level of innovation systems is well founded, there has been scant research on understanding how micro dynamics influence macro behaviours and vice versa. This perspective is of relevance to the developing and newly industrialized countries as their different socioeconomic and political contexts variously affect their path and speed in learning, accumulating knowledge and innovating, which have an impact on a country's economic fortune (Kitanovic, 2007). Regarding this, there has been one study covering Taiwan, South Korea and Singapore, that has investigated such issues in the semiconductor industry (Mathews and Cho, 2000). In sum, in relation to this Lundvall has contended that "the discussion of 'system' above the innovation process may be seen as an intricate interplay between micro and macro phenomena, where macrostructures condition micro-dynamics and vice versa new macro-structures are shaped by micro-processes…by co-evolution and self-organizing. There is a lot of theoretical work to do to model, measure and compare such processes…" (Lundvall 2007, p.110). Proponents of the triple helix model (THM) have taken some steps to address this and these are discussed next.

2.3 Triple Helix Model (THM): university –industry -government

The triple helix model (THM) is one of the models constructed to extend and improve national innovation systems study (Etzkowitz and Leydesdorff, 2000; Leydesdorff, 2012; Lundvall, 2007a). In essence, its proponents defined three actors and the roles and relationships between them to bring forth innovation in the society. That is, it addresses the actors and relationships regarding the first strand of national systems of innovation, as set out above. They have also identified the different roles of the actors as: universities offering education and being the knowledge provider, industry creates new product and services and the government sets the law as well as providing public services (Dzisah and Etzkowitz, 2008; Etzkowitz, 1994, 2003, 2008; Etzkowitz and Leydesdorff, 1995, 2000; Etzkowitz and Zhou, 2006; Leydesdorff and Etzkowitz, 1996, 1998). The proposers of the THM (triple helix model) used the metaphor of the structure model of DNA in the cell to show that an ideal collaboration was one involving: universities, industry and the government. Moreover, a number of researchers observed what they termed the "second academic revolution" happening at: MIT, Stanford, and North Carolina University, where interactions based on science and technology development, involving: universities, industries, and government had enhanced regional and national economic development.

Turning to the evolution of academia, the first academic revolution, as suggested by Jencks and Riesman (1968), refers to when the new mission of research was added to the original university one of teaching. This came about in the 19^{th} century, particularly in the USA, because university presidents, such as Gilman of John Hopkins and Harper of Chicago, were of the opinion that they should be institutions involved in knowledge transmission and cultural preservation, a notion that soon became the norm for American universities. The second academic revolution took place during the 20^{th} century, with the introduction of economic development as a third function of universities, apart from teaching and research. In reality, traditionally, universities had been providing some service to industries and agriculture in some respects for much longer, such as, continuing education programmes and agricultural inputs. However, this new revolution, required universities to go further in their interactions with government and industries to help with economic development than they had previously done so.

Amongst these new developments in universities was the appointment of laboratory leaders in engineering to become supervisors in quasi-firms, many of which eventually became spin off industries. One of the remarkable episodes was the establishment of MIT in the early 20th century, which was envisioned by William Barton Rogers, its first president, as an institute that would integrate basic and applied research for technology development. To this end, MIT commonly took on consulting engineers from industry as professors. By 1920, one of the students in MIT, Vannevar Bush, found out about a great idea during a consultancy, for which an employee in the company in question had been refused development support. Bush and his associates seized on what they conceived to be a potential business opportunity and established a new firm to commercialize it. Subsequently, increasing numbers of people followed in their footsteps by setting up firms around MIT (Dorfman, 1983). During the 1930s, Karl Compton, drafted a plan during the depression that would involve: regional politicians, academics and business leaders, in transforming research carried out by MIT into new companies. However, this plan was delayed by World War II, so it was not until after the cessation of hostilities that he and his colleagues were able to link MIT's technological capacity with the expertise of the Harvard Business School to form a new institution, Venture Capital, in 1946, which acquired its capital for innovation activity through the financial sector and universities, and which later became the American Research and Development Corporation (Etzkowitz, 1983). Subsequently, these joint working practices were taken up on the west coast, with Stanford University being one of the forerunners, whose efforts eventually led to the establishment of Silicon Valley. This collaborative trend is becoming increasingly evident across the globe, with many countries trying to establish similar areas.

The triple helix model was put forward to explain the interaction amongst: universities, industry and government. Etzkowitz and Leydesdorff (2000) identified three different types of triple helix configurations.

Triple helix I: The state controls industry and academia

The first type, helix I, refers to where central government dominates all the interrelationships among these three entities at all levels. This configuration was prevalent in the former Warsaw Pact countries, where the state had control of the direction of all actors and the interactions among them. Some weaker versions of this configuration can be found in Latin America and Norway (ibid), where the governments strongly encourage industries and universities to work in consort, but do not coerce them into doing so as with the former Warsaw Pact countries. These authors (ibid) pointed out that over time the aforementioned three entities in many countries have become increasingly engaged in voluntary interactions, which are to their mutual benefit.

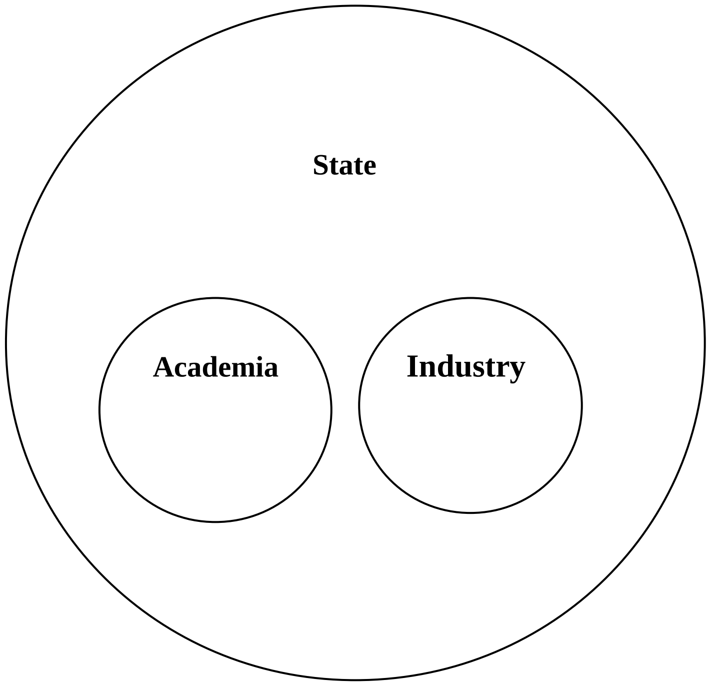

Diagram 2.3: Triple helix I

Source: Etzkowitz and Leydesdorff (2000, p.111)

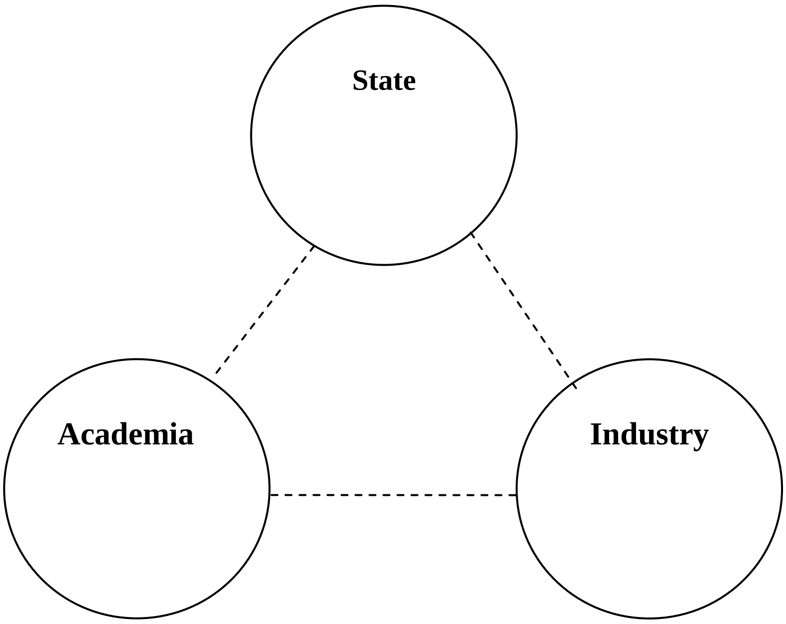

Diagram 2.4: Triple helix II

Source: ibid

In the second triple helix configuration, it is contended that the three actors have clear borders, whereby each performs different functions, such as: universities largely deliver scientific knowledge, governments establish rules to avoid negative side effects and industry creates economic value by exploiting its stock of knowledge and capabilities, with weak boundary management, such as in Sweden.

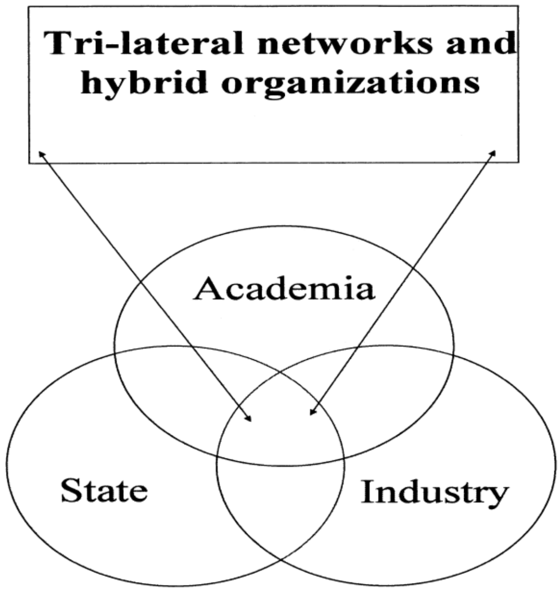

Diagram 2.5: Triple helix III

Source: ibid

Triple helix III

With regards to triple helix III, as shown above, this takes into account the claim that for effective collaboration in relation to economic development: industry, the government, and universities, each have to carry out some of the functions of the others, whilst at the same time interacting with them. In other words, this model addresses the complexity of flux, regarding: communication, networking, and reorganization among the helices (ibid). Moreover, effective collaboration can occur when agents cross the borders of their original remit to conduct some of the functions of other agents. For example, in the case of universities, whose main function is to provide education for students, however, many prestigious ones have developed potential new drugs for some pharmaceutical companies, whose product research used to be invariably conducted by their internal research laboratories. Furthermore, as with triple helix II it overlooks the overlapped functions among these organizations and continuous interactions, which can have a positive economic impact on innovation. Nevertheless, triple helix III addresses an important aspect of economic development, that of flexible boundaries, thus allowing for the igniting of new possibilities for commercializing innovative ideas and consequently contributing to the economic development process. It also captures the dynamics among these three actors, where, in algorithmic terms, both variables and values are always changing (Etzkowitz and Leydesdorff, 2000). Therefore, when today scholars mention the THM they are usually referring to triple helix III. However, the limitation of this model becomes apparent when it is applied to certain different contexts or social settings. In particular, the THM's proponents see research institutes or national laboratories as being static entities, when compared with universities, stating that they are "sometimes considered as a necessary distraction" (ibid, p.118). That is, in their view universities educate students and researchers to build a dynamic flow of human capital, but in industrial laboratories and research institutes human capital lacks this dynamism.

However, research institutes have been playing an important role in some countries, regarding the training of university graduates for work readiness in industry. For example, the ITRI (Chang and Hsu, 1998; Mathews, 1997) in Taiwan has provided support for the semiconductor industry and the ETRI in South Korea has coordinated the DRAM technology development (Kim, 1997; Mathews, 1999) as well as being the first to commercialize the third generation telecommunication system (ETRI, 2011). In addition, other eminent research institutes or government laboratories, such as one leading semiconductor research team at IMEC in Europe, have also been performing this function very well (Collins, 2006). Thus, these RIs are far more than "a distraction" and they are increasingly becoming a necessity for both developing countries (Chen and Kenney, 2007) and tiger economies. Consequently, it is proposed that the THM should be extended to form a new model, inspired by inclusionality, which involves a new actor, namely RIs, as explained next.

After the THM was promoted for more than ten years, other scholars suggested that the model needed updating (Etzkowitz and Zhou, 2006) and in this researcher's opinion, natural inclusionality, as discussed later, could offer one way forward, because its proponents recognize that boundary changes or overlaps need to be managed. That is, it is important to take actions to facilitate energy flows that occur across boundaries and between actors. Moreover, the bounded space should be controlled in a flexible manner that can accommodate new actors/resources, thereby ensuring the energy flows run smoothly and hence, fostering positive economic development.

The THM was a significant development in the endeavour to capture the evolutionary dynamics of the innovation process. However, key limitations have been encountered when scholars have applied it to explain this phenomenon. First, the fact that it uses three actors to theorize the evolutionary process of innovation means that it loses its explanatory power for settings where fewer or more actors are involved. In response to this criticism, its supporters have accepted there is a “neo-differentiation” among the three actors and they have included these in updated versions of the THM, but this still cannot account for contextual differences across nations (Shinn, 2002). One exception was proposed by Garyannis and Campell (2009, 2010), they suggested a quadruple helix to replace the THM, which includes media and cultural based or civil society aspects as a fourth sphere. This is based on the premise that media can promote democracy and free speech in: political, educational, and economic systems. In other words, democracy can help stimulate new ideas and eventually lead to innovations (Campbell, 2006; Carayannis and Campbell, 2012) by enhancing the knowledge cluster and innovation network. Later, they further included natural environment as the fifth sphere, and proposed the quintuple helix (e.g., Carayannis and Campbell, 2010; Carayannis, 2012;). However, their stance has been challenged as unclearly specified, hard to operate, and empirically unproven (Leydesdorff, 2012). Second, the THM has been criticized for focusing mainly on university transformations and paying too little attention to those in: government and industry (Mowery and Sampat, 2005). Notwithstanding this university focus, in reality there has not been much empirical research under the lens of the THM, in particular, because little progress has been made in constructing measurements for testing such factors as the strength of the linkage of activities between actors (ibid). Furthermore, the THM has the same limitation as the NIS in that it was constructed drawing on the experience of developed countries, thus, as explained before, potentially overlooking other actors involved in successful innovations. Even with these limitations, the THM does provide useful provisional guidance for universities in the new industrial economies regarding the possible approaches to making contributions to the national knowledge economy. However, it is posited that it needs modification if it is to provide a robust explanatory foundation for Asian tiger economies, such as Taiwan.

Moreover, these Tiger Economies also face the challenge of having to transform their knowledge infrastructure, industries, and institutions, so as to sustain their competitiveness in the world. Regarding this, Korean scholars have explicitly called for their country to engage in more creativity and to develop more talent (Lundvall, 2010). In Taiwan, there is the added pressure of many industries having moved their production to China to take advantage of lower costs and new firms failing to fill the gap in economic output and employment (Driffield and Chiang, 2009).

In sum, the THM has made some progress in terms of theorizing the dynamics between institutions (university-industry-government) and its impact on national innovation performance, but it is still has some limitations. Firstly, it mainly draws on the experience of the advanced economies (especially the US) (Leydesdorff and Etzkowitz, 1994; Etzkowitz and Leydesdorff, 1995) and thus, does not reflect accurately other countries' innovation trajectories. In particular, it is restricted to only three different spheres within the national boundary and fails to recognize the role of other actors present in innovation in other contexts (Szogs et al., 2009), such as civil society (Carayannis and Campbell, 2009) or research institutes (Huang, 2010). Moreover, THM proponents have attempted to capture the dynamic relationship between university-industry-government and national innovation performance, but the model is not capable of addressing the complex issues pertaining to an NIS, as discussed above. In particular, it cannot elicit the path through which micro dynamics can influence macro structure or how macro structure possibly impacts upon micro behaviours (Lundvall, 2007a).

2.4 Natural inclusionality and innovation study

2.4.1 Origin of inclusionality

Rayner (1997, 1999) developed the concept of inclusionality after he researched mycelia and found what he termed “cord flow” formation through their transformation (Rayner, 1997). He and his associates (Rayner, 1997, 2004, 2006; Rayner et al., 1999; Whitehead and Rayner, 2009) found that the dynamic flow of energy provides the basis for the development of living creatures and that the direction and strength of the flow is determined by the space and the willingness of organisms, which in turn shape the space or landscape which accommodates them. This view coincides with the concept of qi (also known as chi) in traditional Chinese culture, whereby a life force is seen to permeate everything and it is particularly referred to in Chinese medicine and the martial arts. For instance, it is believed that when the qi becomes blocked, poorly circulated or imbalanced in the human body, then people will not function properly or will even fall ill (Lawson-Wood and Lawson-Wood, 1973) and remedies, such as acupuncture, are used to rebalance the energy flow (Hicks, 2011). Moreover, the concept is extended to cover things that in the West would not be considered to be alive as such, like steam from cooking rice and in essence if qi is absent then the entity has no energy flow and thus, is perceived as being dead.

In general, Rayner defined inclusionality as “an awareness of space and the variable fluidity of ideas across boundaries – ultimately formed by what physicists refer to as ‘electromagnetic energy’ – that inseparably line it, as connective, reflective and co-creative, rather than divisive" (Rayner, 2005)[1]. Thus, unlike Darwin's well known perspective that only "the fittest survive" i.e. natural selection, under co-creation it is suggested that the driving forces behind the survival scene are not limited to competition nor is there simple cooperation, but rather what some authors have termed "co-opetition" (Brandenburger, 1997) and thus, that there are many possible paths that a living entity can take to survive.

Inclusionality can be applied to human societies to account for the different perspectives and stress involved their dynamics, for as Rayner (2005) has pointed out:

> "With this idea about 'inclusionality' and the 'complex self', which resonates with many long held spiritual values and principles, we can appreciate ourselves as inextricably coupled aspects of one and another and our living space in dynamic relationship. …We can regard the human subject as a vital participant in and local expression of the wider realm **'energy-space'** that we all emerge from and subside into as **'flow-forms'** – 'relational places' with inner, outer and intermediary aspects rather than independent objects. We are like solutes, which, together with the solvent can produce a solution full of creative potential. Hopefully, we may thereby find a richer, more peaceful and environmentally sustainable way of living together, seeing ourselves as inclusions of the solution

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[1] Adapted from: Rayner, A., 2005. *Space, Dust and the Co-Evolutionary Context of 'His Dark Materials'*.[online] , Available from: http://people.bath.ac.uk/bssadmr/inclusionality/HisDarkMaterials.htm [Accessed 12 May 2009].

rather than rationalistically as solutes abstracted apart from the solvent that brings us into life – individual (dis)contents abstracted from a spatial context."

Rayner (2007)[2] has criticized the distorting impacts on knowledge of popular disciplines of today, which he sees as based on "the wrong logic (objective rationality), the wrong arithmetic (discrete numbers), the wrong geometry (Euclidean), the wrong language (definitive), the wrong scientific method and mode of explication (definitive), the wrong theology (external object God), the wrong systems of governance, education and economics (im-positional)". The advantage of using "logic" as a common ground of thinking is that it simplifies things and perceptions, thereby allowing human beings to draw an artificial line between the inside and outside. However, Rayner (2006) pointed out that although this aforementioned approach makes it much easier to manipulate or study the relationships among people and between them and their environment, as it isolates specific substances or objects for focusing upon; it fails to consider the influence of spaces, treating them as being voids or non-existent during the investigation. Furthermore, logic permits science to give people the false impression that a local object is independent of its surroundings and as such, simply resides in a void. This unquestioning perspective could explain why scientists cannot accurately predict the direction and magnitude of a typhoon or a hurricane, which are influenced by both immediate local and remote (such as solar energy) conditions and spaces (Lumley, 2008). Under the inclusionality lens, whilst the existence of a boundary between an object and other objects or its surrounding environment is recognized, this

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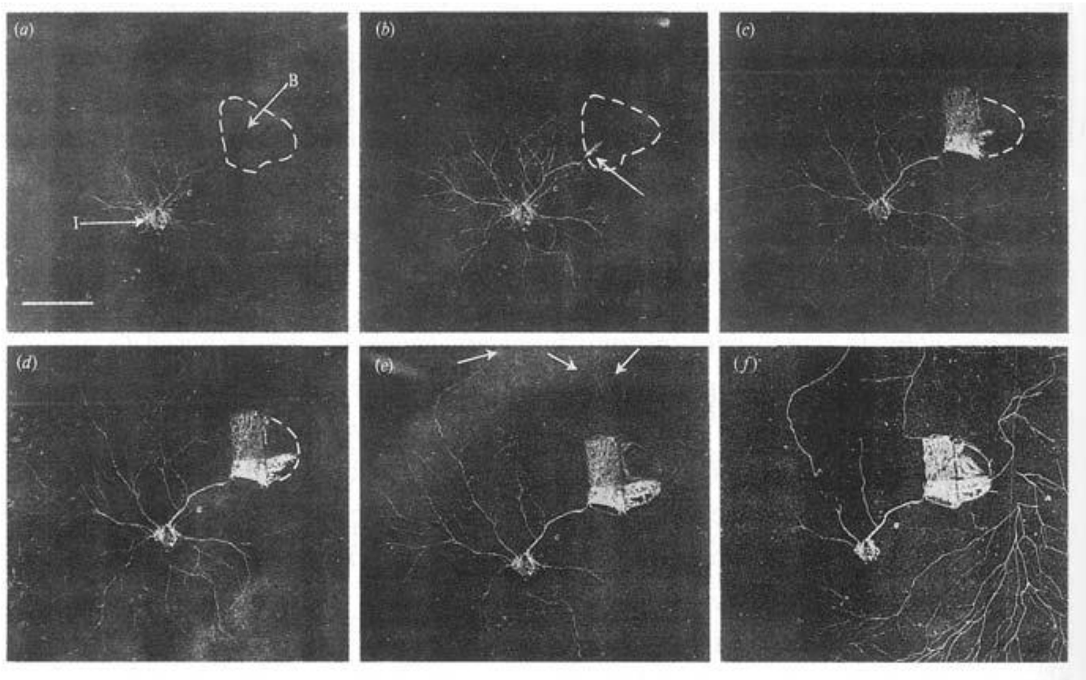
[2] Rayner, A., 2007. Essays and Talks about 'Inclusionality' by Alan Rayner. [online] , Available from: http://people.bath.ac.uk/bssadmr/inclusionality [Accessed 12May 2009].

is not considered to be a fixed barrier, as the logical perspective would suggest, but is permeable to some degree.

Proponents of inclusionality advocate that: matter and time are related to spaces; content cannot be independent from context, and stress that the dynamic flow of energy is not only local, but circulates around all spaces to bring forth the evolution. Moreover, the energy flow is shaped by the spaces, time and matter, but flow, in turn, also shapes spaces. In nature, the energy flow drives the evolution of life, in particular in this regard, as pointed out above.

At the practical level, Rayner (1997) and Rayner et al. (1999) demonstrated how mycelia evolve over time when there is sufficient energy. More specifically, the three basic strategies adopted by mycelia to help them survive are: differentiation, integration and degeneracy. Diagram 2.6 illustrates how mycelia function by adopting a dissipative, or differentiation strategy to seek additional food sources, which involves exploration by stretching the hyphal branches. Once they have found the new food source, they strengthen the link between them so as to be able to exploit it most effectively and eventually the new site will become the centre of this mycelia group.



First, a number of pathways reach out towards the second nutrient block and as the first mycelia links are made, the unconnected ones begin to degenerate. New pathways are laid down that integrate with and strengthen the path that has connected with the nutrient source, resulting in there being a strong channel between the two nutrient areas

Diagram 2.6 The development of a mycelia system between two food sources

Source: Rayner (1997) cited by Tesson (2006, p.126**)**

When the source of energy cannot sustain the dissipative structure which the growing mycelia erect, they will try to save energy by adopting the second strategy of integration, the simplest form of which being self-integration (see diagram 2.7), which involves sealing itself and sharing the available energy (Rayner et al., 1999).

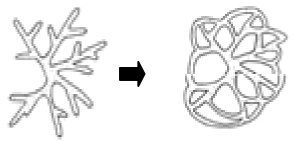


Diagram2.7:Self-integration illustration

Sources: Rayner (1999) cited by Tesson (2006, p.125)

From the above, it can be seen that inclusionality can account for the evolutionary process that most living creatures face, the two most important factors of which being survival and development. More specifically, survival issues relate to: finding food, seeking accommodation and getting rid of predators, whereas development issues are concerned with: reproduction, learning, and growth. Under the lens of inclusionality, Rayner (1997) further identified three strategies that organisms adopt in order to live and flourish: differentiation, integration and regeneration and they all involve determining: when, to what extent and how the boundary between the inside and outside changes as well as the alteration of the level of permeability. In this regard, when the resource is ample an organism will tend to expand its territories and transmit the energy through the boundary, whilst when the energy is limited or the internal structure cannot sustain growth, it will try to consolidate within and reinforce boundaries. When the energy collecting structure can no longer sustain even itself or the explorative structure cannot be supported, degeneracy measures will be initiated which involves: boundary sealing (rigid), boundary fusing, and boundary re-distribution. The main reason for any organism pursuing these strategies is to survive, or to receive the supportive energy to keep them alive. In this researcher's view, these strategies could be adopted by any innovation team to interact with adjacent spaces, the modeling implications of which are explained in more detail later.

Differentiation involves the growing of a dissipative structure whilst the energy supply is ample, because energy loss is not a crucial issue during this phase. Integration refers to the organism's attempt to stop energy loss and use it more efficiently by: sealing, fusing and/or redistributing the boundary. Retreat describes activity where the organism withdraws from a spatial position, probably because the energy source is insufficient for survival or has become exhausted.

Regarding the boundaries themselves, Rayner (2006) observed three different features that can have an impact on the pattern of flow, these being: deformability, permeability, and continuity of boundaries . Deformability is opposite to rigidity in that under this condition boundaries expand or contract to assimilate or release energy sources between the inside and outside. Permeability refers to boundary control of the exchange rate between the inside and outside, whilst continuity boundaries refer to the endeavour to increase or decrease the internal flows by increasing the level of connectivity or resistance, respectively. Continuity refers to what degree the flow can run smoothly inside the boundary.

In human organizations similar processes occur. For instance, research technology institutes (RTIs) or HEIs have to seek energy inputs, such as: funding, talent and other knowledge resources. Moreover, so as to ensure regeneration, these bodies have to develop human resources in the form of cultivating: researchers, managers, and entrepreneurs as windows of opportunity appear and as such, these phenomena are like the mycelia stretch "flow form" structures that explore the space next to them so as to identify new food resources. Furthermore, whilst the effective distribution of energy sources from cell to organ level is essential in this exploratory endeavour for any organism's survival, so too is the efficient spreading of resources. Finally, regarding one previously somewhat neglected process in ecology, that of the recycling process, organisms may retreat from one neighborhood or cells can replenish those which cease to operate with the energy being taken from them and the waste transferred ex vitro, resulting in the landscape in which the living creatures operate being fundamentally altered, something that also needs to be borne in mind when evaluating innovation trajectories.

2.4.2 The application of inclusionality to management studies

The inclusionality perspective has been incorporated into a number of other disciplines, other than biology, so as to advance knowledge in their respective fields, including: transfigurative mathematics (Shakunle and Rayner, 2009), meteorology (Lumley, 2008), and in higher education enquiry (Whitehead and Rayner, 2009). Regarding area management studies, Tesson (2006) introduced the notion of the influence of natural inclusionality in team communication. She suggested that this biological metaphor could be applied to communication theory by illustrating the different communication strategies that teams employed in a competition on new architecture designs during Liveweek in London. In her words, "I suggest therefore that, rather than relying solely on conventional network theory models when we think of 'organization as network', we should be using 'organizations as flow-form network' as an alternative, since this metaphor reflects the natural behaviour of communicative flow in a networked system" (Tesson, 2006, p. 136).

More specifically, in her study in relation to Liveweek, she gathered video recorded data from one design team and after transcribing the dialogue she applied verbal analysis and social network analysis to the team interactions, categorizing the different dialogues into five categories: offering information, organizing, feedback/social exchange, statements about the design context, information seeking statements, and uncategorized. By tracking these interactions between actors within the team, she was able to trace the directions of knowledge flow and she was surprised to find that the people who sought information most often were not those who provided most of it (ibid). However, the author's main contribution to the field of social networking theory was the introduction of the concept of flow form networking taken from biological natural inclusionality. Nevertheless, she found the identified categories were insufficient to capture all the communicative flow forms during the exchanges and the author herself admitted "a communicative flow of some form…just was not permitted under the methods I had chosen for analyzing the event" (ibid, P226). Tesson's (2006) treatment resonates with Rayner's (2004) perspective that environment and flow both shape each other, e.g. the river shapes the bank by erosion, whilst at the same time the new deposits are changing the river's pattern.

Another application of inclusionality is that of change management by Van Tuyl (2009). He challenged well established economic theories, such as perfect competition, and free market thinking, in particular, for not taking account of social wellbeing. More specifically, his major contribution is that after learning about the various theories on change management and having a dialogue with Rayner, he applied the permeable boundary concept contained within inclusionality to develop his 'edge of fluidity' idea, whereby the notion of change agent is transformed into a co-creative catalyst. That is, he stressed the need for people proactively to seek ways of crossing boundaries, thereby seeing them as permeable, in their day-to-day work, because exploiting the virtues of trust, narrative, identity and so on at the individual level leads to effective communication that can foster creativity. Moreover, he pointed out that these forms of interaction can be found within the spaces surrounding groups of people (ibid).

2.4.3 How Inclusionality can enhance the THM

There are some commonalities and differences between the THM and inclusionality. First, both models draw on metaphors borrowed from biology to explain the dynamic relationships among different actors. Regarding the former, the concept of the structure of DNA is used to demonstrate the importance of interaction between: universities, industry and government in an innovation system, whereas for the latter the development of mycelia in microbiological study is employed to enhance understanding of the evolutionary innovative process. Moreover, whilst proponents of the THM pinpoint a three dimensional order of dynamics pertaining to: universities, industry and government, the champions of inclusionality emphasise the dynamic relationship between space (context) and flow (of content). More specifically regarding the latter, innovation is seen to be facilitated by the energy flow being nurtured by both the internal and the external environment and proper boundary management in the various different scenarios induces efficient transmission of this flow.

This idea of flow is also mentioned in an article by the advocators James Dzisah and Henry Etzkowitz (2008), where they referred to the metaphor of the need to remove any arterial blockages in blood circulation to ensure free flow. In relation to this, to counter flow difficulties regarding innovative endeavours, they argued that universities should go beyond the traditional role of training human capital and industry should not just be solely responsible for technology transfer and the government for the regulations. In particular, they called on universities to become actively involved in the commercialization of technology, entrepreneurship training, and to help in local, or national economic development. In their words the "triple helix interactions represent the heart of knowledge-based development with circulation among and within the spheres acting as the arteries that stimulates ideas and policies across from one point to another" (ibid, p.2). In fact, knowledge has often seen at the core of innovation studies (Tidd and Bessant, 2009). However, there are energy flows other than knowledge that need to be considered in the innovation process and these are discussed along with knowledge in the next chapter.

To sum up, in this chapter, first, the literature in relation to the different definitions of innovation has been reviewed, and subsequently, a working definition proposed of it being an evolutionary process involving: idea generation, invention and commercialization, thus eventually delivering value to the market and society. Secondly, the sources of innovation have been identified including: suppliers, users, other companies, networking, etc. Thirdly, literature related to national systems of innovation has been visited as well as the direction for future exploration being identified. More specifically, NSI needs further efforts to provide robust theory that can explain the nature of the development of East Asian tiger economies and those of other developing countries, as most such literature has been focused on developed countries. Moreover, ways in which micro efforts impact on macro performance and vice versa have yet to be clearly elicited and thus this provides a further avenue for fruitful investigation. Finally, the THM as a specific exemplar of an NSI has addressed some of the dynamic issues between universities, industry and government, but there is evidence, particularly coming from non-Western contexts, that other actors are germane to the innovation process. Taking these concerns and other matters raised in the above discussion as a cue, in the next chapter a modified version of the THM is constructed.

Chapter 3 Research questions, research framework and research methods

This research will address the aforementioned insufficiencies of the triple helix model and national systems of innovation regarding their inability to provide robust explanations for evolution of creative projects in the developing countries and tiger economies, such as Taiwan. These insufficiencies, again, are that the THM contains only three actors and is too generalized to address the issue of how micro dynamics can influence the macro structure and performance and vice versa. In this chapter, to begin with, the research questions to be probed in this thesis are presented. Subsequently, continuing the theoretic line of the previous chapter, a framework is developed that involves modifying the triple helix model by drawing on the literature review in chapter 2, in particular, with respect to the notion of energy flow and the inclusionality perspective. The methodological approach and research design are presented and justified next along with clear reasoning for the decision to undertake case studies in preference to other research methods. Further, the other sources of data employed to enrich the analysis are introduced. In addition, the validation process engaged with during the research is explained and so too the ethical considerations.

3.1. Research question

The proponents of the triple helix model (THM) have claimed that it can accommodate the dynamics between: universities, industry and the government, in that it has demonstrated effectively that these actors cross their original boundaries so as to take up roles in other spheres in pursuit of their common mission, namely that of economic progress (Etzkowitz and Leydesdorff, 1995, 2000; Etzkowitz, 2002, 2003; Leydesdorff and Etzkowitz, 1998). Through the THM two aspects have been pin pointed, first, that there are three key actors involved in developing innovations in a specific country and second, the evolutionary nature of the processes that surround innovation. However, it has been criticized for placing too much emphasis on the newly emerging role of entrepreneurship in universities and for paying being insufficient attention to the parts that government and industry are playing (Mowery and Sampat, 2005). Two further key drawbacks associated with this model and its associated perspective on innovation are the lack of space to incorporate other actors (Huang, 2010) and the inadequate treatment of the issues of differentiation and integration. In sum, it is posited that the THM is neither sufficiently inclusive so as to provide comprehensive guidelines for practitioners in the field nor sufficiently detailed to satisfy the gaps in the relevant theory.

To address these limitations, the research question put forward is:

Does the AFM extend the triple helix model by providing a more comprehensive form for exploring the creation process of innovation between industry, universities, the government and research institutes in Taiwan?

The first part of this question is addressed by drawing on the extant THM, which has outlined specific different institutions and the dynamics amongst these (Leydesdorff and Etzkowitz, 1996). More specifically, three forms of dynamics may be elicited, that is, those of the market (industry), knowledge production (the university) and interventions from governance bodies at various levels. Moreover, to refine the existing theory that underpins the THM, a theoretical framework is developed in this thesis that draws on the concepts of natural inclusionality. Furthermore, as the THM is founded on a tri-lateral regime and the focus is largely on the dynamics among these three parties, it is contended that having a grasp of the social knowledge infrastructure of the milieu in which innovation takes place is as significant as understanding changes in technology, when attempting to comprehend the nature of the innovation of interest. In sum, the aim is engage with the concept of inclusionality to build upon the THM, thereby creating a more comprehensive model.

