The Role of University-Business Interaction in Knowledge System and Its Effect on Growth

Submitted by

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A submission presented in partial fulfilment of the

requirements of the University of South Wales/Prifysgol De Cymru

for the degree of Doctor of Philosophy

June 2016

Title: The Role of University-Business Interaction in Knowledge System and Its Effect on Growth

Key Words:

1. Codified Knowledge
2. Elite University
3. Entrepreneurial Knowledge
4. Entrepreneurship
5. Geographical Proximity
6. Innovation
7. Innovation Systems
8. Knowledge Absorptive Capacity
9. Knowledge Based Economy
10. Knowledge Commercialisation
11. Knowledge Dissemination
12. Knowledge Spillovers
13. Outreach University
14. Research-Industry Interaction
15. Scientific Knowledge
16. Tacit Knowledge
17. Technological Cluster
18. Technological Knowledge
19. Technological Progress

Abstract

Knowledge is recognised as the driver of productivity and economic growth, and its role is still being developed. The development of growth theory results in the focus of knowledge shifting from knowledge investment to knowledge spillover. In the meantime, links between knowledge actors are the main consideration of the regional innovation system. Among these links, the interaction between University and business is particularly stressed. Another group of studies regarding the University paradigms show that modern Universities have complemented their basic function of teaching and research with knowledge outreach, and this results in the collaboration between modern Universities and local firms. These literatures from different fields form an overlap, which emphasises the role of knowledge spillover through University-industry in innovation. On the other hand, because of the geographical proximity, networks of University-business interaction are usually localised. There are still some areas not covered by the literature. According to these gaps in the literature, there is need of a framework and statistical evidence to identify the effect of University-business interaction in long-term and short-term growth of a region or nation. It also needs to illustrate the role and various University activities in the regional knowledge system, considering the difference in regional knowledge absorptive capacity and University specialty. Therefore, three research objectives are generated with the design of a particular study for each, including the OECD Study, the UK regional Study and the UK University Study. This research is based on the knowledge production function framework, and extends it with the factors regarding to University-business interaction. Model framework of this research is based on the extended production function. This research builds Structural Equation Modelling (SEM) with the utilisation of a quantitative approach and secondary data. There are two main analysis tools chosen in the data analysis. SmartPLS is dealing with Path Analysis and Structural Equation Modelling (SEM) analysis, while SPSS is dealing with the Linear Regression Analysis, Factor Analysis and Cluster Analysis. The

results of this research not only support the contribution of University-business interaction to economic growth and technological progress, but also discovers that regional variety (in knowledge absorption capacity) and University variety (in speciality), matters to knowledge commercialisation. Accordingly, appropriate regional policy incentives are suggested to promote the networks of University-business interaction, taking into account those varieties between regions and Universities. This research contributes to the knowledge by defining a framework example of knowledge measurement by combining two types of knowledge, and three stages of knowledge, with a dynamic point of view. It develops the knowledge spillover theory and Triple Helix Model with not only proving dimensions of University-business interaction is the engine of regional growth, but also clarifying the relationships of Universities, and different nodes in the knowledge system. This research contributes to practice by recommending three policy directions to focus on: the University-business interaction whilst considering its long term effect and short term effect; University specialty including elite paradigm and outreach paradigm; and regional variety in knowledge absorption. This research also contributes to methodology with aspects in research design, analysis techniques, and statistical tools, since this research is designed with three layers of structural level studies with multi-objective tasks. This allows the studies to switch from the linear perspective to the network perspective. There are some limitations in each part of the study, mainly from the finding application, generalisation and data availability. Further research possibilities could choose target nations with similar knowledge infrastructure and systems to investigate. It could also consider applying a framework with more specific indicators of knowledge transfer. For the regional scale, further research could consider giving more details to possible activities and University types, when the data is available. It could also look at those regions with a similar capacity of knowledge absorption to analyse, to give a more accurate result.

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List of Abbreviation

HEI Higher Education Institutions

TLO Technology Licensing Office

TTO Technology Transfer Office

SMEs Small and Medium Enterprises

OECD Organisation for Economic Co-operation and Development

NIS National Innovation System

RIS Regional Innovation System

SEM Structural Equation Modelling

PLS Partial Least Squares

TFP Total Factor Productivity

GVA Gross Value Added

TEA Total Entrepreneurial Activity

IP Intellectual Property

KTT Knowledge and Technology Transfer

PRO Public Research Organisation

Acknowledgement

Foremost, I would like to express my gratitude to my supervisor David Pickernell for the support of my PhD study and research, for his continued patience, motivation, enthusiasm, and immense knowledge. His guidance helped me during the whole research period, and during the writing of this thesis. I could not have imagined having a better supervisor for my PhD study.

Besides my advisor, I would like to thank Dr. Gabor Horvath and Dr. Ramdane Djebarni for their insightful advice for the research methodology.

I also thank my friend Lisa for providing great help in econometrics and data analysis.

I need to thank all faculty officers, especially previous officer Vicky Jones, and current officer Alison Crudgington, who gave me support during these years of research.

I would also like to thank Gareth Rowlands and Nicholas Condon for being supportive and for helping me with proofreading.

The best outcome from this way of completing my PhD is not only this thesis, but also finding these good friendships along the way.

I dedicate this thesis to my mum Jianping Huang, my family, Stuart A’herne, and my beloved animals Ruby and Goggles for their constant support and unconditional love, and for sticking by my side even when I was irritable.

Chapter 1: Introduction

1.1 Introduction and Context

Economic growth is important at national and regional level. Potential answers to why regions show differences in economic growth rates, and how to generate growth in a specific region or nation, can be traced back to early growth theory itself, which is mentioned by Solow and Swan (1956). According to the model of production function, the basic reason is capital and labour. The growth rates of capital and labour are not, however, the only reasons for economic growth. Role of technology and innovation has become more important in last two decades. Innovation is considered within management literature as one of the cornerstones of continued growth (Tushman and O'Reilly, 1996).

In the discussion of knowledge-based economy (e.g. OECD, 1996), science is also exerting an increasingly large influence on innovation. Therefore, the topic "knowledge and technology transfer" has spurred great interest among academic researchers and policy-makers. The interaction of the business sector and science institutions such as Universities, through the exchange of knowledge and technology, has become a central concern not only for applied technological progress, but also for economic development.

Under the knowledge-based economy, some studies (e.g. Arvanitis et al, 2005; Mueller, 2005;

OECD, 2004) demonstrate that the industry-science relationship is considered to be a major factor contributing to high innovation performance and economic growth at the firm-level, regional level, and national level. This is also consistent with the main argument of new growth theory (Romer, 1986; Lucas 1988; Rebelo, 1991), within which knowledge stimulates technological progress and thus increases productivity. Muller (2005) also argues that the growth rates of labour and physical capital are not the only sources of economic growth. In fact innovation with regards to the knowledge creation and knowledge dissemination are an important element in stimulating economic development. In addition, empirical studies (Plummer and Acs, 2004; Varga and Schalk, 2004; Acs and Varga, 2004; Audretsch and Keilbach, 2004) have shown that knowledge spillovers positively affect technological change and economic growth.

Although knowledge is understood to be an essential driver of economic growth, knowledge is often not linked to economic growth with clear framework and direct evidence. According to the knowledge spillover theory (Audretsch and Carlsson, 2010), new knowledge generates innovations and is commercialised by transforming it into new products, processes and organisations. Businesses and research establishments (i.e. Universities and research institutions) generate new knowledge through research and development activities. The created knowledge may be exploited by them, the knowledge-producer, or by other businesses. However, the possibility to exploit knowledge requires a flow or spillover of the knowledge. Through knowledge spillover other economic actors may also exploit opportunities (e.g. entrepreneurship), resulting in an acceleration of innovation. Based upon the knowledge spillover theory of entrepreneurship (Acs et al, 2006), the commercialisation of knowledge depends on research and development activities of firms and research facilities, entrepreneurship, and science-industry relations. The role of the University has therefore become inextricably linked to knowledge and innovation creation and dissemination.

Since importance of the knowledge transfer to economy through science-industry interaction is demonstrated (OECD, 1996; Romer, 1986; Lucas 1988; Rebelo, 1991), there are some worldwide examples of University-based knowledge system with the success in stimulation of knowledge commercialisation and economy through this interaction. Some well-known examples are Silicon Valley and Route 128 in the US (Saxenian, 1994), and the Cambridge region in the UK (SQW, 1985 and 2000). However, there is accumulating evidence that many OECD countries are lagging behind in terms of interaction between University and business. Based on the production function framework (Cobb and Douglas, 1928), in the last decade many empirical studies of OECD countries start focusing on investigating the contribution of this interaction to economic growth and technological progress, including Germany (Pamela Mueller, 2005), Italy (Medda et al., 2005; Carree et al., 2011), Spain (Duch et al., 2011), and the Netherlands (Belderbos et al., 2004). These studies show that the interface between business firms and science institutions, especially Universities, need to be improved. There are also some UK based evidences. In the UK context, it is argued (e.g. Wright, et al., 2006; Huggins and Izushi, 2008) that University knowledge is not utilised sufficiently. Some studies pointed out that Universities fail to fully facilitate direct and indirect contribution to their local, regional and national economies (Kelly, et al., 2002). Knowledge transfer and commercialisation activities in many Universities do not match their overall potential (Charles and Conway, 2001; Charles, 2003; Wright, et al., 2006). In addition, significant disparities in knowledge absorption among regions are found (Huggins, 2003; Huggins and Izushi, 2008). Moreover, as Morgan (2002) argued, there is too much emphasis placed on the activities of elite Universities. Huggins et al. (2009) point out that the underlying policy in the UK often underestimates the potential of Universities in economic and regional growth. In recent years both national and regional government in the UK have highlighted the importance of science technology to change their innovation performance. It can be seen that the transfer of University-generated knowledge has a focus within government policies at both national and regional levels (Kitson et al., 2009; Lambert, 2003; Sainsbury, 2007; Wellings, 2008).

Accordingly, a number of policy-related questions that need to be explored. These revolve around the degree to which Universities can interact with businesses to positively affect national and regional growth, the processes by which this might occur, and also whether different sets of these processes are captured within different types of Universities. This thesis therefore posits that the contribution of University activities and University-industry interactions may act as a spur for growth. More specifically, this thesis is trying to explain whether part of the reason that regions post different growth rates is related to regional differences in knowledge absorption, and University differences in activities. This kind of study is important because it provides the potential framework to the University-based knowledge system, and the policy incentives to improve the innovation and economic performance of a nation or region. For policy-makers, this research tries to show an intensive exchange of knowledge between Universities and business is not a goal by itself but a means to enhance economic benefits. This study gives recommendations to policy-makers regarding what to focus on, who to focus on, and through which ways to do so, to encourage the short-term and long-term growth in the knowledge-based economy. In addition, measuring knowledge spillover is a methodological challenge in the research field because the knowledge especially tacit knowledge, is often difficult to measure, and the impacts of it usually vary according to different interaction activities. This study provides an instance and solution to measure and analyse the knowledge, the knowledge dissemination, and their consequences within a structured framework.

1.2 Background Knowledge

Analysis of the background literature identified five distinct, though related, groupings, that could be titled as follows: 1.Nature of Knowledge; 2.Knowledge Based Growth Theory; 3.Knowledge Systems; 4.University Roles and Paradigms; and 5.Science and Industry Links. . Crucially, these literatures overlap, all emphasizing that knowledge spillover, via University-Industry interaction, has an important role in economic growth.

In the Nature of Knowledge Literature, there are two categories of knowledge definition. The first definition includes codified knowledge and tacit knowledge ((Lundvall and Johnson, 1994; OECD, 1996). In the second definition knowledge is described with scientific knowledge, technological knowledge, and entrepreneurial knowledge (Rich, 1991; Karlsson and Nyström,2006). There are some aspects of knowledge not covered by these two definitions. It has difficulties in measuring and distinguishing tacit knowledge, and in clarifying the relations amongst each type of knowledge. It also has difficulties in defining the indicators of knowledge flow and measuring the process of knowledge transformation.

The Neo-classical growth model (Solow and Swan, 1956) attempts to explain that long-run growth is exogenously determined by capital accumulation, labour growth, and increases in productivity, and this productivity relates to efficiency in transferring resource to economic output. However in this model, where the technological progress comes from remains unexplained. Based on knowledge production function, in the 1980s the new growth theory (Romer, 1986; Lucas 1988, Rebelo, 1991) explicitly introduces knowledge into models of growth as an endogenous reason of the increases in productivity. This theory explains the role of knowledge in the growth by viewing technology as the primary determinant of growth, and model it as an endogenous variable. More specifically, the R&D-based model considers knowledge investment such as R&D expenditure and human capital, will in turn lead to technological progress, and then economic growth. More recently, the knowledge spillover theory of entrepreneurship (Acs et al., 2006) posits the existence of a “knowledge filter” between investment in new knowledge and its economic exploitation. It identifies entrepreneurship’s role in spillovers of knowledge, which transforms new knowledge into economic knowledge. There are however some weaknesses found in each model. The neo-classical growth model does not explain how and why technological progress occurs. According to the study of Madsen (2008), the Schumpeterian growth model has no explanation as to where the opportunities come from. The first generation of endogenous growth model pays little attention to how spillovers take place, and the second generation of endogenous growth model shows no evidence that R&D will turn into successful innovations, and does not mention much about the knowledge commercialisation role of the entrepreneur. The knowledge spillover theory of entrepreneurship does not have a framework for a clear model to measure the integration of entrepreneurship within the knowledge system, especially with regards to the relationship with knowledge creators such as Universities.

This emphasis of the knowledge spillover theory is consistent with some ideas of the knowledge system concept, such as national innovation system and regional innovation system (NIS). This stresses that the knowledge flow via networks and interactions among actors in a knowledge system can be the key to innovation (Freeman, 1987; Lundvall, 1988,1992; Nelson, 1993). It includes the flow of technology and information among institutions, firms and people. Focusing the innovation system to a regional scale, the regional innovation system (Asheim et al., 2003; Cooke, 2003; Wolfe, 2003; Isaksen, 2002; Malmberg and Maskell, 2002) is based on the localised knowledge networks and interactions. It also provides a specific focus on the informal knowledge flow channels and the tacit knowledge spillovers. Geographical proximity plays a key role in regional innovation systems in terms of localised knowledge activities and knowledge spillover. In addition, Model 2 theory (Gibbons et al., 1994) tends to involve the inter-institutional collaboration with a problem-solving purpose. The Triple Helix Model, (Etzkowitz and Leydesdorff, 1997; Leydesdorff, 1995) categorises those interactions in the innovation systems to the inter-connections between University, Industry and Government. Among them, the University-Industry interaction is especially illustrated in many studies

(Mansfield & Lee, 1996; Fritsch & Lukas, 2001; Fritsch, 2001; Spencer, 2001 and Laursen & Salter, 2004) as the main mechanism to facilitate the knowledge commercialisation, which may result in industrial innovation and economic growth. In the knowledge system part, knowledge is considered with a system's point of view. The theory is developed from an early linear relation-based model to a networks-based model, which focuses on the interactions among different knowledge agents in knowledge process. However there are some weaknesses found in each model of the knowledge system. The national innovation system framework is too broad without the focus on tacit knowledge spillovers, and too fuzzy to explain the specific relations between actors in the knowledge system. The regional innovation system has some problems in clearly addressing the role of geographical proximity such as those effects based on the "degree of proximity". In addition, the regional factor could not be discussed in isolation. Model 2 Concept does not consider research-business specific interaction. The Triple Helix Model could be too abstract, and has difficulty with regards to synergy between agents in the regional system of innovation.

On the other hand, there are a group of studies which focus on University roles and paradigms. It is argued that Universities expand their function from traditional teaching and research to knowledge outreach (Braun, 2006; Morgan, 2002; Abreu et al., 2008). In modern Universities, two basic functions have been complemented by engagement in research collaborations with other agents in the regional knowledge system. Modern Universities are now realised as multi-product organisations which not only create the knowledge, but also disseminate it, with distinction between "elite model" and "outreach model". The University is more important than ever as a provider of knowledge, human capital, and innovation for a region. It can be seen that the activities of some modern Universities particularly focus on the knowledge spillovers from University to localised firms, to meet the regional development needs. However, these University theories are only a broad concept model. The model framework neither focus much on the University classification details, nor on the indicators of University activities.

Another group of literature argues that a science and industry link encourages the technology transfer, and enables businesses to develop new products and processes (Cohen, Nelsen and Walsh, 2002; Spencer, 2001; Mansfield, 1998). University and business interaction especially is recognised as vital to facilitate the exploitation of knowledge and the flow of ideas (Fritsch and Lukas, 2001; Fritsch, 2001; Belderbos et al., 2004). University-based technological clusters offer rich opportunities of knowledge spillovers from Universities, R&D institutes, and other R&D intensive companies in the same technological cluster (Saxenian, 1994; Porter, 1990; Karlsson and Andersson, 2009). Geographic proximity is a major determinant of the transfer of knowledge, and it explains why some successful regions have become more competitive than those that have not adopted a localised knowledge network (Boschma, 2005; Autant-Bernard, 2001; Keller, 2002; Audretsch et al., 2005). Regional capacity in knowledge absorption determines knowledge transfer and impact on regional innovation intensity (Cohen and Levinthal, 1990; Jansen et al., 2006; Miguélez and Moreno, 2013; Grinevich et al., 2011). Internal and external knowledge sources of a region are complementary, and they have to be combined to improve the regional innovative performance. Channels of University-business knowledge transfer categories are provided based on the creator-user network and types of knowledge (Hagedoorn et al., 2001;

Lundvall, 1992; Yusuf, 2008; Karlsson and Johansson, 2005). However, there are some aspects still uncovered by this group of literature. It has no specific illustration to the University's effect on SMEs in terms of knowledge dissemination, and it also has no consideration of different specialities of Universities in knowledge transfer. In addition, although the effect of cluster to knowledge transfer between Universities and firms in the cluster is confirmed, there is no clear framework for the activities of knowledge transfer between University and business. Geographic proximity should not be considered isolated however, as it needs to integrate with the regional systems of innovation. Moreover, not only the knowledge volume, but also the knowledge absorptive capacity, matters to the regional innovation performance. However, this is only recently realised and taken into account in the regional innovation system model, and in addition there is no defined regional scale indicator for the knowledge absorptive capacity, although entrepreneurship is mentioned in a few studies as one of proxies. What is more, it lacks a clear and unified framework, indicators and measurements for the University-business knowledge transfer channel, and there is not much mention of the network between non-SMEs and SMEs.

The above discussion covers the five different groups of literature: 1.Nature of knowledge; 2.Knowledge based growth theory; 3.Knowledge system; 4.University role and paradigm; and 5.Science and industry link. These literatures overlap at one point with regards to emphasizing that the knowledge spillover via University-industry interaction has an important role in growth. Many studies (Cohen, Nelsen and Walsh, 2002; Spencer, 2001; Mansfield, 1998) have supported that this science and industry link is an important mechanism of knowledge flow, which encourages the technology transfer and enables businesses to develop new products and processes.

1.3 Research Gaps and Objectives

This research aims to discover the role of University-business interaction in knowledge system and its effect on growth. According to the main arguments in the above literature, there are some research gaps found. Three research objectives are generated based on these research gaps.

First of all, there are some gaps regarding to the effect of knowledge on growth. It needs a measurement on knowledge process and growth consequences. It also needs a framework focus on network and growth, and a discussion on the effect of University-business co-operation to economy, including its relationship with knowledge investment. Therefore Objective A of this research is to discover the influence of University-business co-operation on technological progress and economic growth. It is also to find out how this network integrates with knowledge investment and entrepreneurship in the growth model.

Secondly, there are some gaps regarding to the regional knowledge system. It needs to define and measure University-business involvement activities. It needs to address the role of entrepreneurship in the knowledge system. There is also a need to find out the effect of these University-business involvements, especially University-SMEs activities to innovation; and to find out how these activities integrate with regional knowledge systems; and to see the patterns and modes of the regional knowledge system by considering the disparities in knowledge absorptive capacity; and finally to see the applicability of each system mode in different regions. Therefore, Objective B is to investigate the effect of University activities on growth, and the role of University activities in regional knowledge systems. It is also to find out if this role shows differences across those regions with different knowledge absorptive capacities.

Thirdly, there are some gaps regarding to University roles and paradigms in the knowledge system. It needs to define and measure the University knowledge-based process. It needs to find out the role of University-business interaction in the process of creation-dissemination-utilisation. It needs to address the unique role of non-SME interaction and SME interaction in the process and to see if different specialties of University show different patterns and results in knowledge commercialisation. It also needs to see the applicability of each system pattern in different Universities. Therefore, Objective C is to illustrate the patterns of University knowledge based systems, and the influence of it on knowledge commercialisation. It is also to see if this influence is different between types of University with different specialties.

1.4 Methodology

The review of international context and UK regional context provide the ideas to build the model framework for this research. This overall framework is formed by three layers of studies with particular methods and variables designed, including the OECD study, the UK regional study, and the UK University study. Each of these is specially designed for each of the research objectives, from the broad national based growth, to zooming in to the University activities and regional knowledge system more specifically, and then further focus on the University paradigm and knowledge commercialisation. This research is based on the knowledge production function framework, and extends it with the factors regarding to University-business interaction. This study covers both codified and tacit knowledge transfer from University and business, and it covers the networks between University and both non-SMEs and small business respectively. It also includes the three processes in terms of University-based knowledge creation, dissemination, and utilisation involved in regional system of innovation.

The Model framework of this research is based on the extended production function. This research builds structure equation with the utilisation of a quantitative approach and secondary data. The secondary data are mainly collected from four datasets, which are Euro Statistics; Global Entrepreneurship Monitor (GEM); UK Annual Business Inquiry (ABI); and Higher Education-Business and Community Interaction Survey (HE-BCI). There are two main analysis tools chosen in the data analysis. SmartPLS is dealing with Path Analysis and Structural Equation Modelling (SEM) analysis, while SPSS is dealing with the Linear Regression Analysis, Factor Analysis and Cluster Analysis .

The choice of SmartPLS for this study is based on the features of this software in requirements (operating system, data), methodological options (path weighting, inner and outer model analysis, resampling methods), and ease-of-use (graphic-based, output format). SmartPLS contains the advantages of both PLS method and SEM technique. Firstly, these are many inter-related elements involved in the University-knowledge based system. Traditional tool and methods struggle in investigation of the inter-relationship and indirect relation involved among variables. SmartPLS allows to draw the relevant factors and latent factors from the complex, and further helps to find out the relationship among them. Secondly, that PLS has its advantages over other techniques when analysing small sample sizes or data with non-normal distributions. Because of the data size and nature in this research, SmartPLS shows to be an ideal tool to choose. Thirdly, SmartPLS is an easy to use tool with graphical user interface. This drag and drop based tool enables the model be clear, and easy to analyse and modify. The use of SmartPLS in this research brings in a possible solution for the research filed, especially for those quantitative studies with small data samples and complex with various related variables.

1.5 Findings

The results from the OECD study demonstrates the positive effect of University-business co-operation on technological progress and economic growth. It also shows evidence that knowledge investment in R&D and human capital indirectly influence growth. In addition, it discovers the substitute relationship between University-business co-operation and entrepreneurship. The results of the UK regional study demonstrate the positive effect of University Core Activity on technological progress and economic growth. It also demonstrates the positive effect of University Knowledge Outreach Activity on technological progress. In addition, it discovers the complementary relationship between University Core Activity and entrepreneurship, and in contrast, the substitution relationship between Knowledge Outreach Activity and entrepreneurship. Moreover, the result also shows that regional disparities result in the different modes of University involvement in the regional knowledge system. The results of the UK University study demonstrates that creation and dissemination of knowledge has an effect on the knowledge commercialisation. It also shows that University interaction with SMEs directly results in the knowledge commercialisation. In addition, it discovers that different Universities show different relationships among knowledge creation-dissemination-utilisation, and there is a substitution relationship in Elite Universities, and a complementary relationship in Outreach Universities.

The results from three layers of study, together provide four main findings regarding improving the economic return benefiting from the utilisation of University knowledge. Firstly, University-business interaction is the key of the University based knowledge system of knowledge process, and it has significant effect on both economic growth and technological progress. Secondly, different University activities have different roles in the regional knowledge system. University Core Activity contributes to both long term and short term growth. University Knowledge Outreach Activity is more likely to contribute to the long-term growth of a region. Thirdly, the economy of regions with high knowledge absorptive capacity benefit directly from the Core Activity, while growth of regions with relatively low knowledge absorptive capacity rely more on the University Knowledge Outreach Activity. Finally, both University knowledge creation and dissemination influence University knowledge commercialisation. In Elite Universities, knowledge creation and knowledge dissemination substitute each other; while in

Outreach Universities, knowledge creation and knowledge dissemination complement each other.

1.6 Contributions

These findings contribute to research fields including the nature of knowledge, growth theory, knowledge system, University roles and science-industry link. This research expands the nature of knowledge, by arguing that when the contribution and consequence of knowledge need to distinguish the codified and tacit nature of the knowledge. It defines a framework example of knowledge measurement by combining two types of knowledge, and three stages of knowledge, with a dynamic point of view. This result supplies the knowledge spillover theory with more activity details, to demonstrate that the interaction between academia and industry amplifies the permeability of the knowledge filter, increases the flow of knowledge, and thus spurs growth. In addition, it generates the idea of the growth model that not only the commercialisation side of University knowledge, but also the different stages of knowledge process. This research also provides solid evidence to distinguish the role R&D investment for the endogenous growth model, and develops the role of entrepreneurship in growth, but indirectly. The findings are consistent with prevalent theory of knowledge systems (e.g. Triple Helix Model; Regional Innovation System; Model 2) by emphasising the importance of knowledge networks in transferring knowledge between science and business in the economy. It particularly develops the Triple Helix Model in not only proving the dimension of University-business interaction is the engine of regional growth, but also clarifying the relationships of Universities, and different nodes in the knowledge system. This research also contributes the knowledge system by revealing the relationship between non-SMEs and SMEs. This research contributes to the field of the University role by specifically distinguishing two University activities (University Core Activity & University Knowledge Outreach Activity) and two University paradigms (Elite University & Outreach University). It confirms the significant role of University-business interaction in the knowledge system. It points out that although the role of University-business interaction is demonstrated, which mode to apply needs to be according to the knowledge absorptive capacity of a region. It also shows the evidence that regional disparities in knowledge absorption matter to the mode of University based knowledge system.

According to the findings of the research, regional innovation policies are recommended to focus on three directions: the University-business interaction with considering its long-term effect and short-term effect; University specialty including elite paradigm and outreach paradigm; and regional variety in knowledge absorption. Policy is suggested to look at the University-business co-operation because it improves the linkage and interface between knowledge supply and demand, and directly contributes to economic growth and technological progress. Policy may need to take into account the different types of University activity. The core activities, such as teaching, research, and formal interaction with large companies, are likely to result in both short-term and long-term regional growth. The knowledge outreach activity of University cannot be neglected too, because these activities, including University spill-offs and interaction with SMEs, are likely to improve the infrastructure of regional knowledge system such as channels of knowledge transfer. These policy stimulations are also suggested to take into account the

University specialty to design the most appropriate incentives, since knowledge creation and dissemination in different groups of Universities may result in different consequences of growth. In addition, policy needs to consider the regional capability in knowledge absorption. In regions with high capacity of knowledge absorption, potential policies could focus on the University R&D activity and interaction with non-SMEs. In regions with low capacity of knowledge absorption, potential policies could focus more on the University knowledge outreach activities and interaction with SMEs.

This research contributes to methodology with aspects in research design, analysis techniques, and statistical tools. This research is designed with three layers of study and multi-objective tasks. Choice of dependent variables include the short-term effect of economic growth and also long-term technological progress. This research applies a structural level of study, which allows the studies to switch from the linear perspective to the network perspective. The research is also designed to group University activities and University types. It helps to clarify those various activities of University, and distinguish their main effect in different University paradigms. This research is in use in multiple analysis techniques, including linear regression analysis, path analysis, factor analysis, cluster analysis and structural equation modelling (SEM). The result of novel analysis techniques, such as SEM in model building and analysis, are combined and compared with traditional techniques such as linear regression. This gives the solidity and confidence to the results. It also provides an pioneer example of application of model framework and method in the research field. The statistical package used in this research are SPSS and SmartPLS. SmartPLS is an easy to use tool with graphical user interface. SmartPLS has some outstanding advantages over other statistical tools, because it allows us to draw the relevant factors and latent factors from the complex, and further helps to find out the relationships among them. It also has advantages in analysing small sample sizes, or data with non-normal distributions.

1.7 Limitations

There are some limitation in each part of study, mainly from the finding application/generalisation and data availability. The possible further research for national scale, could choose target nations with similar knowledge infrastructure and system to investigate. Further research could also consider applying a framework with more specific indicators of national knowledge transfer. It could think to supply the statistical model with some qualitative information for the purpose of real practice in policy. For the regional scale, further research could consider giving more details to possible activities and University types, when the data is available. It could also look at those regions with similar levels of knowledge infrastructure to analyse, to give a more accurate result. Similarly, research of regions in other nation is suggested to add their regional specific factors knowledge indicators. For the problem in data, further research could make a comparison of relevant methods dealing with panel data. It could also consider using other datasets based on the data availability, or other indicators of regional growth and University-business interaction.

1.8 Structure of Thesis

The dissertation starts with an abstract, followed by seven chapters, and ends with appendices. Chapter 1 is an introduction which gives a background and overview of this research. Chapter 2 is a literature review which covers the main theories and studies related to this research topic, and the generation of research objectives according to the gaps in the literature. Chapter 3 gives the description and choice of the methods applied in this research. It also includes the design of the research with three layers of studies in details. Chapters 4, 5 and 6 contain the analysis results from the OECD study, the UK regional Study, and the UK University study respectively. The last chapter is the conclusion of this research with main findings and contributions to knowledge, practice and methodology.

Chapter 2: Literature Review

This research sets out to identify the effect of interaction between Universities and businesses in terms of economic growth and technological progress. There are five main groups of related literature reviewed, as follows. The Nature of Knowledge introduces the knowledge definition, forms of knowledge, and how to measure knowledge. Knowledge Based Growth Theory introduces the historical and more recent models of growth with the contribution of knowledge to economy. The main argument of each model and the development of them are shown as well. In addition, in knowledge system models, the innovation system and some typical knowledge networks are shown. The role of Universities and the paradigm cover both the traditional role and modern role of the University, and the changes to it. Science and industry link shows the importance of University-business interaction and with details of geographical proximity, regional absorptive capacity, and knowledge transfer channels. These literatures are introduced one by one in details. In the end, there is a discussion of this literature together to generate the focus for this research, identify research gaps, and discover objectives.

2.1 Nature of Knowledge

This part of literature focuses on the introduction of knowledge nature, with the discussion of e theory’s main arguments, weaknesses, and research gaps generated accordingly. It contains two elements in detail, including knowledge definition, type and process; and knowledge indicators.

2.1.1 Knowledge Definition, Type and Process

The definition of knowledge was first drawn from the idea of information. Information itself is data that has been processed into a form that is meaningful to the recipient, and can be broken down into bits. Information is described as data that can be easily codified, transmitted, received, transferred and stored. Two typical types are information regarding to "know-what" and "know-why". Know-what refers to knowledge about "facts". Know-why refers to scientific knowledge of the principles and laws of nature. Know-what and know-why can be obtained through reading books, attending lectures, accessing databases (OECD, 1996).

Know-what and know-why show the codified nature of information. Knowledge, on the other hand, is a much broader concept than information. It is seen as consisting of both codified information, and information with intrinsic indivisibility which is difficult to interpret. Thus, knowledge also refers to the tacit side of information, namely 'know-how" and "know-who". Know-how refers to skills or the capability to do something. Know-who involves information about who knows what, and who knows how to do what. It involves the formation of special social relationships which make it possible to get access to experts and use their knowledge (Lundvall and Johnson, 1994). These two kinds of information are based primarily in practical experience. Know-how is typically learned in situations where an apprentice follows a master. Know-who is learned in social practice and sometimes in specialised educational environments (OECD, 1996). Both know-how and know-who are socially embedded knowledge which cannot easily be transferred through formal channels of information.

Accordingly, two types of knowledge are defined and discussed in many studies (such as Lundvall and Johnson, 1994; OECD, 1996), including codified knowledge and tacit knowledge. Codified knowledge is a kind of information which can be packed and transferred, while tacit knowledge implicates the knowledge which involves learning and developing skills, but not in a way that can be written down (Johnson et al, 2002). To expand on this, codified knowledge underlies technological development and product and process advances in most industries. In contrast, tacit knowledge tends to remain embodied within an individual or implicit within a knowledge network, which are more difficult to identify and measure. Cowan, David and Foray (2000) made a theoretical evaluation of tacit knowledge versus codified knowledge. They suggest that very little knowledge is intrinsically tacit, in the sense that it is impossible to codify. Arundel and Geuna (2001) dispute that these criticisms only give doubts about the role of tacit knowledge, but do not counter a need for direct, personal contact in order to effectively transfer knowledge. Polyani (1966) points out that at least part of knowledge will always remain tacit and "non-codifiable". Von Hippel (1988) argued that tacit knowledge is best transferred via face-to-face interactions, since knowledge assets are often inherently difficult to copy.

Both types of knowledge play an important role in the economy. McNicoll et al (2002) suggest that the development of a successful knowledge economy depends on the existence of all forms of knowledge, codified and tacit, brought together in a networked knowledge chain. They work best together and not in isolation. Codified knowledge could be considered as the "material of knowledge" to be transformed, and it creates the base of learning. Knowledge codified and reduced to information can be transmitted over long distances with very limited costs. The development of information technology and communication infrastructures gives a strong impetus for the process of knowledge codifying and transmitting (OECD, 1996). This type of knowledge contributes to the inter-learning process, and further results in regional and industrial innovation. On the other hand, since access to knowledge becomes easier and less expensive, the skills and capability in efficiently using knowledge becomes more crucial. Tacit knowledge, in the form of skills needed to handle codified knowledge, is related to the capabilities for selecting relevant information and disregarding irrelevant information. It is also related to recognising patterns in information, interpreting and decoding information, as well as learning new and forgetting old skills. That is why this type of knowledge is arguably increasing in demand (OECD, 1996).