The second part of the question is addressed by performing data collection of real innovation activities in Taiwan that have been involving collaborations between: universities, research institutes, industry and government. Unlike the original THM, which only involved industry, universities and governments, the AFM extends the model to include additional actors, such asresearch institutes. The purpose of this part of research is to provide evidence to support greater efficacy being obtained from the actor flow model (AFM), based on the concept of inclusionality, when compared with that of the THM.

Finally, the question involves the perspective that there needs to be a move away from the traditional industry-university relationship, as promulgated strongly in the USA, by exploring other possibilities that take into account different socio-economic environments. More specifically, in the context of Taiwan, the research institute has been playing a crucial role in spin-offs and the creation of new technologies and new products (Chang and Shih, 2004; Chang and Hsu, 1998) and hence this gives clear evidence of the need for alternative theory to the aforementioned traditional model. In particular, the relation between RIs and HEIs needs to be brought into any new theory as in this researcher's opinion it would prove beneficial to both of these actors

Another theoretic building block to consider in this thesis is the interaction itself. In this regard, innovation usually involves a group of people, or a community in which inventors can network and interact with others to realize the potential value of their invention and to develop ideas further. That is, the community serves as a symbiont, and people related to it can gain benefits from their mutual symbiosis. However, in the past the focus of research has been on the actor with scant attention being paid to the interactions themselves. The biological concept of natural inclusionality can provide a remedy for this, because it can account for how energy flows between entities shape the surrounding space, whilst the space in which entities are located is also impacting on the energy flows (Shakunle and Rayner, 2009). In the context of innovation, all are developed by human beings and as human society is part of nature, innovation behaviours also involve flows, which take the form of exchanges between inventors or between inventors and other parties involving different types of both tangible and intangible resources. Four types of flow taken from the Forrester's (1961) industrial dynamics model are applied to the new model for this research endeavour, as explained next.

3.2 Research Framework

To facilitate the data collection and to provide important insights the study is focused on not only the actors themselves, but also on how they endeavour to control energy flows during the evolutionary innovation process through boundary management. Proponents of the THM, originally, only vaguely referred to the dynamics among different institutional spheres in the innovation system, but more recently some of them have attempted to cover knowledge and human resources in their work, (e.g. Park et al., 2005; Huang, 2010).

Under the lens of inclusionality it is contended that all living organisms or communities are shaped by energy flow. In this next sub-section, this researcher will draw on Forrester's (1961) industrial dynamics model to identify the sorts of energy flow to be probed in this work. Moreover, the causal relationship between each type of flow and innovation will be considered in detail.

3.2.1 The scope of energy flow

Energy flow can have different meanings for different people. For the purposes of this research, the inclusionality (Rayner, 2000; Tesson, 2006) analogy, whereby blood is used by the human body to bring water, oxygen, and nutrition (resources) to cells and to eject waste, thus helping the body to survive, grow and develop, underpins the adopted approach. To understand the evolution of innovation, it is more effective to study the dynamics of "energy flow" (flow) rather than static "resources" (stock), i.e. energy flow here refers to the flow of resources.

The theoretical line of different types of resources which can produce new products can be traced back to Adam Smith in 1776. He identified the factors/resources of production: land, labour, and capital stock (equipment), which are essential for the production process and the earning of profit. By the 20th century, knowledge had become an important factor (Drucker, 1967; Drucker, 1999; Marshall, 1961) and this has been also recognized in the THM (Park et al., 2005). However, proponents of the

THM model have only considered explicit knowledge and human resources, and thus have overlooked other possible resources, such as those Adam Smith identified.

In this regard, Forrester (1961) was one of the first pioneers who recognized different types of flows, namely: information, personnel, money, material and equipment, and concluded that a successful company has to deal effectively with the dynamic relationship between them. He used these flows to build a dynamic model to explain the widely observed phenomenon of the boom and bust pattern in industry. That is, he was able to explain the process by which lags in meeting consumer demand leads to factory overproduction and subsequent unwanted stock, which in turn results in an economic downturn (ibid). The author went on to conclude that a company or, in fact, any organization needs to manage, effectively, the five dynamic flows in order to flourish. Although this gave a model that is based on a closed system and also generates a rather mechanistic account, this insight regarding information feedback systems has influenced the field of logistics and production management. Moreover, the concepts of stocks and flows have proved useful for understanding the dynamics occurring at both the company and industry levels. Furthermore, Hamel (1999) suggested a similar idea that innovation is the result of the effective use of: ideas, talent, and money. However, Forrester (1961) model would appear to be more comprehensive than Hamel's as many innovations only bear fruit through the discovery of new materials and/or machines.

For the purposes of this study, the labeling of these five flows has been modified, with the material and equipment flows being merged under one category, that of physical flow. That is, the four types of energy/resource flows included are: knowledge (information, both explicit and implicit/tacit), human resources (personnel), money, and physical (material and equipment) as shown in the diagram. More details of these four types of flow and their relationships with innovation are provided next.

3.2.2 The four types of energy flow

Knowledge Flow

Knowledge or information has become an increasingly important resource, in addition to the conventional economic resources (Marshall, 1961), i.e. labour and capital. In this regard, pioneer thinkers, such as Drucker (1967, 1999), foresaw the rising numbers of knowledge workers, whose major jobs would no longer rely on their physical strength, but rather, would depend on seeking information and exploiting it to generate wealth. This development has been vastly accelerated in recent years with the invention and diffusion of information technology (e.g., computers), which has enabled people to: plan, implement, facilitate, and even control the process of new products and services more effectively and efficiently than before.

Knowledge can be categorized into two forms, namely, explicit or coded knowledge and tacit or implicit knowledge (Nonaka and Takeuchi, 1995; Polanyi, 1966), with the former referring to that which can be acquired by reading the text, whilst the latter is knowledge embedded in a person, which can be acquired thorough: observation, practising and interaction. The Panasonic bakery machine represents a well-rehearsed example of implicit knowledge, where researchers attempted to identify the tacit dimensions of a baker's skills in a hotel, so as to capture the best way to develop a bread making machine. However, the debate is still ongoing as to whether this approach for making the implicit explicit actually works.

There are different levels with regards to knowledge management in organizations, for it can range from the personal, interpersonal, team based, intra-organizational, organizational, to the inter-organizational level, as shown in diagram 3.2 (Hedlund, 1994). This author argued that the knowledge diffusion process at the individual and inter-organization level is mainly through external articulation, whereby tacit knowledge is made explicit. By contrast, with regards to dissemination between groups within an organization dialogue is the most effective approach (ibid).

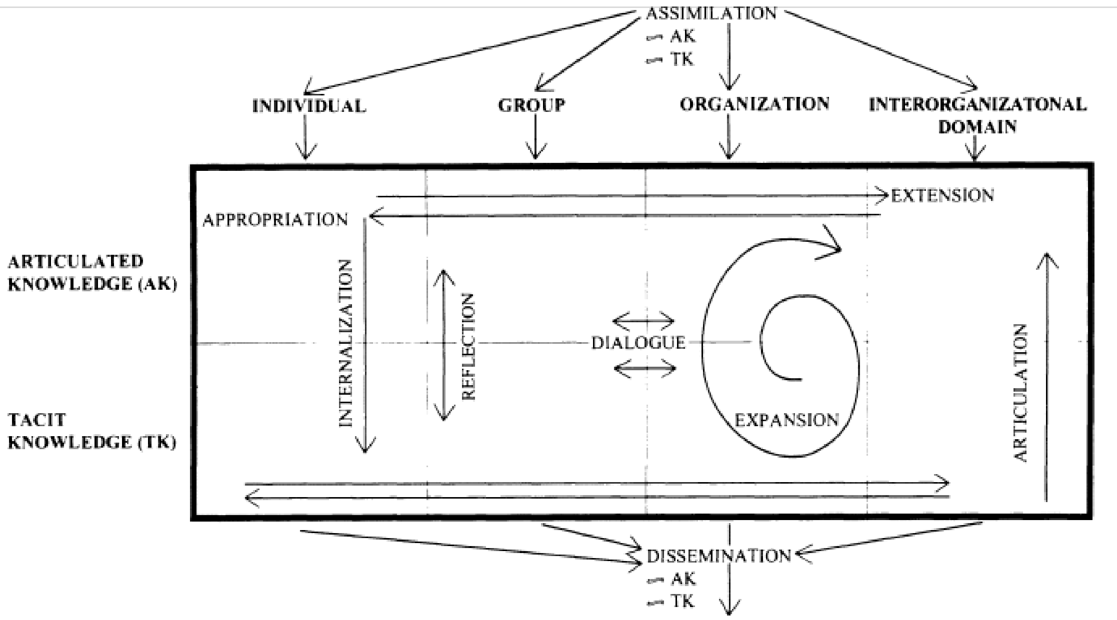


Diagram 3.1: Knowledge articulation and dissemination

Source: Hedlund (1994, p.77)

The tacitness is not the only the barrier regarding the acquiring of knowledge and its subsequent exploitation, for the readiness and capability of the potential receivers can also be problematic. In this regard, there are two distinct but relevant explanations, lack of absorptive capacity (Cohen and Levinthal, 1989) and the failure to share social practices (Brown and Duguid, 2001). Firstly, a number of scholars have pointed to the importance of the level of ability that knowledge acquirers have to absorb knowledge efficiently, that is, their "absorptive capacity" (Cohen and Levinthal, 1990; Cohen and Levinthal, 1989; Jansen et al., 2005; Kim, 1998; Lane and Oliva, 1998; Todorova and Durisin, 2007; Zahra and George, 2002). This refers to the ability of an organization to find useful knowledge, assimilate it, and exploit it to create commercialization value, which is related to the prior knowledge an organization already has (Cohen and Levinthal, 1990). This prior knowledge is most effective if it contains the ability to unlock the implicit often uncodified knowledge resting in the minds of the employees. Moreover, these authors argued that the internal capability (such as own R&D) to learn from other sources is crucial for a firm to prosper and survive, citing two major factors determining the incentive for knowledge assimilation within an organization: the ease of learning and the quantity of available knowledge (ibid). Another crucial factor is having people in the organization who can recognize new knowledge from external sources and who have the knowhow to apply it effectively within (Todorova and Durisin, 2007). Moreover, as the stock of knowledge accumulates this heralds the need to manage it effectively in terms of being able to digest and exploit it well (knowledge transformation), which can have a positive impact on innovation performance (Todorova and Durisin, 2007; Zahra and George, 2002). The other perspective to explain the difficulty in acquiring knowledge is from the social practices perspective, whereby if the employees share the same knowledge network as others, the knowledge can be disseminated to other organizations through this conduit (Brown and Duguid, 2001; Szulanski, 1996). That is, under these circumstances individuals in one organization can acquire knowledge outside their organizations, because they share similar working practice with those another organizations. For example, the graphic user interface (GUI) was initially developed by PARC at Xerox, but Apple learnt about it through their employees' contact with the developers and subsequently, went on to hire some of them. The result was that Apple developed the first commercial graphic based operation system on its Macintosh computer.

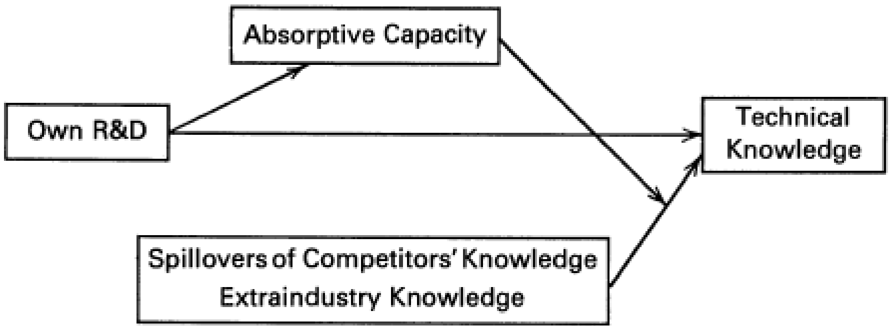


Diagram 3.2: Absorptive capacity and technical knowledge

Sources: Cohen and Levinthal (1990, p.142)

However, some scholars have questioned the clear distinction between tacit and explicit knowledge, preferring to distinguish knowledge about facts (know-what) and that about how to do things (know-how), because they contend that it is nigh on impossible to fully codify the implicit without losing some of the meaning (Cowan et al., 2000; Johnson et al., 2002). Extending this perspective, Jensen et al. (2007) applied a taxonomy proposed by Lundvall and Johnson (1994) in "The Learning Economy", which contains four types of knowledge: know-what, know-why (principles and laws in nature and society), know-who (know who can do what), and know-how, to demonstrate the problem of codifying knowledge, finding the latter two particularly difficult. For instance, because know-who involves the social network through which people can access the right people internally and externally to get tasks performed by them during the innovation creation process, which is highly dynamic and hence, almost impossible to codify accurately. Moreover, as know-how refers to the skill and capability that individuals and organizations have for making products and delivering services, even the most thorough audit cannot elicit effectively what these attributes are, in particular, because some individuals do not even know themselves.

In sum, knowledge can be divided into two different types, tacit (un-codified) and explicit (codified). Moreover, the ease of knowledge acquisition depends on the level of absorptive capacity of an organization and how relevant to its performance is the knowledge practice network shared across its boundaries. In addition, although know-what knowledge, or sometimes, know-why can be learned through codified means, know-how and know-who knowledge usually involves human interaction.

Human Resources Flow

Human resources are important in terms of the quantity and even more so in terms of quality. Regarding them, Tidd and Bessant (2009) have identified four crucial roles in the creation process of innovation. Firstly, there is the technical talent or technological champion who can bring novel scientific and technical knowledge into practice. Usually, they are scientists or engineers who work for: universities, laboratories, or firms. They commit themselves to cracking the seemingly insoluble technical problems and include such people as James Dyson, who invented the cyclone vacuum cleaner, which he subsequently exploited financially by establishing a company (Dyson and Coren, 1998). Secondly, a successful innovation will need someone to sponsor it so that the necessary resources are available to protect the germinated idea, which Tidd and Bessant (2009) termed the organizational sponsor. In Honda, this role is played by the team leader as a heavyweight project manager, who supports a project and can even overturn decisions made by the CEO, if he/she deems it necessary (Fujimoto and Clark, 1995). Thirdly, a business innovator is also required to exploit and even create the opportunities in the marketplace and among the users. A typical example is the creation of the i-Phone by Apple, which came about because Steve Jobs did not like the ugly mobile handsets resulting from collaboration with Motorola. Jobs also found the existing mobile phones contained too many functions users hardly ever used and therefore scrapped some of these to make the phone more efficient and easier to operate. Another attraction for Jobs was the huge market size of the mobile phone, with there being up to 825 million users in 2005 (Isaacson, 2011). Fourthly, there needs to be a gatekeeper who can pass information through informal social structures to the right people in the organization. The world famous design company, IDEO, used the term 'pollinator' to describe this type of talent, someone who is connected with different disciplines and thus, can help in getting the information across boundaries (Kelley, 2005).

Money (Financial) Flow

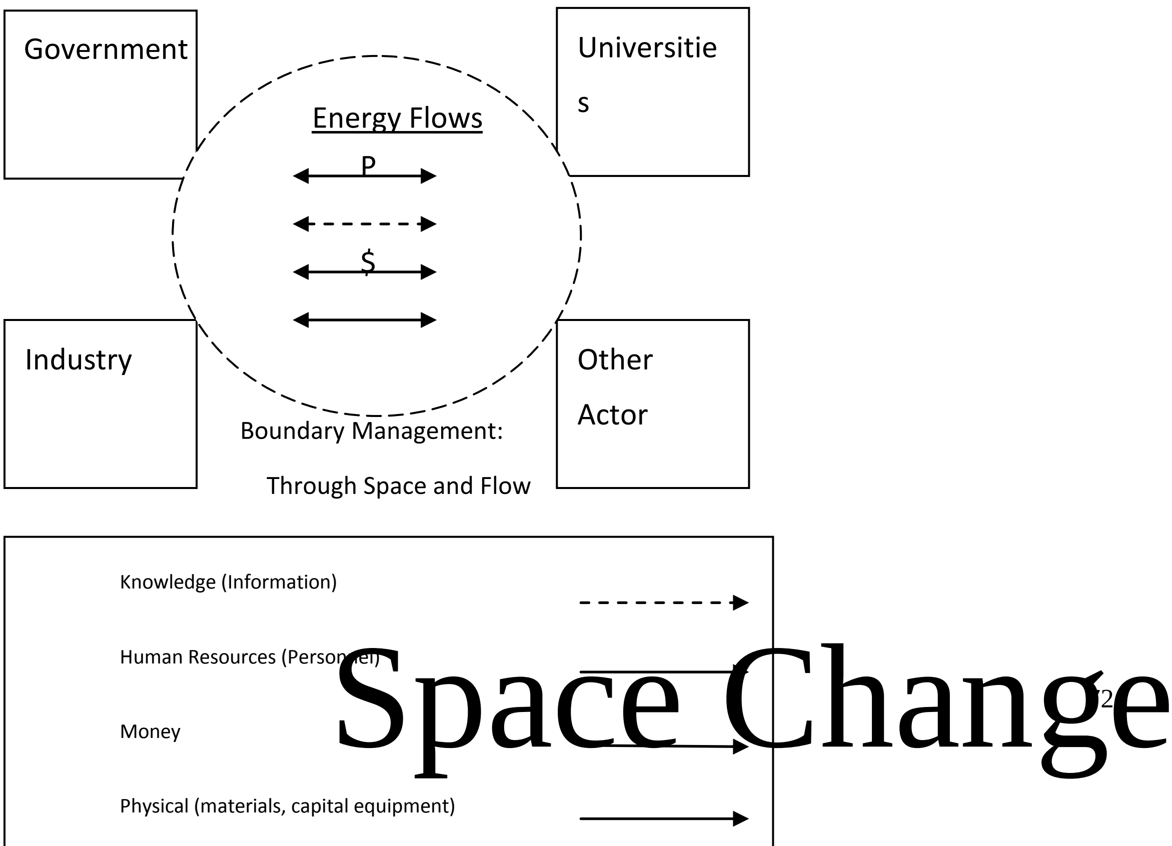
In the past, money was mainly considered as only a medium to facilitate transactions. However, a few scholars (e.g., Dosi, 1990) carried out research into the ways that the adoption of different financial systems, such as credit based or market based, can impact on the evolutionary dynamics of industrial innovation in the long term. Regarding this, in this researcher's opinion, for catch-up economies it is better not to adopt market based evaluation (e.g., market share) by the financial institutions, as domestic companies cannot compete with large frontier companies in terms of funding. In the case of the Silicon Valley miracle, the abundance in financial support at all the different stages, through angel funds or venture capital was essential for success (Cohen and Fields, 1999) and this could not be rivaled by less wealthy nations. In recent years the importance that finance plays in economic growth and innovation has been examined in a number studies. Levine and Zervos (1998) surveyed more than 38 countries and found a positive correlation with economic growth. Moreover, Brown et al. (2009) showed that abundance in financial resources from cash flow and stock issue boosts research and development expenditure in young companies. In turn, R&D investment increases the chances of new innovation and the associated probable boost to productivity of these firms. In sum, identifying sources of finance for innovation is crucial for effective implementation.

Other physical goods flow

There are other physical resources essential for innovation, such as: land, equipment, material and components. In addition, the suppliers who provide material or (specialized) equipment are also a very important element of innovations (Pavitt, 1984; Walker, 1994), for example, in particular, in relation to the food and textile industries. Moreover, location in some cases can be salient, in that industrial clusters facilitate innovatory activities (Cooke et al., 1997; Cooke, 2001; Knight and Harland, 2005).That is, the proximity of materials, components or learning and the close networking of different companies enable cluster formation and regional development. In the next subsection a new model that extends the THM by incorporating energy flow under the inclusionality perspective is put forward.

3.2.3 Actor Flow Model

The framework in diagram 3.3 explicitly accounts for the four main types of flow between/among the different actors, which is not the case in the THM. In addition to recognizing the need to include further actors in the landscape of innovation, another crucial issue is the management of the continuity of resource flows by the organization changing its internal space, whilst simultaneously being shaped by the surrounding environment. That is, an innovation is shaping the landscape and at the same time, the landscape is shaping the innovation. More specifically in the context of this research, the energy flows can shape space, and space can also shape the nature of the movement of the flow. For example, universities can provide training courses for a firm's employees (space), which will subsequently stimulate knowledge exchange (flow) among both entities' different departments.



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Knowledge includes tacit and explicit forms. Human resources include: talented technician, innovation sponsor, business oriented personnel and knowledge gatekeeper.

Diagram 3.3 Research framework: Actor flow model

The literature on boundaries has shown that any organism changes its boundary so as to interact with nearby or remote space (Rayner, 2005) and the purpose for changing the boundary is to obtain energy in order to survive and develop. When this is applied to the management of an organization, managers need to facilitate boundary management to obtain higher levels of effectiveness. In this regard, although the space in which the organization is embedded can have an impact on it, the organization itself is able to change the surrounding environment by altering the permeability and deformity of its internal space, thereby ensuring that flows of resources continue to run smoothly.

In sum, it is posited that the framework in diagram 3.1 can serve as a model to trace the evolutionary process of innovation more comprehensively than the THM. This is because, first, it caters for the possibility that new actors other than: universities, industry and government, as identified in the THM, should be included, in particular RIs. Second, it explicitly accommodates for the content and dynamic directional energy flows between the various actors involved in the innovation process and it is for this reason that this researcher has entitled it the actor flow model (AFM), in contrast to the THM.

Moreover, for the purposes of this study, the labeling of these five flows has been modified and the material and equipment flows have been merged under one category, that of physical flow. That is, the four types of energy/resource flows included are: knowledge (information, both explicit, tacit, and know-who), human resources (personnel), money (financial resources), and physical goods (material and equipment) as shown in the diagram. However, it should be noted that in contrast to Rayner's (2010) perspective, where money is only considered as a symbolic form of flow, for this work it is taken as being a form of energy flow. The justification for this lies in this researcher's opinion that although money is an artificial construct, with both invisible and symbolic elements, it can be used to procure other resources and hence can be seen as another form of energy flow. This view is also supported in a recent study by Brown et al. (2009) who have argued that money or financial assets is also crucial to innovation.

3.3 Research approach and research design

In this thesis the main research focus is on the complex process of how innovation takes place and how universities and other actors collaborate to facilitate its commercialization in real life situations in Taiwan. A qualitative research method was adopted to address the aim as this is appropriate for investigating issues in a complex natural setting, unlike quantitative research which treats the research object as being measurable or controllable in a closed system (Easton et al., 1985). More specifically, a case study approach was chosen, the reasons for which are explained in a later section. Subsequently, the findings are used to test the validity of the actor flow model (AFM) and, thus it is hoped provide new insights for HEIs.

3.3.1 Justification for the adoption of a case study approach

Creswell and Miller (2000) identified three major paradigms or world views that can be adopted when carrying out qualitative research: post-positivist or systematic, constructivist and critical. Regarding proponents of the foremost, they challenge the fundamental assumptions of positivism of: the reality being outside the researcher, data being measurable by quantitative methods and the research being value free. By contrast, qualitative researchers regard reality as being socially constructed, and hence, cannot be separate from the objects that they are enquiring about, and so they see all research as value laden (Denzin and Lincoln, 1994; Lincoln and Guba, 1985). However, like positivists they still adopt a rigorous procedure, such as setting fixed protocols and collecting multiple sources of evidence so as to strengthen the validity of the research (Lincoln and Guba, 1985). Morse (2008) contended that such an approach is also essential for ensuring qualitative research quality. Under the constructivist lens it is argued that there can be multiple social realities that are contextually specific, and it is thus interpretive. The terms validity and reliability are expressed as pertaining to the effectiveness of the data in the particular context, using terms such as trustworthiness and authenticity (Lincoln and Guba, 1985). Lastly, the critical paradigm champions argue that hidden assumptions behind the construction and interpretation of the narrative shall be revealed through investigation as these are subject to the economic, political, and social influences in which they are embedded. For the purposes of this study, in spite of the intention being to employ qualitative research, in order to ensure rigour in the data collection and analysis, a social realist stance between post-positivism and constructionism (Sayer, 1992; Parson and Tilley,

1997) is adopted. The realist worldview in some respects is closer to a post-positivist one, in that under this lens it is accepted that the world exists independently from our recognition of it, knowledge can be wrong and that any research should be laden with theory (see Sayer, 1992, pp.5-6). Within this paradigm two strategies are used, with the first involving taking an established theory to the research field in order to test it (Willis, 2007; Yin, 2003). The second pertains to developing the research design in terms of choosing the methods and form of analysis prior to the beginning of the research. With respect to this, this researcher has developed a theoretical framework prior to the empirical investigation, which tests its validity and hence, can be seen as being consistent with this second method under the realist paradigm.

In general, there are four major qualitative research schools: phenomenology, grounded theory, ethnography, and case studies, with each being based on different conceptual foci (Christensen et al., 2010; Creswell, 2007). Under the phenomenological approach, researchers try to elicit the experience and meanings for people involved in the specific space. Grounded theory involves the researchers seeking explanations about phenomena and/or developing theory based on the analysis of collected (empirical data) data. Ethnographers aim to portray and understand the culture of the focal group(s), whilst those undertaking case studies investigate the detailed narratives of a bounded system (Stake, 2000), which can cover: an individual, a team, an organization, a process or even a nation. Addressing the second research question in this thesis, is not about only investigating the phenomenon of innovation or the culture involved as the phenomenological and ethnographical approaches would be targeted at, respectively, but also in relation to the underlying reasons for the paths that innovations take. Moreover, the research method is not expected to generate a new theory from the data, but rather to provide evidence in support of or to refute a new model. Therefore, a case study approach is deemed the most appropriate to address the three research questions.

The purpose of the case study is to understand how collaborations actually taken place among: research institutes, universities, industry and government bring forth innovations. In particular regarding this, it was considered that this approach would shed light on how innovations emerge and whether the concept of natural inclusionality can be a useful way to account for how research institutes in Taiwan have become effectively involved in the processes of innovation. Before reaching this decision to employ a case study, other methodological strategies were considered, namely, a survey, or an experiment. With regards to the former, this is an effective approach when the nature or structure of a problem can be expressed as a hypothesis that can be tested. However, this current research is exploratory in nature, because there is scant literature in this particular field. Moreover, the relationships between the different variables remain unclear and therefore, meaningful hypotheses cannot be easily postulated. Turning to the experimental approach, although this can deal with "how" and "why" questions (Yin, 2003), it was deemed inappropriate, because the causal relationships among universities, industry, government and the RIs and the variables involved were undeterminable prior to the investigation owing to their being strongly subject to contextual factors. Therefore, this researcher decided that the case study approach was the most suitable for this research.

By undertaking this method scholars aim to provide analytic generalization (Yin, 2003) in which previously established theory is taken to form a template for the new case.

Often, two or more cases are explored in order to either provide support or to invalidate the theory in question, following the principle of replication taken from the experimental method found in the natural sciences. There are three kinds of case study: intrinsic, instrumental and collective (Stake, 2000). An intrinsic case study contains one unique case and the purpose is to understand its uniqueness or particularities. An instrumental case study aims to examine issues or to provide the basis for generalization, whereas a collective case study requires more than one instrumental case to investigate 'a phenomenon, population or a general condition' (Stake, 2003, p.445). Yin (2003) argued investigating multiple cases strengthens the validity of any findings that emerge, in particular, because a single instance may be subject to unique conditions from which little can be learnt. It also can provide more trustworthy and crucial knowledge (Stake, 2003) and therefore, for this research a multiple case study was adopted, comprising two distinct cases.

3.3.2 The choice of cases

The Taiwanese government launched the Advance Technology Research Programme (ATRP) in 2000 to encourage the research institutes to take bold initiatives to develop advanced technology. Later, this government initiative was extended to include universities and the industry. The ITRI, as the largest research institute in Taiwan, received a substantial proportion of the funding allocated to this programme and every four years is required to self-evaluate the performance of those research projects supported by the programme. The evaluation reports of the Advance Technology Research Programme (ATRP), published by the ITRI, provide the government with examples of innovations and these were taken as the starting point for identifying suitable cases for the current study. More specifically, as these were being reviewed, those that met the criteria of having had commercial success, such as significant licensing revenue, were highlighted and four potentially suitable candidates, including: cartilage reparation, AC LEDs, flexible speakers and, flexible display, were identified. The first two were selected for further investigation: one being a case involving in vivo cartilage reparation technology that had taken place in the bio-medical field and the other being AC LEDs in the optoelectronics sector. They were chosen partly because they represented quite distinct fields of research and partly because they were the most advanced of the four innovations in terms of their exploitation and hence, were deemed to offer the likelihood of the collection of the richest data. For instance, these two cases had achieved substantial licensing incomes compared to previous licensing records. . In addition, the AC LEDs innovation had become well known in its field for having been awarded the prestigious R&D 100 Award in 2008 and whilst other two innovation teams had also won prizes and had been licensed, they had yet to realize any noticeable commercial value at the time of the research, in terms of licensing amount.

The rationale behind choosing two distinct, contrasting, cases was because it was considered this allowed for the possible confirmation or refutation (Creswell, 2007; Miles and Huberman, 1994; Stake, 2000; Yin, 2003) of theory from the results. That is, if both cases with their commonalities and differences emerged as being applicable to the proposed model, then this would justify a claim of it having some theoretical validity. In relation to this distinctiveness of the chosen cases, with the first being based in the life sciences, universities usually play a very active role in these circumstances and many biomedical technology companies have been established as spin offs owing to the fact that research initiated in university laboratories is relatively easy to launch (Mansfield, 1991). In fact, at the ITRI biomedical research is only a recently established laboratory (not until the late 1990s) with smaller licensing revenues than other departments and hence, the identified innovation, which has been the most successful in its area, to date, represents a special (extreme case) worthy of being chosen for detailed investigation (Eisenhardt, 1989; Pettigrew, 1988; Yin, 2003). Regarding complex systems industries, such as the semiconductor and information sectors, to which the second case study belongs, it is not so easy to take pure research from university laboratories and scale it up for industrial use, because usually several technologies from different sources/actors are needed for innovation success (Hobday, 1998; Hobday et al., 2000). With respect to this, when comparing these two industrial sectors Mansfield (1991) found that 27 percent of new product development in biomedical industries, such as the drug industry, relied on academic research, whereas in the electronic field only six percent of new products could be described as having these origins.

Having selected the cases the aim was to, first, validate the AFM by assessing the four different identified flows (human resources, knowledge, money and physical resources) and second, to show the extent to which the it could explain how specific inventions become successful commercial products and if this emerged to be a valid approach, what are its implications for HEIs. That is, through illustrating the processes involved in the developmental trajectory of these specific inventions the aim was to elicit the usefulness of the concept of inclusionality. In this regard, as described earlier, natural inclusionality develops and grows, so likewise, whilst the narrative accounts of these two cases unfolded it was believed that the evidence regarding the content and validity of the AFM would be deepened and enriched.

Scholars (Creswell and Miller, 2000; Jick, 1979; Lincoln and Guba, 1985; Lincoln, 1995; Yin, 2003) have suggested one of the best ways to achieve a robust, valid case study is to employ triangulation strategies, specifically, multiple sources of evidence. Therefore, to explore the two case studies in the current research, this researcher included two main types of data, namely, primary and secondary. The former refers to first hand data that is usually obtained in the following ways: interviews, observations, and participant observation. In this research, the interview technique was adopted as this researcher was of the opinion that tacit knowledge and pertinent insights could be most effectively gleaned through interaction with the people who were involved in: inventing, executing and rolling out the two innovations at the heart of the two case studies.

3.4 The validation, data collection, data analysis process

In qualitative research, during the data collection data analysis and validation can be undertaken on an ongoing basis (Creswell, 2003). Therefore, here the three levels of data validation are considered first, followed by explanation and justification of the two major sources of data collection and lastly, the process of data analysis is reported.

3.4.1 The three validation lenses

Creswell (2000) summarized the validity process for three paradigm of qualitative research. As explained above, the stance adopted for this research is that of realists through the carrying out of a multiple case study. In addition, Yin (2003) suggested the multiple-case study has similar experimental design to that found in the natural sciences. As the more rigorous research procedure and enquiry are used in this research, a systematic paradigm is adopted with three different lens, namely, triangulation, member checking, and the audit trial. The first lens is that of the researcher who needs to adopt triangulation to ensure the creditability of the collected data. This can comprise a number of different aspects, such as: multiple sources of data and techniques (primary and second data collection), multiple methods and multiple theoretic explanations (THM versus AFM) (Creswell, 2007; Jick, 1979; Lincoln and Guba, 1994; Yin, 2003). In this study, approximately 10 people were interviewed for each of the two cases, which constituted the first-hand (primary) data. Depending on the case, the significance of the role that each party played in the creation of the innovation differed and thus the decision regarding how many interviewees from each to include for the case study varied accordingly. The interviewees were selected both on the recommendation of the main inventors, and the people in these four spheres who had directly supervised the cases under study.

However, it was suggested by my supervisor at ITRI that some potential interviewees should be replace by alternative interviewees, given potential conflict of. In addition, secondary data in the form of published material was collected and two competing theoretical explanations are applied in the analysis. The second pertains to engaging people in the social setting of the research topic, which involved sending the draft findings back to people directly involved in these two cases, including, the main inventor, his supervisor, and the vice president of their department to ask for their views and as to whether anything needed to be changed or added. Lincoln and Guba (1985, p.314) regarded member checking as "the most crucial technique for establishing credibility." The third lens in the validity process refers to including people who are external to the project to review systematically all the assessment of the research questions, case documents, and analysis. To this end, two validation meetings (more details are provided in Chapter 5) were held to report the findings to nonparticipants and one of the inventors. In addition the first meeting also served as a pilot validation meeting to improve the second one. Through this procedure, the meetings were thus providing audit trails.

3.4.2 Primary data collection: interview and physical artifacts

A realist semi-structured interview design implemented with a protocol

In general, there are three different kinds of interview: structured, unstructured and semi-structure (Parson and Tilley, 1997; Fontana and Frey, 2003). Usually a structured interview design is adopted for undertaking experimental investigation and involves a standardized process with a closed set of possible responses for nearly all or all the questions posed. Whereas, unstructured interviews are used when a social constructivist stance is taken up, with the aim being to explore and interpret phenomena in the real world. The question schedule for this approach is not binding, for after the initial set questions have been put the rest of the interview can be different in all cases. Semi-structure interviews lie between these two and involve setting standard questions that are all asked during the meeting, but space is given to allowing follow up questions when wanting to probe an issue in greater depth. Because under a realist perspective one of the key aims is to test or refine theory, a semi-structure interview is deemed the most appropriate for this research (Parson and Tilley, 1997). That is, such an interview should begin with simple questions strongly related to the main focus of the enquiry, with follow up questions that are considered to be fruitful avenues for the researcher to explore in his/her attempt to validate and/or improve the theory being investigated.

In order to strengthen the reliability of a research endeavour, Yin (2003) advocated the use of a protocol for carrying out interviews in the field. The protocol developed for this study (see appendix 3.1) includes: the purpose of the two case studies, the data collection procedures, the interview questions, the structure of the case study reports, and issues which the researcher must keep in mind throughout the fieldwork.

Turning to the interviews, in keeping with the requirements of the protocol, before initiating the schedule of interviewing it was necessary to review the purpose for which the two case studies were to be carried out, namely, to understand the developmental trajectory of the innovation. Consequently, the main purpose of the interviews was to elicit narrative accounts of the events and circumstances surrounding these trajectories. To these ends, the questions adopted were open-ended and the interview schedule for use with all the participants was semi-structured. Thus, if an interviewee had a novel insight to contribute related to the case, the interviewer had the space to inquire more deeply so as to probe their understanding to its fullest extent. Having completed the interviews, their content was confidentially transcribed and after the evidence from them and the other data sources had been applied to the AFM, the respondents were provided with the relevant outcomes prior to the aforementioned validation meetings, so they could attend them being cognisant of these.

In table 3.1, the interview questions are set out and for each, one or more of the aforementioned four types of flow are ticked, thus showing what aspect of the AFM they pertain to. Moreover, the right hand column indicates where other, non-flow related data, were to be gathered.

Interview questions	4 types of Energy Flow			Other data	
	Human Resources	Knowledge	Money	Physical	
How did the idea of the invention come about in the first place? Did you collaborate with anyone? How did you first get involved in this project?		✓			Identify Actors
Once initiated, how did the project progress? Were there any particular ideas flowing during the process?		✓			Understanding the evolutionary process
What were the funding sources? Where did they come from?			✓		
Was there any help or collaboration with other: team members, universities, firms	✓	✓	✓	✓	

and/or the government					
Did you run up against any challenges during the innovation process? How did you resolve them and if they haven't been resolved, why not?	✓	✓	✓	✓	The nature of the process
What is the future plan regarding this innovation and what has been your part in this development? Are there any other projects on the horizon in near the future?	✓	✓	✓	✓	The plan for commer cializati on
Can you think of any other issues that you think are important for me to know, but I haven't asked about?	✓	✓	✓	✓	Other potentia l issues

Table 3.1 Interview questions matched to type(s) of flow information for applying to the AFM

The interview question schedule encompasses the evolutionary process through which the innovation at the centre of the case study had emerged and the energy flows associated with this journey. That is, questions on the evolutionary process referred to: the origins of the innovation; its conception and commercialization, and finally, the actors, organizations and resources involved, whereas the questions on energy flows covered the following dimensions: monetary resources, flows in the financial support or funding for the project; human resources, as exampled by the arrival, departure or redeployment of key actors; knowledge that in its tacit form is invisible, but some knowledge has been made explicit, being found codified in: reports, conference or journal papers and patents.

As aforementioned, this enquiry involved four different parties, namely representatives from: universities, the research institute, government bodies and industry. However, depending on the case, the significance of the role that each party played in the creation of the innovation differed and thus the decision regarding how many interviewees from each to include for the case study varied accordingly. In the first, the in vivo cartilage reparation case, it became apparent from the background literature (see secondary data sources below) that the government agencies were substantially involved, but in the second there was little evidence of this and hence, although there was some contact with the government office responsible, no direct input from its representatives was included in this latter case. Nevertheless, because in both cases it emerged those actors from industry had provided significant inputs in the innovation process, representatives from the firms involved were included in the interview as were the inventors and members of the commercialization support teams from the universities and the ITRI. The interviews were conducted so as to elicit the nature of the four previously explained energy flows between the various actors.

In these two cases, interviewees from universities, industry, the government, and the research institute were involved. Because of the difficulty to get access to the government official who was in charge of the first case, this researcher decided to hold a telephone interview with the appropriate government official for the second case. Moreover, to address the lack of contact with an official in the first case, extra attention was paid to encouraging the other interviewees to explain in detail there interaction with the government. In addition, when the case was drafted the transcript was sent to a different person in the government for the first case, who fortunately did provide some feedback. The list of interviewees is illustrated in Table 3.1.

Cases / **Actors**	**Cartilage reparation**	**AC LED**
University	NTUH: Dr J, M.D. Dr Chen, M.D.	NCKU: Dr C NCU: Dr H NTHU: Dr Liu
Industry	Exactech: Dr K Mr Lin Dr C CRO:	Tyntech Dr X Epistar Dr Y

	Ms X	
Government	Mr C (Once at ITRI)	Ms Y
Research institute	Dr L Dr Liu Ms S Mr Sh Dr Lee Mr Jang	Mr Lin Dr Chu Dr Yeh Dr Y Mr U Dr L

Table 3.1 Interviewee list for the two cases

Source: This research

However, there are drawbacks associated with interviews as a technique for data collection, such as the interviewees' biases, poor recall, and inaccuracies when expressing themselves (Yin, 2009, P.102) To address these potential weaknesses, it was decided that a high proportion of all those directly involved in each innovation should be interviewed. That is, approximately three quarters of the relevant people were questioned. Moreover, further triangulation of the interview responses was sought through consideration of the appropriate documentation as explained below.

Primary data collection in the field

The two cases were based in two different laboratories at the ITRI, the Biomedical Laboratory (BML) and the Electronics and Optoelectronics Laboratory (EOL). To gain access, the key inventors involved in each case, Dr L and Mr Lin were contacted, and furthermore the directors of the laboratories were informed about the research.

The interviewees that were selected worked in: the research institute (the ITRI), industry, universities, and the government. Regarding the research institute, the main inventor and co-inventor(s) were included as well as the supervisors or deputy supervisors and the vice president in each laboratory. Furthermore, relevant internal consultants and people working on IP protection, licensing and business development at the ITRI, were interviewed. In relation to the university interviewees, these included the key actors who collaborated with the ITRI staff, whereas industrial respondents were those who took responsibility as the point of contact at the licensed companies as well as relevant third parties who facilitated the innovation licensing, such as the contract research organization (CRO) in the first case study. As these two cases both involved inventions, at the interviews the inventors were asked to explain how they worked as well as to provide examples of any relevant artifacts, such as components, prototypes, and tools that could be examined later by this researcher. Where this was not possible, photographs were taken that could be used to help facilitate understanding of what had been developed in each case. In addition, most interviews were recorded (if not possible, the interviewer took notes) and transcribed later for the further analysis.

3.4.3 Secondary data collection

Various sets of data that have been collected for other purposes potentially contain useful insights that could inform this study. The following forms of documentary evidence (documents and archival) are included in this research.

1. Formal studies or evaluations of the innovation case: for example, the Taiwanese government stipulates that the ATRP at the ITRI must write an evaluation report every three years on their advances in technology research.

2. Administrative documents: for example, project proposals, progress reports and budgets related to these innovations.

3. Media coverage and articles published in the research community, such as news about each of the innovations used as case studies that has been released to the press. For instance, when the AC LED won the RD 100 award in 2008, the story was widely reported in newspapers and trade magazines, such as Business Week.

4. Journal papers and patents: The results of ground breaking experiments and new discoveries are usually sent to peer review journals. Moreover, to protect valuable inventions patents are filed so as to enable the original developers to have exclusive rights over all aspects of their: manufacture, marketing or further research

3.4.4 Analysis of the data

After these data were collected, the process of reassembling, categorizing coding, arranging them so as to be able to address the research questions comprised the data analysis (Miles and Huberman, 1994; Creswell, 2003; Easton, 2010). More specifically, open coding (Corbin and Strauss1990; Creswell, 2003) was undertaken, whereby the data was read through and several possible main categories were identified. Subsequently, axial coding was carried out which refers to reviewing these categories and their relationships so as to allow the principal themes to emerge (selective coding) (ibid). Given that a realist analytical approach was adopted, the next task was to see whether and how these themes drawn from the cases aligned with the conceptual framework put forward for examination (Sayer, 1992; Creswell, 2003; Easton, 2010). As the nature of the case studies was to investigate the evolutionary process of innovation, the most appropriate way of mapping out the findings was deemed to be in the chronological order of the identified events pertaining to the four different kinds of energy flow between the different actors (entities). Consequently, the structure and conditions of the generation process (the mechanism according to realists, see Sayer (1992, P.15)) were revealed. Moreover, as aforementioned, two validation meetings were held to present the findings from the two cases and their conceptual underpinning, which allowed people not directly involved (except the inventors) to verify or propose modifications to these research outcomes.

3.5 Ethical considerations in the research

As this research involved interviewing and making extensive inquiries, it was essential to address issues that arose regarding confidentiality. As this researcher is an employee of the ITRI, and as such is an insider, he was able to collect information in the institute much more readily than researchers located outside. However, he needed to remain aware of the basis on which he decided to disclose information to the public, the bias of pre-understanding (Coghlan, and Casey, 2001) and how he could protect the sensitivities of the participants in the study, particularly those who gave interviews. To avoid conflict between the dual roles both a researcher and an organizational member (ibid) of this researcher, he was not involved in the planning, funding, and issues directly impacting upon these two case teams. More specifically, in accordance with Yin's (2003) perspective, three key ethical issues needed to adhered to when conducting the research, as explained next.

3.5.1 Obtain agreement from interviewees and participants in the validation meetings

At the beginning of the interviews, permission was requested from the interviewees to record the conversation and they were informed that detailed transcriptions of the interview would not be made public without their permission, as the main purpose of the data collection was to inform the case study analysis (Creswell, 2007). Moreover, in the meetings the participants were clearly made aware that their role was to assist in the validation of the findings of the case studies and that the video camera was being used for making a recording of the validation process for further analysis. If any participants had felt uncomfortable about the video camera, the researcher would have stopped the recording and have taken field notes instead, which did happen in part of one validation meeting.

3.5.2 Do no harm and protect the participants

Once the draft of a case study had been compiled it was sent to the main inventor and the vice president of the relevant laboratory for them to review. The researcher's supervisor initially considered the contents and if she had had any concerns, she could have forwarded the papers in question to the principal inventors to obtain their feedback, but in the event this was not necessary. Moreover, the director of the technology transfer office read these documents to check that there was no violation of the intellectual property rules of the organization. With respect to the validation meetings, the researcher explained that his role was not that of an authoritative figure, but that of a facilitator who intended to present all the relevant facts and the chronology of the events regarding the innovation, so that the participants could jointly consider these with a view to validating the researcher's: information and claims made.

3.5.3 Concerns regarding privacy and confidentiality

As the case studies were originally selected from the ATRP evaluation report, the identities of some of the interviewees in the study have been previously revealed to a wider audience. However, during the interviewing there were some issues which the interviewees preferred not to have recorded, or appeared to be hesitant about discussing, in which case, the researcher stopped the digital recorder and just listened to their responses. Later, the information that had not been recorded was summarized as notes and the researcher took care not to disclose this matter to those who were not entitled to know about it. Moreover, he promised to consult with the appropriate people at the ITRI before submitting articles for publication or for public presentation.

To sum up, in this chapter, three research questions related to collaboration between universities, the industry, government, and research institute have been put forward. To address them, a realist position has been taken between the post-positivist and social constructionist stances. Moreover, the theoretical framework of the actor flow model has been articulated as well as the adopted research method, case study, having been explained and justified. In order to elicit contrasting outcomes, these two cases of the innovation are chosen from different fields, one being biomedical and the corning from optoelectronics. The rationalities behind these two chosen cases have also been illustrated. First-hand information, including interviews and second-hand information (archival reports and newspaper articles, etc.) were collected for both cases. In addition, the validation measures have also been explained in terms of the triangulation design (multiple sources of data and theoretical explanation) and semi-structure interview protocol as well as the validation meetings that involved inviting some outsiders from each case (more details in chapter 5). Furthermore, the ethical issues of this research have been addressed in relation to treatment of the interviewees and potential pitfalls when undertaking the research.

Chapter 4 Case Study

4.1 Introduction

In this chapter, two innovation cases were presented as a basis for analysis in next chapter. They are from two different disciplines, one bio-materials and the other opto-electronics. Both of them involve investigation of the collaborations among the different institutional actors: universities, industry, government and a research institute, but there are some marked differences in their nature. Moreover, the data collection for these two cases was carried out in accordance with the research framework of the previous chapter. In addition, the proceedings of two validation meetings, which represent the audit trial, are followed to elicit further insights into the findings regarding the cases, in particular, regarding feedback on the interpretations that I made about the subject matter, thus involving an action research perspective. Here, the six question indicators are employed, namely who, what, where, when, why and how (5Ws1H) as a number of scholars have suggested that these form helpful guidelines when conducting enquiry for assisting the codifying of knowledge during the learning process (Chandler, 1997, Johnson et al., 2002). That is, by undertaking this procedure it is possible to identify areas for improvement. More details of this reflection and learning process are reported in chapter 5.

4.2 Case One: From a Novel Scaffold to a Novel Cartilage Reparation Approach

4.2.1 The background

The Industrial Technology Research Institute (ITRI) is the largest non-profit, multi-disciplinary applied research centre in Taiwan, established in 1973, and contains around 6,000 employees including approximately 1,000 PhD researchers (ITRI, 2012). It has been playing an important role in national economic development, having spun off more than 35 companies, one of which is the largest producer of semiconductors in the world, the Taiwan Semiconductor Manufacturing Corporation (TSMC) (Shih et al., 2003). In 1998, foreseeing the potential of expanding into the medical market, the ITRI set up a biomedical centre, which in 2005, after reorganization became a biomedical core laboratory.

4.2.2 Collaboration with the CISRO and testing it at the NTUH

The ITRI endeavoured to build international relationships with many research institutes, universities, and industries. In 1999, the tissue reparation group at the biomedical centre started up a collaboration with the Commonwealth Scientific and Research Organization (CISRO), the largest government sponsored research organization in Australia. CISRO had in fact been working on knee cartilage reparation for many years before this coming together. In order to test the feasibility and safety of this material, which was potentially groundbreaking, the research team at the ITRI approached the National Taiwan University Hospital (NTUH), the most prestigious medical school in Taiwan affiliated to the National Taiwanese University. More specifically, they initially contacted Dr J, professor and dean of the orthopedics department at the NTUH, who in his professorial role was willing to test this new material. The division under the collaboration was that the ITRI would provide the material and the professor agreed to supply the guinea pigs on which to test it. It subsequently transpired that the medical material relating to the scaffold was successful in that it allowed for the culturing of cartilage ex vivo, which could then be replaced in the damaged site, in vitro. The collaboration project with CISRO ended with a company being formed in Australia that mainly supplied this material, but it shut down after only a few years.

4.2.3 A new cartilage reparation collaboration project between the ITRI and NTUH

In 1999, Dr L was recruited to the biomedical centre, having once worked as a post-doctoral researcher in the medical-engineering centre at the NTUH, which involved investigating various medical materials. In 2001, the ITRI finally persuaded the Taiwanese Ministry of Education (MOE) to fund the Advanced Technology Research Programme (ATRP), focusing on exploratory high risk and high potential research projects. The vice-president of the ITRI, Dr Lee, was also the chief director of the biomedical centre and reviewed all the proposals submitted to the ATRP programme. At that time, the vast majority of mainstream research at the ITRI was focused on the popular topic such as stem cells, whilst research into cartilage was a marginal field. When submitting the proposal, Dr L strongly endeavoured to convince the panel of the importance of his research regarding cartilage reparation.

Although not fully convinced by Dr L's proposed university-institute collaboration on the vitro culturing of medical materials, Dr. Lee expressed his willingness to back it because of Dr L’s enthusiasm. By way of explanation, Dr L was motivated to develop something related to the orthopedic field as he had accumulated much relevant research experience before being recruited by the ITRI. In particular in this regard, he was cognisant of the different approaches adopted by medical scientists, which contrasted with the skills of the ITRI scientists at that time who came from a chemical or material science background and largely focused on the perfection of a prototype material itself. Moreover, Dr L had been trained to follow through projects testing every phase of the research, including working with animal subjects, such as mice. However, the ITRI did not have the facilities for animal experimentation in preparation for testing materials on animal subjects. Therefore, Dr L was obliged to go back to the NTUH so as to be able to carry out this pretesting.

Under the ATRP provision, the ITRI commenced a university-research institute collaboration programme in 2002, which encouraged its researchers to work with others based in universities and having identified suitable people, they were to work with them so as to leverage robust ideas and research capabilities. In other words, their mission was to encourage scientists to tap into the large number of PhD scientists scattered across universities in Taiwan, estimated at more than 13,700 individuals (NSC, 2011), and subsequently form working partnerships. Since Professor J had already been involved in the previous CISRO scaffold material project and Dr L also knew him from when he worked at the NTUH, the latter made contact with the former and a collaboration contract between the two was signed in 2001, with an official start date of November 18th, 2002.

Once this commenced, they collaborated in a novel way, that is, Dr J at the NTUH provided the ideas and specified the developmental needs, whilst at the ITRI Dr L conducted the applied research, which involved the modification of the existing materials so as to meet the orthopedist's requirements. The structure of this arrangement was conceived by Dr. L after his post-doc experiences with medical doctors at the NTUH. In this regard, he recognized that hospital doctors are often too busy to apply their practical knowledge to the production of new medical materials and treatments. Nevertheless, as he observed, frequently they came up with good solutions to health problems, but having not to put the real needs of the patients first, meant they lacked the time to test these remedies. As a result, he concluded that someone with extensive medical training was needed who could develop prototypes for testing these ideas, as this would make them more amenable to the conducting of clinical trials once solutions to such problems had been discovered in the laboratories.

There are two types of defects that occur in cartilage: partial thickness and full thickness. Partial thickness refers to defects where the surface of the cartilage is eroded and this can be cured or the symptoms relieved by various surgical procedures, such as abrasion arthoplasty. Regarding full thickness, this refers to defects where the lesion or erosion has reached the subchondral bone and the cartilage cells usually cannot multiply by themselves. This is because the cells situated between the chondrocytes have become gel–like which restricts their growth. Before novel procedures for cultivating cells were introduced, the medical solution was joint excision and replacement surgery when other interventions, such as: debridement and lavage, microfracture, drilling and abrasion arthroplasty had had no effect. In sum, these patients received an artificial joint which lasted for approximately ten to twenty years before needing further replacement (ITRI, 2005).

4.2.4 The existing cartilage reparation solution, Cartcel

In the 1980s, in New York, researchers in certain hospitals had already studied the potential of repairing patients' cartilage by using their own vitro cells and by 1994, a commercial version of this therapy had been published in an article in the New England Journal of Medicine, authored by the University of Goteborg and Sahlgrenska University Hospital, in Sweden. This product was licensed under the name of Carticel and its manufacture was taken up by the Genzyme Tissue Repair

Company. The therapeutic process involved cultivating the patient's cartilage cells (also called autologous chondrocytes) and implanting them back into the damaged area. Usually, an orthopedic consultant carried out arthroscopic surgery to harvest the residual part of the knee cartilage and then sent this on to the Genzyme company. The company then made a culture of the articular cells and in two to four weeks cultivated around 12 million cells. These were subsequently returned to the hospital, whereupon the surgeon opened the knee and repaired the damaged area by implantation, which was fixed in place by using the lower leg tissue (periosteum) to cover the bone (Genzyme, 2010).

4.2.5 The initial cartilage reparation solution

In contrast, the focal case study innovation involved using a different approach. Dr J at the NTUH had many years of experience in treating articular cartilage defects and in light of this, suggested doing vitro cultivation or cartilage experiments on pig subjects, because they have many more genes in common with humans than mice. Initially, they advanced the emerging ex vivo autologous cartilage restoration method that involved replacing the periosteum layer with a biphasic scaffold and to do this they harvested tissues from healthy unstressed cartilage and extracted chondrocytes with enzymes. Next, they multiplied tenfold the number of chondrocytes which took place for a number of hours outside the subject's body. Finally, they put the cultured chondrocytes into the scaffold and placed it in the damaged area. This was a very exacting process and demanded considerable commitment from the teams from both the NTUH and the ITRI. Nevertheless, by 2003 they had reduced dramatically the length of the procedure to four hours, which caused much anxiety amongst the NTUH surgeons who were responsible for the operations. The ITRI team too was under pressure as they had much to achieve in this short time, namely, preparing the scaffold, taking rice sized cartilage cells (chondrocytes) from the unstressed cartilage, releasing the cells with the enzymes and putting them inside the bi-phasic scaffold.

4.2.6 In pursuit of a 30 minute in vivo surgery solution

By 2003, Dr J and Dr L had managed to reduce the cultivation time of the joint tissue to four hours. Even so, it was still a painstaking process, in which the team at the NTUH had to wait for the completion of the ex vivo process, which the ITRI scientists started by preparing the cultivation of the vitro cells, and then waiting for the results. All team members went to the laboratory on a Saturday, as doctors at the hospital were very busy during the weekdays. In 2004, the ITRI hosted a review of its university-ITRI collaboration in an off-site meeting with representatives from the relevant university departments and the top managers of the ITRI, including the president, Dr Lee. When asked his opinion on the progress of the collaboration, Dr J laid down the following challenge: “reduce the four hour cultivation period to something like 30 minutes and get it done as part of the surgery process". In response, Dr Lee said that for this to be possible it was necessary to have a more rapid bio-reactor for multiplying the vitro tissues, to which Dr J countered that the human body provided the best bioreactor and this would be an option if they could put the chondrocyte cells back into the patient with a simple medical procedure. He came up with this idea because of his track record in carrying out successful surgery on vitro cultures by taking some unstressed healthy cartilage tissue from patients, cutting it into tiny pieces and then returning some to vitro tissues in the patients' damaged region (Jang, J. F., 2008). For example, a patient whose cartilage was repaired by transplanting his unstressed autologous cartilage nine months after surgery on

December 14 2002, had his cartilage recovered. This use of autologous (the patient's) cartilage implantation would avoid the possibility of rejection by the neighbouring cells. In sum, through this dialogue the research agenda was re-directed and the researchers in the two organizations became re-focused with Dr J and his team fully supporting this cartilage project.

4.2.7 Dr Jang's suggestion and Intellectual Property (IP) protection

The funding to support the work, however, was not changed significantly until Dr Yue-Teh Jang was asked to carry out a full review of the biomedical projects being run under the auspices of the Advanced Technology Research Programme (ATRP). He was president of Bio-medical Capital Venture, a Vertical Group in the US who was employed as a consultant for the biomedical centre and a member of the ATRP steering committee. In addition, he had worked for various biomedical companies as head of research, for example, at Johnson and Johnson in the US. Moreover, he had started up two biotech enterprises himself and subsequently sold them on to pharmaceutical companies. When he visited the ITRI in 2004, he listened to presentations regarding all of the current biomedical projects, and was most interested in this one. Drawing on his extensive experience and judgment in these matters, he regarded this as having the most potential and recommended that Dr Liu, the general director of the biomedical centre, should extend as much support as was necessary to ensure it flourished. More specifically, Dr Jang supported the setting up of a GMP factory to produce the scaffold materials, a plan which Dr Liu immediately approved, earmarking funding from the Key Component Technology Programme. This programme carried around 50 percent of the total government funding given to the ITRI.

Subsequently, funding from the Key Component Technology Programme began to support the vitro-culturing project, at a rate that was approximately ten times more than that previously allocated to the research and with these resources the team, headed by Dr L, was able to establish a small-scale GMP factory. Dr Jang further advised the research team to file patents in order to protect their inventions and avoid intellectual property (IP) infringements and although previously some patents had been lodged, more systematic patent filing commenced. Today, there are at least seven different inventions protected by filing more than 24 patents internationally, including: tissue homogenizer apparatus and processes for washing tissues, a porous chamber for tissue culture in vitro, a process for producing porous polymer materials, a method of multi-layering culture tissues in vitro, a method of multi-layering tissue repair and a method of culturing cartilage tissue in vitro.

In 2005, after experiments on pigs proved the effectiveness of this new approach, the ITRI and the NTUH prepared the necessary documentation for starting clinical trials. This event marked the first time that the health care system in Taiwan could justifiably claim to have put forward a domestic in vivo product for use in surgery and have reached the clinical trial stage of development. In the past many new products had been sent for approval for human clinical trials by the Healthcare Bureau, but few of these had been originally developed in Taiwan. Dr L and his associates understood the importance of adopting the General Manufacturing Practice (GMP) for the project, as followed by pharmaceutical factories in the medical field and once the funding from the Key Component Technology Programme flowed in after 2005, these protocols were employed to manage the research endeavour. As the feasibility of this new method had been verified in its experimental form, it subsequently reached the stage of commercialization. Regarding this, this research project was referred to the

Technology Transfer Centre (TTC) at the ITRI in order to have the valuation of the technology carried out. The vice president as well as the general director of the TTC, Dr H. and his team were tasked with figuring out the value of the bio-medical product technology, which was problematic as most technology transfer cases referred to developments in the electronic and telecommunication branches of the ITRI. Moreover, as the team was inexperienced in the biomedical area they were unsure about the future prospects for this particular set of technologies. Initially, when this case was submitted to them, the TTC team, based on their previous experience, suggested that a few million dollars (NTD) would be a suitable valuation figure. Dr J at the NTHU disagreed contending that he would be prepared to pay many more millions to buy this technology. His reasoning was based on his rough calculation that ten percent of the population is over the age of 65, and one quarter of them suffer from full thickness vitro cartilage defects amongst whom another quarter require surgical intervention. Using only the data for Taiwan, that added up to potentially 250 thousand clients. Considering the global market and who could afford to pay for the surgery, he estimated that potentially there would be some 6 million patients worldwide. He concluded that the licensing needed to be set at far more than a few million dollars (NTD) and after consultation with Dr Hsu the figure of 30 million (NTD) was settled upon as the valuation.

4.2.8 Receives the attention of Exactech, the fifth largest U.S. bio- material company

Dr L submitted an article on the new cartilage reparation method to the Journal of Biomedical Material Research in 2005 and this paper was noticed by a manager, Steve Lin, who worked for the fifth largest artificial joint company, Exactech, in the US. For a number of years, they had been seeking growth opportunities for expanding their product lines and when Lin found the results of the early experiments using mice he saw these as offering great business potential. By 2006, Exactech had already visited the ITRI more than five times, and showed great interests in this new therapy. However, according to the Basic Science and Technology Laws of Taiwan all intellectual property brought to conceptualization from funds provided by the government has to be first offered to Taiwanese companies. Consequently, the TTC arranged a technology-licensing presentation to place information in the public domain and thereby comply with the statute. Nevertheless, most domestic companies did not express much interest. However, Exactech Taiwan, an affiliate company of Exactech, wanted to go ahead and take out a licence on this new technology as a part of a multi-national biomaterial group as, they could see the potential of this technology and so they participated in licence bidding.

Subsequently, it was evident that Exactech would outstrip other potential domestic medical companies as it had the most appropriate licence for this innovative therapy and several reasons can be advanced for this. First, most of the pharmaceutical companies in Taiwan are small-scale with the two largest focusing on the production of generic drugs. Second, regarding the competitiveness of Taiwanese biomedical material companies, although they have produced some competitive products, their strong market position is due to cost leadership, (i.e. low prices), rather than product innovations. Third, most of them lacked the experience of holding clinical trials and given all this, few domestic companies showed any interest in bidding for the licence. In contrast, when Mr Lin from Exactech opened the bidding, he proposed a price less than the feasible bidding floor. However, Dr L and his associates turned this down as it did not meet their expectations and moreover, as the team had already set up a factory and prepared the necessary documents for entering the clinical trials, they were in the position of being able to commercialize the product themselves. Furthermore, in future when the clinical trials were passed successfully the therapy would be worth even more and hence command an even higher licensing revenue.

During the second round of bidding in the licensing auction, Exactech Taiwan outbid everyone else, offering 80 million NTD (around 1.7million USD) and five percent running royalty (Jiang, 2011), because they saw the great potential of this technology, which ITRI decided to accept. At the time of writing, this is still the highest licensing revenue deal signed in the biomedical field for both the ITRI and the NTUH.

After the licensing contract was signed, Exactech managers and Dr L's team signed a further agreement that the former would pay to continue the clinical trials and established a project with Dr L regarding continuing the GMP factory production. The representative of Exactech Taiwan, Mr C has been working constantly with Dr L since the licence was granted. Mr C at Exactech Taiwan and Dr L at the ITRI, with their teams, had regular meetings by video conference with Exactech's headquarters each Tuesday or Wednesday night (Taiwanese time) in order to discuss the progress of the GMP factory and the clinical trial, which was conducted by the NTUH and administrated by a Contract Research Organization (CRO), Statplus Inc., in Taiwan. Further, Exactech set up two teams in its American headquarters to carry out the licensing of the product, with one dedicated to commercialization and collaboration, which comprised a manufacturing manager and quality control personnel, whilst the other was responsible for the clinical trials team and included four experts. One of these was a former president of the Orthopedist Association in the US, whilst another, who had once worked at the FDA, was a legal consultant. The other two members were Dr L and Dr J, who was to conduct the first clinical trials in Taiwan as a basis for further trials in the US. In fact, MD J was invited to meet the American clinical trial team in order to demonstrate the surgical procedure, as shown in the flow diagram (4.1) below. Such events, held two or three times a year, have provided many useful insights, such as the realization that some of the equipment (e.g. the chondrocyte cell cutting apparatus) would have to be made larger for the Americans, so that they could use it easily and safely.

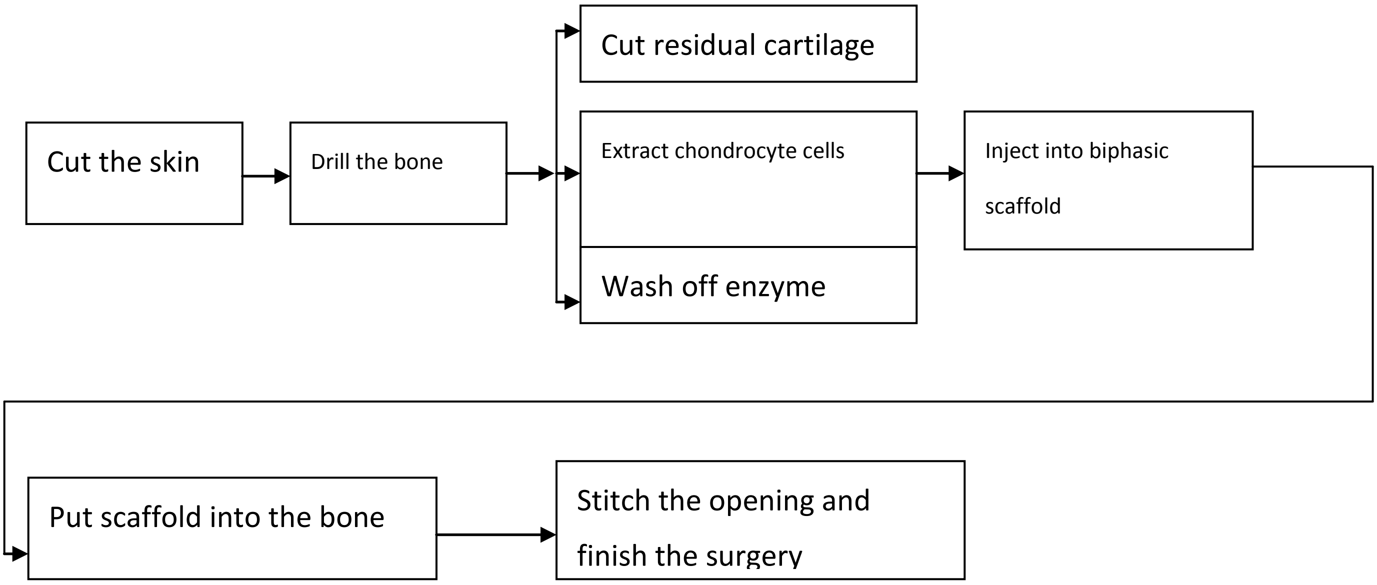

Diagram 4.1: The surgical procedure of cartilage reparation

Sources: This research

To speed up the permission process, the consultant in the National Health Agency (NHA) of Taiwan, who used to work in US, suggested NHA should consider emulating the US approval process in US. Here, biomaterial inventions are not regulated under the strict and consuming drug approval process, but rather they are applied to a different route so as to bypass the strict time consuming procedures. By obtaining permission to take this course of action, the NHA was able to approve the clinical trials in 2008, sooner than otherwise and subsequently, Dr J started an initial study with ten patients, which ran from March to August 2009. The results showed that the new surgery significantly reduced the discomfort experienced by patients. In March 2010, they proposed another trial involving 100 patients aged from 15 to 51 years, who were all suffering from full vitro thickness defects and clinical trials permission for this was obtained in July 2010. However, the clinical trial had to await acceptance by the committees of each individual hospital, but after some delay, on December 1, 2011, surgery to this end at NTUH was approved.

4.3 Case Two: (On Chip) AC LED

4.3.1 The background

The invention of the alternative current light-emitting diodes (AC LEDs) can be traced to a researcher named Min-Der Lin, who left the industry to join the ITRI (Industrial Technology Research Institute) in June, 2004. He was working for an LED package company, Para Light, as a production manager and was interested in developing a high-voltage LED in collaboration with researchers from this company's parent company (Tyntek), because the extant LEDs could only withstand low direct voltage ranging from 1.8 to 3.3 volts. However, this initial attempt at making a high voltage LED was rather ad hoc, as he had not acquired full support from the company. Nevertheless, he still tried to discover a suitable LED design for tolerating higher operating voltage and came to the conclusion that this could be achieved by putting the LEDs in series. In the meantime, the optoelectronics laboratory (which was later merged into the electronics and optoelectronics laboratory (EOL)) at the ITRI was interested in recruiting more engineers from industry, in particular, to address packaging issues in relation to LEDs. Regarding this, Manager Huang was the first one recruited from industry, and he in turn heard that Min-Der Lin was interested in joining the institute, so he offered him a post, which he accepted. He left Para Light in 2004 and was encouraged to pursue his key research interest of high voltage LEDs.