Because of its explicit nature, codified knowledge is possible to be transferred over the physical distance at the individual, firm, regional or even at the national level. Companies can exchange knowledge that is explicit in the form of technologies, documents, products or processes. Similarly countries could exchange explicit knowledge through multilateral agreements on technology transfer, education and training, as well as the direct export and import of products (Fallah and Ibrahim, 2004). However, tacit knowledge is argued more based on the local network, because it is usually exchanged only at the individual level. Exchange of tacit knowledge at the individual level, if it occurs, could be an intended knowledge transfer or an unintended spillover (Fallah and Ibrahim, 2004). There are a group of studies that provide evidence that to acquire tacit knowledge, the main channels are direct inter-personal contact (e.g. Faulkner et al., 1995; von Hippel, 1987; Maskell and Malmberg, 1999).

Marshall (1920) and Schumpeter (1934) have generally categorised knowledge with two terms: market knowledge and organisational knowledge. Karlsson and Nyström (2006) more specifically distinguished knowledge with three concepts: scientific knowledge, technological knowledge and entrepreneurial knowledge

Considered as the public knowledge, scientific knowledge is in the form of basic scientific principles that can form a basis for the development of technological knowledge. This is consistent with Schumpeter (1934), who states that scientific knowledge functions as a background to, or platform for, technological knowledge in the innovation process. Technological knowledge is in the form of inventions (or technical solutions) that either materialise in new products, or can be readily used in the production of goods and services. A typical example of technological knowledge is the patent. Entrepreneurial knowledge comprises business relevant knowledge about products, business concepts, markets, customers. Entrepreneurial knowledge may also cover entrepreneurship experience (Shah et al, 2006).

Each type of knowledge has its unique importance in innovation. It is argued that most of the new scientific knowledge is produced by University R&D activity, while most new technological knowledge is produced by means of company R&D activity. New technological knowledge, new entrepreneurial knowledge or new combinations of existing technological and entrepreneurial knowledge, form opportunities for innovation. It infers that innovation could be attributed to the application of technological knowledge, entrepreneurial knowledge, or the combination of two.

There is also a discussion regarding the access to these types of knowledge. Scientific knowledge has the character of pure public good, and is usually open to acquisition, although it is generally available only to those with the relevant scientific training. Technological knowledge is created as a non-rivalrous, partially excludable good (Romer, 1990). Once the costs of creating new "technological knowledge" have been incurred, this knowledge may be used over and over again at no additional cost. In this sense technological knowledge is non-rivalrous. The partially excludable character of technological knowledge is from the fact that companies generally protect new inventions with patents issued on them. Entrepreneurial knowledge comprises specific knowledge tied to the market and business innovation. It closely connects the entrepreneur's ability in seeking opportunities, organisation, sourcing for the purpose of a new product, new processes, new markets, and new networks (Schumpeter, 1947).

2.1.2 Knowledge Indicators

There is a process to transfer the knowledge input and output. Rich (1991) points out that this process is involved with knowledge creation, dissemination, knowledge utilisation, and the linkage between them. Similarly, in the firm's point of view, Cohen and Levinthal (1990) define absorptive capacity as the ability of a firm to recognise new information, assimilate it, and apply it to commercial ends.

Measuring knowledge is not easy because of its tacit nature and the complicated processes involved. OECD (1996) provides some ideas of indicators in measuring knowledge and its process. Knowledge creation could be represented with R&D expenditure and stock of knowledge capital. According to this argument, indicators of R&D expenditures show direct efforts to enlarge the knowledge base, and inputs into the search for knowledge. Indicators relating to financial and human capital investment approximate the amount of problem solving. These indicators traditionally count formal R&D conducted by the public sector, academia and large manufacturing firms. More recently, the research expenditures by small firms and capital of entrepreneur have started being fully recognised. On the other hand, measuring the stock of knowledge capital could be based on current science and technology indicators. Annual R&D inputs could be accumulated for various countries and industries, and then amortised using assumptions concerning depreciation rates. Similarly, stocks of R&D personnel could be estimated based on annual increases in researchers in particular fields, depreciated by data on personnel movements and occupational mobility. In addition, the patent stock might be approximated using data on use, and the expiration of periods of exclusive rights.

However, it is argued that only a small fraction of all inputs into knowledge creation are attributable to formal R&D expenditures and official research personnel. Successful R&D draws on ideas from many different sources, including informal contact, an entrepreneur’s experiences, and regional networks (OECD, 1996). This emphasised the importance of knowledge dissemination. For the dissemination of knowledge, it is suggested to measure the proportion of knowledge stock which enters into the economy during certain time period. Two proxy indicators which are most frequently used to measure knowledge dissemination are embodied diffusion, and disembodied diffusion. The first one refers to production processes of machinery, equipment and components that incorporate new technology, and the latter one refers to the transmission of knowledge, technical expertise or technology in the form of patents, licences or know-how.

These knowledge creation and dissemination indicators form the starting point for measuring knowledge utilisation. The knowledge utilisation indicators have been developed to translate certain knowledge inputs into knowledge outputs. The measures are based on certain sectors or firms playing a key role in the long-run performance by producing spillover benefits, providing high skilled employment, and generating higher returns to capital. These indicators are usually applied to describe and compare the economic performance of countries or regions.

2.1.3 Discussion and Theory Weaknesses

The main arguments and weaknesses of the theory regarding the nature of knowledge are summarised in the table below. According to these arguments and weaknesses, some research gaps (G1-G2) are found.

Table 2.1: Summary of Nature of Knowledge Literature

Literature	Theory and Model	Author	Argument	Model Weakness	Research Gap
Nature of Knowledge	● Knowledge Definition, Type and Process	OECD (1996); Lundvall and Johnson (1994); McNicoll et al (2002);	Codified-Tacit Knowledge Scientific Knowledge-Technological Knowledge-Entrepreneurial Knowledge	W1.1 difficult to measure tacit knowledge W1.2 difficult to clarify the relationship between each type	G1. Definition rather than process interaction, without considering the mechanism of transformation among each types of knowledge G2. There is lack of unified measurement, which results in the difficulties in measuring the knowledge process
	● Knowledge Indicators	OECD (1996); Rich (1991); Karlsson and Nyström (2006)	Indicator to measure knowledge input-output-process	W1.3 difficult to define the indicator of knowledge flow and measure the process of knowledge transformation	

In the Group Nature of Knowledge Literature, there are two categories of knowledge definition. The first definition includes codified knowledge and tacit knowledge. In the second definition knowledge is described with scientific knowledge, technological knowledge, and entrepreneurial knowledge. There are some aspects of knowledge not covered by these two definitions. It has difficulties in measuring and distinguishing tacit knowledge, and in clarifying the relations amongst each type of knowledge. It also has difficulties in defining the indicators of knowledge flow and measuring the process of knowledge transformation. According to these weaknesses, two research gaps are addressed in this part of literature. Firstly, although in both definitions knowledge is considered having an effect on innovation, these definitions focus more on “What” rather than “How”; there is still a lack of practical measurements of how the knowledge connects to the innovation (G1). In addition, the theory defines that knowledge generates growth through the process of knowledge creation, dissemination, and utilisation, but clearly structures neither the networks involved in these different stages of knowledge process, nor the dynamic linkage between these stages (G2).

2.2 Knowledge Based Growth Theory

This part of the literature focuses on the introduction of knowledge based growth theory, with the discussion of theory main arguments, weaknesses, and research gaps generated according to them. It contains four elements in detail, including new-classical growth theory; Schumpeterian growth theory; new growth theory; and the knowledge spillover theory of entrepreneurship.

2.2.1 Neo-classical Growth Theory

Neo-classical Growth Model (Solow and Swan, 1956) attempts to explain long-run economic growth is exogenously determined by factors of capital accumulation, labour or population growth, and increases in productivity, normally referred to technological progress. The basic framework of the neo-classical growth model is aggregate production function, usually of a Cobb-Douglas production function (1947). According to the neo-classical growth model, when a certain level of capital is added to the economy, returns diminish, but any effect may be offset by the flow of new technology. Although technological progress is considered an engine of growth in this model, there is no definition or explanation of technological processes.

2.2.2 Schumpeterian growth

Schumpeter (1934) is the first one to mention entrepreneurship in the economy growth. The term "Schumpeterian growth" is used to identify a mechanism which is named "creative destruction". This process serves as the fundamental base in the Schumpeterian growth model, and captures the social benefits that result from the endogenous destruction of old products and processes by new ones. It is different because other theoretical approaches usually consider learning-by-doing, human capital or physical capital accumulation as sources of economic growth, whilst the Schumpeterian growth model agues that the new and independent ventures bear the main responsibilities in the process of economic growth through innovation (Dinopoulos, 2006). Schumpeterian growth is a particular type of economic growth which is generated by the endogenous introduction of product and process innovations. The term "endogenous" refers to innovations that result from R&D investments undertaken by forward-looking, profit-seeking firms.

2.2.3 New Growth Theory

The development of Schumpeterian growth theory started in the end of the 1980s motivated by the inability of the neoclassical growth theory to account for the long-run causes of technological progress (Dinopoulos, 2006). Analytical approaches are being developed with the new growth theory, where knowledge is included more endogenously in production functions. This class of models aims to explain the role of technological progress in the growth. R&D-based models view technology as the primary determinant of growth and model it as an endogenous variable. In new growth theory (endogenous growth theory), knowledge is considered to raise the returns on investment, which can in turn contribute to the accumulation of knowledge. Investments in knowledge can increase the productive capacity of the other factors of production as well as transform them into new products and processes. It does this by stimulating more efficient methods of production, as well as new and improved products and services. Since these knowledge investments are characterised by increasing returns, there is a possibility of sustained increases which may lead to continuous rises in growth. Therefore, they are the key to long-term economic growth.

The first generation of new growth models exhibit a counter-factual "scale-effects" property, according to which more resources devoted to R&D are associated with a higher growth rate of total factor productivity (TFP). This model views technology as the primary determinant of growth and models it as an endogenous variable. In addition, in these models the presence of a positive population growth rate results in long-run growth rate of per capita income. The advancement of these R&D-based models of growth is mentioned in the studies of Romer (1986), Lucas (1988) and Rebelo (1991).

Since the mid 1990s, growth theorists have developed a second generation of scale-free new growth models (Schmits,1989; Segerstrom et al., 1990; Segerstrom, 1991, 1995 ; Aghion and

Howitt, 1992). These models fall into two distinct categories according the way of removing the scale effects property, including semi-endogenous growth model and fully-endogenous growth model. The main argument of semi-endogenous growth model is that as technology becomes more complex, sustained growth in R&D resources is needed to maintain a given rate of TFP growth. Semi-endogenous growth model predicts that the long-run growth rate of TFP depends only on the rate of population growth, and therefore it is not affected by policy-related parameters. In other words, the semi-endogenous growth model generates exogenous scale-free long-run Schumpeterian growth. On the other hand, the fully-endogenous growth model removes the scale effects, and builds on the insight that aggregate R&D becomes less effective either because it is spread among more product lines, or because incumbents raise barriers to frustrate the R&D effort of challengers. The fully-endogenous growth model maintains the assumption of constant returns to the stock of knowledge of earlier endogenous growth models, and generates endogenous long-run growth.

These growth models have analysed the long-run growth and welfare effects of a variety of government interventions. Policy (e.g. R&D institution; trade taxes) change product prices and innovation cost. It helps to shift economic resources between consumption and R&D activities. In fully-endogenous growth models, policy would result in the shift of per-capita resources towards R&D activities. It would accelerate the rates of innovation and growth. However in semi-endogenous growth models, this resource shift only generates a temporary increase in the rate of innovation (Dinopoulos, 2006).

The new growth theory builds upon the informational characteristics of knowledge. At the heart this R&D-based growth models is a technology production function that describes the evolution of knowledge creation. Knowledge in these models stimulates technological progress and thus spurs growth. The new growth theory has provided two fundamental contributions by focusing on knowledge breakthroughs. The first is that the investment in knowledge is likely to be associated with to other agents in the economy, which would result in the innovation. R&D investment is thus argued as main source of technological progress by some authors (Romer1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992). The second is that the human capital improves the knowledge creation and knowledge spillover. It is mentioned by Romer (1990) that growth of the knowledge stock proportionally attributes to the amount of labour engaged in R&D. Since the new theory is the one in which long-run per capita growth is driven by knowledge growth, the increase in human capital would result in the technological progress, and then growth in economy.

According to the above function, the rate of production of new knowledge depends on the investment in R&D and human capital (Abdih and Joutz, 2005). There is a group of studies which focus their roles in innovation and the economy.

<u>R&D Expenditure</u>

Based on the study of the USA, Jaffe (1989)'s model provides evidence that expenditures by Universities positively influence corporate patenting activity. Similarly, Acts et al. (1992)

confirms the importance of public research to industrial innovation by reporting increased elasticity for University research expenditures. Based on OECD countries, some studies (Bassanini, Scarpetta and Visco, 2000) find out that knowledge and technologies impact on economic growth. Empirical evidence in this research are generally supportive of a strong and positive relationship between R&D input and economy output or productivity growth.

In addition, some empirical studies examined the variance of knowledge inputs, measured with University research expenditures, and associated research outputs, such as patent citations (Anselin et al., 1997; Piergiovanni et al., 1997; Becker 2003) and the number of innovations introduced to the market (Feldman and Florida, 1994). Some other studies focus on the impact of R&D expenditure and other external R&D on firm level economy in specific. For example, R&D expenditure is an important knowledge input to the firm's performance in some studies (Arundel and Geuna, 2001). Using multiple regression analysis, the research shows that University R&D expenditures are significantly related to new firm formations (BJK Associates, 2002). Medda, Piga and Sigeel (2005) found out that external R&D seems to generate higher returns than internal R&D.

Human Capital

Investments in human capital, namely expenditure in formal education and training, explain the superiority in production of the technically advanced countries (Schultz, 1961). This formal education and training is likely to generate a basic "ability to learn" to personnel, which is vital in the innovation process (Foster, 1987).

These human capital investments are important for firm growth. Layard et al. (1971) point out that in industries where technical progress is rapid, firms lose their markets unless they innovate, and therefore they demand qualified personnel. Similarly Whiston et al.(1980) argue that many highly trained and educated people may be needed to change the design of products, processes and organisations in an environment of rapid technological change. Other authors (Welch, 1970; Bartel and Lichtenberg, 1987; Gill, 1989; Booth and Snower, 1996) argue that in a dynamic context, educated people can take more advantage of available technology and thus be more productive. Accordingly, a shortage of skilled people can result in a failure to develop, or delay in developing, the planned products and the production processes by which they are to be made.

Human capital investments are also important for knowledge flow and innovation process. The increase in human capital enables individuals to perform higher value-added tasks more efficiently and quickly, which translates in higher productivity of labour and capital (Becker, 1964; Barro, 1991; Lucas, 1988). Students and graduates are argued to be important channels through which knowledge is transmitted to the industry (Nelson and Wright, 1992; Murnmann, 2003). Schartinger et al. (2001)'s study with Austrian evidence show that the main knowledge transferring channel between Universities and firms is the mobility of human capital. In addition, using case study material, Senker and Brady (1989) argued the important role of appropriate human resource development strategies to a firm's technological development.

The endogenous growth model has provided two fundamental contributions to growth theory. The first is that the formation of knowledge and human capital takes place as a response to market opportunities. The second is that investment in knowledge and human capital is likely to be associated with industrial innovation in the economy. Although this model is supported with many studies as shown above, it has been challenged in recent years by many authors by arguing that this model fails in explaining the several “paradoxes”.

Some scholars have argued that it is not investment in knowledge that spurs growth. The commercialisation of the results that knowledge produces, is the critical facet of the economic growth (Acs et al., 2009; Audretsch and Keilbach, 2008; Braunerhjelm et al., 2010). The simple correlation between R&D expenditure and GDP growth reveals no systematic relationship. Therefore, this model faces difficulty to explain why countries such as Japan and Sweden with larger R&D stocks and investments grew so slowly during the last few decades. In contrast, other countries with less endowed knowledge, such as Denmark and Ireland, experienced persistent and high growth rates. The role of human capital to growth is also critically argued. Jones (1995) questions the empirical validity of the endogenous model. He argues that in the United States, the number of R&D scientists and engineers has increased sharply over the post-war period, whilst (TFP) growth has been characterized by relative constancy.

2.2.4 The Knowledge Spillover Theory of Entrepreneurship

The endogenous growth theory is the recognition that investments in knowledge and human capital endogenously generate economic growth through the spillover of knowledge. However, this theory does not explain how or why spillovers occur. Schumpeterian entrepreneurship and its role in knowledge commercialisation remain absent in the endogenous models. It is commonly believed that the endogenous growth models need to take the spillover of knowledge and knowledge commercialisation as a consideration.

According to Schumpeter's growth model, an idea or scientific principle is not, by itself, of any importance for economic practice. In fact the inventor produces ideas, and the entrepreneur gets things done. The entrepreneur is the main vehicle to move an economy forward from static equilibrium through innovations. It is also argued that the entrepreneur is an agent that reduces transaction costs (Williamson, 1975). These early theories build the base of the entrepreneurship's role in economy.

In recent studies, entrepreneurship is recognised as an "opportunity seeker" contributing to innovation. As argued in some studies, despite modest R&D investments, small and entrepreneurial firms contribute substantially to aggregate innovation (Audretsch, 1995; Feldman and Audretsch, 1999). Venkataraman (2000) suggests that it comprises the analysis of "how, by whom and with what effects opportunities to produce future goods and services are discovered, evaluated and exploited". Similarly, Wennekers and Thurik (1999) mention that the entrepreneur is innovative, who perceives and creates new opportunities. In 2005, Laster defines that a modern synthesis of the entrepreneur is someone who specializes in taking judgmental decisions about the coordination of scarce resources. The most important role of entrepreneurship here is the opportunity for the exploitation and commercialisation of the knowledge. Entrepreneurship has the ability and persistence to make change. Audretsch (1995) demonstrates that many radical innovations have been introduced by new firms rather than by incumbents, and the set-up of one's own business might be the most promising possibility to commercialise knowledge. From this evidence, it can be seen that the modern theory of entrepreneurship agrees that the innovation result and business success depend largely on the entrepreneur's ability in exploiting opportunities.

A group of empirical studies have examined the role of entrepreneurship in the economy growth. Based on the study of OECD countries, Thurik (1999) provids empirical evidence that increased entrepreneurship, as measured by business ownership rates, was associated with higher rates of employment growth at the country level. Similarly, Carree and Thurik (1999), and Audretsch et al. (2002) find that OECD countries exhibiting higher increases in entrepreneurship also have experienced greater rates of growth and lower levels of unemployment. Acs et al. (2004) and Braunerhjelm et al. (2007) find a positive relationship between entrepreneurship and growth at the country level while the importance of R&D seems to diminish 1990s. The results in the studies undertaken by the Global Entrepreneurship Monitor (GEM) Study (Reynolds et al., 2002) suggest that the growth of countries is positively associated with an entrepreneurial advantage.

Holtz-Eakin and Kao (2003) analyse the impact of entrepreneurship on productivity change over time. This study finds out that a firm birth rate is related to positive changes in productivity. In addition Audretsch and Fritsch (1996), and Fritsch (1997), implementing data on Germany from the 1980s and beginning of the 1990s, fail to detect any evidence of entrepreneurship augmenting growth. However, re-running their estimations for a later time period, Audretsch and Fritsch (2002) found that regions with a higher firm start-up rate exhibited higher growth rates. Their interpretation was that Germany had changed over time, implying that the engine of growth was shifting towards entrepreneurship. Callejon and Segarra (1999) use a data set of Spanish manufacturing industries between 1980-1992 and discover that both new-firm start-up rates and exit rates contribute positively to the growth of total factor productivity. Braunerhjelm and Borgman (2004) find similar effects of entrepreneurship to labour productivity by using Swedish data.

Accordingly, recent knowledge spillover theory of entrepreneurship (Acs et al., 2003; 2006; 2009), argues that the endogenous growth model needs to be modified in order to incorporate the knowledge filter constituting a wedge between knowledge and economic knowledge. This theory posits the existence of a “knowledge filter” between investment in new knowledge and its economic exploitation. It highlights how the entrepreneur influences knowledge spillover and how knowledge thereby can be filtered and substantiated into business activity. According to the nature of the research, public research primarily generates knowledge which does not aim to direct commercialisation. In contrast, industrial R&D usually focuses on the commercial ends. It is seeking to apply knowledge and transform it into marketable products or methods of production. In the knowledge spillover theory of entrepreneurship, the entrepreneur is seen as the main mechanism that ensures both the flow of radical technological change into the economy, and the economic exploitation of the knowledge. It consistent with Audretsch (1995)'s argument by saying that entrepreneurial activity, in terms of taking the opportunity and setting up a business, can be assumed as a mechanism by which knowledge spillover occurs. Founders of the new ventures might have worked for incumbent firms or research establishments before they realized the opportunity with these past experience and networks, and that they are capable of sourcing the knowledge they need for innovation. Through their innovative activity, new ventures may introduce new products or even create new markets. It is said that many radical innovations have been introduced by new firms rather than by incumbents (Audretsch, 1995). Growth is enhanced through individual entrepreneurs exploiting knowledge, even though they are not producing knowledge. Many studies support the argument that public and University research generate positive externalities to the private sector in the form of knowledge spillovers that stimulate technological innovation and productivity (Colomo et al, 2006; Mueller, 2005; Beise et al, 1999).

The knowledge spillover theory of entrepreneurship also argues that the process of starting a new firm commercialises knowledge that might otherwise not be commercialised. The evidence can be seen in studies which have shown that knowledge spillovers do not occur automatically (Anselin et al., 1997 and 2000; Audretsch and Feldman, 1996). In fact, recent waves of empirical evidence linking measures of entrepreneurship activity to economic growth (Plummer and Acs, 2004; Varga and Schalk, 2004; Acs and Varga, 2004; Audretsch and Keilbach, 2004), and most of these studies find out that knowledge spillover activities by entrepreneurship positively affect technological change and economic growth. Jaffe et al. (1993) argues that the knowledge spillovers reflect the benefits firms can have in accessing knowledge that, intentionally or unintentionally, spills over from other firms and knowledge institutions. Therefore, the existence of localised knowledge spillovers is one of the most important explanations for regional differences in innovation (Jaffe et al., 1993).

The key point emphasised in the knowledge spillover theory of entrepreneurship is that, generating knowledge and human capital may be a necessary condition for economic growth, but it is not sufficient. Entrepreneurship policies are important instruments to promote growth. Appropriate entrepreneurship policies need to target the spillovers of knowledge and focus on enabling the commercialisation of knowledge. Such policies are likely to reduce the filter and build a bridge between R&D and commercialised knowledge, or between knowledge and economic knowledge. Examples of such policies include encouraging new-firm start-ups. Entry of new small businesses not only drives competition among firms (Geroski, 1999), forces incumbents to make efficient use of resources (Baumol et al., 1988), fosters innovation of incumbents (Geroski and Jaquemin, 1984), but also acts as a major mechanism of new market creation through the commercialisation of innovation (Audretsch, 1995; Prusa and Schmitz, 1991). It is observed that small newly-created companies have certain market advantages with regards to new technologies (Stankiewicz, 1986).

Since new firms by definition have done no R&D of their own (Acs and Audretsch, 1988), there are always questions arising regarding the way potential entrepreneurs get access to the technological and entrepreneurial knowledge necessary for generating innovations. According to the knowledge spillover theory of entrepreneurship, one important mechanism is that knowledge is diffusing in various knowledge networks for possible exploitation by other economic agents, rather than those who created it. This may be because individual economic agents differ in their capacity to discover, create and exploit innovations. The main difference among economic agents is in the integration of personal, social and professional networks (Birley, 1985; Aldrich and Zimmer, 1986; Szarka, 1990). These networks are important for the knowledge flow and commercialisation. Entrepreneurs generate an entrepreneurial act of organising resources based on these networks to initiate commercial activity. In addition, as an opportunity seeker, the endeavour of entrepreneur is to respond to rapidly changing external environment (Nijkamp, 2003). Thus entrepreneurs always keeps an eye out for the potential knowledge which is created but not sufficiently used by public research or other companies. Entrepreneurship activity therefore is argued as the best way to appropriate returns from such mixtures of technological and entrepreneurial knowledge (Bhide, 1999).

The knowledge spillover theory of entrepreneurship challenges the two fundamental assumptions in endogenous growth models. There are two main contributions of knowledge spillover theory of entrepreneurship. Firstly, it explicitly introduced a transmission mechanism that determines the rate at which the stock of knowledge is converted into economically useful firm-specific knowledge. Secondly, it developed a model that demonstrates the role of entrepreneurship in the exploitation of knowledge.

From the above literature, it can be concluded that when discussing the impact of knowledge to economic growth, the role of entrepreneurship as an agent which exploits the spillover of knowledge, could not be neglected. However, the above review only focuses on the theory development regarding to knowledge and growth, when in practice the flows and spillovers of knowledge usually take place through the innovation system. How knowledge contributes to the innovation and economy can be revealed by distinguishing the relationships and networks among each agent in the knowledge system. This system, and the knowledge processes involved in it, will be discussed in due course.

2.2.5 Discussion and Theory Weaknesses

The main arguments and weaknesses of theory regarding to knowledge-based growth are summarised with the table below. According to these arguments and weaknesses, some research gaps (G3-G5) are found.

Table 2.2: Summary of Knowledge Based Growth Theory Literature

Literature	Theory and Model	Author	Argument	Model Weakness	Research Gap
Knowledge Based Growth Theory	● Neo-classical Growth Model	Solow (1956); Swan (1956); Cass (1965), and Koopmans (1965); Based on (Cobb–Douglas, 1947)	Long-run rate of growth is exogenously determined	W2.1 Does not explain how and why technological progress occurs	G3: Not clear address the role of knowledge investment on growth model
	● Schumpeterian Growth Model	Schumpeterian (1942, 1947)	Entrepreneur's role of opportunities exploitation; Innovation as a resource of growth	W2.2 No explanations on where the opportunities come from	G4: Not explain how and why the technological progress occurs, and No emphasis the role of entrepreneurship in knowledge system
	● New Growth Theory (Endogenous Growth Theory): First Generation of Endogenous Growth Model	Romer (1986); Lucas (1988); Rebelo (1991); and others	Explicitly introduce knowledge into models of growth, and knowledge is endogenous	W2.3 Little attention to how spillover take place	
	● New Growth Theory (Endogenous Growth Theory): Second generation of Endogenous Growth Model — Semi endogenous Model; Fully Endogenous Model	Schmits (1989); Segerstrom, Anant and Dinopoulos (1990); Segerstrom (1991); Aghion and Howitt (1992); Segerstorm (1995)	Does not mention the knowledge commercialisation; Entrepreneur remains absent in these models; Shows no evidence that R&D will turn into successful innovations	W2.4 R&D will turn into successful innovations W2.5 Does not mention the knowledge commercialisation; Entrepreneur remains absent in these models	G5: Not fully explain where the entrepreneurial opportunities come from and no framework of growth based on University knowledge spillover
	● The Knowledge Spillover Theory of Entrepreneurship	Acs, Audretsch, Braunerhjelm and Carlsson (2003); (2006); (2008)	Identify the entrepreneurship's role in spillover of knowledge; introduce the mechanism in converting new knowledge to economic knowledge	W2.6 Does not have a framework to clear model and measure the integration of entrepreneurship with knowledge system, especially the relationship with knowledge creators	

In the knowledge based growth theory part, the main models of growth and the evolution of these models are discussed. The Schumpeterian growth model firstly mentions the role of entrepreneurship in innovation and growth theory. The neo-classical growth model assumes the long-run rate of growth is exogenously determined by some factors, which include knowledge input. In addition, new growth theory explicitly introduces knowledge into models of growth and considers the knowledge as endogenous or partly endogenous. Endogenous knowledge is considered to raise the returns on investment, which can in turn contribute to the accumulation of knowledge. It is developed to explain the knowledge as an endogenous force which drives long-term economic growth. Thus the knowledge spillover theory of entrepreneurship is built to fill the gap between new knowledge and its economic exploitation. It highlights how the entrepreneur influences knowledge spillover and how knowledge thereby can be filtered and substantiated into business activity.

There are however some weaknesses found in each model. The neo-classical growth model does not explain how and why technological progress occurs. The Schumpeterian growth model has no explanation as to where the opportunities come from. The first generation of endogenous growth model pays little attention to how spillovers take place, and the second generation of endogenous growth model shows no evidence that R&D will turn into successful innovations, and does not mention much about the knowledge commercialisation role of the entrepreneur. It is argued that the endogenous growth model needs to be modified in order to incorporate the knowledge filter, constituting a wedge between knowledge and economic knowledge. The knowledge spillover theory of entrepreneurship does not have a framework for a clear model to measure the integration of entrepreneurship within the knowledge system, especially with regards to the relationship with knowledge creators such as Universities.

The new-classical growth model struggles to explain how and why the technological progress occurs, and new growth theory neither has attention on how knowledge spillovers take place, and does include the influence of entrepreneurship. Therefore it is argued that the endogenous growth model needs to be modified in order to incorporate the knowledge filter constituting a wedge between knowledge and economic knowledge (G4). The knowledge spillover theory of entrepreneurship highlights how the entrepreneur influences knowledge spillover, and how knowledge thereby can be filtered and substantiated into business activity. However, this model does not specifically consider the University's role as a resource of knowledge spillover, although the knowledge creator role of a University is always emphasised in regional economy. More particularly, this model does not fully explain where the entrepreneurial opportunities come from, with no framework of growth based on the University knowledge spillover (G5). In addition, the consequence of knowledge investments (i.e. "physical investment" such as R&D expenditure, and "mental investment' such as human capital) and its role in the growth model are being debated. The exogenous model considers these investments as the exogenous factor which contributes to economic growth, whilst the endogenous model considers that these investments are more likely an endogenous reason for total factor productivity. Their direct or indirect effects on growth are still unclear, and these effects may need to be revealed under the context of the knowledge system (G3).

2.3 Knowledge System

This part of the literature focuses on the introduction of knowledge system, with the discussion of the theory's main arguments, weaknesses, and research gaps generated according to them. It contains four elements in detail, including national innovation system; regional innovation system; Model 2 concept; and the Triple Helix Model.

2.3.1 National Innovation System

Some studies summarise the traditional linear model of innovation, and conclude that this model presents a static snapshot of technology performance, neglecting the interaction of various actors in the innovation process (Godin, 2006; Balconi et al, 2010; etc). National Innovation System (NIS), however, is developed to assess the flow of knowledge and technology among people, firms, companies and research institutions. NIS argues the key to the innovative process is on the national level.

Since national innovation systems are composed by agents who affect the knowledge creation, dissemination, and utilisation, innovation is considered as the result of complex relationships amongst agents in the system, including firms, Universities and public research institutions (Edquist, 1997). Within this framework, economic theory and empirical research have focused on inter-firm research collaborations (Hagedoorn et al., 2001), user-producer networks (Lundvall, 1992), or linkages between competing firms (von Hippel, 1988); and between firms and public research institutions such as Universities, government laboratories, and publicly-funded technical institutes (Mansfield, 1991; Mansfield and Lee, 1996; Pavitt, 1991).

In the national innovation system, Universities are widely cited as a critical institutional agent (Nelson, 1993). The literature on national innovation systems emphasizes the importance of strong linkage among various institutions and industry in improving national innovation. This emphasis applies in particular to Universities. The national innovation system (Nelson, 1993; Lundvall, 1992) also stresses the capability of firms to innovate by exploiting the knowledge flow through knowledge linkage (Kline and Rosenberg, 1986; Freeman, 1987). The empirical evidence shows that both formal knowledge flows and unintentional knowledge spillovers have substantial contributions to firm innovation and to public welfare (Arundel and Geuna, 2001).

The national innovation system shifts the linear concept of a knowledge system to a web of interaction relationship, however it is to an extent too broad without the focus on tacit knowledge spillovers, which is constrained to a series of localised factors. In addition, although the national innovation system covers most actors and relations in the knowledge system, it is also too fuzzy to explain the specific relations between knowledge agents.

2.3.2 Regional Innovation System

Since the early 1990s, the concept of the regional innovation system (RIS) has been gaining much attention from policy makers and academic researchers. Some authors (e.g. Asheim and Isaksen, 1997) consider the region as the most appropriate scale to sustain innovation-based learning economies. Extending a national innovation system to a more localised perspective, the regional innovation system is closely related to the emergence of regional clusters of industrial activity.

Similar to a national innovation system, a regional innovation systems is commonly understood as a set of knowledge agents and linkages connecting them. These relationships are conducive to the knowledge creation, dissemination and utilisation but within the constraint of a region. The importance of the regional scale resources and knowledge in stimulating the innovation and growth has been demonstrated in many studies (Asheim et al., 2003; Cooke, 2003; Wolfe, 2003; Isaksen, 2002; Malmberg and Maskell, 2002).

Cooke and Schienstock (2000), and Cooke (2001) have proposed two distinct definitions of a region. In the first definition, a region is described as a geographical area with knowledge agents and innovative networks. The region here is represented by human settlements such as towns, cities and metropolitan regions, providing different instances of functional regions. The diffusion of knowledge takes place within the spatial knowledge networks (Batten et al., 1989; Kobayashi, 1995). The second definition gives an emphasis on the cultural aspects of the region. In this sense a region need not have a determinated area or size. It could be homogenous in terms of specific criteria, such as a particular kind of association or internal cohesion.

In the regional scale, it is observed that there are networks linking research institutions, firms, and individuals. These networks include not only channels of formal knowledge flow, but also contain the informal knowledge flow channels. It is pointed out by the OECD's report (1997) that the smooth operation of innovation systems depends on the fluidity of knowledge flows. The regional perspective highlights the importance of spatial proximity (Bochma, 2005; 2006) to the knowledge flows and spillovers, especially to tacit knowledge spillovers through informal channels. Proximity matters because direct, personal contacts allow firm access to knowledge gatekeepers to discover where and how to access the new knowledge. It implies that knowledge is disseminated more efficiently within the regional scale, and economic activity based on new knowledge has a high propensity to cluster within a geographic region (Audrecht, 1998).

Regional innovation system results in the emergence of concepts such as a "learning region" (Morgan, 1997; Florida, 1995) and a "technological cluster" (Fallah and Ibrahim, 2004). The first one argues that firm specific competencies and learning processes are based on localised resources, skills and institutions, share common social and cultural values, and can lead to regional competitive advantages (Maskell and Malmberg, 1999).

However according to the proximity theory, there are also some side effects of this regional scale system. Boschma (2005) suggests that the importance of geographical proximity cannot be assessed in isolation, but should always be examined in relation to other dimensions of proximity (cognitive, organisational, social, institutional and geographical proximity). In addition, he points out that too much proximity may result in the regional lock-in effect. Not only too little, but also too much proximity may be detrimental to interactive learning and innovation. In addition, regional proximity can be broken down in some cases. For example, some authors argue that the development of Information and Communication Technology (ICT) have changed the spatial organisation of business activity and their location. It lowers costs for codifying knowledge and reduces the need for proximity, while increasing the ability of firms to obtain knowledge from outside (Castells, 1995; Imai 1991; Antonelli 1999; Roberts, 2000).

2.3.3 Model 2 Concept

The “Mode 2” concept of research is originally identified by Gibbons and his colleagues (Gibbons et al., 1994). It is a conceptual framework that has been applied to describe the role of academic research in modern innovation systems. Despite the previous system in which academic research institutions were less closely linked with other institutions, Model 2 research is associated with a more collaborative interdisciplinary innovation system. This inter-institutional collaboration and integration with modern innovation systems has been remarked in by Mowery and Sampat, (2005).

In product based innovation, pure academic research norms may face the difficulties in solving problems in real practice. The main idea of the Model 2 concept is to bring multidisciplinary teams together for a period of time to solve specific problems in the real practice. This collaboration is likely to increase the diversity of knowledge inputs required for research, including resources and skills, as Gibbons and other scholars have argued.

Although the Model 2 framework emphasizes the co-operation among agents in innovation system, especially inter-institutional collaboration, it still lacks consideration on research-business relations, and the knowledge flows and spillovers through it.

2.3.4 Triple Helix Model

"Triple Helix" is an evolutionary model which specifically aims to explain the dynamic communication between the University, industry and government (Etzkowitz and Leytesdorff; 1997). Similar to the Mode 2 concept, the triple helix model emphasizes the increased interaction among institutional actors in industrial economy, but the main focus of the triple helix model is how the overlay of interactions in University-industry-government relations reshapes the innovation system.

According to Etzkowitz and Leydesdorff (1995), there are three elements specified in the triple helix model including: wealth generation (industry); novelty production (academia), and public control (government). In this framework, industry is who internalises R&D functions; Universities are who positions themselves in markets; and governments are who make trade-offs between investments in policies and balanced interventions at the structural level (Leydesdorff, 2009). When three elements are involved, complex dynamics can be expected as a result of their interactions. The triple helix model provides a theoretical model to study the complex dynamic relations among University-industry-government. Furthermore, compared with those historical non-linear dynamics, the triple helix model somewhat reduces the complexity by using University-industry-government relations. However, assessing knowledge transfer within a triple helix model is more complex than in a traditional setting since there are multiple actors included in this model, and each with a different goal and agenda. It is argued by Görling (2006) that what is to be considered a success or not may severely contradict between the actors.

The dimension of University-industry relation has been paid much attention in recent years. The main argument here is that research institution is developing organisational capacity not only to produce knowledge, but also to put them into use. There are a few results of real practice brought in with the application of the triple helix model.

First of all, the knowledge spillover via the University-industry relations is demonstrated. For example, Mueller (2005) explores the knowledge filter by considering University-industry relations and firm formation as drivers of economic growth at the regional level. In this study, entrepreneurship and University-industry relations are the proposed knowledge transmission channels, increasing the permeability of the knowledge filter. In addition, the triple helix model encourages Universities to be actively involved in the formation of firms, which results in the emergence of the recent concept of "entrepreneurial University". Companies learn both how to train their employees, and how to manage knowledge from Universities. Moreover, the triple helix model has also been studied in specific cultural or geographical contexts including with comparative studies (Baber, 2001; Sutz, 2000), and shows a conjunction with cluster approach. Thus the triple helix model is considered as a complement to the cluster strategy (Etzkowitz et al., 2004).

There are also some criticisms addressed to the triple helix model. Cooke (2005) criticised the triple helix model as being too abstract, and there is a fuzziness in using the concept with the unit of analysis in cells. Thus for analysing, the triple helix may be less stable and observable. Another weakness of the triple helix model is attributed to the significant differences between the regulations on the basis of industry, academia and government. It would be difficult to create a framework of synergy among these actors (Leydesdorff, 2006a; Li and Yorke, 1975).

2.3.5 Discussion and Theory Weaknesses

The main argument and weaknesses of theory regarding to the knowledge system are summarised in the table below. According to these arguments and weaknesses, some research gaps (G6-G8) are found.

Table 2.3: The Summary of Knowledge Systems Literature

Literature	Theory and Model	Author	Argument	Model Weakness	Gap
Knowledge System	● Linear Model of Innovation	Godin (2006); Balconi et al, (2010); etc.	Linear relationship between knowledge input and output Presenting a static snapshot of technology performance	W3.1 Neglecting the interaction of various actors in the innovation process	G6: No clear framework having a main focus of networks and growth.
	● National Innovation System	Freeman (1987); Lundvall (1988); (1992); Nelson (1993); etc.	Network and linkages between agents in knowledge system Shifting from linear concept of knowledge system to a web of interaction relationship	W3.2 Too broad without the focus on tacit knowledge spillovers W3.3 Too fuzzy to explain the specific relations between actors in the knowledge system	G7: Not consider the regional differences in knowledge systems
	● Regional Innovation System	Asheim and Isaksen, (1997); Asheim et al. (2003); Cooke (2003); Wolfe (2003); Isaksen (2002); Malmberg and Maskell, (1999); etc.	Taking region as the scale to discuss the knowledge based economy and innvation Considering location proximity to explain the tacit knowledge spillover	W3.4 Too much proximity may result in lock-in effect W3.5 Proximity is not always matters since it can be break down in some way W3.6 Regional factor could not be discussed in isolation	G8: Not specifically discuss on the dimension of University-business involvements
	● Model 2 Concept	Gibbons et al. (1994)	Bringing multidisciplinary teams together to solve specific problems Emphasizing the cooperation among agents in innovation system, especially inter-institutional collaboration	W3.7 Without consideration on research-business interaction	
	● Triple Helix Model	Etzkowitz and Leydesdorff (1994); (1995); (1997); Leydesdorff (1998); (2000); etc.	Interconnections between the University, industry and government Categorising the relations between main actors in the knowledge systems and the role of University in driving the innovation is enhanced	W3.8 Too abstract and difficult to synergy between agents	

Considering knowledge with a system's point of view will give a better understanding on how the knowledge can be transferred to innovation and growth. There are a few stages in the model development of knowledge systems. The early model of knowledge system is based on the linear relation between knowledge and its consequences. Since the 1980s, a group of studies take the National Innovation System's (NIS) account to explain how the knowledge transfers to innovation. This thinking switches the linear relationship to the networks and linkages among the knowledge agents. It focuses on the interactions between different knowledge agents in the knowledge process, including knowledge creation, dissemination, and utilisation. Extending the innovation system to a regional scale, the regional innovation system is based on the localised knowledge networks and interactions. It also provides a specific focus on the informal knowledge flow channels and the tacit knowledge. Geographical proximity plays a key role in regional innovation systems in terms of localised knowledge activities and tacit knowledge spillover. In addition, Model 2 extends an idea of collaboration among agents in the innovation systems. The Triple helix model more specifically structures the various interactions in a knowledge system into the relationships between three main agents in the knowledge based economy: governments, industry and Universities.

In this knowledge system part, knowledge is considered with a system's point of view. The theory is developed from an early linear relation-based model to a networks-based model, which focuses on the interactions among different knowledge agents in knowledge process. However there are some weaknesses found in each model of the knowledge system. The national innovation system framework is too broad without the focus on tacit knowledge spillovers, and too fuzzy to explain the specific relations between actors in the knowledge system. The regional innovation system has some problems in clearly addressing the role of geographical proximity such as those effects based on the "degree of proximity". In addition, the regional factor could not be discussed in isolation. Model 2 Concept does not consider research-business specific interaction. The Triple Helix Model could be too abstract, and has difficulty with regards to synergy between agents in the regional system of innovation.

Since the national system of innovation is argued to be too broad and fuzzy to explain why and how the tacit knowledge spillovers, there is a need to extend the innovation system to a regional scale based on the localised knowledge networks and interactions. Although the regional innovations system theory tries to cover elements of local networks, there is no clear framework for these regional networks involved in the process of transferring the knowledge to growth (G6). In addition, Model 2 extends an idea of collaboration among agents in the innovation systems. The triple helix model more specifically structures the various interactions in a knowledge system into the relationships between three main agents in the knowledge economy - government, industry and Universities. However, there are no specific discussions on the relationship between the University and business (G8). The University's role in regional innovation needs to be discovered, especially these activities which contain knowledge spillovers from University to business. In addition, each region has their unique pattern knowledge proximity involved in their knowledge systems, and it results in the differences in interaction between knowledge agents. However, little evidence is found in current literature considering these regional differences in knowledge systems (G7).

2.4 University Role and Paradigm

This part of the literature focuses on the introduction of a University's role and paradigm, with the discussion of the theory's main arguments, weaknesses, and research gaps generated according to them. It contains three elements in detail, including the mission of the University, the University paradigm, and University activity.

2.4.1 Mission of University

Recent research is defined as scientific research performed in and supported by governmental, academic and charitable research institutions (Narin et al., 1997). As one of the most important components of public research, Universities share the four main functions of public research in the innovation process, which are identified by Kauffeld-Monz (2005): generation of new knowledge; accumulation of this knowledge and of knowledge originating elsewhere; transmission and transfer of all knowledge accumulated; the conversion of research results in innovation. In practice, Universities usually accomplish different activities involving knowledge creation and dissemination, such as teaching, research, product development and consultancy (Nelson, 1993; Gibbons et al., 1994; Edquist, 1997).

Universities are a capital agent of technical advance, not only as scientists and researchers but also as source of knowledge and techniques. Mowery (2005) points out that University research produces various outputs, including scientific and technological knowledge, equipment and instrumentation, human capital and skills, knowledge networks, and prototypes for new products and processes. Some scholars such as Feller (2004) argue that Universities need to focus on the main task of knowledge creation if they aim to increase knowledge commercialisation, while others argue that developing more effective mechanisms for knowledge dissemination to both private and public sectors is more important (Stoneman and Diederen, 1994). Moreover, in addition to existing teaching and research missions, Etzkowitz and Zhou (2006) illustrate a "third mission" of Universities to balance the creation and dissemination of knowledge. Accordingly, in recent years the role of the University is undergoing a series of changes and expansion. It aims to adjust to a better engagement with other agents in the innovation system.

The crucial role of the University in the economy is supported in many studies. Some state the importance of the transfer of University technical knowledge to the industrial growth (Audretsch and Stephan, 1996; Zucker and Darby, 1997). Other studies (Cooke, 2004; Fritsch, 2002) mention the mission of Universities in driving innovation as a core knowledge producing entity. A University is also argued to be the main source providing knowledge for industry and business (Foray and Lundvall, 1996; Garlick, 1998; Kitagawa, 2004; Thanki, 1999). Moreover, a University is recognised by Florax (1992) as a "regional boosters of knowledge" by fostering high quality human capital, which is the determinant factors for knowledge dissemination.

In the innovation system, the role of a 'research University' is especially emphasised. A research University is defined by Karlsson and Andersson (2009) as an institution that is in competition with other similar institutions to generate and disseminate knowledge, with the objective to achieve eminence, reputation and prestige. To achieve this objective these Universities compete for highly reputed faculty. Walshok (1997) argues that research Universities not only carry out research and teaching activities, such as developing new knowledge and training individuals, but also serves the knowledge to regional communities by providing economic, social, cultural, and organisational knowledge.

There is growing literature providing empirical evidence to support the existence of knowledge externalities in regions surrounding research Universities (e.g. Acs et al., 1992; Jaffe et al., 1993; Anselin et al., 2000; Woodward et al., 2003). This evidence is also consistent with the main argument of knowledge cluster theory, which emphasizes the central role of the research University in the cluster to innovation. Some regions with a central research University have experienced successful growth in the last few decades. Examples can be seen as Stanford University to Silicon Valley, MIT and Harvard University to Route 128, and Cambridge University to the Cambridge region (Saxenian, 1994; SQW, 2000). In the UK, the Russell Group of Universities represents the 20 major research-intensive Universities. These institutions influence and achieve impact on a global scale. In addition, as vibrant and dynamic organisations, they actively contribute to their local communities and economies. Russell Group Universities create and catalyse a big ranges of economic activity, which have a significant contribution to the economy of the UK.

In is mentioned in Russell Group Papers (2010) that by the quality of their research and teaching, Russell Group Universities successfully attract international investment in the UK from global research-intensive companies. Russell Group Universities also play a vital role in the development of the regional human capital. For example they support professional development to businesses. In addition, these Universities focus on the interaction with industry, and local firms gain competitive advantage through collaborating with Universities on research and research-based activities. Many firms access the expertise of Universities through and business community services such as consultancy. Moreover, these research Universities also actively establish spin-off companies to encourage the commercialisation of University research.

2.4.2 University Paradigm

Although the research University is one of most important models of Universities, it is argued that modern University paradigms could expand to other models according to their embedment within regional context. Morgan (2002) makes a distinction between the “elite model” of University, which focuses on publishable research and global issues, and an “outreach/diffusion oriented model”, which focuses on teaching, the building of social capital, and local issues. He also argued that to be an outreach, a wider view of the University needs to be recognised. More than just a place of learning and research, the University must act as catalyst for civic engagement and collective action and networking.

Based on this argument, there is a group of studies regarding University paradigms that have taken place which are trying to discover different focuses of Universities in different models of University. Braun (2006) provides a model by considering the role of the University in terms of the traditional role and entrepreneurial Universities. Abreu et al. (2008) stress the diversity of Universities with research Universities and business-facing Universities. Sauer et al. (2007) particularly study the University knowledge transfer activities, including oriented on human capital, classic research and development, enterprises, direct transfers, and informal knowledge transfer channels. Similarly, Hewitt-Dundas (2008) also carries out research to see the differences between Universities in their knowledge transfer, but with the paradigms of post-1992 Universities, group 1994 Universities, and Russell Group Universities.

Most of these literatures agreed that different University activities have different focuses. Thus their impact on the economy could be various. As the variety of knowledge transfer channels between Universities and other agents in the innovation system, it is important to distinguish these different roles to find out the potential that individual Universities may play in their regional economies. According to Lester (2005), this diversity in paradigm reflects a University's particular mission, as well as the various local economic development pathways, and the role the University chooses to play in relation to them.

The studies and frameworks of University paradigm are summarised in the table below.

Table 2.4: Studies of University Paradigm

Studies	**University Paradigms**	**Context**
Morgan (2002)	University Paradigms: ● Outreach/diffusion oriented Model ● Elite Model	Wales Case Study
Braun (2006)	The Role of University: ● Traditional role ● Entrepreneurial Universities	Analysis of two competing approaches
Abreu et al (2008)	Diversity of Universities: ● Research Universities ● Business-facing Universities	UK study
Sauer et al, (2007)	University knowledge transfer activities: ● Oriented on human capital, ● Oriented on classic research and development ● Oriented on enterprises ● Oriented on direct transfers ● Informal knowledge transfer channels	German Study
Hewitt-Dundas (2008)	Differences between Universities in their knowledge transfer: ● Post 1992 Universities, ● Group 1994 Universities ● Russell Group Universities	UK study (HE-BCI and CIS4) Contract Research Income Consultancy Income Facilities and Equipment CPD/CE Course Income IP Income

It is said that the new form of economic competition changes the function of Universities dramatically. They have to - in addition to their traditional role as sources of ideas, knowledge and intellectual capital - become agents of innovations, i.e. entrepreneurial Universities, enhancing regional development and international competitiveness. The transformation of University-produced knowledge into market-oriented innovation depends on the quality of academic entrepreneurship in knowledge dissemination and spillover (Braun, 2006). Most academics agreed that these activities of the Universities for the region are embedded into important local transfer channels (Lawton Smith, 2007). It is possible therefore that stronger support of the University faculty's activities, establishing knowledge transfer, could increase the regional economic impact. The recognition of a University's role expands from the traditional mission of knowledge creation, to knowledge outreach.

2.4.3 University Activities

University has traditionally provided knowledge of know-how (skills and capability) and know-why (general principles and laws). Modern Universities expand their role into know-what (facts) and know-who (establishing collaborative relationships) by also focusing on knowledge commercialisation, consultancy services and collaborative relationship (Charles, 2006).

Traditionally, Universities provide trained graduates and scientific knowledge, irrespective of the regional demand (Bercovitz 2006). In modern Universities, two basic functions of teaching and research have been complemented by proactive engagement in research collaborations with other agents in the regional knowledge system. This activity particularly focuses on the knowledge spillovers from University to localised firms, to meet the regional development needs. Thus Universities have become more entrepreneurial, to mutate into agents of innovation. This transition results in the emergence of phenomenon in recent decades such as entrepreneurial Universities (Etzkowitz et al., 2000; Powers, 2004; Slaughter and Leslie, 1997; Smilor et al., 1993), academic entrepreneurs (Meyer, 2003; Shane, 2004), technology clusters, knowledge transfer offices, University-industry research centres and incubators (Carree et al., 2011). These activities are highly involved in venturing and knowledge commercialisation such as the establishment of spin-off firms, and the exploitation of intellectual property rights (D'Este and Patel, 2007; Huggins, 2008). The modern Universities are now realised as multi-product organisations, as they are more important than ever in providing knowledge, human capital, and innovations for a region (Braun, 2006). These changes allow the University to respond to industrial R&D and regional innovation more quickly and effectively.

It is argued by Karlsson and Andersson (2009) that in many countries institutions of higher education have been upgraded to modern University status. The set of activities and outputs of modern Universities is summarised by Luger and Goldstein (1997), including the creation of new basic knowledge though research; the creation of human capital through teaching; the transfer of existing know-how to businesses, governmental agencies, and other organisations; the application of knowledge to the creation and commercialisation of new products and processes, or the improvement of existing ones; capital investments in the built form, and in equity in private businesses; leadership in addressing critical local problems; co-production (with other R&D organisations) of a regional knowledge infrastructure; the creation of a certain kind of regional milieu favourable to innovation. The details are shown in the table below:

Table 2.5: The Activities of Traditional University and Modern University

Traditional University	**Modern University**
Education; Research; Training	Creation knowledge; Creation of human capital; The transfer of existing tacit knowledge; The application of knowledge to the creation and commercialisation of new products and processes, or the improvement of existing ones; Capital investments in the built form, and in equity in private businesses; Leadership in addressing critical local problems; Co-production of a regional knowledge infrastructure; The creation of a certain kind of regional milieu favourable to innovation
Broad Way	Focus on the regional level

Based on the source: Luger and Goldstein (1997)

In summary, in addition to its broad focus and basic function of education, research and training, Universities now expand their role as a regional centre of innovation, which drives and supports various innovative activities for the region and surrounding area.

2.3.4 Discussion and Theory Weaknesses

The main arguments and weaknesses of theory regarding to the University role and paradigm are summarised in the table below. According to these arguments and weaknesses, some research gap (G9-G11) are found.

Table 2.6: Summary of University Role and Paradigm Literature

Literature	Theory and Model	Author	Argument	Model Weakness	Research Gap
University Role and Paradigm	• University Role	Smilor et al. (1993) Slaughter and Leslie, (1997) Etzkowitz et al. (2000) Powers (2004) Charles (2006) Bercovitz (2006)	Traditional role to Third Mission Regional involvement	W4.1 Only broad concept model	G9: Theory model without clear measurements and direct evidence G10:No discussion to applicability of each paradigm, and activities details G11: Not cover the implication of how each paradigm involve with regional knowledge innovation system
	• University Paradigm	Morgan (2002) Braun (2006) Abreu et al (2008) Sauer et al, (2007) Hewitt-Dundas (2008)	Research University/ Business Facing University Elite University/Outreach University	W4.2 Model framework lack of classification details	
	• University Activities	Luger and Goldstein (1997) Karlsson and Andersson (2009)	Teaching, research, training Knowledge creation and dissemination	W4.3 various activities but with no framework and indicators to measure	

In this University role and paradigm literature, a University's traditional role, modern role and the changes of the role are shown. The main task of traditionally University in education and research In modern Universities, these two basic functions have been complemented by engagement in research collaboration with other agents in the regional knowledge system. The modern Universities are now realised as multi-product organisations which not only create the knowledge but also diffuse it. This is also a distinction between "elite model" of University, which focuses on publishable research and global issues, and an "outreach/diffusion oriented model", which focuses on teaching, building of a social capital and local issue. The activities of a University not only contain teaching, research and training, but also the knowledge dissemination functions which serves to regional business.

However, these University theories are only a broad concept model. The model framework neither focus much on the University classification details, nor on the indicators of University activities. Accordingly, some research gaps are generated based on these weaknesses in the model. First of all, there is not much direct empirical evidence to show the pattern of different paradigms in the knowledge systems respectively (G9). In addition, not only the paradigm itself, but also the applicability of different paradigms and functions, need to take part to generate the best innovation performance, but there is a lack of discussion with regards to the applicability of each paradigm in this field (G10). When discussing the role of the University in regional growth, the involvement of University in a regional knowledge system counts. However, the literature does not cover the implication of how each paradigm is involved with regional knowledge systems (G11).

2.5 Science and Industry Link

This part of the literature focuses on the review of a science and industry link, with the discussion of theory main arguments, weaknesses, and research gaps generated according to them. It contains five elements in detail, including University-business interaction; technological cluster; knowledge transfer and geographical proximity; regional knowledge absorptive capacity; and channels of knowledge transfer.

2.5.1 University-Business Interaction

According to above literature, innovation system theory emphasizes the important role of University and industry linkage. Modern University paradigms also suggest that although the University paradigm can be varied, regions achieve their best innovation performance when science is involved in the interaction with industry. This gives a new mission to the public research part, to serve the regional industry as a knowledge source and innovation booster.

According to the knowledge spillover theory of entrepreneurship, public research hardly results in any commercial end. The generated knowledge needs to flow to industry to get ready-to-produce innovations. Many studies (Cohen et al., 2002; Spencer, 2001; Mansfield, 1998) have supported that science and industry link is an important mechanism of knowledge flow which encourages the technology transfer and enables businesses to develop new products and process. As one of most important forms of public research, a University’s interaction with business and its role to regional innovation is especially focused in recent years.

Many studies argued the important role of research, in terms of the government lab, University research, and private research to industrial innovation and regional growth. According to some recent studies it has a very important meaning to growth and development. The authors argued that Universities are in a better position than government laboratories to provide the research necessary to stimulate economic growth (Leyden and Link, 2011). The transfer and commercialisation of knowledge and research, residing and undertaken in Universities, has come to be viewed as an increasingly important stimulant of economic growth (Etzkowitz, 1998; Bok 2003), particularly for improving the development capabilities and economic performance of regions (Kukliński, 2001; Wolfe, 2004; Shane, 2004; Braunerhjelm, 2005). Some US-based research tends to have adopted a straightforward production function approach, relating investment in University research to innovative outputs, in terms of incomes from collaboration, IP licensing, and University Spin-offs (Mansfield 1995; Jaffe 1989; Adams 1990, 1993; Acs et al 1992, 1994; Feldman, 1994). Similar studies in the EU (Kaufmann and Todtling, 2001; Arvanitis et al, 2005; Beise and Stahl, 1999; Becker, 2003; Monjon and Waelbroeck, 2003) tend to point to a strong positive link between University research and innovation activity across different industries.

University and business interaction is recognised as vital to facilitate the exploitation of knowledge and the flow of ideas (Mansfield and Lee, 1996; Fritsch and Lukas, 2001; Fritsch, 2001; Belderbos et al. 2004). Becker and Dietz (2004) argue that the University and business interaction influences the probability of new products being developed. This interaction is also shown to ascend the rate of innovation in the economy (Spencer, 2001; Laursen and Salter, 2004). This is the reason why Mansfield (1991) and Beise et al (1999) argue that many industry innovations would not have been taken place without close collaboration with Universities.

The Evidence can be found in many empirical studies on different countries and regions. Narin et al., (1997) show that US industry relies on public science as an external source of knowledge. Broström and Lööf (2004) find out that for the knowledge transmission between Universities and Swedish firms has a positive affect on both innovative input and innovative output. In addition, using the data of Swiss enterprises, Arvanitis et al. (2005) discover that knowledge and University technology transfers improve the innovation performance of firms in terms of R&D intensity, sales of innovative products, and labour productivity. Based on German regions, Mueller (2005)'s study shows that University-industry relations, which are essential transmission channels for knowledge spillovers, have a positive impact on economic growth.

Universities are increasingly recognised as knowledge producing entities which provide knowledge for business and industry. As the role of University and business interaction has become more widely recognised, University engagement with regional business has become a core theme in University mission statements (Lawton Smith, 2007). Business also has a need for interaction with Universities; as Chesbrough (2003) points out, firms no longer innovate in isolation, but through a complex set of interactions with external actors. Adams, Chiang and Starkey (2001) argue that both large companies and small firms may benefit from the interaction with Universities. Similarly, Mueller (2005) finds that University-industry interaction is a channel for both small and large firms to generate, receive, apply and commercialise knowledge.

It is found in many studies that to build their competencies, large companies which operate their own R&D departments also tend to co-operate with public research bodies such as Universities. (Fritsch and Lukas 2001; Mohnen and Hoareau 2002; Laursen and Salter 2003; Busom and Fernández-Ribas 2004). Those Universities having a greater number of linkages with large R&D intensive companies, and have significantly higher levels of research income. On the other hand, companies having a greater number of linkages with Universities invest more in R&D (Huggins et al.,2010). Small firms also benefit from the interactions with Universities in different methods of local knowledge spillover. Perkmann and Walsh (2007) find that University-firm interaction is one of the research-industry engagement modes that has the highest impact to regional growth. Because of the cost and risk, small firms usually choose to access knowledge through informal ways such as face-to-face contacts. They require an extensive amount of local knowledge spillovers and networks. Since Universities are assumed to be important sources of localised knowledge spillovers due to their explicit focus on the generation and diffusion of knowledge (Ponds, van Oort and Frenken, 2010). The interaction between local Universities and small firms becomes an important channel of firm level innovation. This is why some studies argue that (Acs et al., 1994; Henderson et al., 1998; Jaffe, 1989) the importance of a University's knowledge is an important determinant for firms' location choices.

However, there are also some studies doubting the role of this local University-business interaction. Huggins et al. (2008) argue that Universities are often wary of engaging with SMEs, which they often regard as inferior and less lucrative collaborators compared with larger R&D intensive companies. Universities are often wary of engaging with a business community dominated by SMEs, which they often regard as inferior and less lucrative collaborators and partners in comparison to larger and more internationally focused and R&D intensive firms (Huggins et al., 2008). Colombo et al. (2006) argue that although knowledge transfer from University to business through interaction, turning it into business innovation, may also depend on the firms' capacity for absorption. In fact, firms with low levels of absorptive capacity (Cohen and Lenvinthal, 1990) tend to source the knowledge locally, while those with higher absorptive capacity are often more connected to global networks (Drejer and Vinding, 2005). Monjon and Walbroeck (2003) believe firms could benefit from international collaboration with Universities and public research institutions, whereas there is little evidence for direct spillovers from Universities.

2.5.2 Technological Cluster

Technological cluster is one of the practical phenomena based on the knowledge spillover theory and research-industry interaction. A technological cluster is a geographical concentration of technology firms. These clusters often form surrounding scientific research centres, such as Universities or national labs. Saxenian (1994) underlines the significant impact of the research infrastructure, in terms of knowledge agents and networks within the cluster, on the innovative capacity of the region. There are some successful cases of technological cluster such as Silicon Valley and Route 128 in the US, and the Cambridge region of the UK.

Many researchers have used the term of cluster to study the regional economics and performance. Krugman (1991) shows that cluster provides advantages in terms of specialised labour pools, intermediate goods, and knowledge externalities. Porter (1990) also argues that a cluster provides a mechanism for exchange of information among companies, whilst they maintain their rivalries.

Business benefits from clusters because they offer rich opportunities of knowledge spillovers from Universities, R&D institutes and other R&D intensive companies in the same cluster. Locating business close to those of competing companies is also a way to reduce uncertainty about the behaviour of competitors. However it may involve the risk that competitors might learn from your own R&D-activities. This implies that opposed to the potential benefits of agglomerations, businesses in the cluster may also have potential costs (Karlsson and Andersson, 2009). Thus, there are incentives existing both to cluster and to separate R&D activities of business (Alsleben, 2004).

2.5.3 Knowledge Transfer and Geographical Proximity

Recent years geographical agglomeration of industrial and research activities, as a phenomena can be found in many regions. It has been argued that many achievements of research and industry can be attributed to their spatial surroundings (Jaffe 1989; Acs, Audretsch et al. 1992; Varga 2000; Fritsch and Schwirten 2002).

There are many studies supporting the contribution of public research to firm innovation is localised. For example, Jaffe (1989) states that knowledge spillovers from academic research strongly bounded in space and firm innovation is more likely to be affected by R&D undertaken by Universities within the same region. Some authors demonstrate this idea, and show that knowledge flows and spillovers from their creators to the user usually take place in certain spatial networks (Batten, Kobayashi and Andersson, 1989; Kobayashi, 1995). Similarly, some studies suggest that knowledge flows from public science to companies decline with geographical distance (Jaffe, 1989; Audretsch and Feldman, 1996).

According to Pavitt (2001), not all created knowledge can be fully exploited. It may be because incumbent firms do not want to take the risk combined with new products or processes. Another reason could be that Universities or research institutions hardly ever translated into new products. The remaining knowledge may only flow within the local network, since Harhoff (1997) argues knowledge as properties of a public good, diffuses only within a short distance from the source. It results in the suggestion that only those firms located in a same geographic region as the knowledge creator are able to take advantage of these knowledge spillovers.

Geographical proximity thus matters to these networks which connect the knowledge provider and receiver. There are a large group of investigations in the spatial dimension of knowledge spillovers which confirm the role of geographic proximity as a major determinant of the transfer of knowledge (Audretsch and Feldman 1996; Mansfield and Lee 1996; Autant-Bernard and Massard 2001; Carrincazeaux et al. 2001; Keller, 2002; Audretsch et al. 2005). Some in particular find evidence that proximity is important to the knowledge transfer between University and business (Mansfield, 1991; Mansfield, 1995; Mansfield and Lee, 1996). It infers that although the types of interaction between University and regional business could be varied, they may be constrained to the local proximity too. Adams (2001) argues that proximity is more important for academic R&D than for research conducted by other firms. Geographical proximity of knowledge networks explains why some successful regions have become more competitive than those that have not adopted a localised knowledge network (Storper, 1997; Lawson and Lorenz, 1999; Huggins, 2000; Bathelt, et al., 2004; Knobben and Oerlemans, 2006). Since knowledge sources have been found to be geographically concentrated, location is crucial to innovation.

However, the importance of proximity is argued to be dependent on the forms of knowledge-codified knowledge (e.g. patents and publications) and tacit knowledge (e.g. personal contacts) (Arundel and Geuna, 2001). According to the nature of tacit knowledge, it is not easy to be transferred over long distances. In the innovation process tacit knowledge is frequently exchanged via personal networks. Face-to-face contact is argued as being especially helpful at the beginning stage of a collaboration (Kauffeld-Monz, 2005). Since these personal networks are only concentrated locally, tacit knowledge tends to be geographically concentrated in metropolitan regions as Feldman (1994) and Vence and Rodil (2003) argue. Therefore the geographical proximity matters to the flows of tacit knowledge.

Bottazi and Peri (2003) show that different geographical locations may have differing costs of accessing and absorbing knowledge. Formal collaboration occurs largely at the national or even the international scale (McKelvey et al. 2003; Ponds et al. 2007) because the cost of transferring codified form of knowledge is basically invariant with respect to distance. However, the cost of tacit transfer is the opposite (Jaffe et al., 1993; Feldman 1994). Thus Audretsch et al. (2005) imply that profits of tacit knowledge is greater in agglomerations or spatial clusters, since their access to tacit knowledge is easier.

There are some controversies about the role of geographical proximity to knowledge transfer. Breschi and Lissoni (2001) comment that other factors, such as the economics of knowledge codification, labour markets, and appropriation strategies, could explain the phenomenon of geographical agglomeration. Boschma (2005) points out that geographical proximity itself is neither necessary nor a sufficient condition for knowledge spillovers to occur. He also suggests that the importance of geographical proximity cannot be assessed in isolation, but should always be examined in relation to other dimensions of proximity (cognitive, organisational, social, institutional and geographical proximity). Ponds, van Oort and Frenken (2010) analyse the effect of knowledge spillovers from academic research on regional innovation, and argue that regional innovation is mediated not only by geographical proximity but also by social networks. As Singh (2005) finds, simply being in the same location has little benefit for knowledge spillovers. There is also a need for networked interaction between knowledge creators and other actors. Some studies show that geographical proximity does not always matter. For example, Cowan, David and Forays

(2000) suggest that very little knowledge is intrinsically tacit, in the sense that it is impossible to codify. In fact, the amount of tacit knowledge is able to be codified. Moreover, it is argued by Dahlstrand (1999) that geographical proximity could lose its importance over time as there is some evidence showing it is more important to new firms than to incumbents (Dahlstrand, 1999). In addition, Audretsch and Stephan (1996) and Zucker et al. (1994) show that scientists in biotechnology can have business connections in far away places.

Some research shows that the geographical proximity can be broken down in certain cases, and knowledge spillovers can occur at different geographical scales. Imai (1991), Antonelli (1999), and Roberts (2000) argue that modern information and communication technology lowers costs for codified knowledge transfer, and reduces the need for geographical proximity, but increases the ability of firms to obtain knowledge from outside. Besides informal networks, Ponds et al. (2010) show formal networks of research collaboration are an important mechanism of knowledge spillovers as well. Therefore the University-industry collaboration is not limited to the regional scale. In fact, science-based collaboration is more likely to be based on the presence of specific knowledge rather than on geographical proximity, as Moodysson et al. (2008) argued. If applicable knowledge is available locally, firms and other institutions will attempt to acquire it, and if not they will look elsewhere (Kingsley and Malecki, 2004). Many firms, therefore, do not acquire their knowledge from geographically proximate areas, particularly those firms based upon innovation-driven growth where knowledge is primarily sourced internationally (Davenport, 2005). In addition, Castells (1995) points out that large firms with the financial resources to seek out knowledge anywhere are able to break the geographical proximity (Castells, 1995). Some studies argue that firms with low levels of absorptive capacity (Cohen and Levinthal, 1990) tend to network locally; those with higher absorptive capacity are often more connected to global networks (Drejer and Lund Vinding, 2007).