When Mr Lin went with his colleague Mr Fei-Chang Hwang, a test engineer, to an illumination conference in Taipei in 2004, they listened to the presentation regarding illumination applications of LEDs and subsequently wondered whether it would be possible to use the semiconductor fabrication process to form LEDs in series inside chips, which could then be plugged directly into an AC socket (Lee and Tsai, 2010). This idea was supported by the division director Mr Chu and Vice Director Mr Yeh, as they could see the potential of this technology, given that the extant LED lamp required an adapter to convert AC into DC and consequently, if they could omit having to use adapters, the cost of LEDs would be reduced significantly. Subsequently, with the support of Mr Chu and Mr Yeh, they asked the electronic circuit design team to collaborate with the packaging team so as to produce AC LEDs. However, this research was not directly supported by any funding from the ITRI's technology programme in any official capacity and the circuit design team had to rely on the redirection of funds from other budgets by these managers during these initial stages.

4.3.2 The AC LED attracts a collaborative research contract with the industry

In order to surmount the funding shortages, in October of 2004 the ITRI signed a collaboration contract with Tyntek, a Taiwanese LED semi-conductor producer, after a visit by senior managers from the institute to that company and they granted funding of a few million NTD (1USD equals 30 NTD). The overall goal of the project was to produce test equipment for Tyntek and in the December of the same year, this team developed the first generation AC LED, which operated at 0.08W with a light efficiency of 10 lumens per watt.

4.3.3 The Three Generations of AC LED Development

In total, this collaborating team has developed three generations of AC LEDs and these are discussed in detail in this section. The first circuit they conceived of in 2004 consisted of two sets of LEDs in series (shown in diagram 4.2), each having one direction, which meant that as the AC changed the current direction, the LEDs on one of these two series were illuminated as the current passed through them. That is, this arrangement allowed for each LED set to take turns in lighting up 1/60 of a second after the current hit. In order to improve the lighting capacity, they introduced a Wheatstone bridge structure in 2005(shown in diagram 4.3), whereby 2/3 of the LED units in a chip could be illuminated when an AC was applied. However, when this solution was compared with the conventional DC LED lighting devices, its efficiency was inferior, as 1/3 of the AC LEDs on the chip were off owing to the need to have rectifiers when the electric flow came from the other direction. The semi-conductor circuit and process teams worked hard to reduce the proportion of LEDs that were off during the other current direction. Eventually, the other team in the EOL that included Dr Yen and Dr Chi, who were working on the semiconductor process, designed a new circuit in 2005 and filed patents in 2006 that pertained to having fewer rectifiers and consequently more lit LEDs at the same time. This third solution involved applying Schottky diode type rectifiers, which can tolerate reverse current up to around 200 volts, thus resulting in a faster forward current and hence, lower forward current drop (shown in diagram 4.4). These scientists included two Schottky type rectifiers in their design and subsequently filed their innovation for a patent in Taiwan in 2005, followed by a further one in the US in 2006.

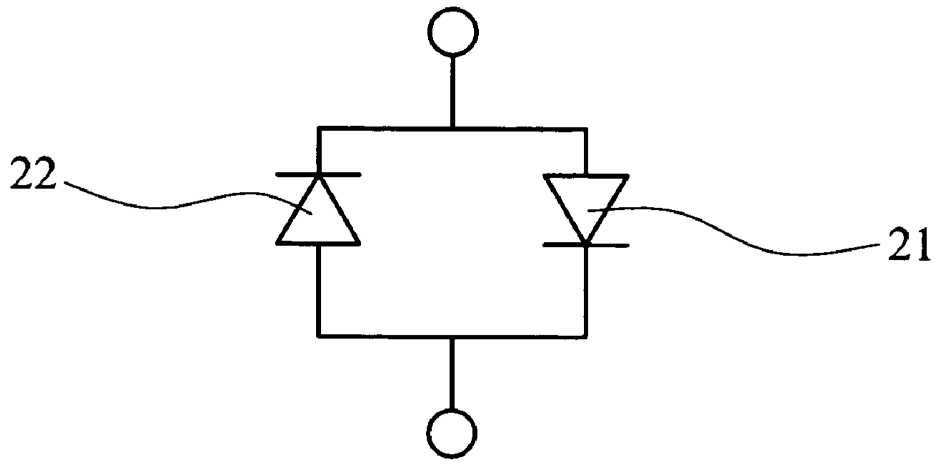

Diagram 4.2 The first generation of AC LED

Sources: ITRI, 2009b

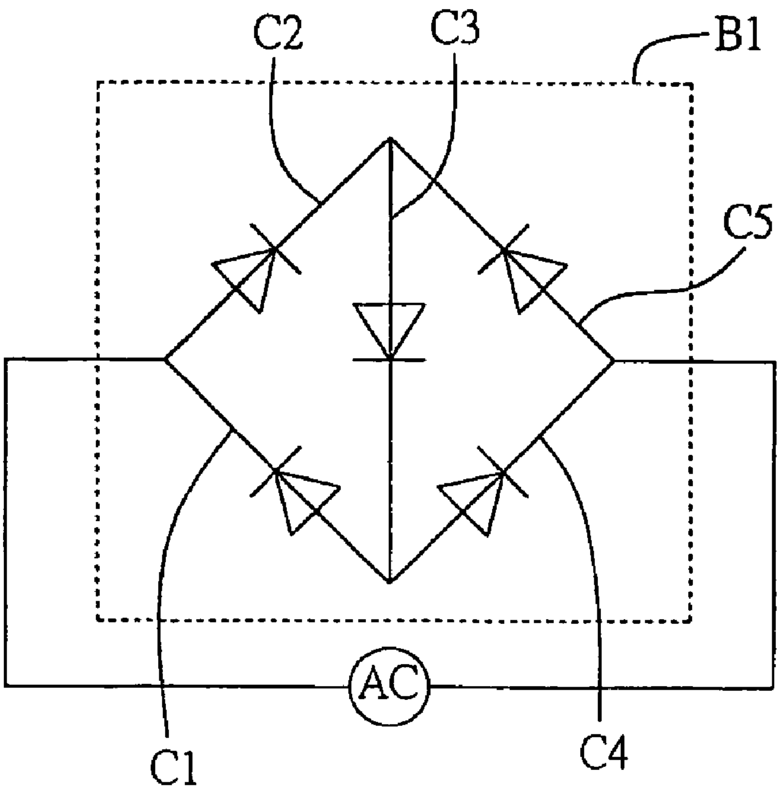

Diagram 4.3 The second generation of AC LED with a Wheatstone bridge

Sources: ITRI, 2009a.

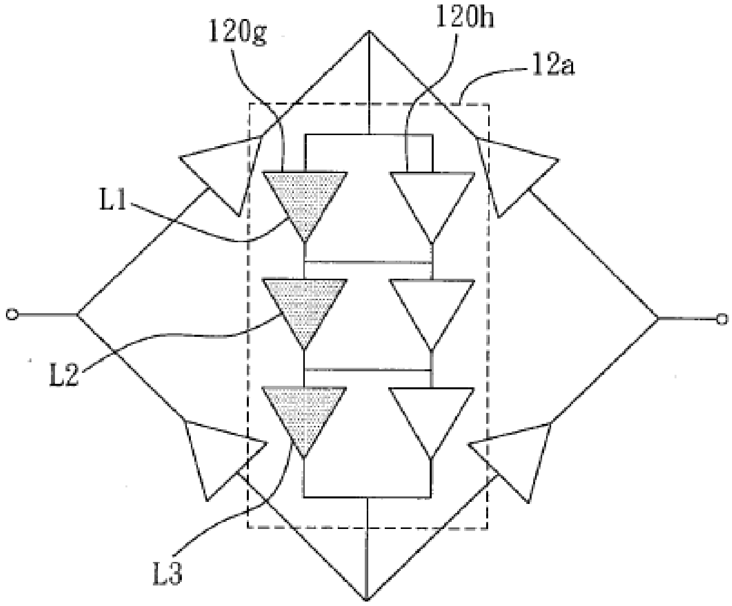

Diagram 4.4 The third Generation of AC LED involved Schottky diodes as rectifiers

Sources: ITRI, 2007.

4.3.4 The Involvement of the Industry

As Min-Der Lin had maintained a good relationship with his former parent company, Tyntek, the company was willing to join the research project and signed a consignment contract with the ITRI. This initial contract, signed in October 2004, was for NTD 4 million. In 2005, a larger collaborative contract was signed for NTD 20 million and, was executed over a period of two years. In December 2005, Tyntek licensed the first and second generations of the AC LED technologies described above. However, the ITRI needed extra funds and so it availed itself of government support through one of the technology research programmes introduced in 2006, but this was conditional on the patent being offered to others in the industry. As a result, a number of other companies obtained licences to use this technology in LED making, including the largest LED chip maker Epistar for the chip in 2006 and two LED packaging companies, Forward Electronics in 2007 and LiteOn Technology 2008 obtained them for the packaging.

4.3.5 Collaboration with universities

At the beginning of the AC LED development, the main interaction was between the ITRI and LED industry, with some financial support coming from the government. However, when it reached the application and commercialization stage, universities were invited to solve some basic issues. To this end, the AC LED team contacted two universities in Taiwan to study two crucial issues. The first issue was cooling, as the AC LED design involved rectifiers and diodes the heat along the circuit can damage an AC LED chip. Therefore, they found a professor at the Department of Mechanics at National Central University to improve the packaging of the chip in relation to better cooling. Another line of cooperation was between Min-Der Lin at the ITRI and Dr Liang Tsorng-Juu at the National Cheng Kung University. Dr Liang has strong expertise in power electronics and he helped in checking whether the AC LED complied with the International Electro Technical Commission Standard. Later, Dr Liang suggested some other possibilities for circuit design to reduce the volatility of power in responding to changes in electricity voltage, but due to funding issues this cooperation was delayed. However, Professor Liang found this topic very interesting, and applied for a grant from the National Science Council to continue the study. His team also filed seven patents with regards to complementary circuit design for AC LEDs.

4.3.6 Winner of the R&D 100 Award

In 2008, the AC LED innovation won the prestigious R&D 100 technological award, presented by R&D Magazine, for being deemed the most outstanding concept penetrating the marketplace in that year. The conveyance of this award attracted many companies' attention in Taiwan and consequently in the same year the ITRI collaborated with 24 national firms to form an AC LED application and research alliance.

4.3.7 IP Protection

With patents increasingly becoming a major element in relation to the commercialization of technologies in Taiwan, the Electronics and Optoelectronics Laboratory decided to nominate several of its researchers to deal with IP issues. In this regard, although at the ITRI, there was a Technology Transfer Office, they were mainly responsible for the application for and the compliance issues around patents and at this time, had little to do with strategic IP planning and management. For this reason, the laboratory decided to send one engineer to the Technology Law School at Chiao-Tung University and various patent lawyers from different agencies were invited to the laboratory to give lectures. With this engineer's received knowledge regarding the LED related patents, the ITRI was able to understand the patenting strategies of a range of multi-national companies, in particular, how to succeed in Patent Cooperation Treaty (PCT) filing through the World Intellectual Patent Office (WIPO). This procedure allows applicants to have 30 months to decide in which countries they would like to apply their patents and as such gives leeway to the petitioner regarding where they wish to develop their business, thereby permitting them to target their expenditures on where the market provides the greatest opportunities. In other words, they can wait before choosing which countries they would like to pursue business activities, thereby being able to see how the market is evolving without having to file multiple patents across the globe. They filed the PCT application for the first circuit design and after a few months they found out that the Seoul Semiconductor in Korea had also recently filed a similar patent. Moreover, it emerged that this firm had also filed one involving a similar design to that of the ITRI's second generation. However, this particular firm had not yet developed the more efficient third generation AC LEDs using the Schottky rectifiers, as described above.

Up until the writing up of this case, the deployment strategies consequent to filing patents have been aimed at pursuing three different areas on the industry supply chain: chip manufacture, packaging, and application. Regarding the LED chip aspect, the three design generations have led to 11 inventions with 42 related filing applications. In the case of packaging, there have been three key innovations: a 3D lighting enhanced plug, improved plug design, and superior electromagnetic induction management than was previously available, resulting in at least 22 patents being filed. Finally, in relation to AC LED applications they have filed more than 18 patents to do with the: control unit, lantern design, and the backlight control, including 42 inch LED TV panel technology, which has been successfully licensed.

4.3.8 Challenges and future prospects

The replacement of electric bulbs by LED technology has been widely encouraged in recent years, owing to the latter consuming substantially less energy (theoretically, saving up to 90 percent). However, because the light emitted by LEDs is more direct on the eyes, new lighting designs are required if they are to be used safely and effectively in domestic situations. On this particular packaging issue, the team at the ITRI has been collaborating with a local company, Forward Technology, to improve

3D light emission and they have also worked with Duck Design, resulting in the development of some prototypes of an LED embedded desk lamp. Another challenge related to the use of AC LEDs for lighting is the cooling aspect. In this regard, although the design of the AC chip in series has eliminated the need for an inverter, this arrangement has resulted in much more heat being generated than with a DC LED (Liu, 2009). The researchers at the ITRI have attempted to solve this problem by improving their 3D package design, but there still remains much room for improvement.

The idea of using AC is very attractive as it can save the cost of having to have a converter. However, the lighting efficiency per area of AC LEDs is still lower than for DC ones, as rectifiers are needed in each direction of the AC flow. Consequently, as personnel at Tyntech have stated, moving towards efficient mass production of AC LEDs, especially those using the third generation technology, still presents many challenges. In particular, DC LED manufacturers are showing signs of being able to develop LEDs, which can tolerate high voltage currents and therefore, in spite of their use of energy inefficiency, their replacement by AC devices is going to take some time. Moreover, because the adaptor in large lighting systems is a relatively small part of the overall cost, those using AC LEDs are unable to compete economically with DC LED ones. However, for a small lamp of less than 10 watts, the AC LED is likely to be able penetrate the market because the AC-DC adapter, has higher relative cost, uses up more space and has lower conversion efficiency (only 70-80% as compared with 95% on a large system). Another issue is that although the third generation design was effective in the laboratory, when it came to mass production the existing production lines were unable to provide sufficiently high yields to be competitive, because of the highly sophisticated Schottky diodes. Regarding this, Epistar, the competitor of Tyntech later licensed the technology in 2006 and was able to reach higher yield rates than the latter. Moreover, the former outbid other companies so as get exclusive licensing of all the AC LED patents from the ITRI.

To sum up, the AC-LED is a novel concept in wafer level design, which may not have been possible if Min-Der Lin had not left industry to join the ITRI, for with his and managers' good relationship with Tyntek they were able to reach resources for the first stage of the innovation. Moreover, with support from the director they were able to work collaboratively with the process team to realize their concept of an AC LED. The funding from the Key Component Technology Programme from the government later speeded up the other developments of circuit design and application. In these cases, the in-house faster patenting practices enabled the ITRI to have a leading role in intellectual property rights as they obtained an earlier prior art date for developing AC LEDs. In addition, the collaboration between the ITRI and the lighting industry was crucial for moving the innovation from prototype to mass production, whereas the university played a lesser role, perfecting the LED lamp design and investigating the fundamental cooling issues.

Chapter 5 Analysis and Validation Meetings

This chapter is arranged in four parts which provides a more complete analysis of the two cases from different perspectives. The first part comprises a chronological table of important events in each case and forms the basis for the subsequent comparison between the THM and actor-flow model aimed at establishing the explanatory power of each regarding successful innovations. Secondly, for each innovation, having presented the chronological table, there is analysis of the events under the THM perspective and this is followed by the same treatment using the AFM. Thirdly, the commonalities and differences across these two cases are articulated and analyzed. Finally, audit trials (the third lens of validation) were conducted in two validation meetings to enhance the creditability of the case studies and to include analysis by people not involved in each case.

The Triple Helix model has two basic tenets. One is the assumption that the interactions between industry, universities, and government facilitate the creation process of innovation. The other is that these three actors will sometimes take on some tasks usually undertaken by other actor(s) to make the innovation process more effective, such as a university playing the role of an industrial laboratory and spinning off a company. THM proponents do accept that the flow of resources between actors enables the process of innovation especially human resources and knowledge. However, as explained in chapter 3, they consider the role of RIs largely irrelevant (Etzkowitz and Leydesdorff, 2000).

5.1 Case One: Articular Cartilage Reparation

5.1.1 A chronology of the Articular Cartilage Reparation development

Here the analysis draws on one of Yin’s (2003) recommendations to start with a chronology of important events in the creation process of the innovation .

No.	The Event	Year
1	The ITRI prepared PLGA scaffolds in collaboration with CISRO on using glue for repairing cartilage	1998
2	Dr L joined ITRI and carried out research on bone material	1999
3	PLGA scaffolds were tested with Dr J at NTUH	2000
4	Dr L made a proposal for a cartilage reparation project, but was granted only NT$300,000	2001
5	The ITRI’s Advanced Technological Research Progamme (ATRP) launched as a collaboration initiative with NTHU	2001
6	The ex vivo project for ATRP was proposed by D L	2002
7	The Collaboration between Dr L and Dr J at NTHU began	2002
8	Dr L put forward the goal of 30 minutes cartilage reparation surgery at a collaboration review meeting,	2003
9	Dr L the development of tissue pulverizer to Chiao-Tung University	2003-2004
10.	Dr L submitted a paper on the results of tests on mice to the Journal of Biomedical Materials Research which attracted the	2004

	attention of Steve Lin of Exactech	
11	Steve Lin and management at Exactech started visiting the ITRI	2005
12	Consultant Jang strongly recommended the allocation of resources for this invention	2005
13	Exactech started visiting the ITRI with a view to licensing the invention	2006
14	The open bid announcement meeting was convened in November	2007
15	A contract research organisation, Statplus Inc, was selected for clinical trial.	2008
16	Exactech, Taiwan bid for and won exclusive licensing for 80million NTD	2008
17	A clinical study 20 people commenced	2008/8
18	Approval for a clinical trial was granted from the government	2010
19	The clinical trial at NTHU was approved and commenced	2011

Table 5.1 The important chronological events of the cartilage reparation case

5.1.2 THM analysis

Using this model and excluding the involvement of the ITRI, two key activities in the case are uncovered, as can be seen in table 5.2. The first is that the collaboration among different actors has been important in the creation of this innovation, especially in relation to knowledge and human resources. In particular, the NTUH conducted the latter stage clinical trials for the reparation, the data from which Exactech is able to be used to gain access to the European market. Second, each actor took on some roles normally expected of others to ensure success. For example, NTUH undertook the initial clinical study without being prompted by industry, which sped up the commercialization process. When the THM model is extended to include the ITRI, in table 5.2 it can be seen that collaborative activity between it and NTUH was at the heart of the initial innovation stages. Moreover, the institute took on a number of functions normally associated with other actors, such as building the scaffold and subsequently mass producing this, which industry would usually be responsible for. However, the THM in its current form where research institutes are seen as being irrelevant would not pick up on some essential aspects that ensure innovatory success. In particular, if Dr L had not left NTUH to join the ITRI he would not have been able to acquire the resources to research into cartilage reparation or he would probably not have had the time. In sum, the major limitation of the THM is that it fails to recognize the interactions between RI and/or other actors.

	Industry	University	Government	***Research Institute***
Industry				*CRO helps RI on clinical trial*
University	Clinical study(1)			*Test of scaffold on mice in 1999*
Government	Sponsorship of advanced research and clinical trial			Sponsorship of research, clinical trial and good manufacturing practice (GMP)
Research Institute ***(Not Included in the THM)***	*Finding the solution for damaged cartilage* *Building up a GMP factory*	*Developing the prototype and surgery kits*	*Coordinate the funding to a university and a contract research organisation (CRO)*	*The fore-runner project with CISRO*

Table 5.2: Application of the THM model to the cartilage reparation case extended to include the RI

5.1.3 AFM analysis

The Actor Flow Model also accepts that collaborations among industry, universities and the government can facilitate the process of innovation, but extends this to include other actors. Moreover, although in later work the proponents of the THM implicitly recognized flow as an important part of the innovatory process (Park et al., 2005), they have not made it a central part of the model, whereas for the AFM this is so. That is, under this lens energy flows in terms of: knowledge, human resources, money, and physical elements (e.g. capital equipment) are seen as being crucial for an invention to become a successfully exploited innovation. These four flows are now analysed according to the different events that took place in the cartilage reparation case. These four sorts of flow were illustrated in different types of arrow as Diagram 5.1.

Knowledge (Information)

Human Resource (Personnel)

Money

Physical (e.g. Materials ,Capital Equipment)

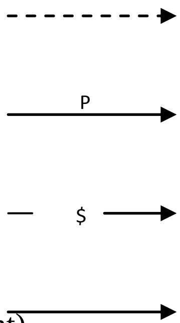

Diagram 5.1: Each type of arrow represents the different types of flow

Source: Adapted from Forrester (1961)

Flow 1: Human Resources

(1) Dr L left NTUH and joined the ITRI in 1999, bringing his past experience and most importantly his close relationship with the doctors (2nd event).

(2) The ITRI invested more human resources in the project funded by the Key Component Research Program in 2005, as the consultant Jang had suggested.

(3) The cartilage reparation technology was licensed to Exactech in 2008 and Dr Chen left the ITRI to join the newly established Exactech Taiwan.

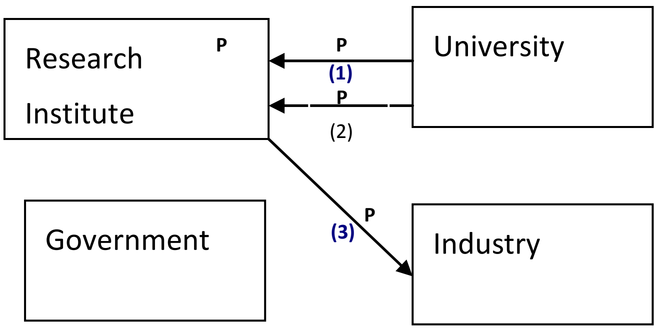

Diagram 5.2: Human resource flows in case one

Flow 2: Knowledge

Knowledge (information), especially tacit knowledge is highlighted here, which is hard codify and can be learnt through socialization (e.g., imitation, interaction, apprenticeship, or training) or through externalization (e.g. by metaphor).

(1) Collaboration between the ITRI and NTUH started, Dr Jiang's team provided human guinea pig experiment results for the biphasic scaffold.

(2) Dr Jiang had the goal of cultivating autologous cartilage cells in 30 minutes in one session of surgery, which contrasted with his previous attempts involving surgical

of the damaged tissue.

(3) Dr Jang, a venture capitalist and consultant for the ITRI, urged the general director to support the project, and to file more patents to protect their invention..

(4) The results of Dr L's experiments released in the Journal of Biomedical Materials and attracted the attention of Exactech.

(5) A consultant at the Department of Health and Dr Chen, the chief of the clinical trials centre at NTHU, persuaded the review committee to benchmark the faster reviewing procedure, the protocol for biomaterial and the requirements for bio-devices at the FDA in the US.

(6) After the consultation, NTUH worked with ITRI a solution tolicense the technology to Exactech Taiwan.

(7) Exactech assisted Dr L in perfecting GMP manufacturing.

(8) Statplus (a CRO) were assigned the task of collecting data for the clinical trial

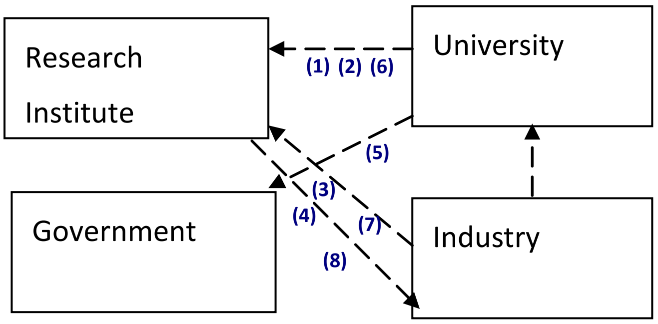

Diagram 5.3: Information flow in case one

Flow 3: Money

(1) The initial research grant was supported half by the ATRP for a trial period in 2001 owing to Dr L's perseverance.

(2) The collaboration project with Dr Jiang at NTUH started in 2002 and involved the conducting of experiments on human guinea pigs.

(3) Owing to consultant Jang's advice to the ITRI leadership, more than 10 million NTD (300,000 USD) from the 2006 Component Technology Research Program budget was allocated to the work.

(4) After licensing, Exactech signed the business contract for further development in the form of producing and improving scaffold manufacture.

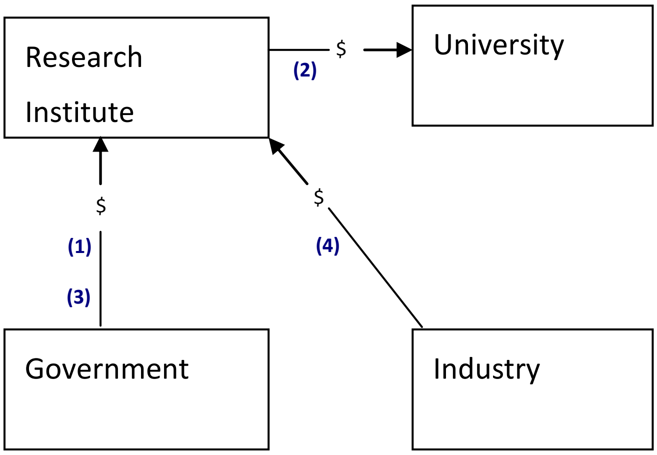

Diagram 5.4: Money flows in case one

Flow 4: Physical flow

(1) Dr L's team continuously developed the scaffold, which they delivered to the NTUH for the conducting of the experiments on human guinea pigs.
(2) A student in Chiao-Tung University produced a new cartilage cutter prototype and filed a patent for it (co-owned by the ITRI).
(3) The cartilage cutter and other utensils in the surgery toolkit have been mass produced by biomaterial companies in Taiwan.

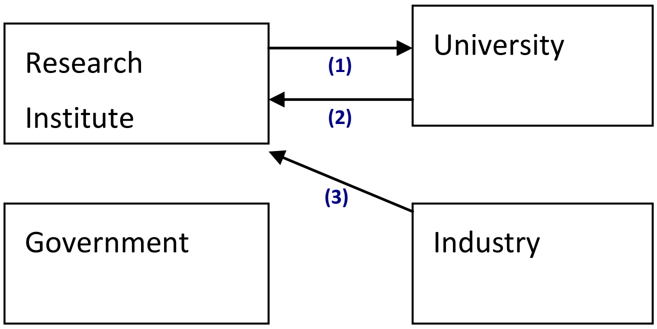

Diagram 5.5: Physical flow in case one

Having identified and mapped the energy flows in accordance with the AFM, this has shed light on the evolutionary process pertaining to the cartilage reparation innovation. That is, clear understanding of the collaborative process between the four actors has been elicited. In terms of the actual outcomes, it can be seen that there was substantial activity involving all four flow types, which evidently led to project success. This provides new information that the THM perspective fails to identify about the requirements of a successful innovation from start to finish. That is, under the AFM optic a number of new possible ways of operating in such circumstances that hitherto may have been overlooked have been uncovered.

5.2 Case Two: AC LED

5.2.1. A chronology of the AC LED development

No.	Event	Year
1	Min-Der Lin left Para Light and joined the ITRI with an interest in developing a high-voltage AC LED	2004
2	Mr Lin and his colleague Mr Fei-Chang Hwang, conceived a possible design during an illumination conference	2004
3	Director Mr Chu and Mr Yeh supported it and asked the electronic circuit design team to collaborate with them as well as providing funds form the Key Component Research Programme budget.	2004
4	Developed the first circuit and signed the first collaboration contract with Tyntek who provided funding of 4million NTD	2004/12
5	Nan-Ya and two other firms joined AC LED application project	2005
6	Developed the second and third generations of circuit design, which improved the lighting efficiency	2005
7	A larger collaborative contract was signed for 20 million NTD, and was executed over a period of two years	2005
8	Tyntek pilot produced an AC LED	2006
9	Forward Electronics licensed AC LED packaging technologies	2007
10	Epistar licensed the chip manufacturing technology	2007

11	Universities invited to study cooling and safety regulations issues.	2007~
12.	AC LED won RD 100 Award	2008
13	AC LED application consortia established with 24 firms who subsequently drafted the standards	2008
14	Epistar pilot produced AC LED chips	2009
15	Epistar cross-licensed the AC LED with Toyoda	2009
16	Global Lighting (GE subcontractor) and Forward Electronics signed a collaboration research project to develop the AC LED bulb	2009~

Table 5.3 The important chronological events of the cartilage reparation case

5.2.2 THM analysis

	Industry	University	Government	***Research Institute***
Industry				
University	Measuring the LED current properties			
Government	Sponsored fees for patent application			
Research Institute (Not Included in THM)	*Linked the LED packaging and manufacturing process teams*		*Redirected resources from other budgets to the AC LED initial study*	

Table 5.4: Application of the THM model to the AC LED case extended to include the RI

There are two implications under the THM lens; firstly, the collaboration between university, industry and government was essential for the creation of the AC LED. Although the major funding came from industry with partial support from the government, universities were required to help with the research issues regarding cooling and standards compliance. In the extended version in table 5.3, it is evident that the ITRI played a very crucial role as they provided the facilities where Min-Der

Lin could undertake the original research. Secondly, in relation to the THM perspective that actors can sometimes take on the role roles of others, industry provided much of the funding for the research, which would usually be expected to come from the government. Moreover, the university funding came from the RI rather than from the government. Finally, unlike in conventional cases the product level research was carried out by industry, the ITRI pursued this product invention when they sensed unmet demands in the market.

5.2.3. AFM analysis

Flow 1: Human Resources

(1) Human resources change occurred when Min-Der Lin left industry and joined the ITRI. He brought his experience and most importantly, a close relationship with the industry through which he was able to persuade Tyntek to continue the funding of these projects.

(2) The ideas of high voltage and AC LEDs attracted Director Chu, and he asked researchers with semiconductor process expertise to join the AC LED project.

(3) The AC LED was less efficient than the DC LED even after the adoption of a Wheatstone bridge design (a third of the LED units on the chip were off at the same time). Subsequently, Dr Yen and Dr Chi from another division at the laboratory created a more efficient circuit design by introducing Schottky diodes as rectifiers.

(4) In the near future, Min-Der Lin is planning to set up a spin-off company with the help of the ITRI.

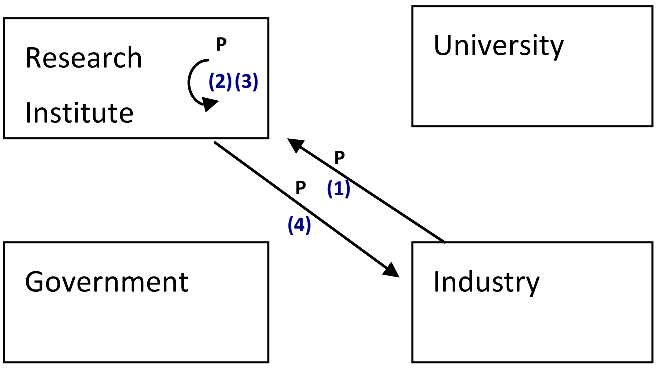

Diagram 5.6: Human resources flow in case two

Flow 2: Knowledge (both tacit and explicit)

(1) Min-Der Lin interacted with Mr Fei-Chang Hwang, a test engineer colleague during a conference break. Their interaction, which had started with a discussion about high voltage LEDs, brought forth the idea of an AC LED,

(2) Tyntek signed the cooperation contracts with the ITRI in 2004 and 2005, the first involving funding to the ITRI to produce prototype machinery and the second being geared towards establishing mass production. Later, in 2006 Epistar was also granted a licence by the ITRI.

(3) Industry feedback on AC LED production issues to the ITRI.

(4) Forward Electronics licensed in 2007 and the first 5 watt AC LED packaging production line was established.

(5) Universities were tasked with finding solutions to the cooling and power issues.

(6) The ITRI has filed patents for: circuit, packaging, cooling and lamp design since 2004.

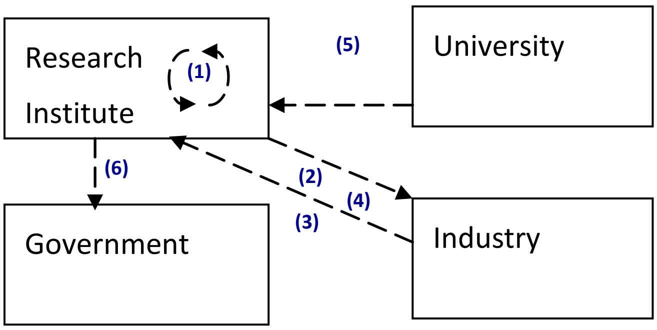

Diagram 5.7: Knowledge flow in case two

Flow 3: Money

(1) The initial research was funded from the opto-electronics laboratory's grant under the Energy Technology Programme in 2004.

(2) Tyntek joined the AC LED circuit project and received test equipment after providing funding of 4 million NTD in 2005. Later Tyntek financed the project with 20 million NTD in 2006.

(3) Forward Electronics licensed the AC LED packaging technology and contracted research on establishing a mass production package line in 2007. Lite On licensed the AC LED packaging technology in 2008 and collaborated with Forward Electronics, a client of GE in the US, to produce a 2 watt AC LED lamp in 2008.

(4) The research into cooling and the electrical properties of the AC LED was allocated to Central and Cheng-Kung universities.

(5) Forward Electronics received a grant from the Industrial Technology Development Programme in 2010 and gave part of it to the ITRI for further research and IP protection.

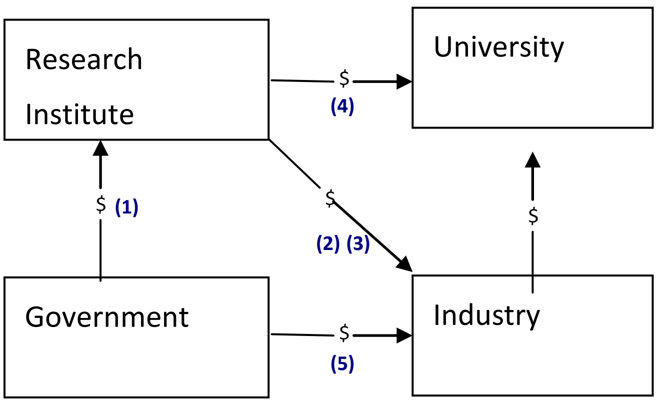

Diagram 5.8: Money flow in case two

Flow 4: Physical Flow

(1) ITRI developed AC LED test equipment for Tyntek and which was subsequently transferred to the company in 2005.

(2) Mass production of the AC LED by both Tyntek and Epistar, with sample chips being sent to the ITRI to check yield rates and seek ways to improve these.

(3) AC LED chips were manufactured and sent to Dr Jiang at Cheng-Kung University to study the electrical properties and whether they were compliant with standards, such as the UL ones.

(4) AC LED packaging results produced by Forward Electronics and the lamp appliance designers sent to the ITRI for them to study.