2.5.4 Knowledge Absorptive Capacity

In addition to geographical proximity, another concept - namely “knowledge absorptive capacity”- is argued to have influenced the innovation performance significantly. This concept was first mentioned in the 1990s. Cohen and Levinthal (1990) assign the term “absorptive capacity” to the general capability of individuals, groups, and firms to recognise the value of new information, how they choose what to adopt, and the apply it to innovation. Jansen et al. (2006) supply this concept with four distinct dimensions of absorptive capacity: acquisition, assimilation, transformation, and the exploitation of external knowledge. Anhaverbeke et al. (2008) stress that innovation and absorptive capacity are connected to each other in a systematic way.

Studies in this field are mainly divided into two scales of knowledge absorptive capacity: firm level and regional level. Cohen and Levinthal (1990) point out that firms’ absorptive capacity determines their ability to in-source externally developed technology or ideas. Firm knowledge of absorptive capacity is furthermore shaped by two factors: on the one hand organisational routines and processes that make internal skills and resources work together (Amit and Shoemaker, 1993; Grant, 1996), and on the other hand power relationships both inside the firm and those with customers and others external stakeholders (Pfeffer, 1981). Bascavusoglu-Moreau and Li (2013) indicate the importance of firms' absorptive capacity in increasing internal capabilities and in benefiting from external knowledge sources. They also highlight the importance of external knowledge and knowledge assets in determining productivity and competitiveness. Cassiman and Veugelers, (2002) argue that internal and external sources of knowledge are complementary, and they have to be combined to improve the innovative performance.

At the regional level, Narula (2004) shows that knowledge absorptive capacity pays particular attention to the growth and development perspectives. There are non-linear inter-relations found between absorptive and technological capacity, external technology flows, and the productivity growth and employment creation. Abreu et al. (2011) find out that differences in absorptive capacity at the firm-level are determinants of regional variations in innovation performance. Differences in firms' absorptive capacity are due to sectional and technological specificities, and both firms' absorptive capacity and sectional structures differ widely across regions . Miguélez and Moreno (2013) investigate the role of regional knowledge absorptive capacity. The capacity determines knowledge flow and impacts on regional innovation intensity. They find evidence from the role of both mobility and networks. It also shows that regional absorptive capacity critically adds an innovation premium to the benefits to tap into external knowledge pools.

Another group of studies agree that entrepreneurship is one of most important part of regional knowledge absorptive capacity. Qian et al. (2012) identify new knowledge as one source of entrepreneurial opportunities, and human capital as the major source of entrepreneurial absorptive capacity. They find that entrepreneurial absorptive capacity is a critical driving force for knowledge-based entrepreneurial activity. High technology and cultural diversity contribute to the vibrancy of regional systems of entrepreneurship. Block, Thurik and Zhou (2012) point out that a high rate of entrepreneurship facilitates the process of turning knowledge into new-to-the market innovation, rather than new-to-the-firm innovation. Paço et al. (2010) emphasised the roles of entrepreneurship education in regional development, yet the connection between adoption of external ideas, invention, and performance has been incompletely specified (King and Lakhani, 2011).

In summary, if proximity provides the pattern of knowledge network and stock intensity, absorptive capacity therefore has regards to the efficiency and potential to transfer the external knowledge to the product through the knowledge network. Not only the knowledge volume, but also the knowledge absorptive capacity matters to the regional innovation performance. However the role of regional knowledge absorptive capacity has only recently been realised and taken into account in the regional innovation system model, and also there is no defined regional scale indicator for the capacity. It still needs solid evidence in empirical studies to show how the knowledge absorptive capacity, together with the regional knowledge system, transfers knowledge to commercial products, innovation, and regional growth.

2.5.5 Channels of Knowledge Transfer

Since the important role of a science-industry link in knowledge transfer is realised, many specific channels for knowledge flow have been introduced in the literature field. Study of these channels not only helps to understand how the knowledge could be acquired, but also provides potential ideas on how to measure the knowledge transfer.

One group of studies is based on the knowledge agents' point of view. For example, channels regarding the knowledge flow between firms are introduced, including inter-firm research collaborations (Hagedoorn et al., 2001), user-producer networks (Lundvall, 1992), and linkages between competing firms (von Hippel, 1988). Similarly, there are also some studies which mention the knowledge flow between firms and public research such as Universities, government labouratories, and publicly-funded technical institutes (Mansfield, 1991; Mansfield and Lee, 1996; Pavitt, 1991). Investigating the academic research and private research with more detail, Adams (2001) provides some methods for obtaining knowledge. The four methods for academic research are outsourcing research, faculty consulting, licensing University patents, and hiring engineering graduates. The other four methods are for private research including outsourcing research, joint research, publications, and patents. Adams also concludes that compared with the knowledge transfer channels between private firms, those channels between academic research and firms tend to be more localised.

Another group of studies focuses on the channels according to the form of the knowledge, respectively codified knowledge acquisition, and tacit knowledge acquisition. Many studies state that codified output of academic research, such as patent and publications, are the most important input to industrial innovation (Narin et al., 1997; McMillan et al., 2000; Cohen et al., 2002). Thus the transfer of codified knowledge is easy to understand, which is usually through channels such as acquisition of a patent, or citation of a publication. However Arundel and Geuna (2001) mention some disadvantages of applying codified knowledge channels to trace knowledge flows. First of all, firms actually using the cited literature is unclear, as some citations have been added by the patent examiner. Secondly, some literature is only cited to build the patent claim without any actual contribution to the invention. Thirdly, these channels are not able to capture tacit information of knowledge transfer such as contract research and inter-personal contacts, which is an essential part of research-firm interaction.

The channels for tacit knowledge transfer are also studied. For instance, Meyer-Krahmer and Schmoch (1998) and Cohen et al. (2002) point out that informal contact are found to be a common channel of knowledge flow between Universities and industry. This claim is also supported by Breschi and Lissoni (2003, 2006) and Singh (2005). Informal knowledge exchange usually takes place via social networks, which are to a large extent localised (Ponds, Oort and Frenken, 2010). Compared with codified knowledge transfer, the transfer of tacit knowledge is usually more complex because tacit knowledge is personally embodied. The main carriers of University knowledge are people who are directly involved in knowledge creation such as scientists and researchers. Thus the direct, inter-personal contacts between with these people is the main way to acquire tacit knowledge, as many studies suggest (Faulkner et al., 1995; von Hippel, 1987; Maskell and Malmberg, 1999). Collaborative research is also suggested as important approach of tacit knowledge transfer (Kingsley et al., 1996; Meyer-Krahmer and Schmoch, 1998; Monjon and Waelbroeck; 2003).

Recently, human capital has been paid more attention to as another channel of knowledge transfer. For example, the employment of University researchers is described as an effective way to transfer knowledge from Universities to firms (Zucker et al., 2002; Gübeli and Doloreux, 2005). Labour mobility is considered another important mechanism for knowledge transfer, as Almeida and Kogut (1999) suggest, because when moving from one site to another, the knowledge embodied in individuals is transferred. Ponds et al. (2009) state that knowledge transfer through labour mobility is often localized as well.

In addition, University spin-off firms are particularly emphasised in many studies as a channel which efficiently transfers the knowledge. Zucker et al. and (1998) and Klepper (2007) point out that University spin-offs form an important mechanism of knowledge transfer from academia to business, and it is becoming an increasingly important means to science commercialisation. According to Huggins et al. (2008), the creation of spin-off firms, is a higher education institution (HEI) knowledge-based venturing. Their value is primarily linked with the regional longer-term growth potential, which is derived from scientific knowledge and intellectual property.

It is argued by Dahlstrand (1999) that public research organisations play a major role in the location decisions of new firms, especially in the case of scientific spin-offs. Zucker et al. (1998) and Klepper (2007) also show that spin-off firms tend to locate in proximity to the parent organisation, and this results in a geographical concentration of these firms around Universities and research institutes. If these spin-off firms are located around the Universities, the University created knowledge could be more directly transmitted to them without much of a barrier, compared with other private companies or firms. In addition, as Rosa and Mohnen (2008) point out, academic staff, graduates, and students are more likely to be hired in these spin-off firms. University faculty members are more easily able to monitor these spin-offs when keeping their academic positions in the same time. All these activities help the knowledge flowing from the University to the business.

As a step towards more clarity and precision in the analysis, a few studies suggest some framework of the knowledge transfer channels. It including various combinations of channels and methods mentioned above, in terms of research-business channels, inter-firm channels, channels of codified knowledge flow, channels of tacit knowledge flow, channels of human capital flow, channels of University spin-offs. Karlsson and Johansson (2005) suggest a separation into the three groups of knowledge flows: transaction based knowledge flows; transaction related knowledge flows; and pure knowledge spillover flows. Gathering important channels from other studies, Karlsson and Andersson (2005) provide a framework including the following elements: personal networks of academic and industrial researchers (Liebeskind, et al., 1996; MacPerson, 1998); spin-offs of new firms from Universities (Stuart and Shane, 2002); participation in conferences and presentations; and flows of fresh graduates to industry (Varga, 2000). Similarly, so called “knowledge intermediary”, as a mechanism of knowledge transfer, is suggested by (Yusuf, 2008). There are four main types of intermediaries: the general purpose intermediary; the specialized intermediary; the financial intermediary; and the institutional intermediary. The general purpose intermediary deals with producing and disseminating the different forms of knowledge (e.g. University and public research institute). The specialized intermediary helps the codifying of knowledge via patenting and the transfer of knowledge to commercial users (e.g. University technology licensing office; technology transfer office). The financial intermediary brings additional tacit knowledge to support start-ups in the forms of managerial know-how, contacts, and skills (e.g. a venture capitalist). The institutional intermediary is often a public agency that offers incentives and various services to encourage knowledge transfer, and facilitate interaction between researcher and business (e.g. local government).

In addition Görlin (2006) has an overview of the methods of knowledge transfer between University and business with a group of activities: licensing; spinning-out/spinning-off; spinning-in; incubators; procurement; spillover; and absorption. Under this framework, licensing is an activity of technological legal protection being licensed to another company. Spinning-out/spinning-off has regards to the movement of technology to a separate, new organisation in order to be commercialised, whilst spinning-in means the technology developed in a certain region or cluster is being commercialised by one of the participating organisations. In addition, incubators refer to new companies built within a business incubator, or organisations specialised in building new companies. Procurement is defined as a non-existing product being bought before being developed. Spillover and absorption are the activities of knowledge being transferred and absorbed by another company or actors in the knowledge system.

The channels of University-business knowledge transfer are summarised in table below, with the information of their indictors and measurements.

Table 2.7 Summary of Knowledge Transfer Channels

Authors	**Indicators**	**Measurements**
Hagedoorn et al. (2001); Lundvall, (1992); von Hippel, (1988)	Inter-firm research collaborations; User-producer networks; Linkages between competing firms;	Outsourcing research; Joint research; Publications; Patents
Narin et al. (1997); McMillan et al., (2000); Cohen et al. (2002) Meyer-Krahmer and Schmoch (1998); Cohen et al. (2002); Kingsley et al. (1996); Monjon and Waelbroeck (2003); Liebeskind, et al. (1996); MacPerson, (1998); Stuart and Shane, (2002); Varga, (2000)	Codified knowledge Tacit knowledge	Citation Informal contact Collaborative research Personal networks of academic and industrial researchers; Spin-offs of new firms from Universities; Participation in conferences and presentations; Flows of fresh graduates to industry.
Yusuf (2008)	Knowledge Intermediary (the general purpose intermediary; the specialized intermediary; the financial intermediary; and the institutional intermediary)	University Technology Licensing office (TLO); Technology Transfer office (TTO) Venture capitalist Local government
Karlsson and Johansson (2005)	Knowledge Flows	Transaction based knowledge flows; Transaction related knowledge flows, Knowledge spillover flows.
Görlin (2006)	Knowledge Transfer	licensing; spinning-out/spinning-off; spinning-in; incubators; procurement; and spillover & absorption
Zucker et al.; Klepper (2007); Huggins et al. (2008)	University spin-off firm	Formal Spin-Offs Informal Spin-Offs Staff Spin-Offs
Zucker et al. (2002); Gübeli and Doloreux (2005); Almeida and Kogut (1999); Ponds et al. (2009)	Human Capital	Labour mobility

2.5.6 Discussion and Theory Weaknesses

The main arguments and weaknesses of the theory regarding the science-business link are summarised in the table below. According to these arguments and weaknesses, some research gaps (G12-G15) are found.

Table 2.8: Summary of Science and Industry Link Literature

Literature	Theory and Model	Author	Argument	Model Weakness	Research Gap
Science and Industry Link	● University Business Interaction	Cohen, Nelsen and Walsh, (2002); Spencer, (2001); Mansfield (1991, 1998); Mansfield & Lee (1996); Fritsch and Lukas (2001); Fritsch (2001); Belderbos, Carree et al. (2004)	Science and industry link encourages the technology transfer and enables businesses to develop new products and process. University and business interaction, especially, is recognised vital to facilitate the exploitation of knowledge and the flow of ideas	W5.1 without specific illustration to the University's effect on SMEs in terms of knowledge dissemination, and it also has no consideration of different specialities of Universities in knowledge transfer	G12: Not specifically reveal if the University and SMEs relationship is where the opportunity comes from G13:Lack of framework of knowledge transfer, especially the University-business specific knowledge transfer and discussion together with geographical proximity G14: Not cover the disparities in knowledge absorptive capacity cross regions and the consequences
	● Technological Cluster	Saxenian (1994); Krugman (1991); Porter (1990); Karlsson and Andersson (2009)	University based Technological Cluster offers rich opportunities of knowledge spillovers from Universities, R&D institutes and other R&D intensive companies in the same cluster.	W5.2 Although the effect of cluster to knowledge transfer between University and firms in the cluster is confirmed, there is no clear framework for the activities of knowledge transfer	

				between University and business.	G15: Not explain the adequate mode of science-industry link for a specific region and the how it integrate with other elements involved in the regional system of innovation
	• Knowledge Transfer and Geographical Proximity	Boschma (2005); Jaffe (1989); Acs, Audretsch et al. (1992); Varga (2000); Fritsch and Schwirten (2002); Audretsch and Feldman (1996); Mansfield and Lee (1996); Autant-Bernard and Massard (2001); Carrincazeaux et al. (2001); Keller (2002); Audretsch et al. (2005)	Geographic proximity is a major determinant of the transfer of knowledge, and it explains why some successful regions have become more competitive than those that have not adopted a localised knowledge network	W5.3 Geographic proximity should not be considered isolated, however, it needs to integrate with the regional systems of innovation	
	• Regional Knowledge Absorptive Capacity	Cohen and Levinthal (1990); Cassiman and Veugelers, (2002); Jansen, Van den Bosch, and Volberda (2006); Narula, (2004); Miguélez and Moreno, (2013); Grinevich, Kitson and Savona, (2011)	Regional capacity in knowledge absorption determines knowledge transfer and impact on regional innovation intensity. Internal and external knowledge sources of a region are complements and they have to be combined to improve the regional innovative performance	W5.4 not only the knowledge volume, but also the knowledge absorptive capacity matters to the regional innovation performance. It is only recently realised and taken account in the regional innovation system model, and also there is no defined regional scale indicator for the capacity	
	• Channels of Knowledge transfer	Hagedoorn et al. (2001); Lundvall, (1992); von Hippel, (1988); Yusuf (2008); Karlsson and Johansson (2005); etc	Categories of channels of knowledge transfer are provided based on the creator-user network and types of knowledge.	W5.5 lack of clear framework, indicator, and measurement. Also no much mention of the network between Non-SMEs and SMEs	

The above literature argues that a science and industry link encourages the technology transfer, and enables businesses to develop new products and processes. University and business interaction especially is recognised as vital to facilitate the exploitation of knowledge and the flow of ideas. University-based technological clusters offer rich opportunities of knowledge spillovers from Universities, R&D institutes, and other R&D intensive companies in the same cluster. Geographic proximity is a major determinant of the transfer of knowledge, and it explains why some successful regions have become more competitive than those that have not adopted a localised knowledge network. Regional capacity in knowledge absorption determines knowledge transfer and impact on regional innovation intensity. Internal and external knowledge sources of a region are complementary, and they have to be combined to improve the regional innovative performance. Channels of University-business knowledge transfer categories are provided based on the creator-user network and types of knowledge.

However, there are some aspects still uncovered by this group of literature. It has no specific illustration to the University's effect on SMEs in terms of knowledge dissemination, and it also has no consideration of different specialities of Universities in knowledge transfer. In addition, although the effect of cluster to knowledge transfer between Universities and firms in the cluster is confirmed, there is no clear framework for the activities of knowledge transfer between University and business. Geographic proximity should not be considered isolated however, as it needs to integrate with the regional systems of innovation. Not only the knowledge volume, but also the knowledge absorptive capacity, matters to the regional innovation performance. However, this is only recently realised and taken into account in the regional innovation system model, and in addition there is no defined regional scale indicator for the knowledge absorptive capacity, although entrepreneurship is mentioned in a few studies as one of proxies. What is more, it lacks unified framework, indicators and measurements for the University-business knowledge transfer channel, and there is not much mention of the network between non-SMEs and SMEs.

Accordingly some research gaps are generated. As one of main forms of public research, a University's activities in interaction with business, especially their contribution to innovation, is particularly focused. University-business interaction is considered to bring innovative opportunities for local business, and contribute to the regional economy. However, when considering the science-industry link, the literature has a lack of discussion regarding geographical proximity together with link mode (G13). When consider the University-business link, the literature does not specifically reveal whether the University and SME relationship is usually where opportunity comes from according knowledge spillover theory (G12). Moreover, geographical proximity matters to this type of regional agglomeration of industrial and research activities, and many achievements of research and industry can be attributed to their spatial surroundings. This compares with another group of theory, namely "regional knowledge absorptive capacity". According to this theory, both internal knowledge generation and knowledge externalisation may constraint to regional network, and the difference in knowledge absorptive capacity in terms of regional knowledge intensity and knowledge networks may explain the varieties in innovation among regions. However, these differences and disparities in knowledge absorptive capacity across regions, and their consequences, are rarely mentioned in the literature field (G14). Finally, the science-industry link mode is mentioned in the literature, such as technological clusters. But it does not explain the adequate mode of science-industry link for a specific region, and the how it integrates with other elements involved in the regional system of innovation (G15).

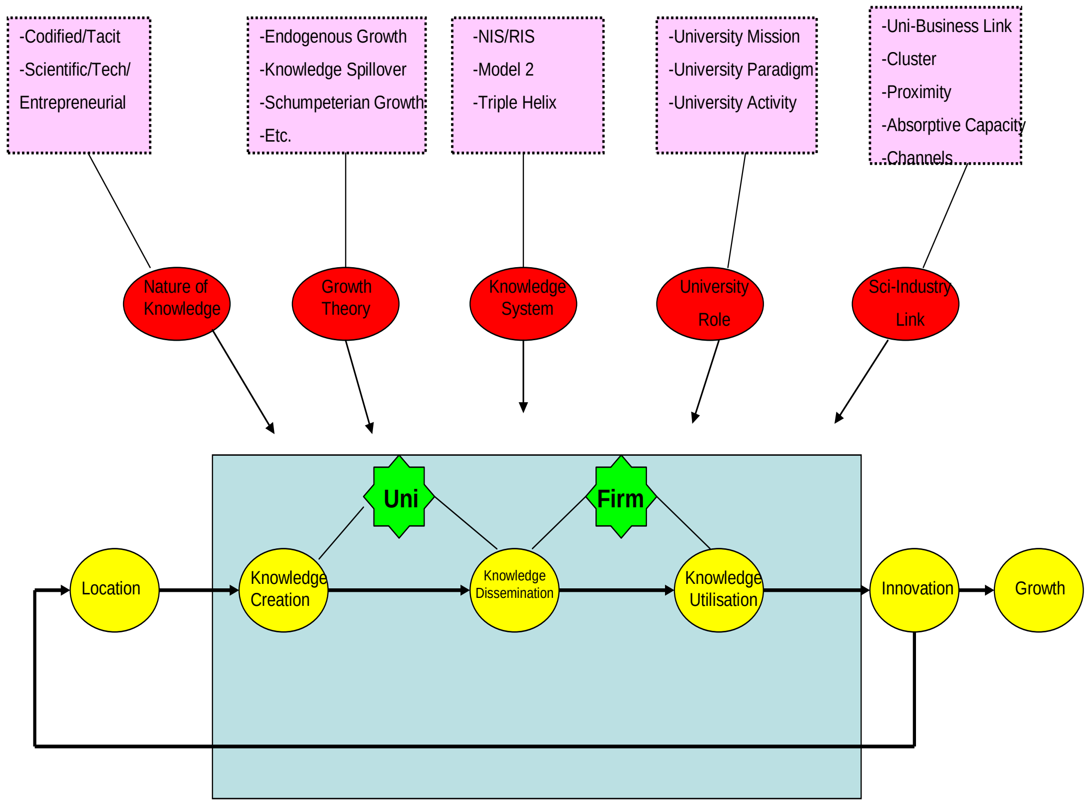
2.6 Research Focus, Gaps and Objectives

Five groups of literature have been reviewed above, including: “Nature of knowledge”; “Knowledge based growth theory”; “Knowledge system”; “University role and Paradigm”; and “Science and industry link”. The following discussion is to illustrate the research focus, gaps, objectives, and questions.

2.6.1 Research Focus

This literature provides a focus for the research, and in addition the position of the University and firm in the knowledge based economy. It is presented below, which also identifies the key activities, actors and outcomes to be studied. It helps to target “What”, “Who”, “How” and “Where” for the research.

Figure 2.1: Focus of the Research



What:

The above literature says "what" to target for this research. In a more specific, knowledge nature, knowledge provides a definition of consisting with scientific knowledge, technological knowledge and entrepreneurial knowledge. According to this definition, new technological knowledge, new entrepreneurial knowledge or new combinations of existing technological and entrepreneurial knowledge, form opportunities for innovation. On the other hand, endogenous theory considers that investments in knowledge, such as R&D activity and human capital, can increase the productive capacity and generate long-run growth. Thus the important contribution of knowledge to growth is addressed. Therefore, "what" to target on this research is the input - knowledge, and the output- growth.

<u>Who:</u>

This literatures gives the information about "Who" to target for this research. On the one hand, as the most important knowledge creator, modern University theory shows that Universities expand from their traditional role of research and teaching, to interact with regional business, and serves as the regional innovation booster. This implies that Universities have an intention to provide the created knowledge to regional business. At the other end, the knowledge spillover theory of entrepreneurship not only demonstrates the importance of knowledge spillovers to the economy, but only suggests that entrepreneurship could be a mechanism leading the spillovers to take place. This implies that a firm has an intention to access regional knowledge. Regional innovation systems emphasise the interactions and linkages among actors within the regional infrastructure. These interactions link the University end to business end, which results in the knowledge transfers from knowledge creator to knowledge user. Through this process, the investment in "raw" knowledge would transform to the market oriented product. This process shows how knowledge investment transfers to economic value through the knowledge creation-dissemination-commercialisation. Main actors involved in this process are University, business, and entrepreneurship, accordingly, they are chosen as "Who" to target by this research.

How:

The literature also provides the context of "How" for this research. Knowledge could not produce such an outcome itself. The knowledge spillover theory of entrepreneurship argues that to achieve economic benefit, knowledge needs to flow. In the literature of science and industry link, the importance of interaction between University and business is to knowledge flow especially emphasised. In knowledge system literature, some approaches of knowledge flows are given. For example, the Model 2 concept suggests the inter-institutional collaboration to solve the problem in real practice. The Triple Helix model provides an overlap interaction model amongst governments, Universities, and industry. Knowledge proximity theory shows the effect of geographical proximity to the knowledge flows and innovation. However, this effect can be varied according to the tacit or codified nature of regional knowledge. With a few frameworks, knowledge transfer channels are given too. They are mainly distinguished into two forms: Formal network (usually for codified knowledge flow) and Informal network (usually for tacit knowledge flow). All these show how and through which the knowledge flows, and this "How" is a main target of this research too.

Where:

Moreover, these literatures suggest "where" should be targeted by this research. Nature of the knowledge shows the codified can be transferred over distance at low cost, while tacit knowledge is usually more localised and difficult to transfer cross location. This is the reason why geographical proximity shows to be important to knowledge transfer. Similarly, regional innovation systems takes the region as a unit to view the knowledge transfer and innovation. The role of the University also shows that modern Universities have a mission to engage with regional business. Many technological clusters can be seen in regional level, with a central University surrounded by high-tech firms. Knowledge absorptive capacity of a region are also shown to influence the efficiency and outcome of the University's commercialisation. However, the knowledge proximity theory shows that it is able to break the geographical proximity in some cases. Thus the international or cross-locational networks are also important for innovation. All these help to form the idea about "where" to target for this research

2.6.2 Research Gaps, Needs and Objectives

There are 15 research gaps (G1-G15) found according to the review of five groups of literature. Those research gaps help to form the three main direction of need (Need A, Need B, Need C) in the research field, and these needs of the research is the main reason for it. Based on these needs, three research objectives are generated respectively (Objective A, Objective B, Objective C). Research gaps, needs and objectives are summarised with the table below:

Table 2.9: **Research Gaps, Needs and Objectives**

Literature	Gaps	Needs	Objectives
2.1 Nature of Knowledge	G1. Definition rather than process interaction, without considering the mechanism of transformation among each types of knowledge G2. Lack of unified measurement, and difficulty in measuring knowledge process	Need A: (Based on G1; G3; G6; G8) Need a measurement on knowledge process and growth consequences; need framework focus on network and growth; need discussion on the effect University-Business cooperation on innovation, and its relationship with knowledge investment Need B: (Based on G2; G4; G5; G7; G8; G9; G10; G12; G13; G14; G15) Need to define and measure University-Business involvement activities; Need to address the role entrepreneurship in the knowledge system; Need to find out the effect these University-Business involvments, especially Uni-SMEs activities to innovation; Need to find out how these activities integrate with regional knowledge systems; Need to see the patterns and modes of the regional knowledge system by considering the disparities in knowledge absorptive capacity; need to see the applicability of each system mode in different regions.	Objective A: To discover the influence of University-business cooperation on technological progress and economic growth. It is also to find out how this network integrates with knowledge investment and entrepreneurship in the growth model. Objective B: To investigate the effect of University activities on growth and the role of University activities in regional knowledge systems. It is also to find out if this role shows differences across those regions with different knowledge absorptive capacity
2.2 Knowledge Based Growth Theory	G3: Not clear address the role of knowledge investment on growth model G4: Not explain how and why the technological progress occurs, and No emphasis the role of entrepreneurship in knowledge system G5: Not fully explain where the entrepreneurial opportunities come from and no framework of growth based on University knowledge spillover		
2.3 Knowledge System	G6: No clear framework having a main focus of networks and growth.		

	G7: Not consider the regional differences in knowledge systems G8: Not specifically discuss on the dimension of University-business involvements		
2.4 University Role and Paradigm	G9: Theory model without clear measurements and direct evidence G10:No discussion to applicability of each paradigm, and activities details G11: Not cover the implication of how each paradigm involve with regional knowledge innovation system		
2.5 Science and Industry Link	G12: Not specifically reveal if the University and SMEs relationship is where the opportunity comes from G13:Lack of framework of knowledge transfer, especially the University-business specific knowledge transfer and discussion together with geographical proximity G14: Not cover the disparities in knowledge absorptive capacity cross regions and the consequences G15: Not explain the adequate mode of science-industry link for a specific region and the how it integrate with other elements involved in the regional system of innovation	Need C: (Based on G2; G5; G8; G9; G10; G11; G12) Need to define and measure the University knowledge based process. Need to find out the role of University-business interaction in the process of creation-dissemination-utilisation; Need to address the unique role of Non-SMEs interaction and SMEs interaction in the process; Need to see if different specialties of University show different patterns and results in knowledge commercialisation. Need to see the applicability of each system pattern in different Universities.	Objective C: To illustrate the patterns & processes of University knowledge based systems and the effect of it on knowledge commercialisation. It is also to investigate if this effect is different among different paradigms of Universities by considering their specialities

According to the research gaps (G1; G3; G6; G8), it needs a measurement on knowledge process and growth consequences. It also needs a framework focus on network and growth, and needs discussion on the effect University-business co-operation has on innovation, and its relationship with knowledge investment. Therefore Objective A is generated to discover the influence of University-business co-operation on technological progress and economic growth. It is also to find out how this network integrates with knowledge investment and entrepreneurship in the growth model.

According to the research gaps (G2; G4; G5; G7; G8; G9; G10; G12; G13; G14; G15), it needs to define and measure University-business involvement activities. It needs to address the role of entrepreneurship in the knowledge system. It also needs to find out the effect of these University-business involvements, especially University-SMEs activities to innovation; to find out how these activities integrate with regional knowledge systems; to see the patterns and modes of the regional knowledge system by considering the disparities in knowledge absorptive capacity; and finally the need to see the applicability of each system mode in different regions. Therefore, Objective B is generated to investigate the effect of University activities on growth, and the role of University activities in regional knowledge systems. It is also to find out if this role shows differences across those regions with different knowledge absorptive capacities.

According to the research gaps (G2; G5; G8; G9; G10; G11; G12), it needs to define and measure the University knowledge-based process. It needs to find out the role of University-business interaction in the process of creation-dissemination-utilisation. It also needs to address the unique role of non-SME interaction and SME interaction in the process; to see if different specialties of University show different patterns and results in knowledge commercialisation; and to investigate the applicability of each system pattern in different Universities. Therefore, Objective C is generated to illustrate the patterns of University knowledge based systems, and the influence of it on knowledge commercialisation. It is also to see if this influence is different between types of University with different specialties.

2.6.3 Research Questions

When three research objectives are formed, detailed research questions (Q1-Q13) are designed for these research objectives. See the table below:

Table 2.10: Research Objectives and Research Questions

Research Objectives and Questions		
Literature	**Research Objectives**	**Detail Questions**
2.1 Nature of Knowledge 2.2 Knowledge Based Growth	Objective A: To discover the influence of University-business co-operation on technological progress and economic growth. It is also to find out how this network integrates with knowledge investment and entrepreneurship in the growth model.	Q1: Does University-business co-operation influence economic growth? Q2: Does University-business co-operation influence technological progress? Q3: What is the relationship between University-business co-operation and knowledge investment, in terms of R&D investment & human capital investment; and their roles in growth model? Q4: What is the relationship between University-business co-operation and entrepreneurship activity; and their roles in the growth model?

Theory 2.3 Knowledge System 2.4 University Role and Paradigm	Objective B: To investigate the effect of University activities on growth and the role of University activities in regional knowledge systems. It is also to find out if this role shows differences across those regions with different knowledge absorptive capacity	Q5: What activities of Universities contribute to regional economic growth? Q6: What activities of Universities contribute to regional technological progress? Q7: What is the relationship between University Core Activities, entrepreneurship, and knowledge proximity? Q8: What is the relationship between University Knowledge Outreach Activities, entrepreneurship, and knowledge proximity? Q9: How are University activities, together with entrepreneurship and proximity involved in regional University-based knowledge system? Q10: Do the disparities in knowledge absorptive capacity across regions matter to the mode of University involvement in regional knowledge system?
2.5 Science and Industry Link	Objective C: To illustrate the patterns & processes of University knowledge based systems and the effect of it on knowledge commercialisation. It is also to investigate if this effect is different among different paradigms of Universities by considering their specialities	Q11: How do University knowledge creation and dissemination processes affect University knowledge utilisation, and then the commercialisation of the knowledge? Q12: Does University-business interaction in the knowledge dissemination process, in terms of Non-SMEs interaction channels and SMEs interaction channels, affects the knowledge commercialisation? Q13: Do different types of Universities show different patterns in the University knowledge creation-dissemination-utilisation process?

For Objective A, four research questions are designed (Q1-Q4). Q1 is to discover whether University-business co-operation influences economic growth. Q2 is to discover whether University-business co-operation influences technological progress. Q3 is to find out the relationship between University-business co-operation and knowledge investment, in terms of R&D investment & human capital investment, and their roles in the growth model. Q4 is to find out the relationship between University-business co-operation and entrepreneurship activity; and their roles in the growth model.

For Research Objective B, six research questions are designed (Q5-Q10). Q5 is to discover whether activities of Universities contribute to regional economic growth. Q6 is to discover whether activities of Universities contribute to regional technological progress. Q7 is to investigate the relationship between University Core Activities, entrepreneurship, and knowledge proximity. Q8 is to investigate the relationship between University Knowledge Outreach Activities, entrepreneurship, and knowledge proximity. Q9 is to find out how University activities, together with entrepreneurship and proximity, are involved in regional University-based knowledge system. Q10 is to find out whether the disparities in knowledge absorptive capacity across regions matter to the mode of University involvement in regional knowledge systems.

Regarding Research Objective C, three research questions are designed (Q11-Q13). Q11 is to investigate how University knowledge creation and dissemination processes affect University knowledge utilisation, and then the commercialisation of the knowledge. Q12 is to find out whether University-business interaction in the knowledge dissemination process, in terms of non-SMEs interaction channels and SMEs interaction channels, affects the knowledge commercialisation. Q13 is to find out whether different types of Universities show different patterns in the University knowledge creation-dissemination-utilisation process.

2.6.4 Summary

This literature chapter reviewed five main groups of literature, including nature of knowledge, knowledge based growth theory, knowledge system, University role and paradigm, and science-industry link. Based on these literature, the research field are shown and then the main focus of this research are addressed, including those “What” “Who” “ How” “Where”. 15 research gaps are then identified according to the weaknesses in each model and theory. According to these gaps, three objectives of this research are defined, and each illustrated with a series of detailed research questions (Q1-Q13). For the purpose of each objective, three research frameworks are designed to structure the concept and measure the research elements, which will be discussed in the next chapter with more information. All these steps are summarised in the table below:

Table 2.11: Summary of Literature Review

Literature	**Research Gaps**	**Research Objectives**	**Research Questions**	**Research Design**
• Nature of Knowledge • Knowledge Based Growth Theory • Knowledge System • University Role and paradigm • Science and Industry Link	G1-G15	Objective A	Q1 Q2 Q3 Q4	OECD Study
		Objective B	Q5 Q6 Q7 Q8 Q9 Q10	UK Regional Study
		Objective C	Q11 Q12 Q13	UK University Study

Chapter 3: Methodology and Research Design

In previous chapters, the relevant literature has been reviewed and the research aim and objectives generated. In this methodology chapter, the main research methods are reviewed with the discussion of method choice for this research. It is followed by an elaboration on research design, with the details in the research context, econometrics, model framework, data source and analysis techniques. This chapter ends with a summary of three layers of research design with appropriate research methods and techniques, in terms of the OECD Study, the UK regional study, and the UK University study.

3.1 Research Method

The main research methods are reviewed in this part, including inductive and deductive approach; types of research; primary and secondary data; qualitative and quantitative method; and research techniques and tools. The choices of the method for this research are also given, with the reason why they are chosen.

3.1.1 Inductive and Deductive Approach

Every research requires a link bridging theory and practice. Gilbert (1993) argued that it is impossible to conduct a purely empirical research that is totally devoid of theory, as research is dependent on theory (Gilbert 1993). The approach of research generally involves either deductive (theory testing) or inductive (theory construction) processes.

According to Saunders et al. (2007), the main difference between inductive and deductive approaches to research is that the deductive approach is aimed at testing theory, whereas an inductive approach is concerned with the generation of new theory emerging from the data. Gill and Johnson (1997) shows that deductive research is a study in which a conceptual and theoretical structure is developed and then tested by empirical observation. Particular examples are deduced from general inferences. Therefore the deductive method is referred to as switching from the general to the particular. Inductive research, however, is a study in which theory is developed from the observation of empirical reality. Thus, general inferences are induced from particular examples, which is the reverse side of the deductive method. Because it involves switching from individual observation to general patterns, it is referred to as moving from the specific to the general.

The comparison of deductive and inductive processes is summarized in the table below:

Table 3.1: Comparison of Research Approaches

Comparison of Deductive and Inductive Approach	
Explanation via analysis of causal relationships and explanation by covering-laws	Explanation of subjective meaning systems and explanation by understanding
Generation and use of quantitative data	Generation and use of qualitative data
Use of various controls, physical or statistical, so as to allow the testing of hypotheses	Commitment to research in everyday settings, to allow access to, and minimise reactivity among research subjects
Highly structured research methodology to ensure reliability	Minimum structure

Source: Gill and Johnson (1997)

Babbie (1992) points out that in actual practice, theory and research interact with one another through a never ending alternation of deduction, induction, deduction, and so forth. They both are routes to constructing theories. This interaction is also mentioned by De Vauss (1996), as two related processes- theory construction and theory testing. Gilbert (1993) also points out that first one has an idea for a theory, perhaps by contemplating the commonalities of a set of causes and inducing a theory. Then one checks it out against some data using deduction. If the theory does not quite fit the facts, induction is used to construct a slightly more complicated, but better, theory.

Creswell (1994) suggests a number of practical criteria about the choice of approach. The most important of these is the nature of the research topic. A topic on which there is a wealth of literature from which you can define a theoretical framework and a hypothesis leads itself more readily to deduction. Accordingly, this research is based on the deductive approach because of the following reasons. The topic is to empirically demonstrate the potential relationships based on theory and models. The model of this research here is based on the modified knowledge production function framework. There are sufficient studies already in this research field. This research develops theory and research questions, and designs research strategies to answer them. In addition, there are quantitative data in existing datasets, and this research will collect the data to measure, test and analyse, and finally to the generation of the findings of quantitative data. Statistical techniques and packages are used for analysis purpose under a highly structured methodology framework. It follows five stages listed by Robson (2002), through which deductive research will process:

- Deducing a testable proposition about the relationship between two or more concepts or variables from theory
- Indicating exactly how the concepts or variables are to measured, which propose a relationship between two specific concepts or variables
- Testing this proposition and relationship
- Examine the specific outcome of result
- If necessary, modifying the theory in the light of the findings

3.1.2 Explanatory Research

Research can be classified according to its purpose. Some important types of research are described as exploratory research, descriptive research, explanatory or analytical research, and predictive research. The definition, purpose, and nature of each type of research can be seen in Saunders et al. (2007)'s book as follows:

Exploratory research is a kind of research which is conducted into research problems where there are very few or no similar earlier studies. The aim of this type of study is to look for patterns, ideas or hypotheses, rather than testing or confirming a hypothesis. Descriptive research is conducted to describe phenomena as they exist. It is used to identify and obtain information on the characteristics of a particular problem or issue. Thus, compared with exploratory research, descriptive research goes further in examining problems as it is undertaken to ascertain and describe the characteristics of the issues. Explanatory research (or analytical research) is a continuation of descriptive research. The researcher goes beyond only describing the characteristics, to analyse and explain why or how the phenomenon being studied is happening. Therefore, this type of research aims to understand phenomena by investigating and measuring causal relations among them. Predictive research goes even further than explanatory research. This sort of research establishes an explanation for what will happen by giving some baseline already known. It forecasts the likelihood of a similar situation occurring elsewhere.

According to above definition and nature of each type of research, this research applies an explanatory (analytical) based research, because the objective of this research is on studying a situation in order to explain the relationships between variables.

3.1.3 Primary data and Secondary Data

Primary Data

The choice of primary data collection is mainly based on the purpose of the research. Kumar (1999) points out that the most suitable primary data collection methodology depends on what kind of information is sought. According to Kumar (1999), research is defined as qualitative if the purpose of the study is primarily to describe a situation, phenomenon, problem or event, and if analysis is done to establish the variation in the situation, phenomenon or problem, without quantifying it. In contrast, if the purpose of the research is to quantify the variation in a phenomenon, situation, problem or issue, if information is gathered using predominantly quantitative variables, and if the analysis is geared to ascertain the magnitude of the variation, the study is classified as a quantitative study.

A survey is a strategy which is often associated with primary data collection. Surveys usually use the carefully random selected samples that enable results to be generalized to wider populations with a high degree of confidence, and the qualities displayed in survey research give it much strength in population validity and reliability (Gill and Johnson, 2002). Therefore, it is a popular and common strategy in business and management research. Bryman (1989) defined survey strategy as “entailing the collection of data on a number of units and usually at a single juncture of time, with a view of collecting systematically a body of quantifiable data in respect of a number of variables which are then examined to discern patterns of association.” Survey is usually associated with the deductive approach (Zikmund, 2000). Survey strategy is perceived as authoritative by people in general. The strategy of survey provides a quick, inexpensive, efficient, and accurate mean of assessing information about the chosen population. Researchers are able to structure, focus, phrase, and ask sets of questions in a manner that is intelligible to respondents based on the understanding of the survey. It offers greater possibility for replication. The user has prior knowledge of the answers likely to be procured (Djebarni, 2003).

The usefulness of surveys can be seen from the data they can provide in answering three main types of research: (1) Descriptive research: the basic aim is to collect information on how some characteristics or other attributes are distributed amongst respondents; (2) Theory testing research: the basic aim is to test the theories formulated from the literature in real life situations; and (3) Theory constructing research: the basic aim is to develop new theories rather than to test them.

By using highly structured questionnaires to gather data in a form which is quantitatively analysable, survey-based strategy is usually regarded as easily replicable and hence reliable (Gill and Johnson, 2002). But this highly structured survey, which is conferred strengths, appears to create a relative lack of naturalism. The context in which data collection takes place will not usually be as artificial as the context of the ideal experiment (Gill and Johnson, 2002). Moreover, respondents might often be constrained or impelled by a hint from an interviewer or the rubric of a self-completion questionnaire. This may result in the situation that the research is fitted into the conceptual and theoretical form, but the respondents are given little opportunity to clearly talk about the matters of their interest. It is usually for these reasons that survey strategy is often considered to be relatively low in ecological validity.

There are two major errors common to survey strategy which are mentioned by Zikmund (2000): random sampling error and systematic bias. The sampling error is caused by chance variation that results in a sample that is not absolutely representative of the target population. It is evitable, but it can also be predicted by using the statistical method. Systematic bias takes several forms. Non-response error is caused by people who are sampled but do not respond, and by those who may differ from respondents in some significant way (Zikmund, 2000). This error can be reduced by comparing the demographics of the sample population with those of the target population, and by making added efforts to contact underrepresented groups.

There are three main types of survey according to Saunders et al. (2007) :

- Self administered questionnaire survey
- Telephone survey utilising a questionnaire
- Face to face interviews utilising a questionnaire

Secondary Data

Primary research is where the researcher collects and analyses data themselves; secondary research is where the data is collected and analysed from secondary sources, for example by government surveys, statistical dataset (Skinner 1991).

Emma (2008) summarises numerous definitions of secondary data analysis which appear in the literature, many with subtle differences. One relatively straightforward definition of the secondary analysis of survey data is suggested by Hyman (1972), as the extraction of knowledge on topics other than those which were the focus of the original survey. Other definitions of secondary analysis have emphasised its usefulness for exploring new research questions; as Glaster (1963) point out, the study of specific problems through analysis of existing data which were originally collected for another purpose. Hewson (2006) also suggest that the further analysis of an existing dataset with the aim of addressing a research question distinct from that for which the dataset was originally collected and generating novel interpretations and conclusions. However, such definitions appear to disregard the potential of secondary analysis in re-analysing existing datasets with novel statistical or theoretical approaches.

It is argued by Glass (1976) that secondary analysis is the re-analysis of data for the purpose of answering the original research questions with better statistical techniques, or answering new research questions with old data. One apparent character of secondary analysis is that it could involve the analysis of someone else's data. It is a collection of data obtained by another researcher which is available for re-analysis (Sobal, 1981). It is commented that even if re-analysis of one's own data is secondary data, research itself is new if it has a new purpose or methodological advance (Schutt, 2007). Similarly, Hakim (1982) point out that secondary data analysis is any further analysis of an existing dataset which presents interpretations, conclusions or knowledge additional to, or different from previous studies.

Whichever definition one favours, secondary analysis should be an empirical exercise carried out on data that has already been gathered or compiled in some way (Dale et al., 1988). This may involve using the, original or novel theoretical frameworks, research questions, statistical approaches. It may be undertaken by the original researcher or by someone new.

Secondary data can include a whole spectrum of empirical forms. It can include data generated through systematic reviews, through documentary analysis as well as the results from large-scale datasets such as the national census or international surveys. Secondary data can be numeric or non-numeric. Non-numeric or qualitative secondary data can include data retrieved second hand from interviews, ethnographic accounts, documents, photographs or conversations. Heaton (1998) and Fielding (2000) have a further discussion on the methodological and substantive implications of the secondary analysis of non-numeric data. But it is beyond the discussion of this research, as this research only applies numeric secondary data. The potential for the secondary analysis of numeric data is huge. The range of numeric empirical data that are suited to secondary analysis is summarized by Emma (2008), including:

- Population census
- Government surveys
- Other large-scale surveys
- Cohort and other longitudinal studies
- Other regular or continuous surveys
- Administrative records

Table 3.2: The choice of Secondary Data and Reason

Methods	Choice	Reason of Choice
Primary Data Collection		● Re-analysis of previously existing data
Secondary Data Collection	✔,	● Impossible to do primary data collection for OECD scale because of the time and resource ● Empirical design and test benefit from previous information

This research chose the secondary data collection and analysis method. There are three main reasons for this choice according to above review of method. First of all, datasets need for this research already exist in OECD scale and UK regional scale. As Kiecolt and Nathan (1985) said, secondary analysis requires the application of creative analytical techniques to data that have been amassed by others, and this type of research can also be based on the re-analysis of previously analysed research data. This fits the purpose of this research, which is trying to use new model framework and analytical method with re-analysis of data in OECD and UK regional scale. In addition, for OECD scale studies which involves in collection of data from many different countries, it almost impossible to carry out based on the time and resource of this research. Thirdly, secondary data often also gives an overview of what has been researched before in the same subject area, which will not only help to chose a research topic and place the research in context, but is also crucial for the decision on research design for the own research (Greenfield, 1996; Bell, 2001). This research is empirically design and has a test benefit from previous models, research, and information.

3.1.4 Qualitative Method and Quantitative Method

The three major research methods in business studies are the quantitative method, qualitative method, or mixed research methods (Saunders et al., 2007). Quantitative refers to descriptions with numbers and statistics, while qualitative refers to descriptions with quality or worth. Quantitative research is the research that relies on the collection and analysis of quantitative data. The number, or numerical descriptions of things and their relationships, are the focus of quantitative research. Qualitative research relies on the qualitative data which is related to the what, how, when, and where of a thing – its essence and ambience. Qualitative research thus refers to the meanings, concepts, definitions, characteristics, metaphors, symbols, and descriptions of things. Mixed methods involve the mixing of quantitative and qualitative methods or paradigm characteristics (Berg, 2007).

Classifying an approach as quantitative or qualitative does not mean that once an approach has been selected, the researcher may not move from the method normally associated with that style. Each approach has its strengths and weaknesses, and each is particularly suitable for a particular context. These strengths and weaknesses for qualitative method and quantitative method are discussed as follows, to provide the reason of method choice for this research.

Qualitative Method

The qualitative method, which is the non-standard way and has a complex nature, draws some significant distinctions from those that result from quantitative method.

Qualitative research, broadly defined, means any kind of research that produces findings not arrived at by means of statistical procedures or other means of quantification (Dunn, 2001). Bouma and Atkinson (1995) define qualitative research methods as those that produce results not obtained through statistical procedures or through any other methods of quantification. Van Maanen (1983) offer a more detailed definition. He described qualitative methods as a range of interpretive techniques used to describe, decode, translate, and come to terms with the meaning of more or less naturally occurring phenomena in the social world. The qualitative method is not used for counting frequencies of such phenomena.

One of the underlying characteristics of the qualitative method is to view events through the perspectives of the individuals being studied. Researchers produce data based on these individuals' words or observable behaviour. Hakim (1987) notes that qualitative research is concerned with individual's own account of their attitudes, motivations and behaviour. It offers richly descriptive reports of individual's perceptions, attitudes, beliefs, views and feelings, the meaning and interpretations given to events and things, as well as their behaviour; displays how these are put together, more or less coherently and consciously, into frameworks which make sense of their experiences; and illuminates the motivations which connect attitudes and behaviour, the discontinuities, or even contradictions, between attitudes and behaviour, or how conflicting attitudes and motivations are resolved in particular choices made."

Another characteristic of qualitative research is that it is relatively unstructured compared to quantitative methods. The research strategy is usually not set out in advance. Thus, the researcher might not have very clear objectives in mind at first. This allows the researcher to focus on unexpected topics that might emerge after he/she has begun the research and which may warrant further investigation. The researcher is given the flexibility to capitalise on chance remarks that might lead to the development of new and unexpected topics (Bryman 1989). Qualitative methods reject the formulation of theories at the beginning of the research, and only produce theories as the research develops. The analysis of qualitative data involves a demanding process and should not be seen as an easy option. Yin (1994) refers to those who leave the data that they have collected unanalyzed for periods of time because of their uncertainty about the analytical process required.

Qualitative research has its own advantages and disadvantages when compared with quantitative research. Hakim (1987) argues that its main advantage is greater validity and less artificiality. The depth of understanding may be greatest with qualitative research.. This is because the people involved are usually interviewed in sufficient detail to warrant the correctness, completeness, and believability of the reports of their accounts. Also, qualitative research can look at past events in greater detail. Another advantage related to qualitative research is that it can help to answer the questions of “how” or “why”. These questions are usually fairly complex and require several factors which may have links between them or even links with other factors which may not on the surface look apparent. Qualitative research helps the researcher to identify patterns of relationships and interactions amongst the various factors and also in acquiring a “feel” for them, something which quantitative research which relies on correlations cannot do. There is another advantage of qualitative research illustrated by Hakim (1987): It is used in conjunction with other types of study to help clarify causal processes and explanations in the form of motivations, or to flesh out reports providing quantitative data with illustrative examples and quotations on typical, minority or deviant cases.

The main criticisms made of qualitative methods are that they are unreliable, untidy, and impressionistic, especially in the earlier stages of research. Allan (1991) observes that whilst the researcher has to be sensitive and keep an open mind to new ideas, suggestions and new relationships that may arise from discussions with respondents, there is a need for the researcher to be systematic in every other aspect of the research. The researcher must include all cases, not just the ones which fit in with current theories but also those that run counter to them. The second problem associated with qualitative methods is the issue of verification. In quantitative methods, the precise procedures used to achieve the data can be replicated by others, thus confirming or refuting the study findings. In the qualitative method, this exact replication in all its detail is impossible. In addition, in qualitative research, where the role of the researcher is to understand and empathise with respondents, critics argue that this there is a danger that the researcher will bring his or her own assumptions into the research, thus affecting the findings. As a result, different researchers will produce analyses based upon their different perspectives (Allan, 1991). Qualitative approaches may also be limited in their ability to contribute towards hypothesis testing and theory building, particularly in terms of the time and expense involved. Another disadvantage that qualitative research has is that the research normally will not be seen as representative due to the small number of people interviewed. Hakim (1987) argues that if qualitative research is seen as weaker compared to quantitative methods, this is because the validity problems in surveys are largely invisible and regularly overlooked, particularly by economists and statisticians who routinely work with large datasets and official statistics.

There are various techniques employed in qualitative research. Amongst them are participant observation, in- depth interviews, observation, and diary methods.

There is no standardized approach to the analysis of qualitative data. There are many qualitative research traditions approaches, with the result that there are also different strategies to deal with the data collected. Tesch (1990) groups these strategies into four main categories:

- Understanding the characteristics of language
- Discovering regularities
- Comprehending the meaning of text or action
- Reflection

There are a number of aids that could be used for help through the process of qualitative analysis, like interviews, observation, document and interim summaries, self-memos and maintaining a researcher's diary.

Quantitative Method

The purpose of the quantitative method is to determine the quantity or extent of some phenomenon in the form of numbers (Zikmund, 2000). The procedure of quantitative method involves translating research objectives to more specified terms, data collection, data analysis, and interpretation of findings. Essentially, the quantitative method is concerned with investigating how a dependent variable Y is affected by the independent variable X (Skinner 1991). Data collected and analysed with the quantitative method can be subsequently coded at different levels of numerical measurement. The data type (precision of measurement) will constrain the data presentation, summary and analysis techniques you can use (Saunders, 2007).

According to De Vauss (1996), one of the main characteristics of quantitative method is that the process of data collection remains distinct from the analysis of the data. In the quantitative method, the collection and analysis of data is usually very structured. What is more, the data collected is systematic and allows for systematic comparison between cases and of the same characteristics. Tests and measures are commonly used in quantitative research to find out respondents' thoughts (Saunders et al., 2007). The quantitative data can be divided into categorical and quantifiable data. Categorical data refers to data whose values cannot be measured numerically but can be either classified into sets according to the characteristics in which you are interested or placed in rank order. Quantifiable data refers to data whose values can actually be measured numerically as quantities. This means that quantifiable data are more precise than categorical (Saunders, 2007). Quantitative data can range from simple counts, such as the frequency of occurrence, to more complex data such as test scores or prices. To be useful these data need to be analysed and interpreted. The researcher may use the computer to analyse the data.

There are many differences between analysis in a quantitative method and that in a qualitative method. First of all, quantitative method collects facts and studies the inter-relationship between sets of facts, and measures using scientific techniques to produce quantified and generalizable conclusion (Bell, 2001). However, a qualitative perspective is concerned with individuals' perceptions and provides insight rather than statistical analysis. Secondly, quantitative research has some advantages as objectivity and reliability, it is relatively easy, and not as time consuming as some other forms of research. It is also viewed as being more scientific (Saunders, 2007). Bouma and Atkinson (1995) point out that quantitative research is structured, logical, measured and wide. Qualitative research is more intuitive, subjective, and deep. Some others, for example, Dey (1993) compares quantitative and qualitative methods according to the data produced, with quantitative data dealing with numbers and qualitative data dealing with meanings that are mediated through language and meaning. Moreover, an analytical stage with quantitative methods will take place only when the data collection has been completed. In quantitative studies a hypothesis is defined before data are collected; on the contrary, in many qualitative studies, a recognizable hypothesis is arrived at quite late in the research (Saunders, 2003). In addition, there are core differences in how each method could contribute to bodies of knowledge. Some authors states that qualitative research offers a so called “worm’s eye” view, whereas quantitative research offers the “bird’s eye” view (Hakim,1987). Quantitative research offers generalised findings for subject matter, while qualitative research is usually more interested in the individual or group. Another difference between qualitative and quantitative research is the method of data analysis employed. As Bryman (1988) points out, quantitative research relies on data which are amenable to statistical analysis, whereas qualitative research requires a different method of analysis. It also shows that results from quantitative research have the advantages on generalisation.

In terms of gathering data for quantitative techniques, there are several typical techniques of quantitative research suggested byauthors (Easterby-Smith et al. 1991) including interviews, questionnaires, tests and observations. The interview form used in quantitative research is the structured interview, where the interviewer asks a series of precise questions in the exact same sequence and in the same manner to each respondent. This can be done either face to face, over telephone or internet, or using a self completion questionnaire.

This sort of highly structured interview is the opposite of the relatively unstructured and free flowing interview commonly used in qualitative research. Observation is another technique commonly associated with qualitative research. Observation is more than just looking or listening; it is defined as “systematic observation” (Saunders et al., 2007). This systematic observation usually involves the use of formal, structured observation instrument or schedule. The observation methods being used are clearly identidied (Saunders et al., 2007), including: the variables to be observed; who or what will be observed; how the observation is to be conducted; and when and where the observations will take place.

On the other side, there are also some shortcomings of quantitative research. Quantitative methods often offer only a surface understanding of the subject matter. The researcher is not invited into the lives of the people being investigated, to know why they make the choices they make, their motivation, etc. In addition, quantitative methods can be rigid and often seem artificial. Moreover, they do not allow room for ‘new’ data.

The design of quantitative research is more difficult compared to that of qualitative research. The researcher has to operationalise the research objectives into a quantitative research design. In addition, what type of data is to be collected has variable definitions which have to be very specific. However, the analysis of quantitative data is usually straightforward compared to qualitative data.

Table 3.3: The Choice of Quantitative Method and Reason

Methods	Choice	Reason of Choice
Qualitative Method		● Numerical data to explain frequency of occurrence rather than the meaning of a phenomenon ● Scientific statistically-based approach with advantages in confidence, reliability, and generality ● Formal and structured and good in explaining relations and effect ● Easy and ready to analyse
Quantitative Method	✔,	

Research methods needs to suit research aims and objectives. The strengths and weaknesses of different research methods need to be assessed before the decision of which method to choose. Both methods with their strengths and weaknesses provide the base for the reason of method choice for this research.

This research applies quantitative method with data collection and analysis because of following reasons. First of all, quantitative data usually investigates the frequency of occurrence of a phenomenon or variable, while qualitative usually focuses on the meaning of a phenomenon. Quantitative data is usually numerical data and qualitative data is usually nominal data (Saunders, et al, 2007). Since this research is based on the numerical data and targeting to the frequency of occurrence, quantitative method is preferred to provide a solid and clear results.

Secondly, the purpose of this research is improve the practice with the help of analysis results for some region/nation, and it has a high requirement in result confidence, reliability and generality. The quantitative method is a more scientific statistically-based approach has advantages over qualitative method in these area. Quantitative analytical method allows the reporting of summary results in numerical terms, and this gives a specified degree of confidence (Saunders et al., 2007). It could have great value to the research which is attempting to draw meaningful results from a large body of qualitative data. It also provides techniques to separate out the large number of confounding factors, which often obscure the main qualitative findings. An additional advantage associated with quantitative method is the issue of verification. The clear and precise procedures in the quantitative research result in that the achieved data can be easily replicated by others, thus enabling the utilisation of the data in the further research. The results with this method could be clearly explained and generalised too. It is usually less subjective and time consuming compared with the qualitative method.

Thirdly, the target of this research is various relationships in a system. Qualitative methods may have difficulty in explaining the effect, complexity and implication involved in variables. The quantitative method is thus preferred, as the data in this way can be formal, structured and distinctly interpreted.

The data collected with the quantitative method is straightforward and can easily be analysed using statistical techniques. This makes analysis a less complicated activity compared to analysing data from qualitative methods. It is easier to detect surface patterns and relationships between factors in this type of research. In addition, quantitative method allows generalisations to be made from the sample to the target population, and it is useful for research that needs explanation of phenomena under investigation.

For this research, quantitative method with secondary data is chosen. In addition to those reasons from the nature of the method itself, as mentioned above, there are also some specific reasons from this research objectives. The nature of Objective A made it most logical to approach at an international level, which lends itself to secondary data analysis rather than primary, because of time and cost considerations. For the UK regional and University based study, examination of the HE-BCI survey shows that variables (proxies) of relevance to the study already included, especially those proxies of knowledge dissemination between University and business, such as consultancy contract, course provided by University to business, business use of University facility and equipment, University spin-offs. Therefore it is determined that this secondary data source was an appropriate one to base the analysis on, supplemented by official data sources (such as Eurostats for growth related variables). There are weaknesses in this dataset . There have, for example, been reports of Universities providing possible unreliable information to the HE-BCI (Rae et al, 2010). However, the study by Guena and Rossi (2011) found that the data collected by the UK through the HE-BCI as the “most reliable” compared to 12 countries including the USA, Germany and France. This suggests that this secondary data source is the most valid and reliable available to researchers, as reflected in its common usage within the literature.

3.1.5 Analysis Tools and Techniques

Glastonbury and MacKean (1991) notes that it is necessary to seek advice on available statistical tools at an early stage in the project. There are various software packages to help analysing data collected from secondary data. Each software has its unique specialty. The choice of software package depends on factors such as availability and the analysis requirement. In this research SPSS and SmartPLS are chosen as two main statistical analysis tools. The data analysis techniques and their functions are summarised in the table below, followed by the discussion.

Table 3.4: Statistical Tools and Techniques in Data Analysis

Software Packages	**Statistical Techniques**	**Additional Tests**	**Function**
SmartPLS	Structural Equation Modelling	Bootstrapping PLS Algorithm	Examine multiple and indirect relationships between variables simultaneously with construction of unobservable variables
	Path Analysis	Bootstrapping PLS Algorithm	
SPSS	Regression Analysis	Durbin-Watson Variance Inflation Factor	Estimate the relationships among variables
	Factor Analysis	Cronbach's Alpha for Factors	Summarize a number of original variables into a smaller set of composite dimensions
	Cluster Analysis		Groups individuals or objects into clusters

<u>SPSS</u>

Originally, SPSS is the abbreviation for the Statistical Package for the Social Sciences (SPSS). Later it is changed to Statistical Product and Service Solutions to reflect the growing diversity of the user base. This is an especially popular package, mainly due to its ease of use and its ability to handle various types of data. In this research, there are three analysis techniques of SPSS involved, according to the research objectives and needs.

The first technique is linear regression analysis with enter method. In statistics, regression analysis is a statistical process for estimating the relationships among variables. It includes many techniques for modeling and analysing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps to understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while other independent variables are held fixed. Linear regression attempts to model the relationship between these variables by fitting a linear equation to observed data.

According to the research questions, this research needs to compare the new developed growth model with other typical models, and also tests the relationship between variables in the new model. In theory, there is a linear relationship between dependent variables and independent variables. Therefore, linear regression analysis with enter method is chosen to execute this analysis. Enter method in linear regression is a useful technique for the model comparison, which can be found using in many empirical studies for in the literature field (e.g. Muller,2005). There are also some additional tests packed with this regression analysis including Durbin-Watson test (DW), and Variance Inflation Factor (VIF) test. Durbin-Watson test (DW) is used to detect the presence of autocorrelation, which is a relationship between values separated from each other by a given time lag in the residuals from a regression analysis. Multicollinearity is a common problem when estimating linear or generalised linear models. The Variance Inflation Factor (VIF) test is applied which helps to find out if two or more independent variables in the regression model are highly correlated, meaning that one can be linearly predicted from the others with a non-trivial degree of accuracy.

The second analysis technique with SPSS is the factor analysis. A factor analysis is a data reduction technique to summarize a number of original variables into a smaller set of composite dimensions, or factors. It is an important step in scale development and can be used to demonstrate construct validity of scale items. According to this nature, factor analysis is a suitable technique which helps to achieve some of the research objectives as this research need to find out the major focus of University from various activities. The additional test with this factor analysis is Cronbach's Alpha for factors, which is to check the reliability of scale items by measuring the internal consistency of these items.

The last analysis technique with SPSS is the cluster analysis. Cluster analysis groups individuals or objects into clusters so that objects in the same cluster are homogeneous, and there is heterogeneity across clusters. This technique is often used to segment the data into similar, natural, groupings. As this research has an objective to find out the roles of different University groups in economy, the cluster analysis is chosen to group these Universities.

The main drawback of SPSS is that it is not suitable for some of the more complex statistical analyses. It means SPSS has difficulty in investigating the relationship among independent variables. It also is difficult to provide the analysis of construct level. In addition, the analysis result with SPSS is usually more reliable with large sample numbers. To overcome these problems, another statistical package which is named SmartPLS is introduced in this research, with the reason why it has been chosen.

<u>SmartPLS</u>

Another important analysis tool used in this research is SmartPLS, dealing with structural equation modeling and path analysis. SmartPLS is a software application for (graphical) path modeling with latent variables. It deals with Structural Equation Modelling (SEM) based on the partial least squares (PLS) method, which is used for the analysis in this software.

- Structural Equation Modeling (SEM)

Structural Equation Modeling, or SEM, is a second-generation multivariate data analysis method that is often used in business research because it can test theoretically supported linear and additive causal models (Chin, 1996; Haenlein and Kaplan, 2004; Statsoft, 2013). Structural Equation Modeling (SEM) is a general term that has been used to describe a large number of statistical models used to evaluate the validity of substantive theories with empirical data. SEM is a chiefly linear, cross-sectional statistical modeling technique. Factor analysis, path analysis and regression all represent special cases of SEM. Path analysis is an example of SEM in which structural relations among observed variables are modeled. Path analysis is an extension of regression analysis in that it involves various multiple regression models or equations that are estimated simultaneously. This provides a more effective way of modeling mediation, indirect effects, and other complex relationship among variables (Lei and Wu, 2007).

Structural Equation Modeling (SEM) usually visually builds a model and examines the relationships that exist among all variables according to the model. Unobservable or latent variables can be used in SEM, making it ideal for dealing with complex business research problems. Latent variables cannot be measured directly, but are indicated or inferred by responses to a number of observable variables (indicators). In SEM, interest usually focuses more on latent constructs and abstract variables, rather than on the manifest variables used to measure these constructs (Lei and Wu, 2007). A Structural Equation Model implies a structure of the covariance matrix of the measures. Once the model's parameters have been estimated, the resulting model-implied covariance matrix can then be compared to an empirical or data-based covariance matrix. If the two matrices are consistent with one another, then the structural equation model can be considered a plausible explanation for relations between the measures.

Compared to regression and factor analysis, Structural Equation Model (SEM) is a relatively young field, having its roots in papers that appeared only in the late 1960s. As such, the methodology is still developing, and even fundamental concepts are subject to challenge and revision. However, there are many advantage of SEM in solving the problems which could not be solved with traditional data analysis package, such as SPSS. SEM enables researchers to examine multiple relationships between variables simultaneously and all the rest of entire model or theory (Steiner, 2006). This extends the ability of statistical method dealing with relationship between dependent and independent variables one at a time (Chin 1998; Hair et al., 2006). SEM has become generally accepted practice for validating research instruments and testing links between constructs (Reisinger and Mavondo, 2006). Another obvious advantage of SEM compared to the first generation statistical techniques is the greater flexibility it provides researchers to connect theory with data. It allows the assessment of relationships between multiple variables, through the construction of unobservable variables, while addressing the measurement error of these latent variables. SEM can test theoretically-based assumptions on measurement, as well as conceptual relationship between constructs (Chin 1998; Chin and Newsted, 1999). SEM has gained popularity across many disciplines in the past two decades due to these strengths in generality and flexibility. With advances in estimation techniques, basic models, such as measurement models, path models, and their integration into a general covariance structure SEM analysis framework have been expanded the modeling of mean structures, interaction or nonlinear relations, and multilevel problems (Lei and Wu, 2007).

- Partial Least Squares (PLS)

There are several distinct statistical approaches to Structural Equation Modeling (SEM). The first approach is the widely applied Covariance-Based SEM (CB-SEM), using software packages such as AMOS, EQS, LISREL and MPlus. The second approach is Partial Least Squares (PLS), which focuses on the analysis of variance and can be carried out using PLS-Graph, VisualPLS, SmartPLS, and WarpPLS. It can also be employed using the PLS module in the “r” statistical software package. The third approach is a component-based SEM known as Generalized Structured Component Analysis (GSCA); it is implemented through VisualGSCA or a web-based application called GeSCA. Another way to perform SEM is called Nonlinear Universal Structural Relational Modeling (NEUSREL), using NEUSREL's Causal Analytics software.

The Partial Least Squares (PLS) approach of Structural Equation Modeling (SEM), which utilises a principle component-based for estimation, is applied for analysis. The approach is also suitable for validating predictive models (Chin, 1998). The PLS assesses the latent properties of the measurement model, and estimates the parameters of the structural model.

Structural Equation Modeling with Partial Least Squares (PLS-SEM) can be evaluated with two criteria. One criterion is the significance of weights, meaning that estimates for the model should be at significant levels. This can be achieved by applying the Bootstrap procedure. The second criterion is multicollinearity, where manifest variables in a formative block must be tested for multicollinearity.

Structural equation modeling (SEM) with Partial Least Squares (PLS) approach shows many advantages and helps to data analysis. PLS is a soft modeling approach to SEM with no assumptions about data distribution (Vinzi et al., 2010). Thus, PLS-SEM becomes a good alternative to CB-SEM when the following situations are encountered (Bacon, 1999; Hwang et al., 2010; Wong, 2010):

- Sample size is small.
- Applications have little available theory

- Predictive accuracy is paramount
- Correct model specification cannot be ensured

It is important to note that PLS-SEM is not appropriate for all kinds of statistical analysis. It also needs to be aware of some weaknesses of PLS-SEM (Bacon, 1999; Hwang et al., 2010; Wong, 2010), including:

- High-valued structural path coefficients are needed if the sample size is small
- Problem of multicollinearity if not handled well
- Since arrows are always single headed, it cannot model undirected correlation
- A potential lack of complete consistency in scores on latent variables may result in biased component estimation, loadings and path coefficients
- It may create large mean square errors in the estimation of path coefficient loading

In spite of these limitations, PLS is useful for structural equation modeling in applied research projects especially when there are limited participants and that the data distribution is skewed. PLS-SEM has been deployed in many fields, such as behavioral sciences (e.g., Bass et al, 2003), marketing (e.g., Henseler et al., 2009), organisation (e.g., Sosik et al., 2009), management information system (e.g., Chin et al., 2003), and business strategy (e.g., Hulland, 1999).