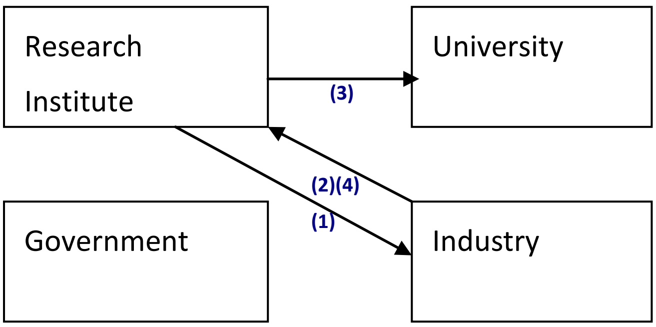

Diagram 5.9: Physical flow in case two

5.3 Cross Case Analysis

Cross case analysis is undertaken with the aid of table 5.5, which compares the background to each innovation and the four different energy flows. This is followed by further discussion regarding these differences.

Items to be compared	**Cartilage Reparation**	**AC LED**
Background industry	Biomaterial	LED industry
Needs	Cartilage defect is still lacking an effective reparation solution	LEDs used in lighting usage can be plugged in to AC electricity directly.
Human resource **- inventor**	Main inventor Dr L is from a university	Main inventor Mr Lin is from industry
Human Resource – inflow	More researchers have to be recruited to support the invention's development	Process and test researchers are invited to join in
Human resource – outflow	One member moves to the licensee's affiliate company, Exactech Taiwan	Mr Lin joins a spin-off company of Global Lighting, a GE subcontractor
Human resources **- networking**	Dr L knows Dr J and the context of NTUH well, in addition to the problem of the current cartilage	Mr Lin knows Tyntek and the critical issues of LED lighting well

	reparation	
Knowledge – invention creation	Interaction between Dr J at the NTUH and the ITRI	Through the interaction between Mr Lin and Mr Huang during the break at a lighting conference
Knowledge – university outflow to RI	Ideas and implicit knowledge from NTHU	The scientific research, such as cooling, failure test ,etc.
Knowledge - industry outflow to RI	GMP and clinical trial experiences from industry	Feedback from the pilot run and collaboration on chip improvement
Knowledge - RI to industry inflow	The surgery and clinical study data to Exactech	The know-how to Tyntek and Forward Electronics
Knowledge outflow to extract value	Paper to the Biomaterial journal attracts Exactech and file patents	File patents to gain priority dates. RD 100 award attracted industry
Money flow – inflow	Government to the RI and the university. Industry's licensing fee to the RI	Industry and government to the RI. Industry's licensing fee to the RI
Money flow - outflow(RI)	RI to university and CRO	RI to university.
Physical flow	RI provides scaffold and	RI provides the tester

- RI outflow to universities or industry	tool kits to the NTUH, which they have manufactured	machine to industry. RI provides the chips to universities to study.
Physical flow **- inflow to the RI**	Outsourcing some tools and subsequently making kits of these and the scaffold to be sold to Exactech.	Industry provides pilot run chips to RI.

Table 5.5 Cross case comparisons

5.3.1Commonalities

The catalyst for these two cases: address the unmet needs

First, both of these inventions were generated from unmet needs, which meant that they corresponded with the notion of user led innovation. In other words, with respect to both it was recognized that the poor performance of extant solutions to the identified problems, namely, defective cartilage and no AC LED lamp without the need for a converter, had to be tackled. Once these problems were solved, because they were user led there was ready made market for the products, which meant that profitable returns came that much quicker than were it otherwise. Moreover, as with inclusionality stressing the mutually shaping dynamics between flow and space, the AFM can also identify several occasions where the ITRI provided spaces to induce the energy flow to run smoothly into the organization as the boundary became permeable. For example, it induced human capital flow by opening positions for researchers from other spheres, in the first case, Dr L was from a university, and in the second Mr Lin was from industry. In addition, these people also brought their extant relationship network and knowledge from their respective spheres which helped facilitate energy flow exchange between them and the ITRI.

Human Resource Flow

Human resources flowing into the RI

In both cases, the main inventors were both from outside the RI, one from a university and the other from industry. Moreover, both came from backgrounds related to the research interest that led to the subsequent invention, Dr L has studied bio-absorbing material and Mr Lin spent his spare time researching into high voltage LEDs and thus, they brought essential new expertise into the RI. Mr L had knowledge on how to conduct mice experiments, whereas Mr Lin was able bring his understanding of high voltages in lighting that made the AC LED invention possible.

Human resources internal flow

When the research outcomes looked promising the investment of the human resources was essential in both cases, if the innovative process was to succeed. As noted in chapter 3, Tidd (2009) identified four key individuals in innovation, the critical technical experts, the influential champion, the business innovator, and information pollinators. In both cases technical experts were strongly involved, but the inventions were licensed to companies without there being an obvious in-house business innovator. In the cartilage reparation case, Dr L was the one who acted as a critical technical expert to host the whole project, Dr Johnsee Lee, partially played the role of champion as he was willing to set up a trial and the business innovator here was delegated to Steve Lin at Exactech who saw the potential future of the project, whilst Dr L played the role of information pollinator. Also, this project recruited more people in both research and manufacturing once the experiment showed positive results and attracted the attention of the consultant Jang in the Bio-medical Lab. In the case of the AC LED, the technical expert and information pollinator were the main inventor, Mr Lin and Mr Huang, respectively, the champion was the director Chu who supported this project by redirecting funding. The ITRI licensed Tyntek and Epistar to mass-produce AC LED. Moreover, the idea became accepted by the director of the EOL, Mr Chu, who redeployed researchers with expertise of semiconductor processing to assist in the project, because Mr Lin would not have made progress working by himself.

Knowledge flow

Knowledge – invention creation

The concept of 30 minute cartilage reparation was conceived gradually by the teams at the ITRI and NTHU, through their interaction at project meetings In particular, exchanges between Dr Lee from the ITRI, who wanted to build a faster culture machine, and Dr J who proposed autologous cartilage reparation surgery, led to this outcome. In the AC LED case, the idea came when Mr Lin and a testing engineer, Mr Huang, discussed issues around high voltage LEDs during the break at a lighting conference.

Knowledge – university outflow to the RI

As mentioned before, for the first case the invention's coming into being was as the result of a joint enterprise between a university and the RI, and the human guinea pig experiment involved feedback from the former to the latter in order to improve the invention, e.g., the different percentage of enzyme to dissolve the vitro cells in was tested to make the waiting time optimal. Moreover, they assigned the tissue pulverizer project to Chiao-Tung University. In the second case, after the AC LED had been tested and developed, the researchers at the ITRI subcontracted the cooling, safety regulation issues for universities to solve prior to their development and commercialization.

Knowledge – university to RI to industry

Before the bidding, the surgical and clinical study data were sent from the NTUH to the RI and after the exclusive licensing was granted to Exactech, this was forwarded to them. In the second case, as pointed out above a university provided feedback to the ITRI, which they shared with Forward Electronics and Tyntek so solutions could be found to lighting problems.

Knowledge - outflow to extract value

Dr L's paper in the Journal of Biomedical Materials attracted the attention of Steve Lin at Exactech. Moreover, Dr L's team put more effort into filing patents after their consultant Mr Chiang made this recommendation. In the second case, those involved with the AC LED inventions aimed to file different patents for its: structure (three generations of LED), process, packaging design, and so on. Regarding this, the ITRI used the priority date patenting to protect the second and third generation of LED circuit design. Subsequently, the ITRI applied for an RD 100 award for the AC LED, which was granted in 2008 and this attracted other companies' interest. That is, both of the innovation collaborations involved efforts to disclose their inventions to a wider audience, in particular, industry, through academic papers and in the latter case, a technology award.

Knowledge to connect: The networking by the inventors, team members and the organisation

In both instances, the inventors were able to connect with other actors through the networks they had built for enhancing their knowledge before joining the ITRI. Regarding this, Dr L undertook his post-doctoral research at the National Taiwan University and therefore, knew the doctors and other staff of importance to his interests there very well. Consequently, at the beginning of the research, with the help of former colleagues he was able to have the mice experiment performed at the NTUH. Similarly, but in a different context, Mr Lin, because he knew Tyntek well, he and the leader of his laboratory were able to persuade them to sponsor and engage in the initial stages of AC LED invention.

Money flow

Inflow from the government and industry to RI

The first case was initially supported through the ATRP from the government and later, it received money from the Key Component Technology Research Programme also from the government, in order to establish a pilot factory. In the AC LED case, government funding was redirected to help to launch the project informally, and was also used to protect the intellectual property. Another common feature is that after licensing, both Exactech in the first case, and Tyntek and Forward in second, provided collaborative research funding to the ITRI.

Outflow : from RI to the industry and university

The ITRI subcontracted the human guinea pig experiments to the NTUH, and later funded a contract research organization (CRO) to run clinical trials. In addition, the National Science Council also granted funding to the NTUH when they applied to continue the experiment. In the second case, the ITRI assigned research projects with attached government funding to three domestic universities for studying the cooling and electronic properties as well as for safety regulation evaluation. That is, government funding was employed in both cases, either fully or partially.

Physical flow

Outflow from RI to universities or industry

In the cartilage case, the ITRI provided the scaffold and tool kits to the team at NTUH to conduct experiments, whilst similarly in the AC LED case the institute supplied the prototype to universities to conduct various studies. In relation to industry, the ITRI manufactured the scaffold that Exactech subsequently bought to conduct clinical trials.

In the same vein, in the AC LED case, the RI developed the tester machine for industry so it could conduct further experiments leading to design improvement.

Inflows to RI

Having developed the toolkit for the reparation, the ITRI outsourced some of these to domestic medical material vendors and also acquired a tailor made machine that allowed them to engage in mass production of the scaffold. In the second case, after the manufacturers had produced the chips according to the ITRI's design, these were return to them for electricity property testing.

5.3.2 Differences

Industry

These two cases are from different technological fields, the first being biomedical, whilst the other is opto-electronics.

Human resources

The main inventors of these two cases are from different work backgrounds, the first from a university, the other from industry. Consequently, it was to be expected that they would collaborate with different parties from a different network on the way to the commercialization of their innovations. After licensing, one member of Dr L's team, Mr Chen, joined the licensee company in Taiwan, Exactech, so as to assist them with the clinical trials. In the AC LED case, the inventors all remained at the ITRI, although the main inventor, Mr Lin, later joined a venture company between the ITRI and Global Lighting.

Knowledge and information

The ideas generation is different in these two cases. The first started with a scaffold, in form of a polymer, which after subsequent interaction between the RI and doctors at a university hospital led to the development of autologous cartilage reparation therapy. As for the AC LED case, the main inventor, Mr Lin, with his embedded knowledge of high voltage co-worked with his colleague, a testing engineer, Mr Huang, to make the necessary breakthroughs. However, in each case the thought process involved sharing knowledge with outside parties.

Money flow

The first case was fully supported by government funding before industry licensed the invention, whereas in the second the majority of the research funding was from industry, as they appreciated the potential of the development and anyway, this was an innovation in a context that was highly unlikely to attract government support. They also both commercialized using different approaches. In the first case, this was through exclusive licensing to an affiliate company of a foreign biomedical material firm, whilst in the second it was through licensing multiple companies.

Physical Flow

In the first case RI provided material and mass produced to the university and industry, but in the second case the industry mass produced the LED wafers for RI to test.

Roles of the universities

For the cartilage innovation the, universities played the role of co-creator in the: ideas generation, experimentation, and commercialization. Of the four flows, human resources were leaving the university to join the ITRI. Moreover, knowledge was constantly exchanged so as to enable clinical trials of the bio-medical material. The money to support the human guinea pig trials flowed from the RI to the university. Further, after licensing, industry also started to interact with the university. As for the physical flow, after the ITRI developed the scaffold and the toolkits, these were tested by Dr J at the university. In fact, the two parties interacted with each other right from the beginning of the case. By contrast, in the second case universities did not join in the research until the industrial pilot took place and there were no human resource movement between them and the ITRI. In terms of knowledge flow, the RI provided a new source of research topics for the universities, which they pursued so as to improve the properties and safety levels of the AC LED, which industry subsequently purchased. As for the money, the RI subcontracted the basic research topic and safety regulations issue to the universities and paid for it. Finally, with regards to the physical flow most interactions were between the RI and industry, with the test samples being collected from the industry by the RI and passed on to the universities. Moreover, the universities were not involved until the mid-stage of the innovation, when the researchers at the RI realized they needed greater scientific understanding regarding the AC LED properties and safety aspects, if the lighting containing them was to be suitable for domestic use, which they were able to provide.

5.4 Validation Meetings (Audit Trial)

This section is devoted to the audit trials and covers the main inventors of each innovation, the managers and staff from the planning office at the ITRI in terms of their: validating the cases, provisional findings and analysis. More specifically after reports on the case outcomes were sent to the main inventors and their supervisors to review as a second validation lens (member checking), the third validation lens, audit trial, was adopted by holding two meetings involving people not directed involved in each case to evaluate the research findings.

5.4.1 Meeting One: On the Cartilage Reparation Case

As explained above, I chose these two particular cases because of their remarkable licensing revenue and hence saw them two potential good models to learn from. After having drafted the first case study articular cartilage, a copy was presented to the main inventor, Dr L, for comments. The same document was also forwarded to Dr Liu, the former Vice President of the Biomedical Laboratory and Dr J at the National Taiwan University. In addition, the office assistant was asked to arrange a best practice sharing meeting in the planning office. She finally found a date suitable for many people on 28 December 2010 and so I called Dr L one week before the meeting to gather feedback on the draft. He asked me why I needed further input from him and I explained that I wanted to ensure that I had understood correctly all that had been undertaken around the innovation So he asked me to come to his office for a discussion where I presented my findings and asked his opinion. He mentioned that he had been invited by Kyoto University to give a talk on this case and then showed me his presentation file, but as the clinical trial was still ongoing he was unable to provide me with a copy. Instead, he suggested that he would like to attend the validation meeting and give a talk, but unfortunately that the proposed original meeting time would not be suitable for him.

Therefore, I thought about having two sessions on the different dates: one for my presentation and the other for Dr L's sharing. However, one drawback to this is that people would not be very enthusiastic about having to attend two meetings on the same topic and what is more, given that managers are very busy at the end of the year, they would be unlikely to commit themselves to both sessions. Therefore, after a discussion with my director, I decided to merge my presentation and Dr L's and the meeting was rescheduled to January 3rd, 2011. She agreed with me and so the assistant booked the meeting room after checking that the relevant supervisors were available at that time. The consideration of the schedule design rested on Dr L having listened to my presentation already, i.e. this determined the order of the proceedings. One of my colleagues, Huang, who once worked in the bio-medical laboratory, asked me whether Dr L was coming, because recently under the new president at the ITRI there had been a decentralization process that meant that departments are now generally left to their own devices and he was concerned that it might be seen that I was pestering him to attend. I reassured him by explaining that Dr L had offered to attend and I had not asked him to do so.

The first meeting schedule was as shown below:

2:30-3:00PM John presents his findings on the articular cartilage reparation case and Q&A

3:00-4:00PM Dr L shares his story on the creation of the new cartilage therapy

4:30-4:30PM Q & A

Episodes during the first meeting

Before the meeting began, prompted by my supervisor at ITRI, I requested permission of the audience to video them and me during the session, which they duly granted. My session started three minutes late and half way through the camera battery ran out so it had to be changed, which used up some of my time. People in meeting room listened to my presentation attentively and I finished almost on time just as Dr L arrived. As he had seldom been to our meeting room, he was accompanied by a colleague of mine who had once worked in the bio-medical laboratory.

Questions after the presentation

Q1: The vice director from the field of chemicals and materials, Dr In-Mau Chen, asked what was the purpose of the meeting given that two similar programmes had already been carried out through the ITRI approximately ten years ago, which suggested he had not read the details on the invitation email.

A1: I answered this was a validation meeting in relation to one case study on innovation, with the key aim being to elicit lessons for its effective commercialization in the future.

Q2: Another question raised by one of my colleagues was since this technology was licensed to a foreign company, Exactech, how come a non-Taiwanese company got the deal?

A2: I replied that the affiliate company of Exactech, Exactech Taiwan, is a Taiwanese company.

The inventor's presentation

Dr L arrived and I supposed he would use the same presentation he showed me the last time I had visited him. Prompted by my supervisor again I asked permission to video the talk. Dr. L asked whether the video would be facing towards the PowerPoint or him and the audience. Then, whilst he was still thinking I decided I did not want to embarrass anyone by filming them and what is more the PowerPoint as I saw did have some confidential material, so therefore, I said would turn it off and switch it back on for the later discussion. Dr L was very happy to share his knowledge on the cartilage reparation and the effective bio-medical cooperation he had experienced with NTUH. To my surprise, he simplified the presentation, giving less technical detail and even took most of the quasi-confidential material out of his slideshow. As there was no video, even though some people interjected with questions during his talk, these were not able to be recorded in detail. However, the basic tenet of most of them was to seek clarification on the subject matter. The presentation lasted over an hour and in fact, only came to end because our assistant came in to remind us that the next meeting in the room was due to commence soon. After the presentation, my colleagues would have like to ask a few questions, but since the time was almost up, he was only able to answer one, which was about the response from the other local companies. After the successful exclusive licensing, the other local companies regretted and would like to influence the government. The general feedback from those who attended the meeting was that they were very impressed by the project, more specifically, Mr Huang at planning office pointed that the close interaction with the university enable this successful innovation after the meeting.

Reflections on the first session

As explained in chapter 4, the 5W1H procedure was next employed to consider the proceedings in the first validation meeting and decide on what could be improved for the subsequent meeting

Why

Although I did explain in the original invitation email that the aim of the meeting was to inform those participating about the cartilage case and that this was about understanding the collaborative process involved, I realized that I had failed to put in the message the novelty of the proposed gathering. That is, I did not write anything about this being an attempt at undertaking ground breaking action research, where the participation would be equally important as the speakers. Therefore, I decided to expand on the purpose of the meeting to include this aspect, in the hope that it might galvanise interest further and hence more likely ensure active participation, perhaps even with pre-prepared questions.

What

After the event, I realized my supervisor had some concerns that I had not forewarned those attending the meeting that I was hoping to video it, which appears to have led to some uneasiness amongst the audience and the guest speaker. Therefore, I decided to inform the attendees of the subsequent meeting of my intentions and to give a clear explanation as to why this would prove beneficial to my research goals. Moreover, I was going to inform the invitees to contact me directly, if they still had misgivings about attending a meeting that was going to be recorded in this way, so as to reassure them that the material would not be shown to anyone who was not entitled to see it and that their anonymity would not be broken. Another issue regarding the substance of the meeting was that I failed to factor in sufficient time for those attending to become involved in fruitful dialogue with the presenters, which would have improved the outcomes.

Who

In my original plan for the validation meeting I did not include the inventor's presentation, for I was unaware that Dr L would express the wish to join me and tell his story during the planning meeting, which turned out to be a very positive experience for all concerned. In this regard, action research proponents emphasize that researchers should not research about people but with them wherever possible. Therefore, because of this rather serendipitous development which improved the outcomes from the validation meeting, I decided to invite the main inventor of the AC LED to the second one.

Moreover, the original decision for the validation meetings was to invite all supervisors in the planning office as well as colleagues who were familiar with bio-medical inventions. However, as the date of the meeting drew near my bio-medical colleagues were busy undertaking newly prescribed tasks and hence, were unavailable. I also tried to invite our executive vice president who at the time was acting as general director for the planning department, but my director said she would prefer not to invite him as he was only just getting to grips with his new post. In spite of this, other senior members in this office, including those in charge of the advanced technology research programme were able to attend. However, I believe it would have been better if I could have attracted more people who were directly involved in the innovation. Further, when the meeting actually took place two supervisors were delayed for approximately half an hour at another one and decided not to interrupt the proceedings in mine. On reflection, it would have been good to reassure their secretary that they would be welcome even if they had been delayed.

Where

The meeting was held on the sixth floor of the tallest building on campus and with hindsight signs for directing people who had seldom or never been to the room before would have been helpful. A solution to this would be to ask the office assistant when she was checking to confirm the numbers that would be attending, whether it would be helpful if she waited for them in front of the lift in the building so as to be able to accompany them to the right room. Another issue that arose, was that initially there was a shortage of chairs and this could be overcome if after the assistant had checked on numbers, she had been asked to go to the meeting room to see if there would be enough beforehand.

When

One thing I failed to undertake methodically was to coordinate with both the office assistant and my supervisor to ensure the maximum attendance of senior staff members. So I decided that next time, first, I would ask the assistant to check when the maximum possible number of such persons would be free and second, would follow this up by asking my supervisor to use her superior position to put greater weight behind the invitations.

How

This refers to agenda setting, providing data, theoretical implications and verification of the case in order to assess how these could be improved for the second session. In particular, I was of the opinion that if I invited the people involved in the case to listen to my findings, they would be able to correct or update it where necessary. Moreover, were they to attend I believed it would represent a practical example of action research, which would be potentially beneficial to all those participating as well as adding to the perceived significance of the event to the attendees.

To sum up, I decided that I would put great effort into ensuring some of those who had been involved in the AC LED innovation would attend the second validation meeting.

In addition, I decided to book the meeting room for an extra hour to avoid the rush that occurred at the end of the first meeting. Moreover, the guest speaker session would come first, so if there was an overrun I could ensure that the meeting ended on time in an unrushed fashion, by matching the inclusionality presentation and discussion with the remaining time. Finally, the invitation email was to declare that there would be a video camera on for recording and verification purposes.

The revised agenda

The revised agenda for the second meeting was drafted as:

2:00-2:05 Introduction: The purpose of the meeting

2:05-3:00 Presentation by inventors ***(if any)***

3:00-3:30 My presentation

3:30-4:00 Q&A and discussion session (it can be extended to another 30 min)

5.4.2 Meeting Two: The AC LED Case

Drawing on the experience gained from the first workshop, this meeting was held at 2:30 PM on March 2nd 2011 in a larger room, just next to the lift where everyone knows that important meetings at the ITRI usually take place and hence, this avoided the remote location problem encountered for the first meeting.

Secondly, the agenda was split into three parts: presentation by the inventor, talk by me and Q and A and discussion, each being allocated approximately half an hour. Prior to the meeting, a summary of the case findings in the form of a chronological list of the events relating to the AC LED development was sent to the inventor, Min-Der Lin and his supervisor, director Dr Chu, to see if they agreed with this perspective.. Mr Lin revised this, in particular adding greater detail, such as information about Global Lighting signing a new business contract with the ITRI and subsequently returned the modified document to me. I invited him to the meeting, which he agreed to as well as sending more application photos of AC LEDs for use in my presentation. However, he did not volunteer to make a presentation, saying that he preferred to participate in the discussion.

Presentation

The meeting was started when the deputy director, Dr Huang, arrived. I presented the research in six sections: introduction, the invention of the AC LED, the research question and framework, results, analysis on the AC LED, and lessons learned from this case. Before presenting these findings, I stressed the fact that these were by no means conclusive or uncontestable and that I would greatly value any constructive criticism or amendments that the meeting's participants wished to volunteer. The presentation lasted half an hour and seven key observations were noted that illustrate this project's success, which could prove useful if applied in other innovatory practice, these being:

1. Recruiting people from industry with ideas who wanted to help in creating an AC LED

2. Interactions among researchers across departments and with external practitioners, such as industry, enabled the development of an AC LED

3. The supportive role of universities who offered their scientific knowledge to overcome problems in the AC LED development.

4. Capturing the value of the invention by using an effective patenting strategy, which resulted in receiving the RD 100 award.

5. Flexible funding such that moneys could flow between different laboratory divisions was essential for successful AC LED development.

6. Focusing on cutting edge technology that would meet the future needs of industry, thereby guaranteeing financial investment in the innovation, but in areas that industry did not have the resources for ensuring success.

7. The research institute developed prototype equipment that with knowledge input from universities was translated into a form that allowed for commercial mass production.

Questions after my presentation

Several colleagues were intrigued to know more details about the challenges the inventors faced during their endeavour in bringing the idea of an AC LED into reality. Fortunately, this time because of extended booking of the room, we had enough time to have a lively discussion, with contributions from more than ten of the passive participants. Some of the questions raised by those attending were focused on knowing more about the technology, the market situation and the evolution of the AC LED.

Q1: My colleague Mr Huang asked: ”Seoul semiconductor also researched into the AC LED, what are the differences or gaps between the ITRI and Seoul?”

A: I responded, as explained when this particular case was covered earlier, that Seoul had developed the first two generations of AC LEDs and seemingly had even patented the first before the ITRI. However, I then went on to explain how the institute had taken the lead for the second and third generation design, that is, it beat Seoul in submitting the second level patent and regarding the third, only the ITRI has introduced the use of the Schottky rectifier for the patent application.

Q2: Dr Chen queried “How far has the AC LED managed to penetrate the lighting industry and what are its predicted future trends?”

A: Mr Lin responded that with low power lamps, such as those less than 5W, the AC LED had a definite advantage.

Q3: Dr Huang inquired “There was about three years silence between when we licensed to Tyntek until Epistar wanted to join in, because the AC LED production was receiving positive feedback. What do you believe would have happened if for the first project we had chosen to collaborate with Epistar instead of Tyntek ?”

A: In response, Mr Lin said that his team had approached all those LED manufactures in Taiwan including Epistar, but this company had expressed the view that the technology was too much in its infancy for them to risk becoming involved.

Q4: Another colleague asked what was the most difficult challenge the inventor and his team faced in developing the AC LED.

A: He responded that is was the lack of support from government funding, which meant he had had to turn to industry for sponsorship. He and the vice president of the laboratory knew the general manager and chairman in Tyntek and they visited them. Later, Tyntek wanted to sponsor the technology development project as they recognized the potential of the research.

Q5: A collegue disagreed with my first observation in regarding to recruiting a researcher from the industry and join ITRI with a good idea to explore. In his view, it may infringe the intellectual property right of his former employer.

A: I answered that in this case, Mr. Lin did not continue the same research, high voltage LED, in his former post. Rather, he started a relevant but different technical approach. Mr Lin added he knew this challenge for more ten years which firms in LED industry have not solved. To know a challenge is one thing, and to solve it is another thing. The value ITRI can add on his idea was people with different expertise in the different department can work together to bring forth a solution.

The second part of the meeting focused on comments on the AFM, probed by two supervisors from the planning office. The first comment was made by Vice General Director Dr Huang. He used to work at the same laboratory as Mr Lin, and knew the team members well. He agreed these observations were quite reasonable and the explanation of the AFM with four types of flow seemed very convincing to him. His only concern was that the model may be an explaining model rather a forecasting one that could foresee the success of collaborations between the ITRI, universities, industry and government. I responded that more case studies and surveys could be undertaken to strengthen its effectiveness.

Moreover, another director, Dr Chen would like to have more comparisons in my presentation between AFM and THM so as he could judge himself the superiority of applying AFM in AC LED case study. This suggestion was well taken and I revised the analysis part to add one subsection dedicated to THM analysis in the first two sections of this chapter.

Reflection on the meeting

In general, the presentation and Q & A sessions were better than the first session. The presentation was finished just on time, which allowed people in the room to have more time to raise their questions. For the Q & A session, Deputy Director Stanley took the chair and invited people to ask questions, before making a few comments. As soon as he finished one of several people asked for more details about the case innovation, as mentioned in last subsection. On reflection, having the inventor make a short presentation in addition to mine meant that the outcomes from this meeting were much better than the first.

I also applied 5W1H when reviewing how the meeting went and found most of the issues raised from the first meeting had been addressed. For example, the purpose of the meeting was reported at the beginning and the ethical issue of informing those attending that the meeting was to be video recorded was also dealt with at this time. More time was allotted to enable people to have prolonged interaction. I conferred with all the managers' secretaries at the planning office about their schedules so as to ensure maximum attendance.

To sum up, in this chapter comparisons have been made between the THM and AFM, so as to assess their usefulness for explaining the evolutionary process of innovation and it has been shown that the latter has greater power to do so than the former. This is because the AFM allows for the inclusion of more actors than the THM as well as it specifically identifying four kinds of generic energy flow that can be observed during the innovation creation process. Although proponents of the THM more recently have recognized that such factors as flow knowledge and human resources are involved, their conceptualization of this is rather vague.

Subsequent to analysis of the two cases employing both models, a cross-case investigation was conducted that showed the common features and differences between the cartilage reparation and the AC LED. By and large, all four sorts of energy flow were found to play essential roles in the creation process of the innovation in both cases. Moreover, it emerged that both inventions addressed unmet needs of users, and came about because of new members from the university or the industry joining the research organization. Further, since they had strong connections with their previous work places they were able to access certain resources from them as well as receiving input from their new employer. In addition, the inventors disseminated their new knowledge to the public, through a journal paper (the Journal of Bio-Medical Materials) in the cartilage case and by being successful in an innovation competition (RD 100 Award) for the AC LED one, which sent out signals that helped in the commercialization process. Further, both innovations received grants from the government for collaborating with a university (ties) and to file patents. Furthermore, the trajectory of each innovation involved ongoing ideas development and application that helped to improve the outcomes.

However, they also they exhibited some differences in terms of the four categories of flow. Firstly, the main inventors came from different spheres to the ITRI, namely, a university and industry. Secondly, the ideas were generated differently, one being from clinical insight at the university hospital and the other from discussion between two researchers at a convention. Thirdly, the main funding sources were also different, for the government fully sponsored the first case, whilst the second received research funding from industry. Lastly, the company, Exactech, relied on the ITRI and the university to provide the scaffold, whereas the ITRI needed help from industry in order to put in place mass production of the AC LED. Furthermore, this researcher adopted audit trials to enhance the validity of the case studies and analysis as showed in the section 5.4. The feedback of inventors and senior managers at the planning office of ITRI were taken to perfect the analysis and enrich the learning on both the validation and the effectiveness of the validation meetings. Some possible conclusions and limitations were also posted by these attendants which was beneficial for the researcher.

Chapter 6 Conclusion: Implications and limitations

After analyzing the findings from the case studies and the validation meetings in chapter 5, in this chapter, the goals of the study and the research question are revisited (section 6.1). Next, the findings and reflections are given in order to draw out the contrasts between the AFM and the THM (section 6.2). Subsequently, the implications arising from the study for collaboration between universities industry, governments and other actor(s) are considered, in particular in relation to universities (section 6.3). Moreover, an account is provided of the contributions of this thesis to both theory and practice (section 6.4). Finally, some limitations and suggestions for future study are identified (section 6.5).

6.1 Revisiting the goals

This thesis was started by setting out the need for a novel evolutionary model that could address the co-evolution that takes place amongst the different institutional actors that have been identified in extant research as playing key roles in innovation processes. More specifically, the proponents of the Triple Helix Model (THM) specified three institutional actors, university, industry and government, whose cooperative interactions have been essential in American examples of successful innovation cases, such as the Boston Route 128 and Silicon Valley experiences. However, the innovation environment can vary across countries, which challenges the appropriateness of the THM model in other contexts. In other words, other countries may not be able to aspire to mimic and transfer directly the processes which led to the development of Silicon Valley in the US to their national context (Hobday, 1994). Moreover, it has been suggested that the THM lacks the flexibility to incorporate other actors into the innovation process and hence, has limited explanatory power when compared with the AFM (Huang, 2010). Furthermore, few empirical studies have effectively supported the THM (Edquist, 2005). Recently, one of these empirical studies using the THM was carried out by Park and his associates (Park et al., 2005). In this article, they adopted patent and paper citations so as to compare patterns of knowledge diffusion and used network analysis to shed light on the dynamic relationships among the three institutional actors. This study however failed to take into account other potential forms of interrelationships amongst the actors as these scholars chose to focus only on knowledge.

Having identified the limitations in previous research regarding innovation, addressing the following research question is the main goal of this thesis:

Does the AFM extend the triple helix model by providing a more comprehensive form for exploring the creation process of innovation between industry, universities, the government and research institutes in Taiwan?

These research questionhave been addressed by the formulation of a revised model, the Actor Flow Model (AFM) and this was adopted for understanding two case studies located in Taiwan for the following reasons. Firstly, the aforementioned model is preferred as it can potentially accommodate other important actors in the innovation creation process. Further it can illustrate in a more systematic format the structure of the interrelationships and dynamic interaction between these institutional actors. This was discussed in chapter 3. Secondly, the investigation of the case studies (chapter 4) and their subsequent analysis (chapter 5) can serve to justify the efficacy of the revised model. That is, the empirical cases test the robustness of the theoretical model, whilst the outcomes of the validation meetings functioned as audit trials that served to verify the case study outcomes and the proffered analysis.

6.2 Findings and reflections

In this section the three parts of the research question are addressed in turn.

My research question is: Does the AFM extend the triple helix model by providing a more comprehensive form for exploring the creation process of innovation between industry, universities, the government and research institutes in Taiwan?

Firstly, How can the Triple-Helix Model be modified so as to provide a more comprehensive model for theorizing the creation process of innovation?

To address this question, a model modified from the triple-helix model (THM) termed the Actor Flow Model (AFM) was constructed that incorporated the idea of flow from the concept of inclusionality so that the insufficiencies of the THM could be overcome. The AFM not only added the possibility of there being other actors, such as research institutes involved in the process, but also allowed for the detailed identification of the dynamics between the actors. More specifically four different categories of energy flow are used to trace the interchanges amongst the actors, namely, human resources, knowledge (information) flow, money flow and physical flow. By applying these flows, the interactions amongst participants can be observed as the evolutionary process of innovation unfolds.

Turning to the case studies, through application of the THM and AFM, these two models were examined in order to demonstrate the effectiveness of their explanatory powers in relation to the creation process of the two innovations. The analysis conducted in chapter 5 showed that the AFM can provide a more detailed account of the innovatory process than the THM, in terms of the range of actors involved and the flow of resources. More specifically, under the THM lens there is a strong emphasis on the interrelationships between universities and industry, with it being contended that universities often take over the role of the latter during successful projects. However, although this was found in the cartilage case, there was little evidence of it in case two, for Cheng-Kung University was only responsible for providing a safe regulation testing service for both the lighting industry and the ITRI. Moreover, in spite of the recognition by THM exponents that exchanges of resources, in particular knowledge, facilitate innovation, the model does not give a clear explanation regarding this particular aspect. In contrast, through the application of the AFM it was possible to trace the four types of flow from the beginning of each invention to the commercialization phase and thus provided a more comprehensive analysis of the whole process than the THM can.

Turning to the next part of the question, two cases were selected to illustrate the interaction and dynamics between: universities, industry, the government and a research institute.