- **Choice of SmarPLS**

Based on the above information, it is supported that Structural Equation Modeling with Partial Least Squares (PLS-SEM) would be an appropriate analysis technique for the objectives of this research, because this research not only aims to find out the relationship between independent variables and dependent variables, but also the relationship among independent variables, and their indirect influence on dependent variables. Moreover, because this research is trying to clarify the main role of University from a group of various University activities, the construct model with latent variables would be useful. Thirdly, the sample size in the dataset is relatively small. Partial Least Squares (PLS) shows its advantages in small sample size over other analysis technique such as Covariance-Based SEM.

The specific tool used to build and test model in this research is SmartPLS (see http://www.smartpls.de/forum/). SmartPLS (Ringle et al., 2005) is a Java-based statistical software particularly dealing with Partial Least Squares Structural Equation Modeling (PLS-SEM). The model is specified by drawing the structural model for the latent variables and by assigning the indicators to the latent variables via “drag & drop” (Temme et al., 2006). The output can be provided with the format of HTML, Excel or Latex. Two available resampling methods in SmartPLS are called bootstrapping and blindfolding. Like other PLS-SEM software such as VisualPLS, the specification of interaction effects is supported.

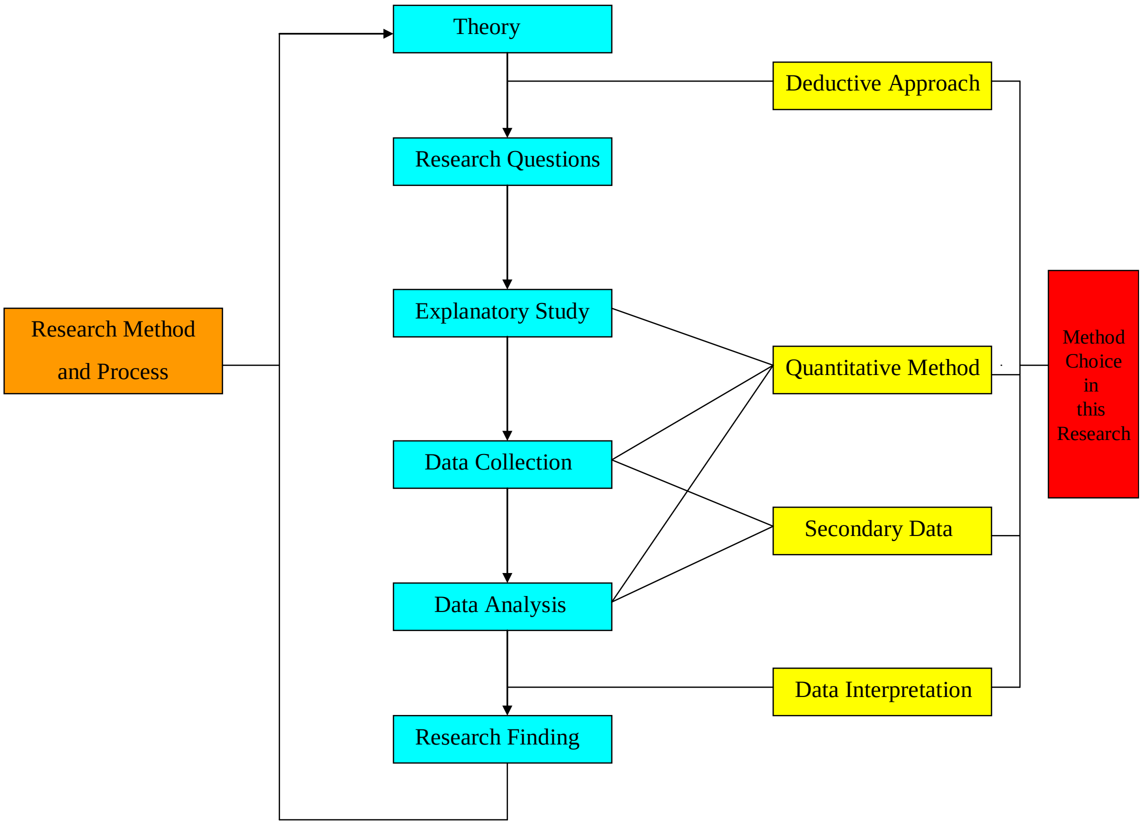
The choice of SmartPLS for this study is based on the features of this software in requirements (operating system, data), methodological options (path weighting, inner and outer model analysis, resampling methods), and ease-of-use (graphic-based, output format). SmartPLS contains the advantages of both PLS method and SEM technique. There are some main advantages. Firstly, these are many inter-related elements involved in the University-knowledge based system. Traditional tool and methods struggle in investigation of the inter-relationship and indirect relation involved among variables. SmartPLS allows to draw the relevant factors and latent factors from the complex, and further helps to find out the relationship among them. Secondly, that PLS has its advantages over other techniques when analysing small sample sizes or data with non-normal distributions. Because of the data size and nature in this research, SmartPLS shows to be an ideal tool to choose. Thirdly, SmartPLS is an easy to use tool with graphical user interface. This drag and drop based tool enables the model be clear, and easy to analyse and modify. The use of SmartPLS in this research brings in a possible solution for the research filed, especially for those quantitative studies with small data samples and complex with various related variables.

3.1.6 Research Process and Choice of Methods

A range of possible methodologies that are possible are introduced above. A deductive approach is adopted because of the nature of the research questions. It means that the theory has been used to deduce questions to consider before research was performed. This research is an explanatory based study, because it aims to understand phenomena by discovering and measuring relations among factors. Quantitative methods are therefore used in this research. The collection of secondary data from statistical datasets is used, rather than from primary data. After the data analysis with SPSS and SmartPLS, the meaning of the result is interpreted to the research finding, to contribute real practice and theory.

The process of this research will be discussed, followed by the method choice. The process of this study is illustrated with the figure below, with the method choice in this research:

Figure 3.1: Process and Method Choice of This Research



According to Finn et al (2000), research needs theory as a framework for analysis and interpretation. In the meantime theory needs research to review, modify, challenge theoretical details. Each study has to consist of a few crucial methods and process, and the order in which these methods are executed will help an appropriate study design.

3.2 Research Design

The research design starts with the aim and objectives of the research, because the research design needs to match them. It then reviews the international and regional context of the research. It also reviews the methods used in other empirical studies within this research field. These reviews provide ideas to form the model framework. Econometrics for the model which is based on the modified knowledge production function are then followed. The details of three research layers are given, with the information regarding to data resource, nation/region, time period, model framework details, econometrics, and the defined indicator and measurement for analysis. All these further help to generate precise and reliable analysis results for this research to interpret.

3.2.1 Aim and Objective

After reviewing the literature, the aim and objectives of this research are defined and made specific and focused, which is stated underneath.

- The aim is to investigate the role of University-business interaction in knowledge system and its effect on growth

There are three objectives generated to achieve the research aim and according to these objectives, more specific research questions (Q1-Q13) are designed. Research objectives and questions are shown as follows:

:

- Objective A: To discover the influence of University-business cooperation on technological progress and economic growth. It is also to find out how this network integrates with knowledge investment and entrepreneurship in the growth model

Q1: Does University-business cooperation influence economic growth?

Q2: Does University-business cooperation influence technological progress?

Q3: What is the relationship between University-business cooperation and knowledge investment, in terms of R&D investment & human capital investment; and their roles in growth model?

Q4: What is the relationship between University-business cooperation and entrepreneurship activity; and their roles in the growth model?

- Objective B: To investigate the effect of University activities on growth, and the role of University activities in regional knowledge systems. It is also to find out if this role shows differences across those regions with different knowledge absorptive capacity.

Q5: What activities of Universities contribute to regional economic growth?

Q6: What activities of Universities contribute to regional technological progress?

Q7: What is the relationship between University Core Activities, entrepreneurship, and knowledge proximity?

Q8: What is the relationship between University Knowledge Outreach Activities, entrepreneurship, and knowledge proximity?

Q9: How are University activities, together with entrepreneurship and proximity involved in regional University-based knowledge system?

Q10: Do the disparities in knowledge absorptive capacity across regions matter to the mode of University involvement in regional knowledge system?

- Objective C: To illustrate the patterns and processes of University knowledge based systems and the effect of it on knowledge commercialisation. It is also to investigate if this effect is different among different paradigms of Universities by considering their specialities.

Q11: How do University knowledge creation and dissemination processes affect University knowledge utilisation, and then the commercialisation of the knowledge?

Q12: Does University-business interaction in the knowledge dissemination process, in terms of Non-SMEs interaction channels and SMEs interaction channels, affects the knowledge commercialisation?

Q13: Do different types of University show different patterns in the University knowledge creation-dissemination-utilisation process?

3.2.2 Context and Model in the Research Field

International Context

Knowledge in the economy is the main driver of the innovation and growth. There is evidence worldwide in different countries. This University knowledge commercialisation is argued to have a great contribution in developing innovative, sustainable and prosperous regional and national economies (Drucker and Goldstein, 2007). This is why the transfer and commercialisation of University created knowledge is taking an increasingly prevalent role within government policies at a number of levels (Lambert, 2003).

In the national level, various empirical studies have suggested the importance of localised academic knowledge to innovation for the USA (Jaffe 1989; Anselin et al. 1997; Adams 2002). Smilar evidence can be seen in many European countries such as, Germany (Pamela Mueller, 2005), Italy (Medda et al., 2005; Carree et al., 2011), Spain (Duch et al., 2011), and the Netherlands (Belderbos et al., 2004).

Consistent with some argument of regional innovation system, Jaffe (1989) shows that knowledge flows from research to industry bounded in space. Accordingly, in the regional level, there is much evidence regarding to the contribution of localised knowledge spillovers to economy (e.g. Bekkers and Freitas, 2008; Mueller, 2005; Arvanitis et al., 2005; Costa and Teixeira, 2005; Becker, 2003; Lööf and Broström, 2005; Duch et al., 2011; Medd et al., 2005; Belderbos et al., 2004). There are also some examples of successful regions which experienced significant growth in the last decades, including Silicon Valley and Route 128 and the Cambridge region, which benefitted from the regional University and knowledge networks (SQW2000; Camagni, 1991; Saxenian, 1994 and 2005).

The University, as one of most important regional knowledge creators and providers, becomes the main booster of regional innovation and economy. With the recognition of the role of knowledge in economy, many countries and regions have implemented innovation policies focusing on the dissemination and utilisation of regional University knowledge. For example, to emphasize the knowledge-based economy, OECD paper (1996) suggests that to government need to particularly consider science and technology, industry and education. Accordingly the main focus of policy incentives is suggested to be University, firm, human capital, and the knowledge diffusion under the regional system of innovation.

UK Regional Context

Within the UK context, there are some unique regional patterns of innovation systems in term of University-business interaction and the knowledge commercialisation. First of all, it is found that the University knowledge is not fully commercialised. Kelly et al. (2002) argue that government in the UK has failed to fully realise the significant direct and indirect contribution of the University to its local, regional and national economies. Porter and Ketels (2003) point out that there is still a lack of understanding in the UK on how to create effective impacts through knowledge transfer from Universities. In addition, some studies argue that the performance of many UK Universities has not matched their potential in terms of knowledge transfer and commercialisation (Charles, 2003; Charles and Conway, 2001; Wright et al., 2006). Huggins et al. (2009) point out that the underlying policy in the UK is often underestimates the potential of the University in economic and regional growth.

In addition, there are disparities existing among UK regions in term of knowledge absorption capacity. Cohen and Levinthal (1990) point out that absorptive capacity is necessary if the value of new knowledge is to be recognised, assimilated, and applied for commercial ends. They also argue that research and development activities not only generate innovations but also increase the firm's ability to identify, assimilate, and exploit externally created knowledge. On the regional level, it implies that the higher level of R&D is likely to provide more opportunities to knowledge creator (i.e. Universities) and user (i.e. firms).

In many nations there are differences of competitiveness in innovation existing across regions. Huggins (2003) and Huggins & Izushi (2008) point out that in the UK this is manifested by the "North-South divide", whereby regions in the southern half of the nation, and in particular, London, South East England, and Eastern England, are the nation's core economic drivers. More northern regions, however, suffer from higher unemployment rates and lower income levels. Regions such as North East England, Wales, Yorkshire and the Humber, and Northern Ireland are significantly uncompetitive in comparison with their southern neighbours. These differences among UK regions may partly be explained by the regional disparities in knowledge absorption. First of all, the contribution of University can be different in different region. It is argued by

Sainsbury (2007) that although Universities do have a crucial part to play in the regional economy, they cannot be expected to contribute equally to this goal, there are significant differences in the wealth generated by Universities according to regional location and the type of institution. Universities in more competitive regions are generally more productive than those located in less competitive regions.

Leading research Universities in the most competitive regions are better placed to establish links with the relatively high number of industrial R&D performers located in close proximity. These links are important contributors to the research income of Universities. However, these networks are only concentrated among a small number of most competitive elite Universities, within the UK's core competitive regions with a big proportion of the UK's most R&D-intensive firms. An example can be seen with Cambridge Region (Hussign et al, 2010). These Universities and firms are capable of breaking geographical proximity. Accordingly, these regions with a rich knowledge environment also show that the evidence of a greater role being played by non-localized networks (Huggins and Izushi, 2007). This may be the reason Huggins et al. (2010) state overall economic and innovation performance of UK regions is generally inversely related to their dependence on the Universities located within their boundaries.

On the other hand, in those less innovative regions, it is argued by Huggins et al. (2010) that Universities do not have the same density of R&D oriented firms in close proximity, with which they can build links. Thus they may be forced switch to cultivate links with firms based at a relative distance. Furthermore, less competitive regions are generally compromised by

Universities that are less research intensive. It infers that they usually have less interaction networks and activities with business. Outreach University networks with large R&D firms in more peripheral regions show to be less dense.

In addition, a firm's innovation performance can be different in different region. It is shown by Audretsch et al. (2005) that in these regions with a higher density of high-technology firms, businesses tend to benefit more from University knowledge. Firms in these regions are usually shown to have a greater number of links with University, and invest more in R&D. Moreover, it can be seen in some studies that compared with other regions, there is more entrepreneurial orientation in high innovative regions. The attitude of Universities to work with local business is shown to be more positive as well (Etzkowitz, 1998; Etzkowitz et al., 2000; Smilor et al., 1993). It can be seen that high innovative regions and low innovative regions of the UK show significant differences in the capability of Universities to effectively transfer their knowledge, and of firms to effectively absorb such knowledge, which is consistent with the argument of Huggins (2008).

Indeed, in recent years both national and regional governments in the UK highlight the importance of science technology to change in the their innovation performance. Thus it can be seen that the transfer of University-generated knowledge is taking a focus within government policies at both national and regional levels (Kitson et al., 2009; Lambert, 2003; Sainsbury, 2007; Wellings, 2008). UK policy incentives also have paid attention to the third mission of University with encouraging local engagement of Universities, to stimulate regional economic development (Charles, 2003; Goddard and Chatterton, 1999; NCIHE, 1997). However according to Morgan (2002), too much

Author	Independent Variables	Dependent Variables	Model	Data Resources

emphasis had been placed on HEI activities of the elite model. According to the above different regional patterns in innovation and University knowledge commercialisation, it is suggested by Wellings (2008) that regional variations need to be considered in policy as in innovation performance and the influence of University research commercialisation and knowledge transfer performance. It refers to the requirement of policy to better account for the diversity of Universities and the regions in which they are located.

3.2.3 Model and Method Used in the Research Field

In this research field, there are many empirical studies focusing on determinates of economic growth and total factor productivity. A review of the data and methods these studies used would advise the appropriate model design and method choice for this research. These relevant studies are summarized in the table below:

Table 3.5: Review of Data and Methods in Relevant Studies

Rudi Bekkers and Isabel Maria Bodas Freitas (2008)	• Impact of industrial sectors • Knowledge characteristics • Scientific disciplines • Individual and organisational characteristics	• Knowledge transfer from University to firms	Binary logistic regression model	Netherlands- Survey on four industrial sectors
Anthony Arundel and Aldo Geuna (2001)	• Firm size • Activity in foreign markets • R&D intensity • Codified knowledge • Quantity and quality of the scientific base	• Importance of domestic and foreign PROs	Ordered logit model	Europe's largest industrial firms- PACE survey, relevant data for up to 615 firms are available from the 1993
Pamela Mueller (2005)	• Fixed capital formation • Employment • R&D in private industries • R&D in Universities • Start-up rate • University-industry relations	• Economic Growth • Total Factor Productivity	Extended knowledge production function framework; Panel Regression with fixed effect	German- Social Insurance Statistics, 1987 – 2000. Federal Statistical Office.
Spyros Arvanitis, Nora Sydow and Martin Wörter (2005)	• Informal contacts • Conferences/ publications • Common labouratory • Graduates employment in R&D • University researchers' participation in firm R&D • Common courses • Joint R&D projects • Research contracts • Consulting	• R&D expenditure • Innovation product sales	Matched-pairs analysis	Swtzerlandsland- Survey of enterprises, 2005
Charlie Karlsson and Martin Andersson (2005)	• Intra-municipal accessibility • Intra-regional accessibility • Extra-regional accessibility • University R&D • Industrial R&D	• Change in industrial R&D • Change in University R&D	Simultaneous equation approach	Sweden- SCB questionnaires, Swedish Road Administration (SRA), 1995-2001
Roderik Ponds, Frank van Oort and Koen Frenken (2009)	• University R&D • Private R&D • W space University R&D • W space private R&D • W network • Firm size • Employment	• Regional patent intensity	Extended knowledge production function framework; Pooled cross-sectional spatial model; Binomial	Netherlands- European Patent Office, Ministry of Education and Science, 1999-2001

			estimations	
Julio M. Rosa and Pierre Mohnen (2008)	● Distance ● Absorptive capacity ● Foreign control ● Same province ● Past experience with University Firm and University characteristics	● R&D payments to Universities ● Total R&D	Gravity models of international trade	Canada-Survey on research and development in Canadian industry, 1997-2001
Joana Costa and Aurora A. C. Teixeira (2005)	● Firm characters ● Openness ● Geographical Proximity ● University as determinant of location ● Interaction skills and R&D ● Education	● R&D intensity ● Human capital Intensity	Ordered logit regression,	Portugal- Community Innovation Survey(CIS) and R&D surveys, 2004
Gabrielsson, Jonas (2009)	● Entrepreneurial experience ● Private sector working experiences	● Research commercial	Linear multiple regression analysis	Questionnaire survey
Becker (2003)	● R&D expenditures intensity ● R&D labour intensity	● Product innovations ● Process innovation	Extended Linear Model	German-1990-1992, 1993-1995 Mannheim Innovation Panel Survey
Lööf and Broström (2005)	● R&D support ● Valid patents ● Demand ● Obstacles to innovation ● MNE ● Market focus ● Firm size ● Export	● Expenditures on R&D ● Patents applications ● New products sale	Cross-sectional propensity score matching estimator.	Sweden- Community Innovation Survey (CIS) 1998-2000
Martin Carree Antonio, Della Malva and Enrico Santarelli (2011)	● Teaching, ● Research ● Intellectual Property Rights ● Entrepreneurship	● Growth of gross value added	Linear regression	Italy-2001-2006
Andre Van Stel, Martin Carree, and Roy Thurik (2005)	● Entrepreneurship Activity	● GDP growth ● Per capital income ● Growth competitiveness	Linear Regression	36 countries- Global Entrepreneurship Monitor (GEM) The Global Competitiveness Report (GCR),1999-2003, 1992-2000
Néstor Duch, Javier García-Estevez, Martí Parellada (2011)	● University creation of human capital ● University research ● University technology transfer	● Growth of gross value added	Extended knowledge production function	Spain University, 1998-2006

			framework ; Regression	
Belderbos, Carree and Lokshin (2004)	• R&D co-operation with Universities • Co-operation with suppliers are • Co-operation with competitors	• Labour productivity • Growth of new product sale	Extended knowledge production function framework; Regression	Dutch enterprises- Community Innovation Survey (CIS)
Medda, Piga and Siegel (2005)	• Collabourative research with Universities	• Growth of total factor productivity	Production function model with respect to time	Italian firms -1998, MediocreditoCentrale Survey (1998)

Traditional study of determinates of growth usually apply the production function framework. However, as Arundel and Geuna (2001) point out, the disadvantage of the traditional production function approach is that there is little information on how the knowledge from research reaches firms. Many recent studies are more focused on the interaction between research and industry (Bekkers et al., 2008; Mueller, 2005; Arvanitis et al., 2005; Costa and Teixeira, 2005; Duch et al., 2011; Medda et al., 2005; Belderbos et al., 2004). With extended production function frameworks, these studies investigate the relationship between the knowledge factors and growth, in terms of economic growth usually measured with gross value added, and technological progress usually measured with total factor productivity in these studies (e.g. Mueller, 2005; Carree et al., 2011; Stel et al., 2005; Duch et al., 2011; Medda et al., 2005; Belderbos et al., 2004).

Some authors (e.g. Arundel and Geuna, 2001; Stel et al., 2005) focused on internationally level of study, and trying to find out the general evidence of the contribution of knowledge to growth. In addition, Jaffe (1989) concludes that there are important and strongly bounded in space (at the state level) knowledge flows from research to industry. Accordingly, a large number of national and regional studies based on more tightly defined technological areas provided statistical evidence for the existence of localised knowledge spillovers (e.g. Bekkers and Freitas, 2008; Mueller, 2005; Arvanitis et al., 2005; Costa and Teixeira, 2005; Becker, 2003; Lööf and Broström, 2005; Duch et al., 2011; Medda et al., 2005; Belderbos et al., 2004). In line with these insights, many countries have implemented regional innovation policies based on the evidence.

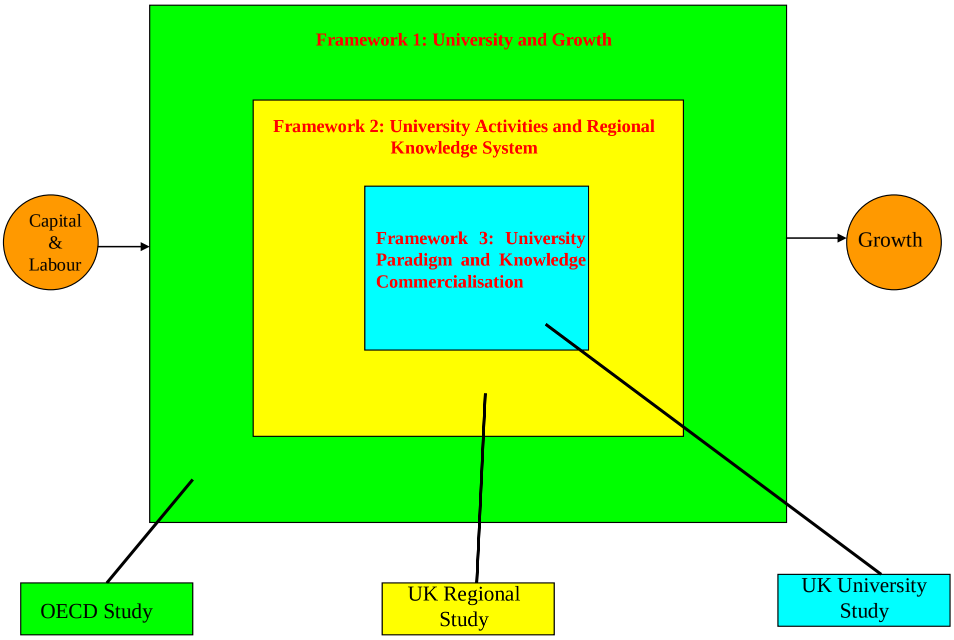
Many previous studies used the number of patents as a measurement of knowledge output. The weaknesses of this measurement were mentioned by some authors (Jaffe et al., 1993; Thompson et al., 2005), as for example it does not provide a full coverage of industrial sectors and it does not always correct for the quality of patents by using for instance patent citations. In addition, this measurement only covers the codified side of knowledge without giving much information on the tacit side, such as knowledge dissemination through the research-industry network.

Some studies were trying to investigate this network, by using a different type of data, such as payments for R&D services from research to Universities (Mueller, 2005). Some are particularly focused on the network between University and small business entrepreneurship (e.g. Arundel and Geuna, 2001; Rosa and Mohnen, 2008; Gabrielsson and Jonas, 2009; Carree et al., 2011; Stel et al., 2005). Some others are specifically focused on the spatial knowledge spillovers (e.g. Karlsson and Andersson, 2005; Ponds et al., 2009; Rosa and Mohnen, 2008; Costa and Teixeira, 2005; Becker, 2003). Distance is often measured by the contiguity of statistical metropolitan areas and administrative regions (Jaffe et al, 1993; Autant-Bernard, 2001; Karlsson and Andersson, 2005) or the distance between an enterprise and a University (Rosa and Mohnen, 2008).

3.2.4 The Overall Model Framework

The above review of international context, UK regional context, and methods in the research field, provide the ideas to build the model framework for this research. This overall framework is formed by three layers of studies with particular methods and variables designed, including the OECD study, the UK regional study, and the UK University study. Each of these is specially chosen for each of the research objectives, from the broad University based growth, to zooming in to the University activities and regional knowledge system more specifically, and then further focus on the University paradigm and knowledge commercialisation. This research is based on the knowledge production function framework, and extends it with the factors regarding to University-business interaction. This study covers both codified and tacit knowledge transfer from University and business, and it covers the networks between University and both non-SMEs and small business respectively. It also includes the three processes in terms of University-based knowledge creation, dissemination, and utilisation involved in regional system of innovation.

Figure 3.2 Overall Model Framework



The main reasons of the framework choice are listed with the table below:

Table 3.6: Model Framework and Choice

Model Framework	Reason of Choice	Ideas based on	To Answer
OECD Study: University Knowledge and Growth	• Knowledge production function needs to be modified with clear factor of knowledge spillover from University • It needs a broad multi-country framework regarding the effect of University knowledge through University-business interaction on growth, to see if it is a national specific phenomena • It needs clear indictors for knowledge transfer and output to help the for long-term and short-term policy	• **International Context** • **Model and Method Used in the Research Field** • **Model and Method Used in the Research Field**	Objective A

UK Regional Study: University Activities and Regional Knowledge System	● Science-industry link, especially the role of University-business interaction need to be focused in regional growth ● There is a need to consider knowledge system with geographical proximity, and choose a region to zoom in as the scale to see the specific University activities and interactions with business ● There is a need to consider the regional differences in knowledge absorption as UK regions shows imbalance in innovation and knowledge ● There is a need to see the role of specific University in the regional knowledge system	• **Model and Method Used in the Research Field** • **UK Regional Context** • **UK Regional Context** • **Model and Method Used in the Research Field**	Objective B
UK University Study: University Paradigm and Knowledge Commercialisation	● University role in economy and its potential is not fully recognised in the UK ● Studies are mainly focused on the role of the elite University in the regional knowledge system and economy ● It lacks the evidence to show the linkage between UK Universities paradigms and knowledge commercialisation. Find out the pattern of different types of University in knowledge commercialisation may be an dimension to help the encourage the full use of University knowledge. ● Practical reason for research and analysis because UK HEFCE database provides formal and updated data for most of the University in the UK for more than 10 years	• **UK Regional Context** • **UK Regional Context** • **Model and Method Used in the Research Field** • **UK Regional Context**	Objective C

The OECD study is chosen for the research Objective A. According to the review of the international context, UK regional context, and methods, there are three reasons for this choice. There are a group of studies which use various approaches to add knowledge factors, in terms of knowledge resource and networks, into production function framework (Mueller, 2005; Carree et al., 2011; Ste et al., 2005; Duch et al., 2011; Medda et al., 2005; Belderbos, et al., 2004). Based on these studies, knowledge production function needs to be modified with clear factors of knowledge spillover from University. There are many studies on the international scale in the research field (Jaffe 1989; Anselin et al. 199; Adams 2002; Mueller, 2005; Carree et al., 2011; Stel et al., 2005; Duch et al., 2011; Medda et al., 2005; Belderbos et al., 2004), however, these studies are all varied in their focus, scale, framework and research design. It needs a broad multi-country framework regarding the effect of University knowledge through University-business interaction on growth, to see if there is a national specific. There are also many studies based on the consequences of knowledge (Lambert, 2003; Arundel and Geuna; 2001; Jaffe et al., 1993; Thompson et al., 2005; Drucker and Goldstein, 2007), but they do not distinguish the indicator of knowledge output with direct and indirect effect. Accordingly, it needs clear indictors for knowledge transfer and output to help the for long-term and short-term policy of a regional growth.

The UK Regional study is chosen for the research Objective B. According to the review of the international context, UK regional context, and methods, there are four reasons for this choice. A big group of studies focus on the science-industry link and the role of it in regional economy (Jaffe, 1989; Bekkers and Freitas, 2008; Mueller, 2005; Arvanitis et al., 2005; Costa and Teixeira, 2005;

Becker, 2003; Lööf and Broström, 2005; Duch et al., 2011; Medda et al., 2005; Belderbos et al., 2004). According to these studies, the science-industry link, especially the role of University-business interaction, needs to be focused in regional growth. These studies also show that it needs to consider the knowledge system with geographical proximity, and choose a region to zoom in as the scale to see the specific University activities. In addition, according to studies of the UK regional context, there is an obvious imbalance in innovation across UK regions, and commercialisation of the University knowledge does not match the potential of the University in the region (Cohen and Levinthal, 1990; Huggins, 2003; Huggins and Izushi, 2008 ; Audretsch et al., 2005; Kitson et al., 2009; Lambert, 2003; Sainsbury, 2007; Wellings, 2008). It could attribute to two potential reasons: one from the University side, and the other from the regional side. On the University side, the focus of the University activity is varied across regions. On the regional side, there are disparities existing among UK regions in knowledge absorptive capacity. Therefore, there is a need to see the role and activities of specific University in the regional knowledge system, and to consider those differences in knowledge absorption across UK regions.

The UK University study is chosen for the research Objective C. According to the review of the international context, UK regional context, and methods, there are four reasons for this choice. Although the commercialisation of University is agreed as one of the main contributors of regional economy in many studies (Hall, Link et al. 2000; Cohen, Nelson et al. 2002; Geuna et al. 2004), the role of University was not fully realised and promoted in the UK (Kelly et al., 2002; Porter and Ketels, 2003; Charles, 2003; Charles and Conway, 2001; Wright et al., 2006; Huggins et al., 2009). In recent years both national and regional governments in the UK highlight the importance of

University knowledge in changing their innovation performance. However, the current system of the UK Universities shows that elite Universities (e.g. Russell Group Universities) in the most competitive regions are better placed to establish links with businesses than those other Universities in less innovative regions (Etzkowitz, 1998; Etzkowitz et al., 2000; Smilor et al., 1993). Thus there is a need for a study to provide evidence to show the linkage between UK Universities paradigms and knowledge commercialisation, and to highlight the role of outreach side of University. Finding out the pattern of different types of University in knowledge commercialisation could be a dimension to help the full use of University knowledge. There is also a practical reason from data and analysis, because the UK HEFCE (Higher Education Funding Council for England) database provides formal and updated data for most of the Universities in the UK for more than ten years. The utilisation of the information from this dataset could have great value in supporting regional policy.

3.2.5 Econometrics

The model of this research is based on the production function framework. There are a number of methods to estimate potential economic output that are normally categorised into two groups: statistical and structural. In the first group, the production series is divided into the trend and cyclical components. On the other hand, the structural method attempts to create an explicit supply model for a given economy relying on economic theory. Among the structural methods, the production function method has a special place. In economics, a production function relates physical output of a production process to physical inputs or factors of production. The original purpose of the production function is to address allocative efficiency in the use of factor inputs in production and the resulting distribution of income to those factors, while abstracting away from the technological problems of achieving technical efficiency. According to the mathematical definition of a function, a production function is assumed to specify the maximum output obtainable from a given set of inputs. The production function, therefore, describes a boundary representing the limit of output obtainable from each feasible combination of input.

The production function can assume different forms, and the Cobb-Douglas functional specification (1947) and Solow-Swan Growth Model (1956) are most often used. The functional formula represents a link between output and production inputs.

It's most standard form for production of a single good with two factors, the function is

$$Y = AL^{\beta}K^{\alpha}$$

where:

Y = total production (the real value of all goods produced)

L = labour input (the total number of person/hours worked)

K = capital input (the real value of all machinery, equipment, and buildings)

A = total factor productivity (the level of technology and efficiency of its use)

α and β are the output elasticities of capital and labour, respectively. These values are constants determined by available technology. Output elasticity measures the responsiveness of output to a change in levels of either labour or capital used in production. Further, if

$\alpha + \beta = 1$,

the production function has constant returns to scale, meaning that doubling the usage of capital K and labour L will also double output Y. If

$\alpha + \beta < 1$,

returns to scale are decreasing, and if

$\alpha + \beta > 1$

returns to scale are increasing. Assuming perfect competition and $\alpha + \beta = 1$, α and β can be shown to be capital's and labour's shares of output.

Logarithmic linearization simplifies the function and provides for clear separation of coefficients. Using logarithmic transformation, the function assumes this form:

$$lnY_t = ln\, A_t + \alpha\ ln\, L_t + \beta\ ln\, K_t \qquad \text{(Equation 1)}$$

$$\text{Thus, } TFP = ln\, A_t = lnY_t - \alpha\ ln\, L_t - \beta\ ln\, K_t \qquad \text{(Equation 2)}$$

while t stands for time.

Total factor productivity (TFP), also known as the “Solow residual”, is obtained directly from the above equation. Total Factor Productivity is often seen as the real driver of growth within an economy and studies reveal that whilst labour and investment are important contributors. It is the ratio of net output to the sum of associated labour and capital (factor) inputs. This means that total factor productivity is determined by the difference between actual output and the weighted average of production factors. To obtain the most accurate possible estimate of total factor productivity, a correct measurement of labour and capital inputs is required.