In addition, the case study approach was adopted to investigate this research question and two cases were chosen from different sectors so that the commonalities and differences could be highlighted. One case investigated the collaboration over a bio-medical material, and the other that of a collaborative development in the field of opto-electronics. Both involved an RI, universities, industries, and the government. The evidence that emerged regarding the collaboration among these four spheres indicated that the RI played a crucial role in developing the prototype and delivering the technology to industry with the assistance of the other actors. However, the degree of importance of these actors varied between the two cases. For example, in the first case, the university, the National Taiwan University Hospital (NTUH), provided a critical research idea regarding creating the cartilage reparation solution and it worked closely with the RI. In contrast, in the second case, the universities were involved after the main invention had been revealed to the industry. That is, in the former case the university benefited from the collaboration with the RI after they identified a very promising research topic for exploration. In contrast, regarding the latter case, industry and the RI worked closely with the intention of moving on swiftly to the mass production stage after the (on-chip) AC LED technology transfer, without involving a university.

In addition to the three actors included in the THM, a fourth actor, a RI, namely the ITRI of Taiwan, was found to undertake tasks originally performed by industry for both case study innovations. For instance, in the first case, the RI developed the prototype of a scaffold and later in the collaboration with a university hospital established a GMP factory to fabricate it. They also collaborated for the clinical trials, which would usually be carried out by industry. In the second case, the RI developed the testing machine for the industry, which would usually be the responsibility of another company.

By using the AFM, which encompasses inclusionality in order to discuss the four types of energy flow, has appeared to be more effective in illustrating the collaborations and dynamic relationships than the THM. Moreover, the four actors identified in the AFM were found to have contributed at least to some extent in these two innovation cases on their way to commercialization. Considering the points that the two cases have in common, in both the inventors came originally from sectors other than the RI with one being from a university, and the other from the semiconductor packaging industry. They helped to foster the social network across the borders between the two different spheres, i.e. their original milieu and their new one, which facilitated the dissemination of knowledge and achieving of funding. That is, they brought in complementary resources to the ITRI that helped nurture the innovations. Moreover, both innovations involved the ITRI working in collaboration with universities to conduct scientific research or experiments. They also collaborated with industry, after licensing the technologies to them by providing contract research services and physical goods at different stages of the process. In these two cases, the government supplied the funding positive externality wholly in the first case and partially in the second, which compensated for the lack of investment in research from the private sector and was aimed at providing a positive externality to the participants in each of the focal industries (Mansfield, 1996). The participants also received some assistance regarding regulations, easing the clinical trial for bio-material in the first case, and standards, AC LED domestic standards in the second. In sum, the four institutional actors were all involved in the creation of the innovations but level of engagement varied by stage and by case. Moreover, the variation in the employment of the different actors between the two cases can be attributed to fact that they pertained to different industry sectors and this, which has also been observed by Tidd (2001), is discussed in more detail next.

The university was the lead user in the first case, as they not only gave feedback to the RI, but also brought their insight and ideas to the development. In case two, the HEIs carried out the basic research and were testing service providers. Moreover, the relevant industry was involved at different stages of the trajectories of the two examples. Regarding the first innovation, industry was not involved until the journal paper had attracted the attention of managers at Exactech, to whom, subsequently, the ITRI's technology was exclusively licensed. In the second case, industry was involved from the outset so that the invention could be brought to mass production with minimum delay. To this end, the AC LED related technologies were distributed under non-exclusive licenses to different firms in order to diffuse the innovation. The government played different roles according to the characteristics of the two sectors. More specifically, in bio-medical industry, the FDA (Food and Drug Administration) in Taiwan keeps the industry highly regulated and requires that bio-materials are safe, with no expense spared. However, in the LED sectors, the government was trying to help domestic firms gain a technological advantage over their global competitors by engaging the RI to set a high industrial standard for the AC LED. In sum, the government assisted both innovations in terms of setting regulations, but their actions were driven by different motivations according to their perceived needs of the two industrial sectors involved.

The third part of the question has been addressed by exploring the aforementioned dynamics between: universities, industry, the government and a research institute in the Taiwanese context.

Regarding this, it was elicited that if HEIs in Taiwan collaborated with other spheres in the innovation process, they could contribute to making commercialization of any outcomes more effective. As reported in the previous chapter, HEIs can contribute their ideas and basic research. In both the case studies the HEIs played a specific role in the trajectories of these two technologies. The first case, the clinical study team, led by Dr J, a professor at the National Taiwan University and a medical doctor at National Taiwan University Hospital (NTUH), provided very significant user insight regarding the surgery cartilage reparation solution. In the second example of the on-chip AC LED, the universities acted as partners to improve the electrical and cooling properties as well as facilitating standards compliance, regarding which they had a specific expertise.

Regarding this research, the importance of HEIs in the innovation process has been ascertained, for without their collaboration, the issues that needed addressing (e.g. the thirty minute time limit for the in vivo cartilage reparation concept) would probably not have been identified nor could the fundamental scientific issues (e.g. the cooling and standard compliance issues with the AC LED) have been solved. In fact, Dr L in respect of the first case, gave a very vivid image when he put forward the metaphor that medical doctors at universities are the pilots, the RI builds the prototype, and that industry mass produces the planes. For case two the RI brought its unresolved problems related to basic research to the universities, which found the issues intriguing and subsequently continued their line of enquiry by obtaining other funding to put into the area. However, the roles of the HEIs in the two cases varied, probably owing to the nature of the different industrial sectors involved. In the bio-medical sector universities usually take a very central position regarding new ideas, whereas in the opto-electronics field, the mass production of AC LEDs by industry is crucial and the universities enhanced the innovation in terms of working on the products and product safety and efficiency.

In sum, the findings support the view that in the bio-medical industry, university hospitals can provide precious pioneering insights into clinical contexts, which can lead to what Von Hippel (1988) termed user-driven innovation as medical doctors' needs were addressed. Regarding the second case, the role of HEIs was not so central to the project, but they were still able to provide invaluable knowledge that helped it progress in the right direction of improving the AC LED design. However, Taiwanese HE has generally had little collaborative involvement with other actors in the past and so these and similar developments could be seen as a useful guide for HE managers in the future. Moreover, similar interaction to that provided to the main innovation actors in the form of the validation meetings organized through the planning office at the ITRI are proposed here as a fruitful avenue for drawing universities into similar projects as those studied in this thesis.

6.3 Implications

The outcomes of this study have theoretical and practical implications, both at the national and institutional levels. That is, regarding the former, this concerns the general implications for research and practice relating entire national innovation systems (e.g., Lundvall, 1992), whilst the latter, focuses on the AFM actors and flows, in particular, with respect to HEIs.

6.3.1 Macro level: national system of innovation (NSI)

In this research an extended model, the AFM, which extends the THM theory employing the university-industry-government triad to include other organizations (e.g., non-governmental organizations), which are increasingly becoming part of the national economic landscape (Drucker, 1990). Moreover, the AFM identifies four different types of energy flow which can facilitate successful innovation, if exploited effectively. That is, under this lens the complex interactions between University-Industry-Government-Research Institutes and maybe other actors can be analysed in terms of human resources, information or knowledge, money and other physical flows. It is granted that more recently THM proponents have acknowledged the need to address some these dynamic relationships, but their guidance has been rather vague (Edquist, 2005) and insufficient for accommodating other actors and contexts (Huang, 2010).

The leaders of universities as well as those in other spheres are frequently consulted by governments to generate effective national innovation policy and this particularly so in Taiwan. Under the lens of the AFM, the various actors should be encouraged through national policy to accommodate for new potential actors and identify the energy flows that will help to facilitate the innovatory process. Having made this assessment, they can then take actions to facilitate dynamic interactions amongst the different actors by creating space for energy flows through the removal of any identified obstacles. Moreover, they can help generate effective innovation policy through benchmarking, using their imagination, supporting experimentation, and working to ensure that the tasks and responsibilities are shared out effectively amongst the different actors. Regarding the role of government, apart from the policy aspect above, it should endeavour to assist the efficient movement of the four types of the energy flow, in particular, targeted strategic funding and as a key agent for fostering networking at the national level. Through such a strategy, not only will existing innovations be more successful, but new seeds for further invention are much more likely to germinate. Furthermore, the government or other actors should ensure that there is constant monitoring to check whether what has been put in place to nurture inventiveness and successful innovatory outcomes remains appropriate and, if not, to make proposals for further modification.

6.3.2 Micro Level: the HEI

In general, two major tasks can be identified in the creation process of innovation: exploration and exploitation (March, 1991; Gupta, 2006; Chesbrough, 2006). The former involves seeking novel useful knowledge, which when discovered offers the opportunity for creating new products or services for the market or society. However, new knowledge is only of value when it is converted into products and services through commercialization.

Universities have long been regarded as an important source of scientific and technological investigation for uncovering new knowledge. However, it is only much more recently that there has been the development encouraging them to exploit the value of their knowledge by setting up technology transfer offices and taking other initiatives. In spite of this now being on the agenda, the results of these initiatives have not been as effective as the policy makers expected (Mowery and Sampat, 2004). Therefore, universities, as a players in a NSI, need to reassess the role that they should adopt in innovation collaborations in order to increase their impact on both the market and society. On the other hand, the AFM provides the leaders of HEI a framework of possible energy flow to enable or nurture the seeds of innovation to: sprout, grow and eventually bear fruit. In sum, according to the AFM perspective the participants in an innovation project need to assess constantly, collaboratively and dynamically, which actors should play what roles in the innovatory process, then it would be easier to avoid unproductive outcomes, in particular, for universities.

The leaders in universities should proactively seek to accommodate collaboration partners from other spheres and create a space for them as a central part of their research strategy. Having identified the outside actors they should work cooperatively to ensure optimal energy flow regarding the four identified types as well as be prepared to modify their policy so as to be in alignment across all the participants. As has been discussed in this research, universities are best at basic research involving the generation of scientific ideas, whereas RIs and industry excel at research application, which clearly sets out the fault lines that these actors should usually follow. Managers in HEIs should also create opportunities, through temporary sponsorship, for example, to encourage their employees to find placements in outside settings that will stimulate their ideas as well as encouraging appropriate people to visit their universities to see what goes on. In the cartilage reparation case, Dr L finished his post-doctoral research at the university and then joined the ITRI, who helped him to set up the experiment using human guinea pigs by providing facilities, resources and effective experimental techniques. Moreover, with Dr J's arrival from the NTUH the ITRI was able to draw upon his knowledge, which resulted in the speedy commercialization of an innovation that may not even have happened otherwise. In the second case, universities were involved in helping to solve problems to do with AC LEDs, such as cooling and safety compliance, on the way to commercialization. In general, by acquiring external funding, as happened in both cases, HEIs can participate in the innovation process, which in turn helps to build their resources through networking.

As mentioned in chapter 1, the Bayh-Dole Act in US was aimed encouraging universities to license or establish new firms from their new technology resulting from academic research. However, Mowery and Sampat (2004) questioned whether this approach was appropriate in other contexts. It may be also applicable to the case of Taiwan where universities are not so well endowed.. Moreover, as pointed out previously, the THM fails to see the relevance of RIs as important actors in the innovation process and by this omission implying that universities have a greater role. However, in both licensing and the impact of spin-offs, RIs in Taiwan are performing much better than universities according to licensing revenue. For example, in 2003, in total, universities received USD 28,890 millions (NSC, 2011) of research funding sponsored by government, but their licensing revenue was USD 3.3 millions (Kuo, 2005). Whereas the ITRI received USD 303 millions from the government, alone it contributed around USD 18 millions (5 times more than the universities) in the same year (ITRI, 2004). The economic impact of the establishment of technology transfer offices in universities as well their incubator companies apparently have been limited. However, in spite of this, the strength of the research conducted in universities is that it has a basic science orientation, which RIs and industry are unable to match. In particular, in the bio-medical discipline, universities and university hospitals can offer new insights and new ideas that can subsequently be commercialized. However, it is proposed here that it is usually more effective for a RI and/or industry to take up the baton from universities in order to exploit the potential of technological development. That is, rather than becoming too involved in commercialization, it may be best for universities in Taiwan to focus on basic research, in particular, because of the difficulties of acquiring resources. As indicated in the case studies, especially the first, Dr J had the in vivo experience but did not enough time and resources to continue the development of scaffold and toolkits for surgery, which eventually was taken up by the ITRI

To sum up, the AFM has both policy and strategic implications at both the macro and micro levels of the innovation system. At the NSI level, this perspective requires government and other stakeholders to recognize that other actors than the three identified in the THM may need to be involved if an innovation is to be successfully created and exploited. Moreover, it is recommended that government national innovation policy, especially in Taiwan, should be oriented towards collaborative projects by multiple actors as well as ensuring that any obstacles to energy flows between them are tackled. In addition, at the micro level managers in universities, RIs and industry should be introduced to the AFM as a blueprint for helping them to manage their innovatory activities more effectively. That is, the model can be used prior to the commencement of a project or to help monitor progress so that ongoing adjustments to energy exchanges can be made covering.

6.4 Contributions of this thesis

In this thesis, a new model, the actor-flow model (AFM), which builds on the Tripe-Helix Model, has been put forward. As mentioned, the originators of the THM (Etzkowitz and Leydesdorff, 2000) played down the importance of bridging organizations such as research institutes in the innovation system. However, Shapiro (2011) has found that such institutes were essential for the industrial development in two newly developed countries: Korea and Taiwan. In order to make THM applicable under these circumstances he combined the government and research institutes into government laboratories as these were largely sponsored by governments. However, his model seemingly failed to explain situations in which research institutes undertake their own initiatives or in which they negotiate with the government rather than merely carry out government industrial policy. In other words, interactions between governments and research institutes are neglected in this model.

The AFM is aimed at addressing the deficiencies of the THM, namely, being restricted to three actors, the theoretical interactions among these being only vaguely considered (Huang, 2010) and the contextual differences in tiger economies, such as Taiwan, being neglected. Firstly, it allows for other possible actors, such as research institutes being included. Secondly, the interaction between the different actors can be observed for four different kinds of energy flow, thereby providing a dynamic comprehensive picture of the innovation process. These two differences to the THM have emerged because of two key concepts underpinning the AFM, one being inclusionality taken from biology, as proposed by Rayner (1999, 2006, 2010) and the other is system dynamics, attributed to Forrester (1961). Taken together it has been put forward that these two theoretical concepts allow for more insightful strategic thinking than with the THM. The inclusionality perspective promotes cultivating and facilitating the energy flow as being crucial for survival and development, whilst the systems approach provides the categories of energy flow, that need to be considered during the innovation process. To this researcher's knowledge, except for some prior work on knowledge flow and the brain drain (Park, 2005), this is the first attempt to accommodate the full spectrum of flow into analysis of the innovation system.

Thirdly, whilst the THM drew on the lessons from NSIs in developed countries, such as the United States, the AFM provides a model suitable for exploring innovations in newly developed countries or tiger economies like Taiwan. A number of scholars have argued that most NSI studies have considered the experience of developed countries and that their outcomes can shed little light on the innovatory trajectories of developing and newly developed countries (Adeoti, 2002; Gu, 1999; Intarakumnerd et al., 2002; Inzelt, 2004; Kitanovic, 2007; Szogs et al., 2009). OK? However, there is clear evidence that East Asian countries like Korea, Singapore and Taiwan, and Latin American countries like Brazil (Lundvall, 2006) have not undergone the same experiences as developed countries regarding innovation and even amongst these nations no common pattern has occurred. Consequently, because the AFM in this research has only enquired into the NSI in Taiwan, it can not be assumed that the trajectories of other nations have been following the same path and further investigation would be needed to test the exportability of this model.

In practical terms, by drawing on the four types of energy flow, those involved in innovatory activities cannot only identify resources at the outset of a project, but also by bearing in mind their existence can be more ready to recognize new opportunities as they arise. For example, in this research it has been elicited that the catalyst for the innovatory activities was when new employees arrived at the ITRI from university or industry, bringing their subject expertise as well as well-developed social networks. The latter proved to be a crucial conduit for acquiring new resources in tandem with the knowledge and network arrangements of the ITRI as each project progressed. It allowed for greater energy flow than were it otherwise. Further, through boundary management, the ITRI, being at the centre of the innovations, recognized the importance of work being delegated to other actors as well ensuring that was publicity through patents or other means, so as to draw in more funding and thus, move the commercialization process forward. In other words, it is posited that systematically employing the AFM at different stages in an innovatory project will assist management in universities, RIs, industry, and the government to identify the best configuration of resources as well help in deciding the roles of each of these actors. In particular, the new model allows managers in the different spheres of the NSI including those in universities to evaluate and manage the energy flow/resources to enable innovation. Further to this, the various actors could use the model to analyse what aspect of their function is well endowed with resources as well as having strong channels for energy flow and therefore likely prove to be an effective area for further seeding. The two focal cases have demonstrated that rich insights that can be gained by innovation participants when the AFM is applied.

6.5 Limitations, and suggestions for future study

Because the model is a new development and has only been employed to investigate two cases, it may well be that there are other factors, as yet unidentified, that need to be included, if it is to have universal applicability. It is likely that new insights would emerge were the model applied more widely.

Moreover, the analysis of different energy flows did not cover the causal interrelationship between the different sorts of energy flow, which may also have played crucial roles during the making of these two products. Take one of the most arguably critical interactions, that between human resources and knowledge as an example. In the first case, the main inventor, Dr L left the National Taiwan University Hospital (the university) and joined the ITRI (RI). He brought to the ITRI not only himself (human resources), but also coded knowledge of the mice experiments and the tacit knowledge of how to work with the medical doctors (both are know-hows). Later, because of the involvement of medical doctors, Doctor J can contributed his successful experience regarding autologous cartilage cultivation and surgery enabled him to propose with some justification that the team should pursue 30 minute autologous cartilage reparation surgery. Finally, the experiment results published in a journal paper (explicit knowledge diffusion) attracted the attention of Steve Lin at Exactech who subsequently engaged the firm's medical and commercial teams, such that the research team was able to modify their prototype and hence prepare for clinical trials (knowledge flow) in other countries, such as the U.S. In the second case, the main inventor, Mr Lin was recruited from Para light, the daughter company of Tyntek (the industry), to the ITRI (RI) and thus it can be seen that this human resource flowed inwards. In addition, when Mr Lin came to the ITRI he brought his contacts in Tyntek (know who) and consequently he acquired two research contracts with them to get financial support (financial flow) for the AC LED development. However, the project would not have been possible without help from the team members (human resources) of semiconductor processing who collaborated with Mr Lin to produce the prototype. These examples illustrated the complex interactions between different types of energy flow could play important roles in the evolutionary process of innovation.

In addition, another limitation of this research is it having mainly considered the context of the Taiwanese NSI and hence there is strong possibility that different actors and directions of flow will emerge when the AFM is applied in other contexts. Regarding this, although Taiwan is one of the newly developed countries or the tiger economies is characterised by different institutional and historical contexts, even when compared to the other tiger economies of East Asia: Hong Kong, Singapore and South Korea. For example, the small and medium enterprises (SMEs) form the major part of the private sector in Taiwan, whereas large companies (chaebolas) have made up much of Korean's private sector (e.g. Samsung). The reason for this situation in Taiwan is that when the ruling party, Chinese Nationalist Party (or Kuomintang) settled on the island after retreated from mainland China, they brought with an acute distrust private large companies which they considered exploited others and hence proactively discouraged them and any mergers that could lead to their creation. Consequently, with the predominant SMEs having few resources for conducting in house research and development in order avoid losing the competitive advantage of such labour intensive industries, the leaders of the Taiwanese government in 1973 took the bold initiative of establishing a new research institute, ITRI(Shih et al., 2003). Many overseas Chinese scientists who worked in high-tech sectors in the U.S. were invited back to Taiwan to work with the ITRI or to start up their own companies. Later, the ITRI has successfully established the semiconductor sector in Taiwan by setting up several spin off companies, such as Micro-electronics and TSMC (the world's largest independent semiconductor foundry) in a close proximity area, Hsin-chu Science Park, the Taiwanese silicon valley. ITRI also formed at least two consortia to facilitate catch-up for the domestic IT companies, by providing them with a common-design blue print for computer motherboards. At the same time, a brain drain took place from the ITRI to the private sector, which also stimulated growth in the high tech sector (Mathews, 1997; Shih et al., 2003). The successful imitation and catch up strategies allowed Taiwan to enter and flourish in the high tech global market for the past three decades.

However, this model became less effective for Taiwan in recent years (Dodgson, 2009) owing to the rapid growth of developing countries, such as China and India, with their own government-led catching up programmes and importation of expertise, respectively. Another contextual limitation of the Taiwanese situation is that in spite of the government promoting direct collaborations between universities and industry, its "innovation capacity is heavily reliant on building the capability of SMEs and continues to depend greatly on government leadership through technology-capability-enhancing institutions, such as the ITRI" (Hu and Mathews2009, p.138), which does not necessarily appear to be the case for other nations. Therefore, when interpreting cases using the AFM for other nations, it is important to remember that research institutes or their equivalents as found in Taiwan may not be present and that also other actors may play the key roles. In other words, the path dependent historical evolution of a country's innovative activities must not be overlooked.

Further, it is accepted that there are different models in NSI studies, networking research and the AFM framework cannot address all the issues raised, given the breadth of this literature. Therefore, to redress these issues, it is proposed that the framework be used to investigate other innovatory activities to elicit whether it needs extending or modifying in any way.

The case study approach employed in this thesis can be criticised for being subject to researcher bias. Moreover, because third party validation including all stakeholders could not be carried out owing to insufficient time, there may well have been a degree of collusion between the researcher and the other participants in the validation process. That is, between them they may have exaggerated the success of the approach, because they were to some extent its subject, whilst an outsider could have provided a more objective view. Therefore, to remedy these shortcomings a survey of academics and practitioners in the field of innovation is proposed that explains the AFM and requests their input with regards to its relevance to their endeavours, thereby providing the third validation lens needed for this form of qualitative research..

The analysis drew out the dynamics of the energy flow during the innovation creation process, but did not elicit how best to manage flow and space which could be an avenue for future research. In addition, the different strategies, i.e., differentiation, integration, and regeneration, of inclusionality could be also explored to provide more complete picture of the evolution of innovation process. Finally, although the data collection involved rigorous analysis of the innovative trajectories, there was no in-depth probing of government policy and the ideas/drivers/missions for each of the actors. This meant that the dimension of the underpinning institutional arrangements in each case was not elicited, in terms of potential conflict and areas of agreement.

Consequently, some of the observed actions lacked comprehensive interpretation. Therefore, future work should entail probing the institutional policy environment and the ideas orientation of the different actors in order to provide deeper explanation for the observed behaviours in innovation case studies.

Chapter 7 Learning and Reflection

7.1 Becoming aware of action research and benchmarking

When I came to Bath in 2005 an impressive lecture was given by Judi Marshall and it was the first time I had encountered action research, in particular, action inquiry. This involves four modes of integrated communication: framing, advocating, illustrating, and inquiring. Framing involves stating the purpose of an investigation and the dilemma that needs to be resolved as well as putting forward which assumptions are or not shared. Advocating refers to making a claim, declaring an objective and/or suggesting a strategy, which is usually accompanied by an illustration, in the form of a story with concrete evidence in: visual, audio or written form. The last aspect of communication is inquiry, where the researcher's activities hopefully result in the discovery of the new that he/she can then disseminate. However, although action inquiry provides a comprehensive template for addressing a research project, it does not go as far as explaining how to make value laden judgments that can be employed to identify how to improve the status quo. Therefore, I searched for another form of action research that could improve the practice.

It was action science that could provide a sense of direction for researchers to follow that involved questioning underlying assumptions that would result in a profound changing of underpinning values. This was proposed by Argyris et al. (1985) and his associates after they observed discrepancies between people's actions and espoused intentions. Moreover, they pointed out that there is always a theory behind action based on rationality that is expressed in a non-verbal or implicit way and to be more effective, one has to find the espoused theory (value) and the theory-in-use that is behind this action. To explain the superiority of this approach, Argyris (ibid) developed two theory-in-use models, Model I and Model II, as shown in figure 7.1 below. Each of these models consists of three major elements, as illustrated in simplified form below, which shows that the governing variable leads to action strategies that are implemented. The authors pointed out that that usually people adopt single loop learning (Model I), whereby they change their strategies to tackle the situation, but do not query their basic assumptions, which results only in a short term win. However, their concept of action science introduced the notion of "free and well-informed choices", which can lead to double-loop learning (Model II). That is, when unintentional results appear, under this lens actors need to look for new action strategies, whilst at the same time examining the underpinning governing variables and assessing their applicability given the change in outcomes.

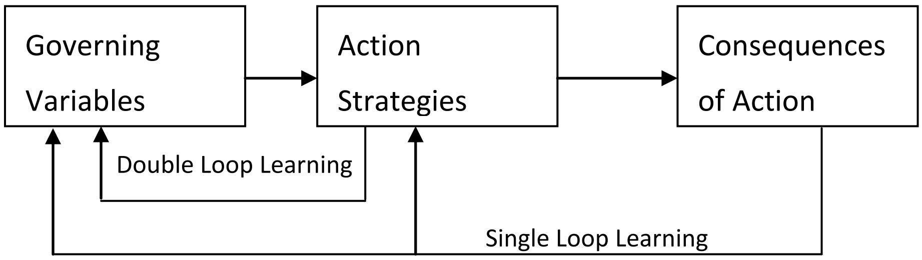

Diagram 7.1 Single and double loop learning

Adapted from: (Argyris and Schön, 1974)

That is, the main difference between Model I and Model II is the orientation towards the governing variables, in that in the former case these are not questioned, being taken for granted, whereas in the latter they are rigorously analysed to see if they hold. Argyris and Schon (ibid) identified four variables for each model and four action strategies and when put side by side, as in the figure below, it can be seen that Model II is superior as a learning approach.

Items	Model I	Model II
Variable One	Set goals and achieve them	Valid Information
Strategy One	Unilaterally design and control the situation	Design a situation in which one can realize assumptions, carry out action strategy and thus get results
Variable Two	Winning is most crucial	Free and informed choices
Strategy Two	Control work and task	Tasks and work are co-controlled
Variable Three	Avoid expressing negative feeling	Internal and constant commitment
Strategy three	Protect oneself unilaterally	Learning orientation of self protection, and bi-lateral protection
Variable Four	Rationality	Same as above
Strategy Four	Protect others unilaterally	

Table 7.1: The comparisons between Model I and Model II

Source: ibid

7.1.1 Learning from assignment 1: the journey of action science

The action science perspective of Model II has profoundly influenced my practice, by providing me with a comprehensive framework for understanding how to intervene, but also why I should do so in the first place. I applied this method when I embarked upon my first DBA assignment, which involved a case study on the setting up of a patent quality index proposed by me, showing how I was involved and how my input shifted the position of the managers concerned with this aspect of the ITRI. Regarding this, the vice director in my division, Mr Fan, instead of strongly advocating the benefits of introducing these particular indices, agreed with the shortcomings that he and I had identified. Consequently, he was able and willing to appraise the president of the issues involved in a balanced way, so that he was able to make a well informed choice about what would happen next. The result was that in spite of the highlighted limitations the proposed indices were approved by both the core team and at general management meetings.

To sum up, what I learnt from this action science approach was to stop unilaterally controlling the learning process and start cooperating, by providing free and informed choices, rather than trying to always win, which corresponds to Argyris and Schön’s (1978) concept of organizational learning. Unilateral control is predominant in many societies/organizations and involves leaders endeavouring to deprive agents of free will by coercing to conform to their world view. Moreover, in organizational settings managers use performance evaluation to rank the employees, thus feeding the win scenarios. HEIs and research institutes, unfortunately, are rarely an exception. For instance, when I reflected on my own place of work I realized that there were many events where people just wanted to win to save face. Consequently, crucial information has often become distorted leading to the effectiveness of implementing decisions being compromised.

Another turning point in my learning journey occurred when I reviewed an article that explored the thinking and background of one of the founders of action research, Kurt Lewin. As a Jewish exile from Germany during World War Two, he reflected on the process through which the will of Hitler was able to mobilize nearly all Germans to massacre the Jewish minority and how this might be avoided in future. To this end, in his article (Lewin, 1946, 34-46) "Action Research and Minority Problems", he established the basic process of action research, which involved evaluating the situation, drafting a strategy, implementing it, reflecting on the results and re-evaluating and so on, hence it being cyclical in form. Perhaps most importantly, given his motivation, he stressed his view that action research should emphasize democratic and participatory values, rather than simply being leadership driven.

7.1.2 Learning from assignment 2: the journey of appreciative inquiry

While I was preparing the second assignment, I came across the concept of appreciative inquiry (AI), developed by Cooperrider and Whitney (2005), which places stress on unconditional positive questions and what has and will be done well instead of problem solving as informed by deficit thinking (e.g. what we lack in the first place). The underpinning assumptions regarding AI also are different to other learning models, with these pertaining to: discovery, dream, design and destiny, which researchers can use to engage people, as shown in the diagram 7.2.

I applied this approach in the aforementioned work, by proposing an improvement project through the Employee Suggestion System at work, which involved inviting inventors who have written essential patents to give a talk and this was accepted by the relevant committee. The project was assigned to Ms X, at the Technology Centre, who asked why I had made this suggestion and I responded that I believed it would be useful for other researchers to learn from these experienced people. I got the impression she was not very happy to be delegated this task and therefore, I tried to reassure her by telling that I did not wish to increase her already heavy workload and that I had contacted three inventors already. Unfortunately, she seized on this somewhat negative comment, by telling me that what I was doing was bound to increase pressure on her and her team. Anyway, she instructed me to plan the whole improvement project, which involved hosting an appreciative inquiry type meeting.

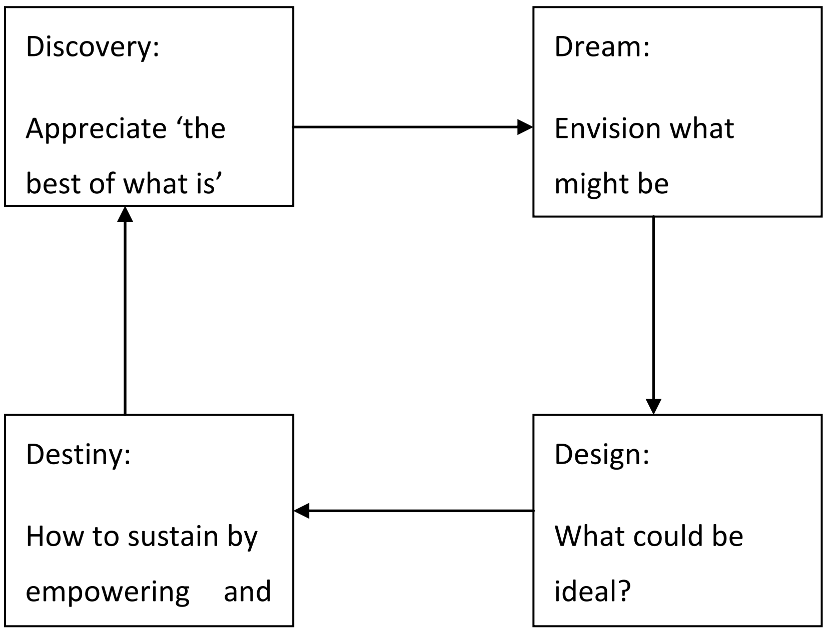

Diagram 7.2: Appreciative Inquiry Cycle

Source: Revised from (Cooperrider and Whitney, 2005, P.16)

I suggested a sharing AI type meeting one month hence, and several voices among Ms X's team members, among them, two managers pointed out to me that it would be very hard to find people who had left the institute to join industry or a university, who would be enthusiastic to participate in this sharing type meeting, because they would be too busy. However, they did help me identify a list of high quality patents as well as the contact details of the inventors and I called at least 10 of them that same evening. Most of the responses were positive and one of them even said that he had taught people how to patent on many occasions. When I hosted a preparation meeting and asked what progress had been made, I was surprised to find that of the two managers, one had not called anybody on their contact list allocation and the other said no one he spoke to was willing to come. I shared my experience of staying late at the office to call people and explained that there was a lot of good feedback and even those who could not attend the proposed meeting expressed the wish be invited again at a later date. One of the managers said, “You have better communication skills and that is why you got a positive response”, which made me get the sense that they wanted me to do all the contacting. Moreover, even though the task had been assigned to their team, their leader appeared reluctant to ensure that it was carried out, as it involved more work and although she did not express this explicitly, her subordinates could sense it, so they did not feel under any pressure to deliver. In my opinion, in order to do this or any other job well, enthusiastic internal commitment and good collaboration is an essential element and I felt at the time that in my organization this was hardly encouraged in performance reviews, which meant that employees participated with minimal compliance on such matters.

I found the inventors by using the top 5% most frequently cited US patents in a particular field in the same granted year. Three inventors were selected, according to their availability, from different disciplines, one from chemical engineering, another from mechanics and the third from the information technology sector (text to voice). Two of the three inventors were still working at the ITRI, however, one of them was a part-time consultant, with his main responsibility being as a professor in a private university in Tao-yuan. I interviewed them individually beforehand in order to appraise myself of their process of creation that led to their inventions being patented. To facilitate this process, I used a model developed by Kao (1991), which involves: probing the contexts lying behind an invention, identifying the person who has conceived it, eliciting the tasks undertaken and establishing the nature of the organization to which the inventor belongs. Subsequently, I wrote three small case reports and sent them to each inventor to get feedback. It emerged that the contexts and rationales behind each invention were very different, one was to do with designing around an existing patent, one about applying expertise to help the inventor's child, and one involved applying a metaphor to construct a new nanometre polymer.

Next, I called a pilot sharing meeting with all three inventors along with the director of the Patents Management Division, Ms X. I invited the director so that she could learn about the learning processes involved and thus, would be able to assess what would be the most appropriate agenda for the formal meeting. The pilot sharing meeting, based on AI, went very well, with each inventor being happy to explain their history of inventing in a relaxed and cheerful manner. They were proud of their inventions that had been cited by other inventors and they did all concur that their inventions were discovered by accident. Moreover, they all expressed the view that they strongly valued the support they had received from middle-level managers, mainly at the director level. The workings of the ITRI are slightly different from most universities in Taiwan, where the major task is to seek funding and to write research reports, whereas the former gets guaranteed grants from the Department of Industrial Technology (DoIT) under the Ministry of Economic Affairs. Consequently, the DoIT does not want innovative research in interesting topics, requiring its money to be invested in discoveries that will have a significant economic impact and this is the key driver for the leaders of projects. That is, because the ITRI is dependant on this funding source economic considerations when carrying out innovations are paramount.

I submitted a conference paper based on the pilot workshop data, entitled “Learning to Patent” to the Annual Conference of the Chinese Society for the Management of Technology (CSMOT), in 2006, which was accepted. When I presented it the conference room was full of people who listened attentively and wanted to know more about the topic. One of my friends came along and wondered if I could provide more detail on each case, regarding how the inventors discovered and created these inventions. The schedule was tight, however, the professor who hosted the session, Dr Chang, expressed the view that is was very interesting topic and he was impressed with the research design. He urged me to expand the sharing meeting to more people at the institute, which I had already decided would be the case.

The responsibility for moving things forward now rested with Ms X, but she was not very positive about the sharing meeting as she was busy with routine jobs, so she tried to delegate all things relating to it to me. I felt very upset, because I had just been granted a scholarship to stay in Bath to conduct my research one month later. I urged her to speed up the process, and when she asked me why, I explained. She suggested that when I came back we could do it together. However, I tried to persuade her to hold the meeting in spite of my not being able to be there, by pointing out that she had participated in a successful pilot, so she would know how to conduct it and I had provided her team with a list of names of the inventors who wished to attend. She proposed that it could be held in June when I came back for the semester break, but I was dissatisfied and continued arguing. Then she became furious and shouted at me, telling me to stop bothering her and walked away. Later, she sent me an email informing me that her boss, the general director, Dr Wang, had decided to postpone the institute-wide sharing meeting. I went to see him and he told me of this decision in person, which I unwillingly accepted.

In contrast with traditional research which is started by identifying problems, AI focuses on things that have already been done well. Moreover, it engenders the implicit assumption that unconditional positive thinking can best deliver the potential of human beings. This approach proved very useful when I engaged with people who created the inventions (facts), for they appreciated the praise they received for the successful aspects of their lives. However, if the environment is more confrontational and less cooperative, AI can be hard to sustain. Moreover, on occasion, in the real world it is necessary address negative problems, particularly when there is a crisis and AI under these circumstances can be difficult to follow, but that does not mean that its sentiments should be completely ignored at these times. There is a tendency in most work settings, including the ITRI, for people to invest much more energy (including emotional energy) in the bad things than in the good, because our biological make up, based on evolution, has required us to pay most attention to danger in order to survive. Therefore, to counter this tendency and live a better balance life, we need to be proactive in bringing positive energy into the work context. This is best achieved through accepting the reality of any situation and dealing with it, rather than ignoring obvious difficult to accept facts. As a consequence, it is proposed that managers, no matter whether in higher education or industry, should take heed of Drucker’s (1967) advice, that an effective manager knows how to develop the strength in people, including himself, instead of just minimizing their weaknesses.

The second reflection is on the unsuccessful attempt to work with the Technology Transfer Centre to host an expanded sharing meeting or affirming workshop. I initiated the proposal, and subsequently receive a phone call from Ms X, but I failed to interpret her view on the matter accurately, thus not initiating sufficient interaction at the outset. When she did ask my advice, I tried to empathize with her, but I violated a key principle of AI, that of unconditional positive inquiry, by mentioning that I did not wish to overburden her. This stimulated her negative thought processes, which resulted in her trying to devolve the responsibility onto my shoulders. Moreover, at first I did not tell my colleagues or Ms X that I was being sent abroad to conduct research for two years, preferring to keep a low profile to avoid envy regarding my good fortune, which led to Ms X and other colleagues still hoping they could delegate most of the work to me. I was angry with Ms X for delegating the responsibility for setting up the meeting, but in my culture the impulse of saving face is so strong that I did not explicitly express my concern that no one was helping me. From an action science perspective, Ms X had acted unilaterally when she asked her supervisor to postpone the meeting to an undetermined date.

I would do it differently next time in several ways. Firstly, I would ask whether she would like me to help in the coordination for the meeting through a discussion aimed at clarifying its purpose. However, if she asked me to take on full responsibility I would refuse her politely, saying something like “I shall be very happy to contribute ideas, but I am afraid it is not my job to implement it”. In terms of the AI perspective, I advocated the idea and I was supposed to deliver the whole message, including both the pros and cons, before opening it up for other people to challenge. On reflection, instead of making a direct proposal I should have inquired about my colleagues' training needs. Moreover, I could have held a pilot workshop as an illustration of what was on offer so as to address any negativity. Further, if Ms X had still tried to transfer the responsibility for setting up the main meeting, I would have framed my response in terms of dividing the labour according to our areas of expertise, mine being training or tutoring. The most important thing is accepting that I could not do everything myself and explaining this clearly to Ms X, rather than worrying about saving face.

7.1.3 Learning from assignment 3

In March 2007, I received a grant from my institute which was sponsored by the Elite Programme of the Taiwanese government. When I wrote the research proposal, I focused on the aim of combining best practice and benchmarking with my understanding of innovation, by considering the practice of the most innovative companies. In terms of content, having browsed a report released by Business Week, entitled "The World's 50 Most Innovative Companies", which listed these companies based on a questionnaire sent to managers around the world by the Boston Consulting Group, I identified Toyota, Canon in Japan, Boeing and IDEO in the US as my benchmarking targets to learn best practice. This proposal was approved and supported by my supervisors.

I chose benchmarking as my third assignment for two reasons. First, because this was consistent with my research proposal, as explained above, which was to consider the best practices of the most innovative companies in the world. Second, I was astonished to find out that although it was claimed that HEIs had adopted the practice for at least ten years, in contrast to their counterparts in industry, no case studies had been carried out on it. Not specifically referring to benchmarking relating to innovations, Camp (1989a), in his book "The Search for Industry Best Practices that Lead to Superior Performance", identified several different categories of benchmarking, including: internal, direct product competitors', industry leaders' and generic. The last two types are both in accord with the concept of innovative ideas, but I decided to concentrate on the generic form for the assignment as this can be associated with a new paradigm in business innovation termed "open innovation". Open innovation captures new practices of innovation in an industry, whereby organizations either take brilliant ideas from outside and commercialize them or allow the dissemination of ideas across their own border so that they can be commercialized by other suitable companies (Chessbourgh, 2003). That is, the main focus is not only on how the innovative ideas or inventions are generated, but also how they can be commercialized, i.e. it covers the whole innovation process. This assignment took me a long time, for although it was first handed in in 2009, it was not until 2011 that I had feedback that required me to revise it. The main criticism of the examiner was my emphasis being placed on the need for open innovation to be applied in the HE setting, because HEIs had failed to take up generic benchmarking. He pointed out that ESMU benchmarking was already working in this way and after I reviewed the established procedure on their website I realized he was right. However, the reason I had missed this was because it was not until 2009 that ESMU held a few workshops on benchmarking, coordinated by pilot institutions, of which Bath was one. Having to revise my work actually became a blessing in disguise, because whilst looking for new literature to strengthen my arguments I came across a DVD, entitled "Re-imagination" containing a speech by Tom Peters (Atterberry, 2004), the management guru. In the video, he argued that any innovative company cannot rely on benchmarking in the new century as it needs to engage with re-imagination rather than imitation to enter new potential markets, which was a major insight for my overall research goal. In general, successfully completing this assignment was quite a long drawn out challenge, but subsequently, I submitted a conference paper on open innovation which contained two case studies.

Be focused, be persistent and keep up to date with current developments, are the main learning outcomes from this assignment. As pointed out above, it was a difficult assignment and a number of drafts were been sent back and forth between me and the examiners. One of them, Dr Dale, received my assignment and offered some very helpful suggestions, such as producing more comparisons on benchmarking between HE and industry. Unfortunately, when he retired there was the aforementioned long delay, probably caused by this and I should have been more persistent regarding the marking of the assignment. Subsequent to Dr Dale's departure, two directors of study provided me with useful suggestions on my revised draft. On the one hand, Dr Rajani Naidoo advised me to draw more upon the higher education literature and suggested a few sources for me to consult, whilst on the other hand, Dr Jeroen Huisman, advised me to look into the new development of benchmarking by the European Centre for Strategic Management of Universities (ESMU), and the Centre for Higher Education Development (CHE). From this input I was able to identify a wider spectrum of benchmarking that was happening in the HE field. Moreover, it was at this stage that I became convinced that generic benchmarking in this sector has received little attention from researchers, compared with industry.

For the fourth assignment, relating to the research methods used in the thesis, aresearch question was identified, and the choices of a case study and action research were explained and justified. More details on the writing of this assignment are provided in the next section on writing the thesis as it was germane to this.

7.2 Thesis

7.2.1 The journey of searching for a research topic

As explained above, whilst making the research proposal back in Taiwan I came across the “Most Innovative Companies” list on the internet (Businessweek, 2007) and selected several companies to approach, with the idea of seeing what could be learnt by HEIs from industry. One company that had advanced most in the ranking, (from 70th in 2006 to 21st in 2007) was Boeing, because they had launched a very innovative jet programme, the Dreamliner or Boeing 787. So I made contact with people on the Empower programme at Boeing through an acquaintance at the University of Washington, who put me in touch with a senior engineer. I also, unsuccessfully, approached affiliated companies of my institute (ITRI) in California and Japan, to see if they could get access to Google and Toyota, respectively. However, none of them had any insider contacts in these organizations. Regarding the Toyota attempts to make contact, cold calling is not acceptable in relationship oriented countries, such as Japan, but eventually, my friend in the China Productivity Centre (CPC) informed me that they had arranged a business visit to Toyota and invited me to join them. However, when we got there I was only able to meet with people in the public relations department and not with the research department that had launched the hybrid. During the same visit, the CPC also arranged for us to see the executives at Kyocera and Rohm, with the former providing personnel from the PR department and the latter introducing us to the head of research, who was very helpful and agreed to see me again.

The following year I flew to Boeing in the US and Rohm in Japan to interview the appropriate managers so as to gain understanding of the creation process for their two products of interest and the results of this enquiry were published in a conference paper. The intention was to build on this for my thesis, but Rajani Naidoo, our director of studies, after reviewing my paper, pointed out that it would be a very good topic for a conventional doctorate in business administration, but did not encompass higher education, which was my remit and therefore, I had to reconsider my research topic.

Meanwhile, my provisional supervisor, Judi Marshall, who had been very supportive, with many helpful suggestions, left the university. When I arrived in Bath, I identified two professors who were deeply involved in the action research field, Dr Peter Reason and Dr Jack Whitehead and I approached both of them at this time to ask them to take on the supervisory role. However, Dr Reason told me he had his own PhD and master programme and so it would not be possible, but Dr Whitehead was very enthusiastic about my intention to probe into the innovation process in Taiwan and thus, expressed his willingness to be my supervisor.

After the aforementioned conference paper on the two case studies, entitled "Towards Open Innovation: Reaching out for Innovation - the Case Study of Boeing and Rohm", was accepted, in 2008 Dr Whitehead asked me what my thesis was to going to cover. I proposed that I research the most innovative companies to see what could be learnt for innovation policy in Taiwan. He agreed that this would be useful, but being aware of the fact that I had already investigated a number of innovations in that country, he suggested I extend this to considering reconfiguration of the national innovation system in its entirety. He reinforced this by pointing out that context is an extremely significant aspect of innovatory activity. In a further conversion with Dr Naidoo she expressed similar sentiments to her concerns regarding the first proposed topic: it would be hard to use industrial innovations to provide new insights into the HE sector. Therefore, I had to search for another suitable topic.

I stayed in Bath full- time during 2007 to 2008 and so was able to attend lectures and participate in other activities on campus. Dr Whitehead hosted a Monday conversation group in the Claverton Rooms, where different perspectives on research covering different fields, including: education, mathematics, management, and biology, were discussed. At one of these, Dr Rayner, a microbiology professor in the department of biology, introduced those present to the concept of natural inclusionality that he had arrived at after conducting various experiments on the development of mycelia, or fungus, as explained in chapters 2 and 3. Subsequently, I elicited that natural inclusionality has been applied to different disciplines since it was espoused, including: biology, mathematics, education, and psychology (creativity study). Moreover, I became cognisant of the fact that an evolutionary perspective, under Darwinian rules, has been central to the development of economic theory and thus, could be a potential way in to extending this perspective to that of inclusionality. I also decided that the triple helix model could form a good starting point for building the subsequent AFM, using these theoretical concepts. Consequently, I now had a sense of what my research would entail, but I still had to find a way of integrating this with the HE context.

I left Bath when my sponsorship finished at the end of 2008, being keen to apply my new learning to the real world setting. Back at work, my supervisor suggested that we should propose something useful for our institute. Regarding this, when I had been undertaking the benchmarking assignment, I became aware that the ITRI had done little work on internal benchmarking in relation to the process of innovating. Therefore, I proposed to conduct a benchmarking exercise on recent high profile inventions created by researchers at the ITRI that had been successfully commercialized in terms of licensing or spin offs. Three cases were identified from the press and internal reports, including cartilage reparation, on chip AC LEDs and flex up displays. I was particularly interested in the first two cases, because the patterns of the collaborations between the research institute and university-industry-government varied so much. Moreover, I realized that these innovations could not have been successful without the participation of a university(ies).

7.2.2. The validation process

Conventional case studies have validation criteria, including both internal and external validity. When I read the personal account of the creator of action science, (Argyris 2003), I was strongly impressed by his argument for a third form of validity, implementability validity. With management being an applied science it is an ideal subject for this treatment, especially because there have been large numbers of theoretical articles in the discipline that have no real world applicability. Moreover, proponents of action research purport that research should be shared and co-created by the stakeholders (even outsiders), rather than just rest with the researcher and so to comply with this view I held the validation meetings as an integral part of the study.

As noted in the chapter 3, the validity of these two cases in terms of their justifying the AFM, resides in the different person inquiries. Regarding this, the first two sections of chapter 5 offered the first person inquiry, which involved comparative analysis to elicit the explanatory power of the THM and AFM. This section is devoted to the audit trial that took place during the validation meetings, which included the main inventors of each innovation and the managers and staff in the planning office at the ITRI, who were able to forward policy recommendations to top managers and even to the government.

Regarding the first case of cartilage reparation, I reported my findings at the meeting and subsequently Dr L gave a more detailed presentation on his innovation. After the meeting, I was heartened by the fact that one colleague pointed out to those present the importance of the university hospital as a driver for the cartilage innovation and other ideas during the process. Another colleague, Mr Wang, said that when he had been working for A*STAR, a research institute in Singapore in 2007, they were engaged in collaborative biomedical projects in hospitals. Dr L put forward the metaphor of an aeroplane and its pilot for his invention, whereby a medical doctor is the pilot who flies the new plane, which has been designed and prototyped by the research institute and subsequently is mass produced by medical firms. Extending this, he explained that the designers and manufacturers have to listen to the needs of the pilot before building the plane. I found this metaphor from this inventor very valuable, because it provided strong support for my perspective on innovation put forward in this thesis. After the successful cartilage case, Dr L and his team kept working with doctors at the NTUH on new projects related to orthopedics. With regards to how the meeting was accepted, the facial gestures of the attendees showed that they were enjoying it and at the end they were very appreciative, which helped improve my confidence that what I doing was a valuable addition to the work of the ITRI. Subsequent to the validation meeting, Dr Sung, who was responsible for the biomedical field in the planning office of the ITRI, but who had been unable to attend, prompted by my findings, was asked by the president proactively to identify other collaborative projects in this area of work, with industry and universities. To this end, he held a meeting with doctors and medical researchers later to flesh out any good potential future projects.

During the discussion part of the meeting more than half the time was spent on dialogue between the inventor and the other attendees. I knew that Dr Chen had wanted the outcome to represent some type of silver bullet for mapping the ITRI's future collaborative activity, but neither he nor I tried to steer the meeting towards this goal, in my case so as to avoid an uncomfortable situation. With hindsight I realize I should have taken control and insisted that we evaluate the validity of my case findings and the use of the AFM, rather than continuing to talk simply about the innovation itself.

The case of AC LED was reported in the second validation meeting and this time two more senior managers were in attendance. There was more time for the question and answer session as had I reserved the room for two and half hours. This time we did get round to talking about the different types of energy flow, regarding which I advocated that we should recruit people from industry with ideas that could lead to successful innovations. One colleague, Dr Hu, was not so enthusiastic, because of his concerns about the intellectual property problems that this might entail. Mr Lin supported my position, arguing that if a researcher knows his industry well, he would be cognisant of the unsolved issues in that industry and regarding the property rights issue, he said that provided safeguards were put in place to ensure that what an incomer brought from industry had not previously been worked upon then there should be no problem.

Next, when we considered money flow, I pointed out that I had found that the role of government funding was indispensable in these two cases. However, as Mr Lin pointed out because in the AC LED case applied research was required the government would not provide direct funding and so the inventors had to rely on the ITRI redirecting some of its budgets in the initial stages; so the source was still the government, but indirectly. He attributed this failure to get direct funding to the constitution of the reviewing committee for the ITRI, which had university professors as well as scientists who were loath to allocate money to a project that they saw as being questionable in terms of its novelty. Consequently, when the inventors needed more financial input rather than simply going upstream to find a manufacturer for their invention, they created downstream demand by introducing it to a packaging company, who then decided to establish a new product line that would require mass production of the AC LED. Lastly, I asked the inventor about university involvement in case two, which as explained previously was regarding issues to do with commercialization rather than initial research, and he informed the meeting that they had actually drawn on the services of three of them, rather than just one as I had previously assumed. Consequently, I realized that sometimes there is probably more scope for universities to employ their basic research skills post commercialization rather than during the initial innovation stages. All of this input from colleagues based in the planning office and the inventor provided further information that allowed me to see the bigger picture.

Owing to there being more time and no presentation for the second meeting there was much more time for discussion and in particular, there was considerable focus on the validation issues to do with my research. For example in this respect, it was one of the directors from planning office, Dr Chen, who suggested that if I wanted to show the superiority of AFM, I should undertake a comparative analysis of it with the THM for both the two focal cases, which I subsequently did, as presented in chapter 5. Other participants said it would have been more helpful, if I had explained the differences and similarities between the two cases, rather than considering them separately, which again I took note of and incorporated this aspect into chapter 5 of this thesis as well.

7.3 Learning from the thesis as whole

In this subsection, disclosure of the learning process whilst working on the thesis is presented according to the three of different reflection questions in the following three sections originating from Gibbs (1988).

7.3.1 What has been done well in the process?

No sooner than I had submitted the second assignment, I started the process of looking for an appropriate topic for my thesis. In relation to this, when I started my DBA programme I had strong intentions to focus on innovation management at different levels, including the personal and team based levels as well as the organizational, regional and national ones. Consequently, probing the relevant literature on product innovation, large systems innovation, open innovation, national innovation systems and regional innovation allowed for identification of the research gaps that I could address later in my thesis. Regarding these, I considered covering issues such as: research management, open innovation, generic benchmarking and evolution economics in HE settings. However, in spite of my seeking a subject early on it took a while to identify an appropriate form of innovation that related to the higher education field.

A doctoral thesis requires the writer to provide new contributions to knowledge and inter-disciplinary study has proved to be an important source in prior research. In particular, because innovation is a topic widely studied by different disciplines, e.g. economics, sociology, management, and higher education studies, I saw it as potentially fruitful to review the literature on these. Moreover, some pioneers have already successfully conducted innovation studies in this way, with one notable example being that of Nelson and Winter (1982), who developed evolutionary economics by combining standard economics and Darwin's theories from biology, thus breaking new ground.

Thanks to help from the deliverers of the DBA (HEM) programme, during my stay in Bath I was able to consult several different experts in various academic subject areas, to name a few there was: Professor Mike Hobday in innovation management, Dr Alice Lam in human resources, Dr Roger Dale in sociology, Dr John Morecroft in system dynamics and Dr Alan Rayner in biology. They and others provided me with insightful guidance that helped in the identification of the right process for integrating the different disciplines. Eventually, having recognized that the existing co-evolutionary theory of the THM could not explain the innovation institutional reality in Taiwan, in which research institutes (RI) also play a crucial role, I came to the conclusion that this would be an ideal lacuna to address. In addition, I realized

that the THM proponents' accounts of flows of resources between actors during the innovation process was rather vague and provided limited understanding, so I decided enlist the concept of natural inclusionality to shed stronger light on these.
If I had not attended the Monday Senior Common Room Group hosted by Dr Jack Whitehead at Claverton Rooms at our university, I would probably not have met Dr Alan Rayner and learned about his inclusionality perspective. In fact, during these meetings I listened to many different perspectives, from both within and without the university, for Dr Whitehead invited many academics and practitioners from around the world, which enriched the depth and breadth of my knowledge. These get togethers made me cognisant of the way that Dr Whitehead was creating space for knowledge flow exchange and this helped me to zoom in on the different types of energy flow for the written thesis.

As explained in chapters 4, I hosted two validation meetings to share my findings with the inventors and colleagues so as to get feedback, which would take understanding of the innovative processes forward. In fact, these meetings became a catalyst for collaboration policy change at the ITRI, because now it has adopted a strategy of systematically co-working with medical doctors to address their clinical needs at more (university) hospitals in Taiwan. Moreover, since the research was carried out the AC LED has successfully been transferred to the largest LED wafer provider, Epistar. In fact, after the writing up of this case this action also became one of the drivers for enabling that company to cross license with one of the largest Japanese LED producers, Toyoda Gosei. Finally, the intellectual strategies revealed in the second meeting, as adopted by the AC LED team, were highly praised by the government.

7.3.2 What has not gone so well?

At the beginning, I wanted to establish a novel theory and carry out: case studies, citation analysis and action research. However, Dr Alan Reid reminded me during a lecture that for a doctorate one has to make an original contribution to knowledge, but not develop completely new theory and so I realized that this initial goal was overambitious. In particular, I became appraised of the fact that doctoral study is like a project with strict limitations on time and resources. Moreover, as my degree study was for a DBA in higher education management, I had to be reminded by our former director of study, Dr Naidoo, when I handed in my third assignment about bearing in mind the boundaries, because I was in danger of straying from them in terms of my subject choice. Regarding this, on reflection, I would have saved time if I had discussed with her earlier when I was considering the possible thesis topic.

I invited Judi Marshall to be my supervisor when I had finished my first assignment, which she agreed to and I found her feedback very useful. However, she left the University of Bath in late 2007 and the difficulties of finding a new supervisor and my aforementioned over ambition meant my next two assignments were heavily delayed I tried to knock on doors of professors, and I found only two candidates in my radar, Dr Jack Whitehead and Dr Peter Reason. I knew the former from just shortly after 2006 so it was easy to ask for his support. However, in 2009 he retired from the university and even though he was given a two year term time only contract, when I went back to Bath in 2011 I found that he was spending most of his time at Hope University in Liverpool and so I would need to find someone else for supervision. On reflection, these breaks in having a supervisor could have been avoided if I had always ensured that I had a Plan B.

7.3.3 What could I have done differently?

Because I was a part-time student, I spent almost seven years completing the DBA, which is acceptable. However, I believe that if I had started writing assignments earlier, I would have been quicker deciding on my thesis content and hence, graduated before now. In fact, when I realized I was not making sufficient headway, in about 2008, I committed myself to spending 30 minutes to one hour a day and have kept to this, even with work responsibilities, which has led to my completing the thesis successfully. Moreover, fortunately one of my new supervisors, Dr Roger King, made a rapid turnaround with any work I sent, providing very useful constructive criticism that I could then respond to in a timely fashion. In particular he advised me to avoiding writing long and complex sentences as well as pointing out that there was lack of transition in my academic writing, which I believe I have since addressed. In addition, he also provided some useful suggestions on the relevant literature and writing during the supervision process. For instance, it was he who he introduced me to Florida's book, The Rise of the Creative Class, which provided me a social class perspective in understanding the possible reasons talented people gather together. My second supervisor after my return, Dr Edward Kasabov, also provided helpful criticism, especially on the literature review and research methods. In particular, he gave important input on how I should streamline the literature so as to not leave myself open to the accusation by the examiners that it was too broad in its coverage.

Our former director of study, Dr Naidoo, was kind to me and provided many valuable suggestions. I consulted with her when my former provisional supervisor, Dr Whitehead, was about to retire from the university. He had inspired me to go beyond existing mainstream innovation approaches to create my own theoretical perspective, in terms of sense making. Dr Naidoo steered me towards Dr Roger King, given his expertise is in innovation policy in higher education and we met in June 2011 at the University of Bath, with him later agreeing to become my supervisor. I sent him my work chapter by chapter and his aforementioned quick responses helped to give me the confidence to continue so as to complete the qualification.

As an English as a second language student, I was struggling to express myself in academic English. When I was staying in Bath in 2007, I attended the academic writing course through the information provided by Angel, a PhD student in education, which helped me improve my writing standard. However, as I was finishing my assignments and started my writing my thesis in 2008, I found that academic writing at this level was not easy even for a native speaker. I tried two lecturers in ESL at the university to provide me with tutorials, but they were not of much help. Subsequently I met Junko, a PhD student in the Department of Education, who had recently graduated. She recommended me to send a piece of my writing to her friend, a native English speaking teacher, M. He was amazing, for he quickly identified where my English writing was not clearly structured and explained how some passages were repetitive and unnecessary. His critical opinions allowed me to find weak connections in my writing, rework the unclear parts, and to report my writing in a more logical manner to readers. I really learnt a lot from this interaction, for it helped me develop my reasoning in an effective manner as well as stimulating and improving my self-reflective practice. Finally, I especially want to express my gratitude to another supervisor of mine, Jeroen Huisman. His kind assistance, guidance and encouragement accompanied me to walk through a crucial last mile of my journey, including Viva Voce.

7.4 Last few words

The learning journey of the DBA (HEM) began in 2005 and although even years have passed since I applied for the programme, it seems just like yesterday. I think it has been a very worthwhile time of my life as I have been able to learn from different professors and practitioners with an extensive range of knowledge. From the four assignments for the first stage of my programme, I learned about action research and benchmarking. More specifically, I encountered three different branches of action research: action inquiry, action science and appreciative inquiry. Writing the thesis proved more of a challenge, for the reasons explained above and took a total of four years to complete. Nevertheless, in spite of all of the ups and downs in completing the DBA programme, I have found it an immensely rewarding experience that I can now take forward to enrich the remainder of my career.

References

Adams, R., Bessant, J. and Phelps, R., 2006. Innovation Management Measurement: A Review. *International Journal of Management Reviews,* 8(1), pp.21-47.

Adelman, C., 1993. Kurt Lewin and the Origins of Action Research. *Educational Action Research,* 1(1), pp.7-24.

Adeoti, J. O., 2002. Building Technological Capability in the Less Developed Countries: The Role of a National System of Innovation. *Science and public Policy,* 29(2), pp.95-104.

Amabile, T. M., Conti, R., Coon, H., Lazenby, J. and Herron, M., 1996. Assessing the Work Environment for Creativity. *Academy of Management Journal,* 39(5), pp.1154-1184.

Amabile, T. M., 1998. How to Kill Creativity. *Harvard Business Review,* 76(5), pp.76-87.

Argyris, C. and Schön, D. A., 1974. *Theory in Practice: Increasing Professional Effectivness.* San Francisco: Joseer-Bass.

Argyris, C., Putnam, R. and Smith, D. M. L., 1985. *Action Science:Concepts, Methods, and Skills for Research and Intervention.* San Francisco: Jossey-Bass.

Audretsch, D. B. and Stephan, P. E., 1999. Knowledge Spillovers in Biotechnology: Sources and Incentives. *Journal of Evolutionary Economics,* 9(1), pp.97-107.

Barbro, B., Bertil, . S. and Shattock, M. L., 1979. Innovations and Innovation Processes in Higher Education. *Higher Education,* 8(2), pp.221-223.

Baregheh, A., Rowley, J. and Sambrook, S., 2009. Towards a Multidisciplinary Definition of Innovation. *Management decision,* 47(8), pp.1323-1339.

Birkinshaw, J., Bessant, J. and Delbridge, R., 2007.. Finding, Forming, and Performing: Creating Networks for Discontinous Innovation. *California Management Review,* 49(3), pp.67-84.

Braczyk, H. J., Cooke, P. N. and Heidenreich, M., 1998. *Regional Innovation Systems: The Role of Governances in a Globalized World.* London: Routledge.

Brandenburger, A. M., 1997. *Co-Opetition : A Revolution Mindset That Combines Competition and Cooperation.* New York: Broadway Business.

Brown, J. R., Fazzari, S. M. and Petersen, B. C., 2009. Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom. *The Journal of Finance,* 64(1), pp.151-185.

Brown, J. S. and Duguid, P., 2001. Knowledge and Organization: A Social-Practice Perspective. *Organization Science*, pp.198-213.

Camp, R. C., 1989. *Benchmarking: The Search for Industry Best Practices That Lead to Superior Performance.* New York: Quality Resources.

Carayannis, E. G. and Campbell, D. F. J., 2006. *Knowledge Creation, Diffusion, and Use in Innovation Networks and Knowledge Clusters: A Comparative Systems Approach across the United States, Europe, and Asia.* Westpoint: Praeger.

Carayannis, E. G. and Campbell, D. F. J., 2009. 'Mode 3'and'quadruple Helix': Toward a 21st Century Fractal Innovation Ecosystem. *International Journal of Technology Management*, 46(3), pp.201-234.

Carayannis, E. G. and Campbell, D. F. J., 2010. Triple Helix, Quadruple Helix and Quintuple Helix and How Do Knowledge, Innovation, and Environment Relate to Each Other? *International Journal of Social Ecology and Sustainable Development*, 1(1), pp.41-69.

Carayannis, E. G. and Campbell, D. F. J., 2012. Mode 3 Knowledge Production in Quadruple Helix Innovation Systems. *SpringerBriefs in Business,* 7, pp.1-63.

Carlson, C. R. and Wilmot, W. W., 2006. *Innovation-the Five Disciplines for Creating What Customers Want.* New York: Crown Business

Chang, P.-L. and Shih, H.-Y., 2004. The Innovation Systems of Taiwan and China: A Comparative Analysis. *Technovation*, 24(7), pp.529-539.

Chang, P. L. and Hsu, C. W., 1998. The Development Strategies for Taiwan's Semiconductor Industry. *Engineering Management, IEEE Transactions on*, 45(4), pp.349-356.

Chen, K. and Kenney, M., 2007. Universities/Research Institutes and Regional Innovation Systems: The Cases of Beijing and Shenzhen. *World development,* 35(6), pp.1056-1074.

Chen, S. H., 2002. Global Production Networks and Information Technology: The Case of Taiwan*. Industry and Innovation*, 9(3), pp.249-265.

Chesbrough, H., 2003a. The Governance and Performance of Xerox’s Technology Spin-Off Companies. *Research Policy*, 32(3), pp.403-421.

Chesbrough, H. 2003b. The Era of Open Innovation. *MIT Sloan Management Review,* 44(3), pp.35-41.

Chesbrough, H. W., 2003c. *Open Innovation: The New Imperative for Creating and Profiting from Technology.* Boston: Harvard Business School Press.

Chesbrough, H., 2006. The Era of Open Innovation. *Managing innovation and change*, p.127.

Christensen, J. F., Olesen, M. H. and Kjaer, J. S., 2005. The Industrial Dynamics of Open Innovation--Evidence from the Transformation of Consumer Electronics. *Research Policy,* 34(10), pp.1533-1549.

Christensen, L. B., Johnson, R. B. and Turner, L. A., 2010 *Research Methods, Design, and Analysis.* 11th ed. Boston: Pearson.

Clark, B., 1998a. The Entrepreneurial University: Demand and Response. *Tertiary Education and Management,* 4(1), pp.5-16.
Clark, B., 1998b. *Creating Entrepreneurial Universities: Organizational Pathways of Transformation. Issues in Higher Education.* New York: Elsevier Science Regional Sales.
Clark, B., 2001. The Entrepreneurial University: New Foundations for Collegiality, Autonomy, and Achievement. *Journal of the Programme on Institutional Management in Higher Education,* 13(2), pp.9-24.
Coghlan, D. and Casey, M., 2001. Action Research from the Inside: Issues and Challenges in Doing Action Research in Your Own Hospital. *Journal of Advanced Nursing,* 35(5).674-682.
Cohen, S. S. and Fields, G., 1999. Social Capital and Capital Gains in Silicon Valley. *California Management Review,* 41(2), pp.108-130.
Cohen, W. and Levinthal, D., 1990. Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly,* 35(1), pp.128-152.
Cohen, W. M. and Levinthal, D. A., 1989. Innovation and Learning: The Two Faces of R & D. *Economic Journal,* 99(397), pp.569-596.
Collins, L., 2006. Opening up the Innovation Process. *Engineering Management Journal,* 16(1), pp.14-17.
Cooke, P., Gomez Uranga, M. and Etxebarria, G., 1997. Regional Innovation Systems: Institutional and Organisational Dimensions. *Research Policy,* 26(4-5), pp.475-491.
Cooke, P., 2001. Regional Innovation Systems, Clusters, and the Knowledge Economy. *Industrial and Corporate Change,* 10(4), pp.945.
Cooper, J. R., 1998. A Multidimensional Approach to the Adoption of Innovation. *Management decision,* 36(8), pp.493-502.
Cooper, R. G., 1994. Third-Generation New Product Processes. *Journal of Product Innovation Management,* 11(1), pp.3-14.
Cowan, R., David, P. A. and Foray, D., 2000. , 2000. The Explicit Economics of Knowledge Codification and Tacitness. *Industrial and Corporate Change,* 9(2), pp.211-253.
Creswell, J. W. and Miller, D. L., 2000. Determining Validity in Qualitative Inquiry. *Theory into practice,* 39(3), pp.124-130.
Creswell, J. W., 2007. *Qualitative Inquiry and Research Design: Choosing among Five Approaches.* London: Sage.
Csikszentmihalyi, M., 1997. *Flow and the Psychology of Discovery and Invention.* New York: Harper Perennial.