What is more, the growth rate of aggregate output is broken down into the contributions from the growth of capital and labour. The growth rate of aggregate output can be written as

$$\Delta Y = \Delta A + \alpha(t)(\Delta K) + [1 - \alpha(t)](\Delta L)$$

Accordingly

$$\Delta Y = \alpha_1 \Delta K + \alpha_2 \Delta L + \alpha_3 X_1 + \alpha_4 X_2 + \alpha_5 X_3 + \dots\dots + \varepsilon \qquad \text{(Equation 3)}$$

To extend

$$Ln(Y_t / Y_0) = \alpha_1 Ln(K_t / K_0) + \alpha_2 Ln(L_t / L_0) + \alpha_3 X_1 + \alpha_4 X_2 + \alpha_5 X_3 + \dots\dots + \varepsilon \qquad \text{(Equation 4)}$$

Symbol Δ represents the part of change in the factors. In addition to capital and labour, these factors (x1,x2,x3 ……) are the knowledge and other factors included in the model, while α is coefficient, and ε is constant.

These equations provide basic framework of this study. The three layers of research design will further include the knowledge and entrepreneurship relevant factors into the model with more specific details.

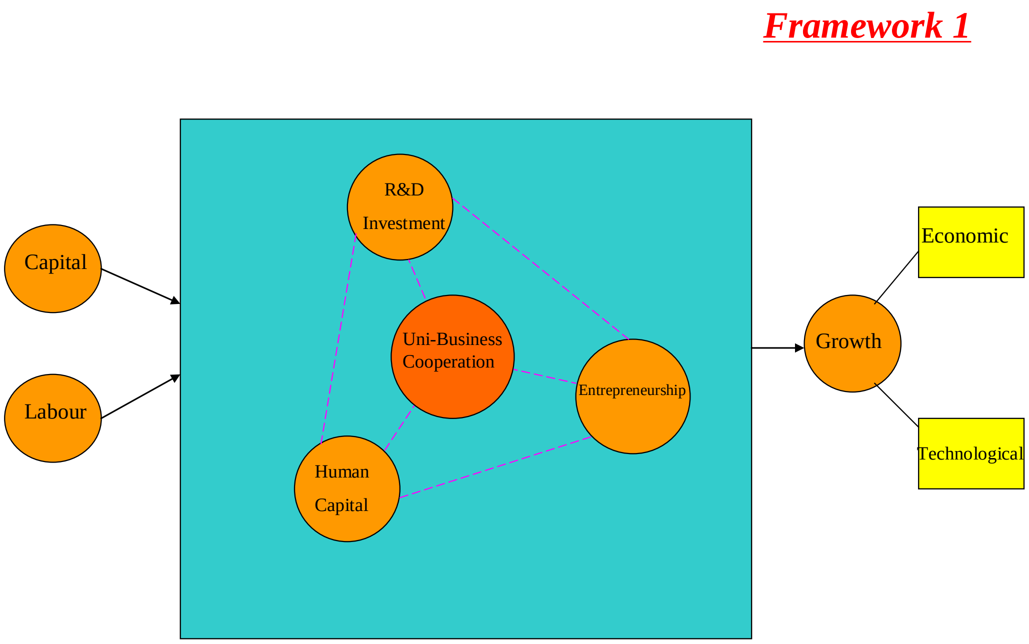
3.2.6 Design of The OECD Study

The details of the OECD study design, including model framework, source of data collection, variables and measurements, and main techniques in analysis, are discussed below.

Model Framework

The elements and relations involved in University and growth framework is summarised with the figure:

Figure 3.3: Framework 1- University and Growth



Through evolution of growth theory, the role of knowledge in growth has been recognised, and is still being further recognised. Since the input of knowledge resource was firstly realised as an endogenous factor of growth (Romer, 1986; Lucas, 1988; and Rebelo, 1991), the effect of knowledge to growth is more and more emphasised. It switches from the recognition of knowledge as an exogenous factor of growth to the endogenous reason which triggers growth. The consequence of the knowledge input also switches from the economic outcome to the lead to the technological progress, which lead to the innovation based growth. Based on the new growth theory (Schmits, 1989; Segerstrom et al.,1990; and Segerstrom, 1991), this innovation consequence will loop back to the regional pools of knowledge, and will not only regenerate further economic results, but also contributes to the competitive advantages of a region or nation, in terms of technological advances, knowledge insensitiveness, and innovative capability. In addition to this, besides “what”, “how” the created knowledge been utilised to create growth is shown in the knowledge spillover theory (Acs et al., 2003; 2006). It reveals that entrepreneurship is an important agent which exploits the knowledge through their network. With the help of knowledge, business innovation is likely to be achieved with a market oriented product. This commercialisation of knowledge will generate economic benefits according to this theory. It can be seen that the knowledge based growth theories are developed from the focus on those resources of knowledge creation, to utlisation of knowledge by business through the knowledge dissemination activities, especially those parts of spillover knowledge absorbed by business entrepreneurships.

There are empirical studies around that argue for the investments of knowledge. These investments are mainly recognised as two types: either financial capital investment, or human capital investment (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992), which still present their effect on growth. However, according to Romer (1990), those capital investments are more directly to contribute the knowledge creation rather than the economic consequences, because if the created knowledge can be transferred to economic consequences has many constraints in terms of innovation systems, business attributes, and national /regional knowledge absorptive capacity. Similarly, whether the investment in human capital results in growth is also challenged. The common debate is that the human capital investment is more likely to fulfil the entrepreneurship activity and intensify the knowledge network of a location, rather than influence the economic growth.

Another group of theory captures the system view of knowledge. When innovation systems theories (Freeman, 1987; Lundvall, 1988; and Nelson, 1993) try to address these agents/elements and the networks involved, Model 2 concept (Gibbons et al., 1994) is specified as the concept of “interaction” and “co-operation” in the problem solving. Based on these theories, the triple helix model (Etzkowitz and Leydesdorff, 1994; Leydesdorff, 1998) focuses on the relations among research, industry, and governments in the innovation system. Within these relations, the interaction between research and industry is especially pointed out as the engine to kick the innovation system. Accordingly, a big group of literature emerged to argue the interaction between University and business, and its role and mode in knowledge creation, dissemination and utilisation (Rich,1991). This argument cross some essential ideas of the University paradigm studies (Morgan, 2002;Braun, 2006; Abreu et al., 2008), which shows that University expands its primary mission of teach and research to the third mission of engagement with social and regional society and industry. This results in many Universities exploring their knowledge outreach tasks to complement its knowledge creation function.

There are some rivalries between the main argument of this group of theory, and the main argument of entrepreneurship theory. Entrepreneurship is recognised as an important factor of growth in many knowledge based growth models and studies (Solow, 1956; Swan, 1956; and Acs, 2003). However, the concept of University-business interaction (Cohen et al, 2002; Spencer, 2001; Belderbos, Carree et al., 2004) is trying to argue that the businesses which have the connection with Universities are more likely to carry out the innovation activities by which the economic consequence will be achieved. In this case, whether entrepreneurship itself still matters to the growth, or loses its position to these businesses which co-operate with Universities, is unknown. To an extent, according to the literature of University-business interaction, these activities may bring in the knowledge spillover, and this may result in the entrepreneurship activities by the exploited of these knowledge spillover. Reversely, the entrepreneurship may also enhance the rate of utilisation of knowledge, which would also like to strength the University-business co-operation. This relationship is unclear in current literature. To make clear, these questions and relations would help address the main focus of policy incentives either on University-business co-operation, entrepreneurship, or on the enhancement of relationships between the two.

In addition, as mentioned above, the role of knowledge investment to growth, in terms of R&D investment and human capital investment, is not clear. Making clear their relationship with entreprenship activity and University-business co-operation may help to have a full understanding of their role in innovation.

Data and Measurement

The details of data and measurement of the OECD study are summarised with the table below:

Table 3.7: Data and measurement Summary of the OECD Study

Data Summary	OECD Study		
Year and nation	EU Countries 02-08: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, Hungary, Latvia, Lithuania, Netherlands, Norway, Portugal, Romania, Slovakia, Slovenia, Spain 02-04, 06-08: France, Germany, Italy 02-06: United Kingdom 04-08: Luxembourg 06-08: Sweden		
Variable	**Description**	**Data Source**	**Format**
GOV (Economic Growth)	Annual Growth of Gross Value Added, At Basic Price, Percentage Changed, 2004,2006,2008	Eurostat: National Account	%
TFP (Technological Progress)	Total Factor Productivity, portion of economic output not explained by capital and Labour (By technology)		$TFP=Y-\alpha K-\beta L$
Capital	Growth of Gross Fixed Capital Formation, Percentage Changed, 2004,2006,2008	Eurostat: National Account	%
Labour	Growth of Employment, Percentage Change, 2004,2006,2008	Eurostat: Labour Force Survey (LFS)	%
Co-Uni	Firms Cooperation with Universities or other higher education institutions,Percentage,2002-2008	Eurostat: Community Innovation Survey (CIS)	%
R&D Expenditure	R&D Expenditure Euro per Inhabitant, 2002,2004,2006	Eurostat: Science, Technology and Innovation	Ln
Human Capital	Human Resource in Science and Technology between 25-64, Percentage, 2002,2004,2006	Eurostat: Science, Technology and Innovation	%
Entrepreneurship	High Tech Enterprise Birth Rate (% Active Enterprises), 2003,2005,2007	Eurostat: Structural Business Statistics	%

This OECD study is based on EU countries (including Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, Hungary, Latvia, Lithuania, Netherlands, Norway, Portugal, Romania, Slovakia, Slovenia, Spain, France, Germany, Italy, United Kingdom, Luxembourg, and Sweden). It covers this in three time periods (including 2002-2004; 2004-2006; 2006-2008). Data for this OECD study are collected from Euro Statistics. Eurostat's task is to provide the European Union with statistics at European level that enable comparisons between countries and regions. Eurostat offers a whole range of important and interesting data that governments, businesses, the education sector, journalists and the public can use for their work and daily life.

OECD study is based on the framework of equation 3 as follows.

$$\Delta Y = \alpha_1 \Delta K + \alpha_2 \Delta L + \alpha_3 X_1 + \alpha_4 X_2 + \alpha_5 X_3 + \ldots\ldots + \varepsilon \qquad \text{(Equation 3)}$$

According to the theory, some factors are added into the model including University-Business co-operation, Entrepreneurship, Human Capital, and R&D Expenditure. Therefore, the equation can be written as:

$$\Delta Y = \alpha_1 \Delta K + \alpha_2 \Delta L + \alpha_3 \, Uni + \alpha_4 \, Ent + \alpha_5 \, Exp + \alpha_5 \, HC + \varepsilon \qquad \text{(OECD Econometrics Framework)}$$

This is the OECD econometrics framework. Where output ΔY is Economic Growth. ΔK is growth of Capital and ΔL is growth of Labour. Uni is University-Business Cooperation. Ent is Entrepreneurship. HC is Human Capital.

Economic Growth is represented with annual growth of gross value added (GVA) at basic price, and it is collected from Eurostat National Account. Growth of Capital is measured with growth of gross fixed capital formation with percentage changed, and it is collected from Eurostat National Account. Growth of Labour is measured with growth of employment with percentage change and it is also collected from Eurostat National Account. Technological Progress is measured with Total Factor Productivity, which can be calculated through Equation 2 (see model econometrics). In addition, University and Business Co-operation is represented by the percentage of firm co-operation with Universities or other higher education institutions in the Eurostat Community Innovation Survey (CIS). Entrepreneurship is represented with high tech enterprise birth rate in Eurostat Structural Business Statistics. R&D Expenditure is represented with R&D expenditure with euro per Inhabitant. Human Capita is represented with percentage of human resource in science and technology between age of 25-64. They are both collected from Eurostat Science Technology and Innovation Statistics.

The descriptive Statistics are shown (see Appendix I).

This OECD study contains a linear regression analysis of SPSS with enter method, to compare the new model with typical model of growth. It will also test the relationship between independent variables and dependent variables. The Durbin-Watson test and Variance Inflation Factor (VIF) test will also be included. In addition, this OECD Study includes the Path Analysis with SmartPLS, to find out the indirect relationship between variables.

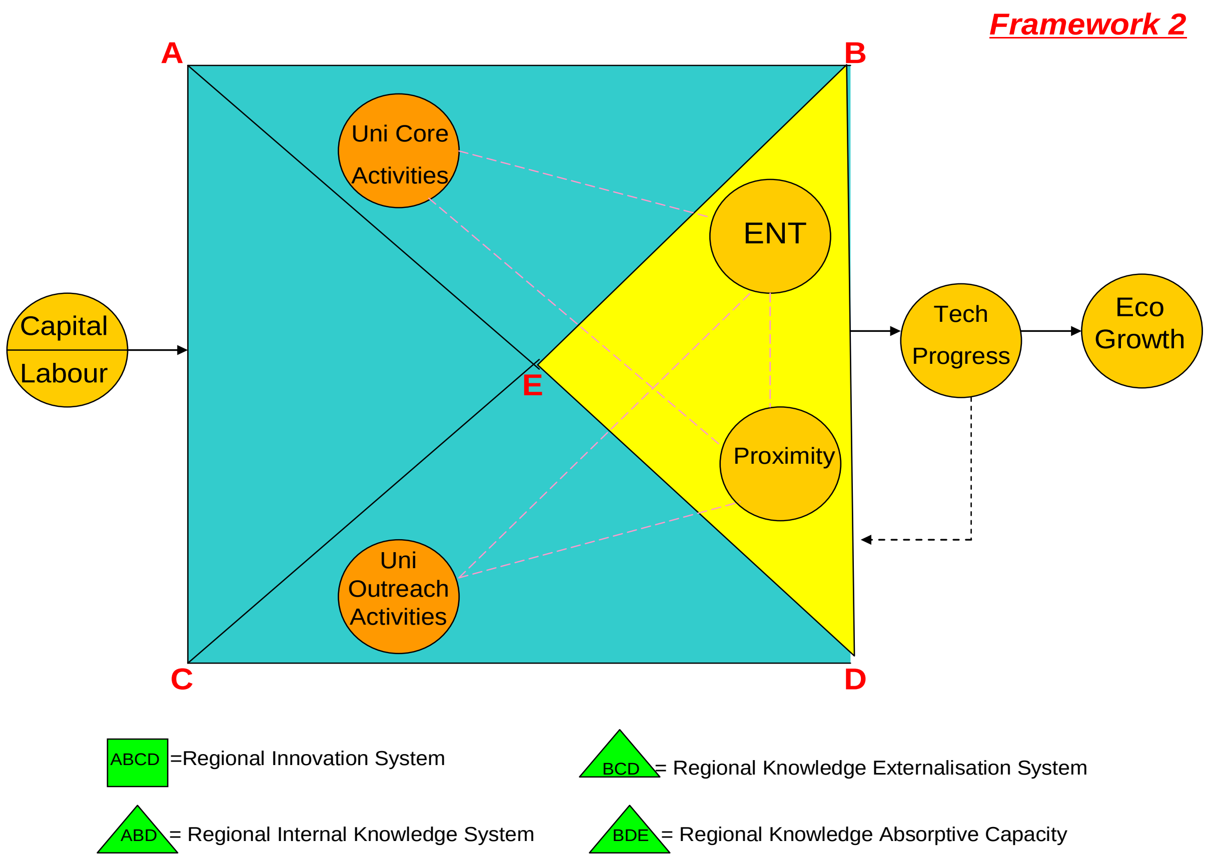
3.2.7 Design of The UK Regional Study

The details of the UK regional study design, including model framework, source of data collection, variables and measurements, and main techniques in analysis, are discussed below.

Model Framework

The elements and relations involved in University activities and regional knowledge system framework is summarised with the figure:

Figure 3.4: Framework 2- University Activities and Regional Knowledge System



Combining the knowledge based growth theory with innovation system theory, it can be see that the capital and labour add value through the innovation system, which result in the technological progress and economic growth. In addition, based on the theory of knowledge absorptive capacity (Cohen and Levinthal 1990; Miguélez and Moreno, 2013; Qian et al., 2012; Bascavusoglu-Moreau and Li, 2013), the technological progress potentially contributes to the regional pool of knowledge, and leads to a long-term growth through enhancing regional knowledge absorptive capacity.

Since the University paradigm theory (Morgan, 2002; Braun, 2006; Sauer et al, 2007) expands the University mission to knowledge transfer and regional engagement, the function of modern Universities may cover both core activities (e.g. knowledge creation and large company based interaction), and knowledge outreach activities (e.g. knowledge dissemination and SME based interaction). Linking this theory with the concept of regional knowledge absorptive capacity, two systems of regional knowledge can be formed. These core activities of University, together with regional pattern such as entrepreneurship and geographical proximity, forms the regional internal knowledge system. These outreach activities, together with regional pattern such as entrepreneurship and geographical proximity, form the regional knowledge externalisation system. Both systems contribute to the regional growth through the knowledge creation-dissemination-utilisation process. Together they cover the main function of the region innovation systems. The overlap part of two systems, is likely to represent the regional knowledge absorptive capacity.

According to University paradigm and regional innovation system theory (Asheim et al. 2003;

Cooke, 2003; Isaksen, 2002), Universities show an important role in regional growth, especially after it expands its core function with knowledge outreach. However, these literatures did not reveal how University core activities and outreach activities contribute to regional technological progress and economic growth respectively. As both core and outreach activities of University involve many regional systems, essentially to generate growth, the regional entrepreneurship and proximity may matter. Finding out the relationship among these University activities, regional entrepreneurship and proximity, would help to give an in-depth view of regional internal knowledge system and knowledge externalisation system. In addition, Miguélez and Moreno (2013) point out that regional differences in innovation and growth could attribute to different knowledge absorptive capacity among regions. To understand how University activities perform in regions with difference knowledge absorptive capacity, would give an idea to the choice of policy incentives to promote most suitable University activities based on the regional knowledge absorptive capacity.

Data and Measurement

The details of data and measurement of the UK regional study are summarised in the table below:

Table 3.8: Data and Measurement Summary of the UK Regional Study

Data Summary	UK Regional Study		
Year	2002-2009		
Region	12 UK regions: East Midlands; East of England; Greater London; North East England; North West England; South East England; South West England; West Midlands; Yorkshire and the Humber; Wales; Scotland; Northern Ireland		
Variable	**Description**	**Data Source**	**Format**
GVA	Growth of Gross Value Added	Annual Business Inquiry (ABI)	% (compared with 2001)
TFP	Total Factor Productivity (Technological Progress)		TFP=Y-αK-βL
CAPITAL	Growth of Net Capital Expenditure	Annual Business Inquiry (ABI)	% (compared with 2001)
LABOUR	Growth of Employment	Annual Business Inquiry (ABI)	% (compared with 2001)
HRST	Human Resources in Science and Technology, % Employment	Euro Statistics	%
AGG	Proximity, Agglomeration Externalities, Population Density, (Inhabitants per km2)	Euro Statistics	Ln
ENT	Total early stage Entrepreneurial Activity (TEA) Rate	Global Entrepreneurship Monitor (GEM)	%
RDP	Total intramural R&D expenditure in High Education Sector(£Thousands)	Higher Education-Business and Community Interaction Survey (HE-BCI)	Ln
UCCS	Consultancy Contracts with SMEs	(HE-BCI)	*1000/Population,
UCBN	Courses for Buisness Community with Non-SMEs (£Thousands)	(HE-BCI)	*1000/Population,
UP	Collabourative research involving Public Funding and funding from business to University(£Thousands)	(HE-BCI)	*1000/Population,
IPN	IP income from Non-SMEs Commercial Businesses(£Thousands)	(HE-BCI)	*1000/Population,
FSPIN	Formal Spin-offs, not HEI owned, Number still active which have survived at least 3 years	(HE-BCI)	*1000/Population,
SSPIN	Staff Start-ups, Number still active which have survived at least 3 years	(HE-BCI)	*1000/Population,

This UK regional study is based on 12 regions of UK (including East Midlands; East of England; Greater London; North East England; North West England; South East England; South West England; West Midlands; Yorkshire and the Humber; Wales; Scotland; Northern Ireland). It covers the in 8 year's data from 2002 to 2009. Data for this UK regional study are collected from four datasets, including Euro Statistics, Global Entrepreneurship Monitor (GEM), UK Annual Business Inquiry (ABI), and Higher Education-Business and Community Interaction Survey (HE-BCI).

Global Entrepreneurship Monitor (GEM) is an annual assessment of the entrepreneurial activity, aspirations and attitudes of individuals across a wide range of countries. GEM explores the role of entrepreneurship in national economic growth, unveiling detailed national features and characteristics associated with entrepreneurial activity. The data collected is 'harmonized' by a central team of experts, guaranteeing its quality and facilitating cross-national comparisons. Annual Business Inquiry (ABI) is a survey contains employment and financial information. This release deals with the financial inquiry which collects information for about two thirds of the UK economy, covering agriculture (part), hunting, forestry and fishing; production; construction; motor trades; wholesale; retail; catering and allied trades; property; service trades. The financial variables covered include turnover, purchases, employment costs, capital expenditure and stocks. Approximate Gross Value Added (GVA) is calculated as an input into the measurement of Gross Domestic product (GDP). The Higher Education-Business and Community Interaction survey (HE-BCI) is an annual survey which examines the exchange of knowledge between Universities and the wider world, and informs the strategic direction of "knowledge exchange" activity that funding bodies and higher education institutions (HEIs) in the UK undertake. The surveys collect financial and output data per academic year. Results are summarised in the annual survey reports which provide information on a range of activities, from the commercialisation of new knowledge, through the delivery of professional training, consultancy and services, to activities intended to have direct social benefits. HE-BCI is the main vehicle for measuring the volume and direction of interactions between UK Higher Education Institutions (HEIs) and business and the wider community. The survey collects information on the infrastructure, capacity and strategy of HEIs, and also numeric and financial data regarding third stream activity (that is, activities concerned with the generation, use, application and exploitation of knowledge and other University capabilities outside academic environments, and distinct from core activities of teaching and research). The activity definition of HE-BCI is included (See Appendix II)

This UK regional study is based on the framework of equation 3 as follows.

$$Ln(Y_t / Y_0) = \alpha_1 Ln(K_t / K_0) + \alpha_2 Ln(L_t / L_0) + \alpha_3 X_1 + \alpha_4 X_2 + \alpha_5 X_3 + \ldots\ldots + \varepsilon$$ (Equation 4)

According to the theory and result of factor analysis, some factors are added into the model including University Activities, Entrepreneurship, and Proximity. Therefore, the equation can be written as:

$$Ln(Y_t / Y_0) = \alpha_1 Ln(K_t / K_0) + \alpha_2 Ln(L_t / L_0) + \alpha_3 U_i + + \alpha_4 Ent + \alpha_5 Pro + \varepsilon$$ (UK Regional Econometrics Framework)

This is the UK regional econometrics framework. Because the data of Capital (Gross Fixed Capital Formation) in the UK regions is not available, regional Net Capital Expenditure is chosen as the variable to represent Capital according to the suggestion of Blades and Schlochtern (1998). In their study, five types of capital were compared, and Capital Expenditure showed to be an ideal variable to calculate growth. Therefore, K_t is the Net Captial Expenditure in the year of t, and K_0 is the Net Capital Expenditure in the year of 2001. The growth of Capital (Net Capital Expenditure) based on the price of 2001 can be calculated. Similarly, the Economic Growth (Gross Value Added) and Labour Growth (Employment) based on the price of 2001 can be figured out too. Then Technological Progress represented with Total Factor Productivity can be calculated through Equation 2 (see model econometrics). In addition, University Activities in terms of knowledge creation, knowledge outreach, non-SMEs focus, SMEs focus, are included in the model U_i, where i =1, 2, 3,…… represents each sort of University activities. Entrepreneurship represented with Total Early Stage Entrepreneurial Activity (TEA) rate is collected from Global Entrepreneurship Monitor (GEM). Geographical Proximity is represented with Population Density (Inhabitants per km2) and collected from Euro Statistics. Moreover, these variables regarding University and business interaction are collected from Higher Education-Business and Community Interaction survey (HE-BCI). They include R&D Expenditure (Total intramural R&D expenditure in High Education Sector); University Consultancy Contracts to SMEs (income associated with consultancy); University Courses for Non-SMEs (revenue generated by continuing professional development courses); University and Business Collaborative research (public funding of research project); IP income from Non-SMEs (income from patents, copyright, design registrations and trade marks); University Formal Spin-offs (companies set-up based on IP that has originated from within the HEI but which the HEI has released ownership, survived at least 3 years); Human Capital (Percentage of human resource working in science and technology); and Staff Start-ups (companies set-up by active HEI staff but not based on IP from the institution, and have survived at least three years). There is a factor analysis by SPSS run with above variables, to clarify some main University activities. A Cronbach's Alpha test is included with the factor analysis.

The descriptive Statistics are shown (see Appendix III).

Structural Equation Modeling (SEM) analysis is run with SmartPLS, to find out the contribution of those University activities (from the result of above factor analysis) on growth. It is also to find out the relationship between these activities on entrepreneurship and geographical proximity.

Finally, because this study covers eight years' of regional data, a panel data takes the fixed effects (FE) into consideration (Hedges and Vevea, 1998). With FE, it is assumed that each independent variable has its own individual characteristics that may or may not influence the dependent variable. Importantly, the FE removes the effect of those time-invariant characteristics from the predictor variables so that the predictors' net effect can be assessed. There are a few approaches for fixed effects calculation and the approach used for this research is included (See Appendix IV).

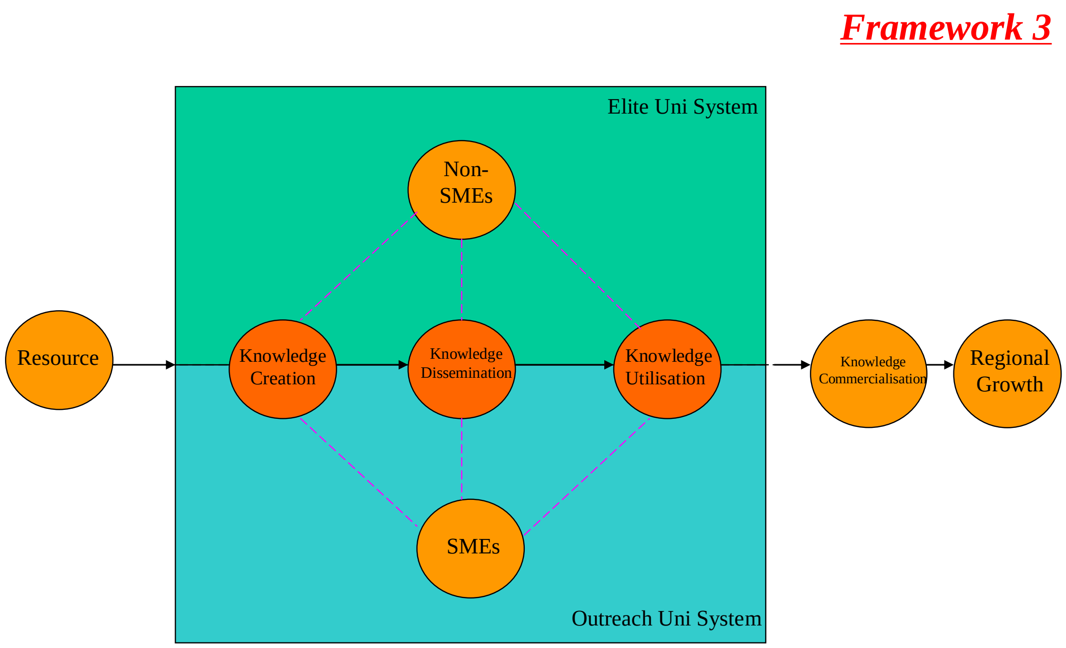
3.2.8 Design of The UK University Study

The details of the UK University study design, including model framework, source of data collection, variables and measurements, and main techniques in analysis, are discussed below.

<u>Model Framework</u>

The elements and relations involved in University paradigm and knowledge commercialisation framework is summarised with the figure, and are discussed as follows:

Figure 3.5: Framework 3- University Paradigm and Knowledge Commercialisation



Mogan (2002) shows that both core and outreach activities cover the interaction with business, and they both generate growth through a knowledge creation-dissemination-utilisation process (Rich, 1991). However, according to the literature of science and industry link (Cohen et al, 2002;

Spencer, 2001; Belderbos et al., 2004), there is variety in the modes of Universities in generating growth. These modes are usually based on the University specialty. A typical example is technological cluster (Saxenian, 1994; Krugman, 1991; Porter, 1990; Karlsson and Andersson, 2009), which are usually formed with elite University and high-tech businesses. Another example can be those outreach Universities which serve the knowledge transfer in relatively less innovative areas (Braun, 2006; Abreu et al, 2008; Slaughter and Leslie, 1997; and Etzkowitz et al., 2000). According to these studies, there are also some arguments that certain Universities focus mainly on large companies, and other Universities tend to interact more with small business.

It is hard to say there is a best mode, because the choice of University interaction with business is based on its speciality. However, it may result in different consequences. According to studies (Bercovitz, 2006; Hewitt-Dundas, 2008; Karlsson and Andersson, 2009), some Universities develop their international networks and world reputation in knowledge creation, while others try to infrastructure their regional network and involvement. Some Universities have a strategy of long-term blue-sky thinking, while others focus on the short-term economic return. Some Universities directly contribute to the national/regional economy, while others are more indirect, focusing on enhancing the regional knowledge absorptive capacity. Because of these differences in regional knowledge absorptive capacity and University speciality in the same region, different Universities may show different aspects and patterns. Similarly, some types of Universities in different regions may also show different aspects and patterns. Understanding these varieties in regions and Universities would give a better view of University activities in terms of knowledge creation, dissemination, and utilisation, and also the economic consequences. It would also help to set different policy incentives according these varieties, to transfer the knowledge to growth efficiently.

Data and Measurement

The details of data and measurement of the UK University study are summarised in the table below:

Table 3.9: Data and Measurement Summary of the UK University Study

Data summary	**UK University Study**		
Year	2007-2009		
University	All UK higher education institutions (HEI)		
Variables	**Description**	**Data Source**	**Format**
AS	Number of Academic staff	Higher education-business and community interaction survey (HE-BCI)	Zscore
CRT	Research Contracts Total (£Thousands)	(HE-BCI)	Zscore
CCN	Consultancy Contracts with Non-SMEs Commercial (£Thousands)	(HE-BCI)	Zscore
CN	Courses for Business Community with Non-SMEs Commercial (£Thousands)	(HE-BCI)	Zscore
EFN	Facility and Equipment Related Service with Non-SMEs Commercial (£Thousands)	(HE-BCI)	Zscore
CCS	Consultancy Contracts with SMEs (£Thousands)	(HE-BCI)	Zscore
CS	Courses for Business Community with SMEs (£Thousands)	(HE-BCI)	Zscore
EFS	Facility and Equipment Related Service with SMEs (£Thousands)	(HE-BCI)	Zscore
PF	Income from research related activities - collabourative research involving public funding (£Thousands)	(HE-BCI)	Zscore
SPINH	Number of Spin-offs with some HEI ownership	(HE-BCI)	Zscore
IP	Intellectual Property Income Total (£Thousands)	(HE-BCI)	Zscore

This UK University study is based on all UK higher education institutions (HEI). Data is collected from Higher Education-Business and Community Interaction Survey (HE-BCI) from 2007-2009. The samples of Universities and institutes in this survey are shown (See Appendix V)

According to Rich (1991) and Cohen et al. (1990), the utilisation of University knowledge accounts for a big portion of growth, and also the growth generation of knowledge is through the system of knowledge creation, dissemination, and utilisation. Therefore Equation 3 can be extended to:

$$\Delta KU = \alpha_1 \Delta KC + \alpha_2 \Delta KD + \varepsilon$$ (University Econometrics Framework)

In this framework, KU is the utilisation of University knowledge by business. It is measured by a University's income from intellectual property, collaborative research, and spin-offs. KC is the University-business interaction in knowledge creation, and it includes variables of Academic Staff (measured by the number of academic staff), and Research Contracts from Business (contract income identifiable by the institution as meeting the specific research needs of external partners). KD is the University-business interaction in knowledge dissemination, and is measured by SMEs and non-SMEs cost on the interaction with University in terms of Consultancy Contracts (income associated with consultancy), Courses for Business (revenue generated by continuing professional development courses), and Facility and Equipment Related Service (income associated with the use the HEI's physical academic resources by external parties).

The descriptive Statistics are shown (see Appendix VI).

Focusing on these variables, Structural Equation Modeling (SEM) analysis is run with SmartPLS, to find out the relationship between University-business interaction in knowledge creation, dissemination, and the mutilation of University knowledge. What is more, Cluster Analysis with SPSS is included. The aim of it is to group the Universities, and then to see if the relationship shows various patterns in different groups of University.

3.3 Summary

This chapter introduced the method and design for this research. First of all, the research methods are then studied with strengths and weaknesses for each method, to help the choice of most appropriate methods. According to the nature of the research objective, this research chooses the explanatory research with deductive approached to generate research questions from theory and literature. Moreover, this is quantitative research based on secondary data.

Model framework of this research is based on the extended production function. With the study of this framework and review of methods in similar researches, three layers of study designed, including the OECD study, the UK regional study, and the UK University study. The details of three research layers are given, with the information regarding to data resource, nation/region, time period, model framework details, econometrics, and the defined indicator and measurement for analysis. All these further help to generate precise and reliable analysis results for this research to interpret. These studies together aim to provide comprehensive answers to research questions.

The secondary data are mainly collected from four datasets, and they are Euro Statistics; Global Entrepreneurship Monitor (GEM); UK Annual Business Inquiry (ABI); and Higher education-business and community interaction survey (HE-BCI). There are two main analysis tools involved in the data analysis. SPSS is dealing with the Linear Regression Analysis, Factor Analysis and Cluster Analysis, while SmartPLS is dealing with Path Analysis and Structural Equation Modeling (SEM) Analysis. With the function of these techniques, the research question can be precisely answered with reliable results. The details of data analysis, research results, and findings are shown in next three chapters.