Dahlman, C. J. and Nelson, R., 1995. *Social Absorption Capacity, National Innovation Systems and Economic Development. In:* B. H. Koo and D. H. Perkins, ed. *Social Capability and Long-Term Economic Growth*. London: McMillan Press Ltd. pp.82-122.
Damanpour, F., 1996. Organizational Complexity and Innovation: Developing and Testing Multiple Contingency Models. *Management Science,* 42(5), pp.693-716.
Deiglmeier, K. and Miller, D. T., 2008. Rediscovering Social Innovation. *Stanford Social Innovation Review,* 6(4), pp.34-43.
Denzin, N. K. and Lincoln, Y. S., 1994. *Enter the Field of Qualitative Research. In*. N. K. Denzin and Y. S. Lincoln, ed. *Handbook of Qualitative Research*. 1st ed. London: Sage. pp.1-17.
Dodgson, M., 2000. *Policies for Science, Technology and Innovation in Asian Newly Industrializing Economies. In:* L. Kim and R. Nelson, ed. *Technology, Learning, and Innovation: Experiences of Newly Industrializing Economies*. Cambridge: Cambridge University Press. pp.229-268.
Dodgson, M., 2009. Asia's National Innovation Systems: Institutional Adaptability and Rigidity in the Face of Global Innovation Challenges. Asia Pacific Journal of Management, 26(3), pp.589-609.
Dorfman, N., 1983. Route 128: The Development of a Regional High Technology Economy* 1. *Research Policy,* 12(6), pp.299-316.
Dosi, G., 1990. Finance, Innovation and Industrial Change. *Journal of Economic Behavior & Organization,* 13(3), pp.299-319.
Driffield, N. and Chiang, P., 2009. The Effects of Offshoring to China: Reallocation, Employment and Productivity in Taiwan. *International Journal of the Economics of Business*, 16(1), pp.19-38.
Drucker, P., 1967. *The Effective Executive.* Oxford: Butterworth-Heineman.
Drucker, P., 1984. *Innovation and Entrepreneurship.* London: Collins.
Drucker, P., 1999. *Management Challenges for the 21st Century.* New York: Harper Business.
Duncan, R. B., 1972. Characteristics of Organizational Environments and Perceived Environmental Uncertainty. *Administrative Science Quarterly*, pp.313-327.
Dyson, J. and Coren, 1998. *Against the Odds: An Autobiography.* London: Orion Business Books.
Dzisah, J. and Etzkowitz, H., 2008. Triple Helix Circulation: The Heart of Innovation and Development. *International Journal of Technology Management and Sustainable Development,* 7(2), pp.101-115.
Easton, G., 2010. Critical Realism in Case Study Research. *Industrial Marketing Management,* 39(1), pp.118-128.

Edquist, C., 1997. *Systems of Innovation: Technologies, Institutions and Organizations.* London: Routledge.
Edquist, C., 2005. *Systems of Innovation. In:* J. Fagerberg D. Mowery, and R. R. Nelson., ed. *The Oxford Handbook of Innovation*. Oxford: Oxford University Press. pp.181–208.
Eisenhardt, K. M., 1989. Building Theories from Case Study Research. *Academy of Management Review,* pp.532-550.
Eisenhardt, K. M. and Galunic, D. C., 2000. Coevolving: At Last, a Way to Make Synergies Work. *Harvard Business Review,* 78(1), pp.91-101.
Eldredge, N. and Gould, S. J., 1972. Punctuated Equilibria: An Alternative to Phyletic Gradualism. *Models in paleobiology,* 82, pp.115.
Etzkowitz, H., 1983. Entrepreneurial Scientists and Entrepreneurial Universities in American Academic Science. *Minerva,* 21(2-3), pp.198-233.
Etzkowitz, H., 1994. *Academic-Industry Relations: A Sociological Paradigm for Economic Development. In:* Leydesdorff and V. D. Besselaar, ed. *Evolutionary Economics and Chaos Theory*. pp.139-51.
Etzkowitz, H. and Leydesdorff, L., 1995. The Triple Helix---University-Industry-Government Relations: A Laboratory for Knowledge Based Economic Development. *East Review,* 14(1), pp.14-19.
Etzkowitz, H. and Leydesdorff, L., 2000. The Dynamics of Innovation: From National Systems and “Mode 2” to a Triple Helix of University–Industry–Government Relations. *Research Policy,* 29(2), pp.109-123.
Etzkowitz, H., Webster, A., Gebhardt, C. and Terra, B. R. C. (2000) The Future of the University and the University of the Future: Evolution of Ivory Tower to Entrepreneurial Paradigm. *Research Policy,* 29(2), pp.313-330.
Etzkowitz, H., 2002. Networks of Innovation: Science, Technology and Development in the Triple Helix Era. *International Journal of Technology Management and Sustainable Development,* 1(1), pp.7-20.
Etzkowitz, H., 2003. Innovation in Innovation: The Triple Helix of University-Industry-Government Relations. *Social Science Information,* 42(3), p.293.
Etzkowitz, H., 2003. Research Groups as ' Quasi-Firms': The Invention of the Entrepreneurial University. *Research Policy,* 32(1), pp.109-121.
Etzkowitz, H. and Zhou, C., 2006. Triple Helix Twins: Innovation and Sustainability. *Science and Public Policy,* 33(1), pp.77-83.
Etzkowitz, H., 2008. *The Triple Helix: University-Industry-Government Innovation in Action*. London: Routledge.
Fagerberg, J. and Srholec, M., 2008. National Innovation Systems, Capabilities and Economic Development. *Research Policy,* 37(9), pp.1417-1435.

Elahi, K. Q. and Rahman, M. L., 2006. Micro-Credit and Micro-Finance: Functional and Conceptual Differences. *Development in Practice,* 16(5). pp.476-483.
Forrester, J. W., 1961. *Industrial Dynamics.* Waltham, MA: Pegasus Communications.
Fontana, A. and Frey, J. H., 2003. *The Interview: From Neutral Stance to Political Involvement. In:* N. K. Denzin and Y. S. Lincoln, ed. *The Sage Handbook of Qualitative Research*. 3rd ed. London: Sage. pp.695-727.
Franzoni, C. and Lissoni, F., 2006. *Academic Entrepreneurship, Patents, and Spin-Offs: Critical Issues and Lessons for Europe*. CESPRI working paper No.180.
Freeman, C., 1987. *Technology Policy and Economic Performance: Lessons from Japan.* London: Pinter.
Freeman, C., 1991. Networks of Innovators: A Synthesis of Research Issues. *Research Policy,* 20(5), pp.499-514.
Freeman, C. and Perez, C., 1988. Structural Crises of Adjustment, Business Cycles and Investment Behaviour. *In*. G. Dosi, C. Freeman, R. Nelson, G. Silverberg, and L. Soete , ed. *Technical Change and Economic Theory.* London: Pinter Publishers. pp.38-66.
Fujimoto, T. and Clark, K., 1995. *Product Development Performance.* Cambridge: Harvard Business School Press.
Celikel-Esser F., Tarantola, S. and Mascherini, M., 2007 *Fourth European Community Innovation Surveys.* Fermi: Institute for the Protection and Security of the Citizen Institute for the Protection and Security of the Citizen.
Galli, R. and Teubal, M., 1997. Paradigmatic Shifts in National Innovation Systems. *Systems of innovation*, pp.342-370.
Genzyme, 2010. *Highlight of Prescribing Information*[online]. Cambridge, MA: Genzyme Biosurgery. Available from: http://www.carticel.com/~/media/Files/Carticel/Carticel-PI.pdf [Accessed 01 March 2011].
Gibbons, M., 1994. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies.* London: Sage.
Granstrand, O., 2000. *Corporate Innovation Systems: A Comparative Study of Multi-Technology Corporations in Japan, Sweden and the USA.* Gothenburg: Chalmers University of Technology.
Gu, S., 1999. *Implications of National Innovation Systems for Developing Countries: Managing Change and Complexity in Economic Development.* Maastricht: The United Nations University, Institute for New Technologies.
Habermas, J., 1984. *The Theory of Communicative Action.* Cambridge: Polity Press.

Habermas, J. and Mccarthy, T., 1987. *The Theory of Communicative Action: Reason and the Rationalization of Society.* Boston: Beacon Press.
Hamel, G., 1999. Bringing Silicon Valley Inside. *Harvard Business Review,* 77(5), pp.70-84.
Hansen, M. T. and Birkinshaw, J., 2007. The Innovation Value Chain. *Harvard Business Review,* 85(6), pp.121.
Hargadon, A. and Douglas, Y., 2001. When Innovations Meet Institutions: Edison and the Design of the Electric Light. *Administrative Science Quarterly,* 46(3), pp.476-501.
Hedlund, G., 1994. A Model of Knowledge Management and the N Form Corporation. *Strategic Management Journal,* 15(S2), pp.73-90.
Hekkert, M. P., Suurs, R. A. A., Negro, S. O., Kuhlmann, S. and Smits, R., 2007.Functions of Innovation Systems: A New Approach for Analysing Technological Change. *Technological Forecasting and Social Change,* 74(4), pp.413-432.
Hobday, M., 1994. The Limits of Silicon Valley: A Critique of Network Theory. *Technology Analysis & Strategic Management,* 6(2), pp.231-245.
Hobday, M., 1998. Product Complexity, Innovation and Industrial Organisation. *Research Policy,* 26(6), pp.689-710.
Hobday, M., Rush, H. and Tidd, J., 2000 .Innovation in Complex Products and System. *Research Policy,* 29(7-8), pp.793-804.
Hobday, M., Rush, H. and Bessant, J., 2004. Approaching the Innovation Frontier in Korea: The Transition Phase to Leadership. *Research Policy,* 33(10), pp.1433-1457.
Hu, M. C. and Mathews, J. A., 2009. Estimating the Innovation Effects of University-Industry-Government Linkages: The Case of Taiwan. *Journal of Management & Organization,* 15(2), pp.138-154.
Huang, C.P., 2010. Beyond the Triple Helix Model; a Case Study on the Making of a New Cartilage Reparation Solution. *International Conference on Asia Pacific Business Innovation and Technology Management,* 23-25 January 2010 Bali, Indonesia.
Ilyenkov, E., 1974. *Dialectical Logic: Essays in Its History and Theory.* English Edition (1977). London: Central Books.
Intarakumnerd, P., Chairatana, P. and Tangchitpiboon, T., 2002. National Innovation System in Less Successful Developing Countries: The Case of Thailand. *Research Policy,* 31(8-9), pp.1445-1457.
Inzelt, A., 2004. The Evolution of University, Industry and Government Relationships During Transition. *Research Policy,* 33(6), pp.975-995.
Isaacson, W., 2011. *Steve Jobs.* New York: Simon & Schuster.

Israel, P., 1998. *Edison: A Life of Invention.* New York: Wiley.
Jansen, J. J. P., Van Den Bosch, F. A. J. and Volberda, H. W., 2005.Managing Potential and Realized Absorptive Capacity: How Do Organizational Antecedents Matter? *The Academy of Management Journal*, pp.999-1015.
ITRI, 2005. *Method and Carrier for Culturing Multi-Layer Tissue in Vitro*. US Patent 6,884,621.
ITRI, 2007. *Ac Light Emitting Assembly and Ac Light Emitting Device*. US patent application 20070131942.
ITRI, 2009a. *Alternating Current Light-Emitting Device*. US patent 7474681.
ITRI, 2009b. *Structures of Ac Light-Emitting Diode Dies*. US patent 7531843.
ITRI, 2012. *ITRI Overview*[online]. Hsin-Chu, Taiwan: Industrial Technology Research Institute. Available from: http://www.itri.org.tw/eng/econtent/about/about01.aspx [Accessed 1 April 2012].
Jang, J. F., 2008. A Breakthrough on Cartilage Reparation at National Taiwan University Hospital. *United Daily News (Chinese Version)*, 19 March, Health and Medicine.
Jencks, C. and Riesman, D., 1968. *The Academic Revolution.* New York: Doubleday.
Jensen, M. B., Johnson, B., Lorenz, E. and Lundvall, B., 2007. Forms of Knowledge and Modes of Innovation. *Research Policy,* 36(5), pp.680-693.
Jiang, C. C., 2011. Bi-Phasal Cartilage Reparation Technology. *NTU Alumi Bimonthly (Chinese Version),* 74, pp.10 - 13.
Jick, T. D., 1979. Mixing Qualitative and Quantitative Methods: Triangulation in Action. *Administrative Science Quarterly*, 24(4), pp.602-611.
Johnson, L. D., Neave, E. H. and Pazderka, B., 2002. Knowledge, Innovation and Share Value. *International Journal of Management Reviews,* 4(2), pp.101-134.
Kahn, K. B., Franzak, F., Griffin, A., Kohn, S. and Miller, C. W., 2003. Editorial: Identification and Consideration of Emerging Research Questions. *Journal of Product Innovation Management,* 20(3), pp.193-201.
Kauffman, S. A., 1993. *The Origins of Order.* New York: Oxford University Press
Kelley, T., 2005. *The Ten Faces of Innovation: IDEO's Strategies for Defeating the Devil's Advocate and Driving Creativity throughout Your Organization.* New York: Currency.
Kim, D. H., 1993. The Link between Individual and Organizational Learning. *The Strategic Management of Intellectual Capital,* Fall, pp.41-62.
Kim, L., 1993. *National System of Industrial Innovation: Dynamics of Capability Building in Korea. In:* R. Nelson, ed. *National Innovation Systems: A Comparative Analysis*. Oxford; Oxford University. pp.357-383.

Kim, L., 1997. *Imitation to Innovation: The Dynamics of Korea's Technological Learning.* Harvard, Harvard Business Press.
Kim, L., 1997a. The Dynamics of Samsung's Technological Learning in Semiconductors. *California Management Review,* 39(3), pp.86-100.
Kim, L., 1998. Crisis Construction and Organizational Learning: Capability Building in Catching-up at Hyundai Motor. *Organization Science,* 9(4), pp.506.
King, R., 2011. Power and Networks in Worldwide Knowledge Coordination: The Case of Global Science. *Higher education policy,* 24(3), pp.359-376.
Kitanovic, J., 2007. The Applicability of the Concept of National Innovation Systems to Transition Economies. *Innovation: Management, Policy & Practice,* 9(1), pp.28-45.
Knight, L. and Harland, C., 2005. Managing Supply Networks: Organizational Roles in Network Management. *European Management Journal,* 23(3), pp.281-292.
Lall, S. and Teubal, M., 1998. "Market-Stimulating" Technology Policies in Developing Countries: A Framework with Examples from East Asia. *World Development,* 26(8), pp.1369-1385.
Lane, D. C. and Oliva, R., 1998. The Greater Whole: Towards a Synthesis of System Dynamics and Soft Systems Methodology. *European Journal of Operational Research,* 107(1), pp.214-235.
Laredo, P., 2007. Revisiting the Third Mission of Universities: Toward a Renewed Categorization of University Activities? *Higher education policy,* 20(4), pp.441-456.
Lee, S.-C. and Tsai, C.-H., 2010. *The Led Legacy: How Heroes Built LED Business in Taiwan (Chinese Version).* Taipei: Bookzone.
Levine, R. and Zervos, S., 1998. Stock Markets, Banks, and Economic Growth. *American Economic Review*, pp.537-558.
Lewin, K., 1946. Action Research and Minority Problems. *Journal of Social Issues,* 2(4), pp.34-46.
Leydesdorff, L. and Etzkowitz, H., 1996. Emergence of a Triple Helix of University-Industry-Government Relations. *Science and Public Policy,* 23, pp.279-286.
Leydesdorff, L. and Etzkowitz, H., 1998. The Triple Helix as a Model for Innovation Studies. . *Science and Public Policy,* 25(3), pp.195-203.
Leydesdorff, L., 2000. The Triple Helix: An Evolutionary Model of Innovations. *Research Policy,* 29(2), pp.243-255.
Leydesdorff, L., 2012. The Triple Helix, Quadruple Helix,..., and an N-Tuple of Helices: Explanatory Models for Analyzing the Knowledge-Based Economy? *Journal of the Knowledge Economy*, pp.1-11.

Liao, C. J., Lin, Y. J., Chiang, H., Chiang, S. F., Wang, Y. H. and Jiang, C. C., 2007. Injecting Partially Digested Cartilage Fragments into a Biphasic Scaffold to Generate Osteochondral Composites in a Nude Mice Model. *Journal of Biomedical Materials Research* , 81 (3).567-577

Lincoln, Y. and Guba, E., 1985. *Naturalistic Inquiry.* Beverly Hills: Sage.

Lincoln, Y. S., 1995. Emerging Criteria for Quality in Qualitative and Interpretive Research*.* *Qualitative Inquiry,* 1(3), pp.275-289.

List, F., 1841. *The National System of Political Economy.* English Edition (1904). London: Longman.

Liu, K. T., 2009. *The Myth of Ac Led(Chinese Version)*[online]. Available from: http://www.ledinside.com/forum/viewtopic.php?t=1022 [Accessed 1 March 2011].

Liu, X. and White, S., 2001. Comparing Innovation Systems: A Framework and Application to China's Transitional Context. *Research Policy,* 30(7), pp.1091-1114.

Lowe, R., 2006. Who Develops a University Invention? The Impact of Tacit Knowledge and Licensing Policies. *The Journal of Technology Transfer,* 31(4), pp.415-429.

Lumley, T., 2008. *A Fluid-Dynamical worldview: The Fall and Rise of the 'Sailboating Psyche'.* Victoria: Printorium Bookworks.

Lundvall, B. A., 1988. Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation*.* *Technical change and economic theory,* 369,

Lundvall, B. A., 1992. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.* London: Pinter.

Lundvall, B.A., 2007a. National Innovation Systems? Analytical Concept and Development Tool*.* *Industry and Innovation,* 14(1), pp.95-119.

Lundvall, B.A., 2007b. *Higher Education, Innovation and Economic Development. In:* J.Y. Lin AND B. Pleskovic, ed. *Annual World Bank's Regional Bank Conference on Development Economics: Higher Education and Development,* January 16-17, 2007 Beijing. Washington: The World Bank, pp.201-228.

Lundvall, B.A., Intarakumnerd, P. and Vang, J., 2006. *Asia's Innovation Systems in Transition.* Cheltenham: Edgar Elgar Publishing.

Lundvall, B.A. and Johnson, B., 1994. The Learning Economy. *Journal of industry studies,* 1(2), pp.23-42.

Lundvall, B.A., Joseph, K. J. and Chaminade, C., 2010. *Handbook of Innovation Systems and Developing Countries: Building Domestic Capabilities in a Global Setting.* Cheltenham: Edward Elgar Publishing.

Malerba, F. and Orsenigo, L., 1997. Technological Regimes and Sectoral Patterns of Innovative Activities *Industrial and Corporate Change*, 6(1), pp.83-118.

Malerba, F., 2002. Sectoral Systems of Innovation and Production. *Research Policy,* 31(2), pp.247-264.
Mansfield, E., 1991. Academic Research and Industrial Innovation. *Research Policy,* 20(1), pp.1-12.
March, J. G., 1991. Exploration and Exploitation in Organizational Learning. *Organization Science,* 2(1), pp.71-87.
Marshall, A., 1961. *Principles of Economics.* London: McMillan.
Marshall, J., 2001. *Self-Reflective Inquiry Practices. In:* P. Reason and H. Bradbury, ed. *Handbook of Action Research*. London: Sage. pp.433–439.
Martin, R. L. and Osberg, S., 2007. Social Entrepreneurship: The Case for Definition. *Stanford Social Innovation Review,* 5(2), pp.28-39.
Mathews, J. A., 1997. A Silicon Valley of the East: Creating Taiwan's Semiconductor Industry. *California Management Review*, 39(4), pp.26-54.
Mathews, J. A. and Cho, D. S., 2000. *Tiger Technology: The Creation of a Semiconductor Industry in East Asia.* Cambridge University Press.
Mathews, J. A., 2001. National Systems of Economic Learning: The Case of Technology Diffusion Management in East Asia. *International Journal of Technology Management*, 22(5), pp.455-479.
Mathews, J. A., 2002. Competitive Advantages of the Latecomer Firm: A Resource-Based Account of Industrial Catch-up Strategies. *Asia Pacific Journal of Management*, 19(4), pp.467-488.
Mc fadzean, E., O'loughlin, A. and Shaw, E., 2005. Corporate Entrepreneurship and Innovation Part 1: The Missing Link. *European Journal of Innovation Management,* 8(3), pp.350-372.
Metcalfe, J. S., 1995. Technology Systems and Technology Policy in an Evolutionary Framework. *Cambridge Journal of Economics,* 19(1), pp.25-46.
Miles, M. B. and Huberman, A. M., 1994. *Qualitative Data Analysis: An Expanded Sourcebook.* London: Sage.
Morgan, J. and Liker, J., 2006. *The Toyota Product Development System: Integrating People, Process, and Technology.* New York: Productivity Press.
Morse, J. M., Barrett, M., Mayan, M., Olson, K. and Spiers, J., 2008. Verification Strategies for Establishing Reliability and Validity in Qualitative Research. *International Journal of Qualitative Methods,* 1(2), pp.13-22.
Mowery, D. and Sampat, B., 2005. *Universities in National Innovation Systems. In:* J. Fagerberg, J., Mowery, D. C. and Nelson, R. R., 2005. *The Oxford Handbook of Innovation.* Oxford: Oxford University Press. pp.209-239.

Mowery, D. C., Nelson, R. R. and Ziedonis, B. N. S. A. A., 2001. The Growth of Patenting and Licensing by Us Universities: An Assessment of the Effects of the Bayh-Dole Act of 1980. *Research Policy,* 30(1), pp.99-119.
Mulgan, G., Tucker, S., Ali, R. and Sanders, B., 2007. *Social Innovation: What It Is, Why It Matters and How It Can Be Accelerated.* London: The Young Foundation.
National Science Council, 2011. *Indicators of Science and Technology.* Taipei: National Science Council.
Nelson, R. R. and Winter, S., 1982. *An Evolutionary Theory of Economic Change.* Cambridge: Belknap Press.
Nelson, R. R., 1993. *National Innovation Systems: A Comparative Analysis.* Oxford: Oxford University Press
Nelson, R. R. and Rosenberg, N., 1993. *Technical Innovation and National Systems.*
Nelson, R. R. and Winter, S. G., 2002. Evolutionary Theorizing in Economics. *Journal of Economic Perspectives,* 16(2), pp.23-46.
Niosi, J., Saviotti, P., Bellon, B. and Crow, M., 1993. National Systems of Innovation: In Search of a Workable Concept. *Technology in society,* 15(2), pp.207-227.
Nonaka, I. and Takeuchi, H., 1995. *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation.* Oxford: Oxford University Press.
Nuvolari, A., 2004. Collective Invention During the British Industrial Revolution: The Case of the Cornish Pumping Engine. *Cambridge Journal of Economics,* 28(3), pp.347.
Oecd, 1997. *National Innovation Systems.* Paris: OECD Publications.
Park, H., Hong, H. and Leydesdorff, L., 2005. A Comparison of the Knowledge-Based Innovation Systems in the Economies of South Korea and the Netherlands Using Triple Helix Indicators. *Scientometrics,* 65(1), pp.3-27.
Parson, R. and Tilley, N., 1997. *Realistic Evaluation.* London: Sage.
Patel, P. and Pavitt, K., 1994. National Innovation Systems: Why They Are Important, and How They Might Be Measured and Compared. *Economics of Innovation and New Technology,* 3(1), pp.77-95.
Pavitt, K., 1984. Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory. *Research Policy,* 13(6), pp.343-373.
Pettigrew, A., 1988. Longitudinal Field Research on Change: Theory and Practice. *Organization Science,* 1(3), pp.267-292.
Polanyi, M., 1966. *The Tacit Dimension.* New York: Doubleday.
Rayner, A., 1997. *Degrees of Freedom: Living in Dynamic Boundaries.* London: Imperial College Press.

Rayner, A., 2004. *Inclusionality: The Science, Art and Spirituality of Place, Space and Evolution* [online]. Available from: http://people.bath.ac.uk/bssadmr/inclusionality/placespaceevolution.html [Accessed 29 November 2008].
Rayner, A., 2005. *Space, Dust and the Co-Evolutionary Context of 'His Dark Materials'*.[online] , Available from: http://people.bath.ac.uk/bssadmr/inclusionality/HisDarkMaterials.htm [Accessed 12 May 2009].
Rayner, A., 2006. *Natural Inclusion - How to Evolve Good Neighbourhood.* Bath: Self-published on CD.
Rayner, A., 2007. *Essays and Talks about 'Inclusionality'*.[online], Available from: http://people.bath.ac.uk/bssadmr/inclusionality [Accessed 12 May 2009].
Rayner, A., 2010. Inclusionality and Sustainability - Attuning with the Currency of Natural Energy Flow and How This Contrast Economic Rationality. *Environmental Economics,* 1(1), pp.98-108.
Rayner, A., 2011. Space Cannot Be Cut: Why Self-Identity Naturally Includes Neighbourhood. Integrative Psychological and Behavioural Sciences. *Integrative psychological & behavioral science,* 45, pp.161-184.
Rayner, A. D. M., Watkins, Z. R. and Beeching, J. R., 1999. *Self-Integration-an Emerging Concept from the Fungal Mycelium. In:* N.A.R.Gow, G.D.Robson, and G.M. Gadd, , (eds.) *The Fungal Colony*. Cambridge: Cambridge University Press. pp.1-24.
Readings, W., 1996. *The University in Ruins.* Cambridge: Harvard University Press.
Reason, P. and Bradbury, H., 2006. *Handbook of Action Research.* Concise Paperback Edition. London: Sage.
Re-Imagine! Business Excellence in a Disruptive Age. 2004. DVD. Directed by Atterberry, C. Cambridge: Enterprise Media.
Ring, P. and Van De Ven, A., 1994. Developmental Processes of Cooperative Interorganizational Relationships. *Academy of Management Review,* pp.90-118.
Roberts, E. B., 2001. Benchmarking Global Strategic Management of Technology. *Research-Technology Management,* 44(2), pp.25-36.
Rosenberg, N., 1982. *Inside the Black Box: Technology and Economics.* Cambridge: Cambridge University Press.
Rothwell, R., 1992. Successful Industrial Innovation: Critical Factors for the 1990s. *R&D Management,* 22(3), pp.221-240.
Ryle, G., 1949. *The Concept of Mind.* Chicago: The University of Chicago Press.
Saxenian, A. L., 1991. The Origins and Dynamics of Production Networks in Silicon Valley. *Research Policy,* 20(5), pp.423-437.

Saward, M., 2000. *Democratic Innovation: Deliberation, Representation and Association.* London: Routledge.
Sayer, A., 1992. *Method in Social Science: A Realist Approach.* London: Routledge.
Schiele, H., 2006. How to Distinguish Innovative Suppliers? Identifying Innovative Suppliers as New Task for Purchasing. *Industrial Marketing Management,* 35(8), pp.925-935.
Schumpeter, J. A., 1934. *The Theory of Economic Development.* Cambridge: Harvard University Press.
Sethi, R., Smith, D. C. and Park, C. W., 2002. How to Kill a Team's Creativity. *Harvard Business Review,* 80(8), pp.16-17.
Shakunle, L. O. and Rayner, A. D. M., 2009. Transfigural Foundation for a New Physics of Natural Diversity. *Journal of Transfigural Mathematics,* 1(2),
Shane, S., 2004. *Academic Entrepreneurship: University Spinoffs and Wealth Creation.* Cheltenham: Edward Elgar Publishing.
Shapiro, M. A., 2011. The Triple Helix Paradigm in Korea and Taiwan. In. M. Saad and G. Zawdie, ed. Theory and Practice of Triple Helix Model in Developing Countries. London: Routledge. pp.119-145.
Shih, C. T., Ju, B. U., Jian, H. G. and Lee, R. F., 2003. Visible Brain. Hsin-chu, Taiwan: Industrial Technology Research Institute.
Shinn, T., 2002. The Triple Helix and New Production of Knowledge: Prepackaged Thinking on Science and Technology. *Social Studies of Science,* 32(4), pp.599-614.
Shinn, T. and Lamy, E., 2006. Paths of Commercial Knowledge: Forms and Consequences of University-Enterprise Synergy in Scientist-Sponsored Firms. *Research Policy,* 35(10), pp.1465-1476.
Slaughter, S. and Leslie, L., 1997. *Academic Capitalism: Politics, Policies, and the Entrepreneurial University.* Baltimore: The Johns Hopkins University Press.
Slaughter, S. and Leslie, L. L., 2001. Expanding and Elaborating the Concept of Academic Capitalism. *Organization,* 8(2).154-161. Slaughter, S. and Rhoades, G., 2004. *Academic Capitalism and the New Economy: Markets, State, and Higher Education.* Johns Hopkins University Press.
Stake, R. E., 2000. *Case Studies. In*: N. Denzin and Y. Lincoln, ed. *Handbook of Qualitative Research*. 2nd ed. London: Sage. pp.435-454.
Stake, R. E., 2003. *Qualitative Case Studies. In*: N. Denzin and Y. Lincoln, ed. *The Sage Handbook of Qualitative Research*. 3rd ed. London: Sage. pp.443-466.
Szogs, A .,Cummings, A., and Chaminade, C. ,2009. Building Systems of Innovation in Less Developed Countries: The Role of Intermediate Organizations. *Proceedings of the 7th Globelics International Conference,* 6-8 October 2009, Dakar, Senegal. Atlanta: Georgia Institute of Technology.

Szulanski, G., 1996. Exploring Internal Stickiness: Impediments to the Transfer of Best Practice within the Firm. *Strategic Management Journal*, 17(1), pp.27-43.
Teece, D., 1986. Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy. *Research Policy,* 15(6), pp.285-305.
Tesson, K. J., 2006. *Dynamic Networks. An Interdisciplinary Study of Network Organization in Biological and Human Social Systems. Thesis* (Ph.D.). University of Bath.
Thursby, J. G., Jensen, R. and Thursby, M. C., 2001. Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major Us Universities. *The Journal of Technology Transfer*, 26(1), pp.59-72.
Thursby, J. G. and Thursby, M. C., 2001. Industry Perspectives on Licensing University Technologies: Sources and Problems. *Industry and Higher Education,* 15(4), pp.289-294.
Tidd, J., 2001. Innovation Management in Context: Environment, Organization and Performance. *International Journal of Management Reviews*, 3(3), pp.169-183.
Tidd, J. and Bessant, J. R., 2009. *Managing Innovation: Integrating Technological, Market and Organizational Change.* 4th ed. San Francisco: John Wiley & Sons.
Todorova, G. and Durisin, B., 2007. Absorptive Capacity: Valuing a Reconceptualization. *The Academy of Management Review,* 32(3), pp.774-786.
Torbert, W., 2003. *Action Inquiry: The Secret of Timely and Transforming Leadership* San Francisco: Berrett-Koehler
Utterback, J. M., 1971. The Process of Technological Innovation within the Firm. *Academy of Management Journal*, pp.75-88.
Van Tuyl, G. J., 2009. *From Engineer to Co-Creative Catalyst; an Inclusional and Transformational Journey.* Thesis (Ph. D.). University of Bath.
Von Hippel, E., 1976. The Dominant Role of Users in the Scientific Instrument Innovation Process. *Research Policy,* 5(3), pp.212-239.
Von Hippel, E., 1988. *The Sources of Innovation.* Oxford: Oxford University Press.
Von Hippel, E., 2005. *Democratizing Innovation.* Boston: MIT Press.
Walker, G., 1994. Asset Choice and Supplier Performance in Two Organizations-Us and Japanese. *Organization Science,* 5(4), pp.583-593.
Whitehead, J., 1989. Creating a Living Educational Theory from Questions of the Kind, "How Do I Improve My Practice?". *Cambridge Journal of Education*, 19(1), pp.41-52.
Whitehead, J. and Mcniff, J., 2006. *Action Research: Living Theory.* London: Sage.

Whitehead, J., 2008. Using a Living Theory Methodology in Improving Practice and Generating Educational Knowledge in Living Theories. *Educational Journal of Living Theories*, 1(1), pp.103-126.
Whitehead, J. and Rayner, A., 2009. From Dialectics to Inclusionality [online].Available from: http://www.actionresearch.net/writings/jack/arjwdialtoIncl061109.pdf [Accessed 1 May 2010]
Willis, J., 2007. *Foundations of Qualitative Research.* London: Sage.
Yin, R. K., 2003. *Case Study Research: Design and Methods.* 3rd ed. London: Sage.
Zahra, S. A. and George, G., 2002. Absorptive Capacity: A Review, Reconceptualization, and Extension. *Academy of Management Review*, pp.185-203.
Zucker, L. G. and Darby, M. R., 1996. Star Scientists and Institutional Transformation: Patterns of Invention and Innovation in the Formation of the Biotechnology Industry. *Proceedings of the National Academy of Sciences,* 93(23), pp. 12709-12716.
Zucker, L. G., Darby, M. R. and Armstrong, J., 1999. Intellectual Capital and the Firm: The Technology of Geographically Localized Knowledge Spillovers. *Economic Inquiry,* 36, pp.65-86.
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Appendix3.1: Case Study Protocol

A. Case study and goal of the protocol

a. Research Question for case study: How the collaborations among the research institute and the university-industry-government really are happening in Taiwan? What roles HEIs have played? This has to be the same as on page 1 and page 8, what happened to the other RQ?

b. Theoretical Framework for case study: Actor Flow Model

c. Role of protocol: a standard for guiding the researcher to conduct study

B. Data collection procedure:

a. Visiting Sites and making contacts with Dr.L at BML and Mr.Lin at EOL

b. Data Collection Plan:

(a). Interviewees: inventors, their supervisors and their staff in the research and commercialization sections, collaborators in universities, contact representatives in industry, government officials.

(b). Artifacts of the said inventions and related goods

c. Preparation before the interview

(a).Contact the person to be interviewed

(b).Check the background of interviewees through the internet and intranet, including their research and accomplishments.

(c).Started from the standard interview questions and review the information obtained so far, and questions which are not fully answer yet.

C. The outline of case study

a. The origin of invention

b. The development of invention (including resources, collaboration with other actors)

c. The commercialization process of the invention (patents, collaboration)

d. The challenge and future prospects

D. Questions for interviews

Turning to the interviews, in keeping with the requirements of the protocol, before initiating the schedule of interviewing it was necessary to review the purpose for which the two case studies were to be carried out, which was to understand the developmental trajectory of the innovation that was the particular matter of interest. Subsequently, the main reason for proceeding with the interviews was to elicit the narrative accounts of the events and circumstances surrounding these trajectories. Secondly, interview content will be transcribed into texts which will not reveal to the public as agreed by the interviewees and the author, and composition of the case study will send to the inventors to review. To these ends, the questions are open-ended and the interview schedule for use with all participants is semi-structured. Thus, if an interviewee has a novel insight to contribute related to the case, the interviewer has the space to inquire more deeply so as to probe the interviewee's understanding to its fullest extent. However, the individual may know a piece of the innovation, so the author will modify the interview questions to conduct them more effective.

May I suggest that you put the questions in a table and cross tabulate them against the flows that **<u>you anticipate you</u>** will gather information about from the respondents' answers. If you tick off the questions against the flows, then you can also see which RQs you will be gathering data about from the interview questions. Just a suggestion- to make it look more tidy and to show your interview question schedule is carefully constructed.

a. How the idea of the invention came about in the first place? Did you interact with anyone? Or how did you first get in touch with this project(collaborators)

b. How was the project continued? Were there any particular ideas flowing during the process (knowledge)? What were the funding sources (money flow) (by year)? Was there any help or collaboration with other team members, or with universities, industry, and/or the government (Human resource flow)? Doesn't work putting these flows in the sentences like this

c. Did you run up against any challenges during the innovation process? How did you resolve them? If any one of these hasn't been resolved, why not?

d. What is the future plan regarding this innovation and what is your part in this?

e. Are there any other projects on the horizon in near the future? E.g. innovations and collaborations.