Chapter 4: Analysis and Finding of OECD Study

4.1. Introduction

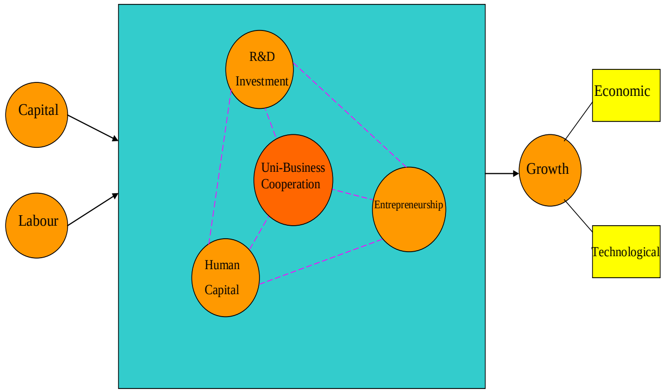
This OECD study is designed for research objective A, which is to discover the influence of University-business co-operation on technological progress and economic growth, and also to find out how this network integrates with knowledge investment and entrepreneurship in the knowledge system. It is trying to answer the research question Q1-Q4 in detail.

Historically, Neo-classical Growth Model (Exogenous Growth Model) pointed out that the long-run growth rate is exogenously determined. Capital, labour and some other exogenous factors are realised to contribute to economic growth. In the 1980s the New Growth Theory (Endogenous Growth Theory) introduced knowledge into models of growth, and argued that growth is endogenous. Since then the knowledge investment and entrepreneurship as factors are included in the empirical studies as determinates of growth. More recently, knowledge spillover theory of entrepreneurship identifies the entrepreneurship's role in spillover of knowledge. Entrepreneurship exploitation and spillover of knowledge were introduced to the growth model and became the main topic of debate. Based on these theories, factors including capital, labour, entrepreneurship, knowledge investment, and knowledge spillover are chosen as the independent variables of measurement, which may potentially influence the growth consequences. Among these variables, knowledge investment is represented by the indicator of R&D expenditure and human capital, and knowledge spillover is represented by the indicator of University-business co-operation.

Two types of growth are defined as the output, or dependent variable. One is economic growth, measured by the growth of gross value added. Another way of growth accounting could be to estimate TFP (Total Factor Productivity) growth rate or the rate of technological progress, subtracting from the growth rate of economic output that part of the growth rate that can be accounted for by the growth rate of the inputs capital and labour. (see Solow residual, 1956). Total factor productivity (TFP) can be taken as a measure of an economy's long-term technological change or technological dynamism.

This part of study is based on the model framework 1 (see details on the summary table below). The Econometrics used for this study is $\Delta Y = \alpha_1 \Delta K + \alpha_2 \Delta L + \alpha_3 Uni + \alpha_4 Ent + \alpha_5 Exp + \alpha_5 HC + \varepsilon$ (where K is Capital; L is labour; Uni is the University-business cooperation; Ent is entrepreneurship activity; Exp is R&D expenditure; HC is human capital). Following Solow (1956), the production function is assumed that economic output is determined by physical capital K, labour L and the level of technology A(t) (also called total factor productivity, TFP). The growth rate of aggregate output is broken down into contributions from the growth of capital and labour. Regional aggregate output Y is measured by gross value added of all industries (at constant 1995 prices). The physical capital stock K is calculated with gross fixed capital formation (investment at constant 1995 prices). The number of employees measures labour L. According to production function, $TFP = \ln A_t = \ln Y_t - \alpha \ln L_t - \beta \ln K_t$, thus $\Delta TFP = b_1 Uni + b_2 Ent + b_3 Exp + b_4 HC + \varepsilon$. This research is focused on the study of OECD countries from the years 2002-2008. Most data of the variables are collected from the Eurostat database under the different catalogues of survey (see http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes).

Table 4.1 Summary of the OECD Study Design

Research Questions to Answer	Econometrics	Model Framework	Variables/ Measurements	
Q1: Does University-business cooperation influence economic growth?	$\Delta Y = \alpha_1 \Delta K + \alpha_2 \Delta L + \alpha_3 Uni + \alpha_4 Ent + \alpha_5 Exp + \alpha_5 HC + \varepsilon$	***Framework 1*** 	GOV (Economic Growth)	Annual Growth of Gross Value Added, At Basic Price, Percentage Changed, 2004,2006,2008
Q2: Does University-business cooperation influence technological progress?			TFP (Technological Progress)	Total Factor Productivity, portion of economic output not explained by capital and Labour (By technology)
Q3: What is the relationship between University-business cooperation and knowledge investment, in terms of R&D investment & human capital investment; and their roles in growth model?			Capital	Growth of Gross Fixed Capital Formation, Percentage Changed, 2004,2006,2008
Q4: What is the relationship between University-business cooperation and entrepreneurship activity; and their roles in the growth model?			Labour	Growth of Employment, Percentage Change, 2004,2006,2008
			Co-Uni	Firms Cooperation with Universities or other higher education institutions,Percentage,2002-2008
			R&D Expenditure	R&D Expenditure Euro per Inhabitant, 2002,2004,2006
			Human Capital	Human Resource in Science and Technology between 25-64, Percentage, 2002,2004,2006
			Entrepreneurship	High Tech Enterprise Birth Rate (% Active Enterprises), 2003,2005,2007

4.2 University-Business Co-operation and Growth: Result of Regression Analysis

4.2.1 University-Business Cooperation and Economic Growth

Using SPSS, a regression analysis (Enter Method) is carried out for the Economic Growth Model (Model I and Model II) with above data. The choice of Enter Method is because it provides the flexibility of comparison between models. The analysis result is presented with the table below:

Table 4.2: OECD Economic Growth Model Result with Regression Analysis

Gross Value Added	**Model (I)**	**Model (II)**
Growth of Capital	.215** (7.175)	.218** (8.170)
Growth of Labour	.417** (2.810)	.474** (3.575)
R&D Expenditure	-.008** (-2.929)	-.009** (-3.389)
Human Capital in Science	-.057 (-1.417)	-.089* (-2.425)
High Tech Enterprise Birth Rate	.070 (1.826)	.052 (1.513)
University-Business Co-operation		.130** (4.084)
Constant	.060** (5.666)	.059** (7.075)
R^2-adj	.696	.760

Durbin-Watson	1.730	1.881
F	30.362	34.769
Sig.	.000	.000

Note: * significant at 5%-level, ** significant at 1%-level, t-values in parentheses

Based on the theory and relevant study, in economic growth model, these factors (Growth of Capital; Growth of Labour; R&D Expenditure; Human Capital; and Entrepreneurship) are included in the model to run the analysis. In Model (I), the result shows that:

- Capital positively influences economic growth
- Labour positively influences economic growth
- R&D expenditure negatively influences economic growth

By adding a factor of University-business co-operation to the model, the result of Model (II) found out that:

- Capital and labour positively influences economic growth
- R&D expenditure negatively influences economic growth
- Human Capital negatively influences economic growth
- University-Business co-operation positively influences economic growth

4.2.2. University-Business Co-operation and Technological Progress

Similarly, the result of the Technological Progress Model (Model III and Model IV) is shown in the table below:

Table 4.3: OECD Economic Technological Progress Model Result with Regression Analysis

Total Factor Productivity	**Model (III)**	**Model (IV)**
R&D Expenditure	-0.06*(-2.367)	-.007** (-2.769)
Human Capital in Science	-.061(-1.567)	-.087* (-2.418)
High Tech Enterprise Birth Rate	.059 (1.528)	.040 (1.122)
University-Business Cooperation		.125** (3.816)
Constant	.053**(5.287)	.052** (5.821)
R^2-adj	.250	.387
Durbin-Watson	1.826	2.037
F	8.117	11.081
Sig.	.000	.000

Note: * significant at 5%-level, ** significant at 1%-level, t-values in parentheses

In Model (III), the only factor related to the technological progress is R&D expenditure:

- R&D expenditure negatively influences technological progress

When including the factor of University-Business Co-operation, the Model (IV) shows that

- R&D expenditure negatively influences technological progress
- Human Capital negatively influences technological progress

- University-Business co-operation positively influences technological progress

According to the above tables, variables in Models (II) account for a higher percentage of variance than Model (I), and factors in Models (IV) account for a higher percentage of variance than Model (III). This study of OECD countries illustrated that the University-business co-operation is an important factor which contributes to both economic growth and technological progress. Durbin-Watson shows there is no self-collinearity existing in variables. Because data in this OECD broad study is not able to cover geographical specific factors which may also be important for the model, thus the relatively low R^2-adj value shows that these variables may not account for all information to the technological progress model.

4.2.3 Discussion

Table 4.4 : OECD Result Discussion 1

<table>
<tr><th rowspan="2">Knowledge to Growth</th><th rowspan="2">Model</th><th rowspan="2">Effect</th><th colspan="2">Relevant Literature and Theory</th></tr>
<tr><th>Literature</th><th>Theory</th></tr>
<tr><td rowspan="2">Knowledge→ Economic Growth</td><td>Model (I)</td><td>Capital ↑
Labour ↑
R&D Expenditure ↓
Human Capital
Entrepreneurship</td><td rowspan="4">● Nature of knowledge
● Knowledge based growth theory
● Knowledge system
● University role and paradigm
● Sciences and Industry Link</td><td rowspan="4">● Codified Knowledge and Tacit Knowledge
● Know Indicators
● New Growth Theory (Endogenous Growth Theory)
● The Knowledge Spillover Theory of Entrepreneurship
● National Innovation System
● Model 2
● Triple Helix Model
● Changes of University Role
● University-Business Interaction</td></tr>
<tr><td>Model (II)</td><td>Capital ↑
Labour ↑
R&D Expenditure ↓
Human Capital ↓
Entrepreneurship
Cooperation ↑</td></tr>
<tr><td rowspan="2">Knowledge→ Technological Progress</td><td>Model (III)</td><td>R&D Expenditure ↓
Human Capital ↓
Entrepreneurship</td></tr>
<tr><td>Model (IV)</td><td>R&D Expenditure ↓
Human Capital ↓
Entrepreneurship
Cooperation ↑</td></tr>
</table>

Note: Significant positive effect: ↑ ; Significant negative effect: ↓

According to the results in both Model (I) and Model (II), growth of capital and labour have positive effects on economic growth. Capital and labour are prevalently recognized as the main factor of economic growth. This result is consistent with the basic rule of Neo-classical Growth Model (Exogenous Growth Model), in which economic growth is exogenously attributed to capital and labour accumulation.

By adding a factor of University-Business Cooperation, the main finding in Model (II) and Model (IV) discovered that co-operation between Universities and businesses also shows a significant positive influence on the economic growth and technological progress. This result is consistent and develops the main arguments of five literatures groups:

First of all, this result develops the literature of "nature of knowledge". It is consistent with the theory of the codified knowledge and tacit knowledge (Lundvall and Johnson, 1994; and OECD, 1996), but provides empirical evidence on an international scale that dissemination of tacit knowledge has a significant effect on growth. The added factor University and business co-operation is a channel of knowledge dissemination. Based on the main idea of the theory, codified knowledge such as publications and patents seem to be essential inputs to industrial innovation, and the need to transfer from Universities to businesses (Narin et al., 1997; McMillan et al., 2000; and Cohen et al., 2002). Similarly, tacit knowledge, such as collaborative and contracted research activities (Kingsley et al., 1996; Meyer-Krahmer and Schmoch, 1998; and Monjon and Waelbroeck, 2003), the employment of University researchers (Zucker et al., 2002; Gübeli and Doloreux, 2005), and informal contacts (Meyer-Krahmer and Schmoch, 1998; and Cohen et al., 2002) show to be important forms of knowledge, which need to be transferred to generate innovation. However, tacit knowledge is relatively difficult to transfer compared with codified knowledge, as it is usually constrained to a certain network or location. Therefore, University-business co-operation, which may not only help the flow of codified knowledge, but also the tacit knowledge flow, is shown to be especially important for innovation attributed to the tacit knowledge spillover. This result also contributes to the indicator of knowledge. Measuring knowledge, especially the knowledge dissemination, is always a challenge in the research field. This study provides a possible indicator of knowledge dissemination, which is University-business co-operation for the choice of future research.

Secondly, it contributes to the "knowledge based growth theory". This result is consistent with New Growth Theory (Endogenous Growth Theory; Romer, 1986; Lucas, 1988; and Rebelo, 1991) which shows that knowledge is an endogenous reason for growth, since in the result, knowledge not only contributes to economic growth, but also the technological progress, which represents the ability of transferring the capital and labour to economic output. Moreover, this result accords with the main ideas of Knowledge Spillover Theory of Entrepreneurship (Acs et al., 2003; 2006 ;2008) which emphasizes the outstanding role of knowledge spillover to business innovation, but further extends it to the University specific knowledge spillover.

In addition, this provided broad international evidence for a group of studies which argued the important role "science-industry link" plays to the economy. Some scholars have tried to assess it, and have found a positive impact of science upon economic performance (Adams, 1990; Jaffe, 1989; and Acs et al, 1992). Narin et al (1997) have shown that US industry relies on external sources of knowledge centred on public science. Some other studies specifically focus on highlighting the role of University knowledge to the economy (Smilor et al.,1993; Slaughter and Leslie, 1997). They argue that compared with public research, University research more commonly results in a strongly market-oriented product. If the generated knowledge is transferred via cooperation it may accelerate technology transfer and enable firms to develop new products and processes (Cohen, Nelsen & Walsh, 2002, Spencer, 2001, Mansfield 1991 and 1998). Belderbos, Carree et al. (2004) pointed out that Universities are in a better position than government labs to provide the research necessary to stimulate economic growth.

Similarly, this result stresses the importance of University based networks in “knowledge system”, which is common to the main argument of Model 2 theory (Gibbons et al., 1994) in terms of problem solving focused relationships among people, and National Innovation System Theory (Freeman, 1987; Lundvall 1992; and Nelson, 1993) in terms of the network and linkages between different agents in a knowledge system. More specifically, the result is coincident with one dimension of triple helix model, which is that University-business networks are demonstrated as the key trigger of the innovation process.

Moreover, this result is also consistent with the “University role and paradigm” literature. Under this category, many studies shows that apart from its traditional role of teaching and research, Universities have expanded their functions to interact with businesses, promoting knowledge dissemination as its third mission. For instance, on the topic of large surveys of firms and Universities, these authors have found that public research organisations (PROs), especially Universities, as a source of knowledge for innovating companies (Arundel & Geuna, 2004, Klevorick et al., 1995, Cohen, Nelson and Walsh, 2002, Laursen & Salter, 2004). This has led to the idea that Universities are significant contributors to industrial innovations. It provides not only the ready-to-market product, but also the technology, approach, and solution for the industry. University-business seems to an ideal way of transferring all these knowledge, according to the result of the model (IV), which discovers a positive effect of University-business co-operation on technological progress.

The reason why co-operation between Universities and business significantly contributes to the economic growth and technological progress of a nation can be traced back to the nature of knowledge itself. When regard to the role of research in innovation processes, four functions can be identified, and they are according to Kauffeld-Monz (2005): generation of new knowledge; accumulation of this knowledge and of knowledge originating elsewhere; transmission and transfer of all knowledge accumulated; and the conversion of research results in innovation. Muller (2005) points out that knowledge needs to flow before it can be applied and commercialised externally. Hence, knowledge transmission channels are needed. According to the studies based on the knowledge spillover theory of entrepreneurship, University-industry relations are prevalently demonstrated as possible knowledge transmission channels which penetrate the knowledge filter and stimulate knowledge flows. This co-operation between Universities and businesses encourages the transfer of both codified knowledge and tacit knowledge.

However, the results of above Model (I-IV) do not find any relationship between entrepreneurship activity and growth, in both economic growth models and technological models. It indicated that in OECD national level, entrepreneurship (measured by the High Tech Enterprise Birth Rate) has no direct influence on the economic growth and technological progress. This is in contrast with most growth theories which emphasised the role of entrepreneurship in knowledge economy, such as the Schumpeterian Growth Model, the Knowledge Spillover Theory of Entrepreneurship; etc. It could be attributed to the following reasons. First of all, entrepreneurship factors are partly substituted by the University-business co-operation, since the co-operation constitutes the relationship between University and both non-SMEs and SMEs. Moreover, according to the innovation proximity theory (Boschma, 2005), the effect of entrepreneurship on growth has a geographical constraint as the knowledge transferred from research to entrepreneurship are usually embedded in the local knowledge proximity. The national level study does not include such proximity as a factor.

In addition, the results in the Model (II) and Model (IV) found negative significant relationships between R&D expenditure and growth. Similarly, human capital is also found to be negatively related in both economic growth and technological progress models. These results contrast with endogenous growth theory, which argues the significant contribution of knowledge input such as R&D expenditure and human capital in economy. It may because of two reasons. First, the R&D expenditure and human capital perhaps contribute to the growth indirectly, through their influences on University-business co-operation and entrepreneurship. In addition, it may also because the input of R&D expenditure and human capital are more likely to bring a long run of economic consequences, rather than an instant benefit.

Thus, the next step of the analysis is to test these hidden effects of R&D expenditure, human capital, and entrepreneurship on growth with path modelling.

4.3 R&D Expenditure, Human Capital, Entrepreneurship and Growth: Result of Path Modelling Analysis

The above regression analysis found out the effect of University-business co-operation on economic growth and technological progress. However, the indirect relationship and inter-relation of factors in the model are still vague. This section of path modelling analysis with Smartpls is trying to investigate the indirect relationship between knowledge factors and growth. It is also trying to find out the inter-relation among variables.

In path modelling analysis with SmartPLS, Formative Measurement Models can be evaluated with two criteria. One criteria is the significance of weights meaning that estimates for the model should be at significance levels. This can be achieved by applying the Bootstrap procedure. The second criterion is multico-llinearity where manifest variables in a formative block must be tested for multi-collinearity (Wong, 2013). Reactive Measurement Models can be evaluated according to the following criteria. One criterion is called factor loadings which should be higher than 0.7. Another criterion is the so-called composite reliability. According to Henseler (2012), the composite reliability as a measure of internal consistency should be higher than 0.6. In the Average Variance Extracted (AVE) criterion the average variance should be higher than 0.5.

4.3.1 R&D Expenditure, Human Capital, Entrepreneurship and Economic Growth

Figure 4.1: OECD Path Modelling Analysis Result of Economic Growth

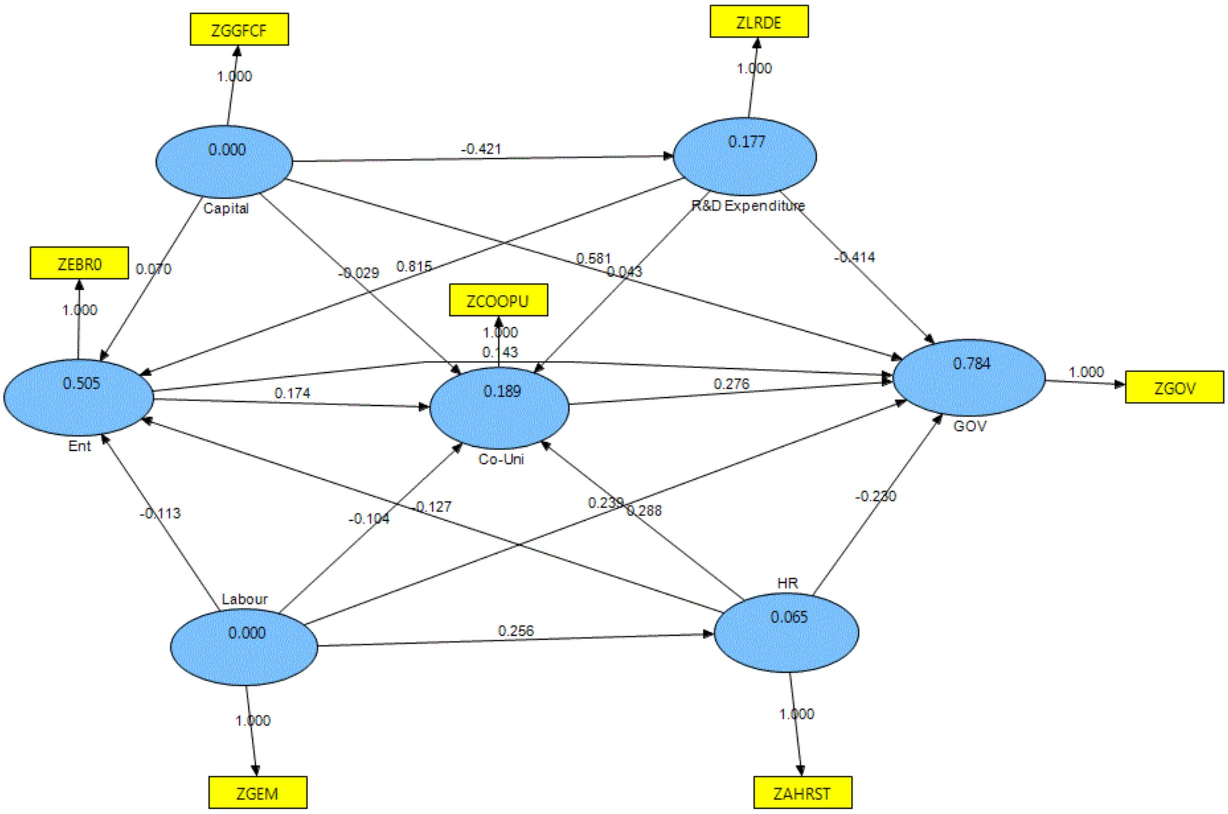


Table 4.5: OECD Total Effects and Bootstrapping Result of Economic Growth

	Capital	Co-Uni	Ent	GOV	HR	Labour	R&D Expenditure
Capital		-0.094727 (0.241153)	-0.272428 (0.726355)	0.690305* (5.818808)			-0.420776* (3.730184)
Co-Uni (University-Business Co-operation)				0.275774* (3.470663)			
Entrepreneurship (High-Tech Birth Rate)		0.174397 (0.986053)		0.190867 (1.858832)			
GOV (Growth of Gross Value Added)							
HR (Human Capital)		0.265799 (1.935767)	-0.127382 (0.814098)	-0.174680* (2.576262)			
Labour		-0.056092 (0.910009)	-0.145156 (1.128963)	0.144354* (3.346974)	0.255647* (2.464270)		
R&D Expenditure		0.185048 (0.196875)	0.814873* (5.979008)	-0.247057* (2.815303)			

Note: bootstrapping t-values in parentheses, * Significant (t>=1.96), case 65, sample 500

- University-industry co-operation positively influences economic growth

- R&D expenditure negatively influences economic growth
- Human capital negatively influences economic growth
- R&D expenditure positively influences high tech firm birth rate

See also the result of PLS quality criteria including AVE, Composite reliability, R square, Cronbach Alpha, Communality, and Redundancy (Appendix VII).

4.3.2 R&D Expenditure, Human Capital, Entrepreneurship and Technological Progress

Figure 4.2: OECD Path Modelling Analysis Result of Technological Progress

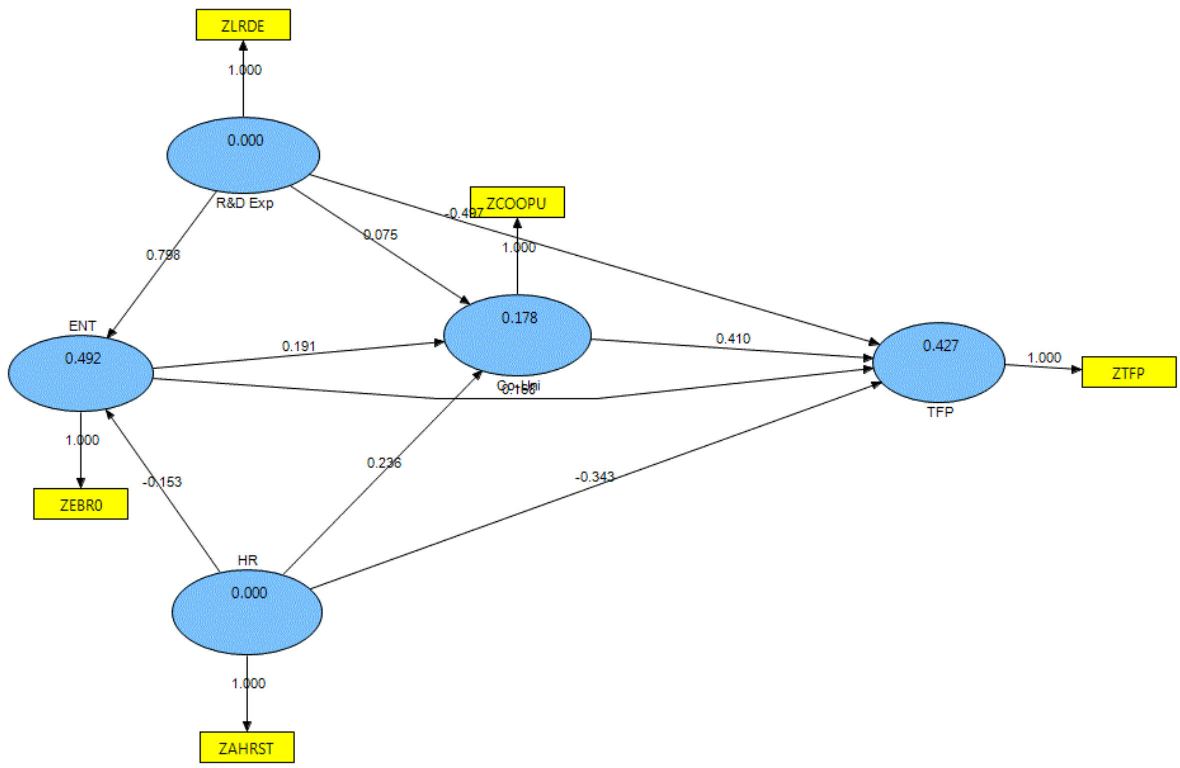


Table 4.6: OECD Total Effects and Bootstrapping Result of Technological Progress

	Co-Uni	ENT	HR	R&D Exp	TFP
Co-Uni (University-Business Co-operation)					0.409765* (3.509794)
Entrepreneurship (High-Tech Birth Rate)	0.190848 (1.083973)				0.246600 (1.345186)
HR (Human Capital)	0.207281* (1.990094)	-0.152642 (0.949425)			-0.283465* (3.267266)
R&D Expenditure	0.226940 (0.389655)	0.797666* (6.189595)			-0.269422* (3.506107)
TFP (Total Factor Productivity)					

Note: bootstrapping t-values in parentheses, * Significant (t>=1.96), case 65, sample 500

- University-industry co-operation positively influences technological progress
- R&D expenditure negatively influences technological progress
- Human capital negatively influences technological progress
- R&D expenditure positively influences high tech firm birth rate
- Human capital positively influences University-business cooperation

See also the result of PLS quality criteria including AVE, compostit reliability, R square, Cronbach Alpha, Communality, and Redudancy (Appendix VIII)

4.3.3 Discussion

Similar to the result of regression analysis, University-business co-operation has a positive effect on both economic growth and technological progress in this path modeling analysis. In addition there are also some other relations found as follows:

Table 4.7: OECD Result Discussion 2

Factors	**Effect**		**Relevant Literature and Theory**	
	Direct	**Indirect**	**Literature**	**Theory**
R&D Expenditure	R&D Expenditure ↓ Economic Growth R&D Expenditure ↓ TFP	R&D expenditure ↑ Entrepreneurship	● Nature of Knowledge ● Knowledge Based Growth Theory	● Knowledge Indicator ● New Growth Theory (Endogenous Growth Theory)
Human Capital	Human Capital ↓ Economic Growth Human Capital ↓ TFP	Human Capital ↑ University-Business Cooperation	● Knowledge Based Growth Theory ● Role of University and Paradigm ● Science and Industry Link	● New Growth Theory (Endogenous Growth Theory) ● Change of University Role ● University-Business Interaction ● Technological Cluster
Entrepreneurship	No	R&D expenditure ↑ Entrepreneurship	● Knowledge Based Growth Theory ● Knowledge System ● Science and Industry Link	● Schumpeterian growth ● The Knowledge Spillover Theory of Entrepreneurship ● Triple Helix Model ● University-Business Interaction

Note: Significant positive effect: ↑ ; Significant negative effect: ↓

R&D Expenditure

According to the path modelling analysis results, R&D expenditure shows a negative effect on both economic growth and technological progress. This result questions whether R&D expenditure is an adequate knowledge indicator to investigate the economic return. In fact, the relationship between R&D expenditure and growth is debatable in the research field. After endogenous growth theory introduced in 1980s, there was a prevalent focus of research on the R&D inputs and its impact on economy. Empirical studies examined the variance of knowledge inputs, measured as research expenditures, and associated research outputs, measured in terms of either patent citations (Jaffe et al., 1993; Anselin et al., 1997; Piergiovanni et al., 1997; Becker 2003) or the number of innovations introduced to the market (Acs et al., 1992; 1994; Feldman and Florida, 1994). Most of this research found strong and positive relations between R&D expenditure and innovation consequences. This results in the tremendous R&D investment competition in the industry. However, there is also some contrary evidence. For example, a study showed that University R&D expenditures were not significantly related to economic growth (BJK Associates, 2002).

Although there are no direct contributions found between R&D expenditure and growth, the result reveals a positive relationship between R&D expenditure and entrepreneurship. To extend, the investment in R&D is likely to enhance entrepreneurship activities, in terms of the high-tech enterprise start-ups. This gives the suggestion that R&D expenditure may indirectly result in the economic growth and technological progress through the entrepreneurship innovation process. This is due to the unique nature of different types of R&D investment. Industrial R&D is mainly directed to commercial ends, seeking to apply knowledge, and transform it into marketable products or methods of production (Jaffe, 1989; Fritsch and Slavtchev, 2005). This sort of R&D investment may likely bring growth in the economy and technology. However, R&D investment is not always aimed at short term gains in commercialisation. Some investments may focus more on the long run advantages of scientific knowledge creation, especially in public research and Universities which also have the social objective of knowledge production and regional development. This part of R&D expenditure may not be directed to growth in short period. That is why some research (Jaffe, 1989; Fritsch and Slavtchev, 2005) believed that the effect of public and University R&D on economic development is more indirect in nature than entrepreneur R&D.

Human Capital

Similar to R&D expenditure, the result shows that human capital is negatively related to both economic growth and technological progress. This is contrary to the arguments in many studies. Following the endogenous growth theory, there is much research focused on the role of human capital in economy. Some studies demonstrate the important role of human capital in technological changes (Whiston et al., 1980; Bartel and Lichtenberg, 1987; Gill, 1989; Booth and Snower, 1996; Schartinger et al, 2001). According to these authors, educated persons can take more advantage of available technology and thus be more productive. Other studies are trying to emphasize the role of human capital to business growth. These studies discovered positive relationships between human capital and firm survival rate (Ace et al, 2006), new firm growth (Stam and Garnsey, 2006) and the success of new technology-based businesses (Colombo and Grilli, 2005).

To explain this result, some authors (Bartel and Lichtenberg, 1987; Wozniak, 1987; Steedman and Wagner, 1989; Faulkner and Senker, 1994; Rios-Rull et al., 1996) have argued that to generate positive growth, the human capital level has to be compatible with the levels of technology and innovation in the region. In other words, a region with a high level of knowledge but low level of human capital mostly fails to grow, because the knowledge could not be transferred and applied efficiently by the low level of human capital. In addition, a region with a low level of technology but high level human capital may also have problems with growth because there is insufficient knowledge stock in this region which can be transferred to commercial ends. The data of this part of research is collected from OECD nations with different technology and innovation levels, thus a negative relationship between human capital and growth was found.

Another explanation can be similar to R&D expenditure. The input in human capital may not lead to a short term growth in the economy. This part of investment in human capital may aim to increase the capability of knowledge creation, absorption, and network proximity, it can also be a long term return for those investments transferred to the product, and then growth.

In addition, another potential reason why human capital does not show a positive contribution to growth, could because its influence is partly substituted by University-business co-operation, as these is a positive relationship found between human capital and University-business co-operation in the technological progress model. It reveals that human capital intensifies the knowledge network, which will further result in the interaction between research and industry. Because the University-business co-operation is demonstrated to influence the technological progress positively, therefore, the human capital may indirectly affect the technological progress. This evidence is consistent with the theory of University paradigm (Morgan, 2002; Braun, 2006; and Abreu et al., 2008), which suggests that the change of University role results in some University focus on the integration the knowledge source and outreach it to business, rather than just the creation side of human resource. It is also consistent with the phenomenon of technology cluster (Saxenian,1994; Krugman,1991; and Porter, 1990), which is an area where the University is surrounded by high-tech firms with a pool of abundant human resource and knowledge networks between Universities and firms. University-business interaction and human capital are there together, to foster the knowledge transfer efficiency and business innovation performance.

Entrepreneurship

The results of both economic growth model and technological progress model, shows no direct evidence that entrepreneurial activity has an influence to growth. It implies that the factor of entrepreneurial activity lost its effect on growth in the model to the University-businesses co-operation. In other words, those businesses co-operating with Universities are most likely to generate either economic growth or technological progress.

This result is in contrast to some literature which agrees that entrepreneurial activity, especially high-tech start-ups, is a reason of growth or the mechanism leading to growth. For example, the Schumpeterian growth model considered the entrepreneur as a source of growth. At the macro level entrepreneurship is seen as a driver of structural change and job creation. At the micro level entrepreneurship is the engine behind the formation and subsequent growth of new firms (Stam et al., 2007). By investigating whether Total Entrepreneurial Activity (TEA) influences GDP growth for 36 countries, Stel, Carree, and Thurik (2004) showed that entrepreneurial activity is important for economic progress, and countries that are high in terms of this activity also grow relatively quickly. High potential start-ups and their influence are especially emphasised in the literature. It has been said that in order to promote economic development, policy makers should focus on high-growth firms such as high technological firms (Friar and Meyer 2003). This is confirmed in some other empirical researches: more consistent positive evidence has been made for the effect of high-potential start-ups (Wong et al. 2005) and fast-growing firms (Mason 1985; Kemp et al. 2000) on economic growth. However, this result enhances the recognition of University-business interaction, which is consistent with triple helix model. It shows that compared with one node of "entrepreneurship", the network between two nodes, which is the co-operation between University and business weights more in the growth model.

To explain this result, entrepreneurship activity's role to growth is replaced by the University-business co-operation. It can be explained with a group of entrepreneurial theories and data. The knowledge spillover theory of entrepreneurship identifies the entrepreneur's role in spillover of knowledge, and converting new knowledge to economic knowledge (Acs et al, 2003; 2006; 2008). Although the entrepreneurial activity may contribute to the economy by the job creation, tax revenue etc, the main contribution of entrepreneurs to the economy is its knowledge utilisation and spillover roles (Thurik, 1999, Reynolds et al., 2002, Holtz-Eakin and Kao, 2003, Braunerhjelm and Borgman, 2004). The economic growth and technological progress depend largely on the entrepreneurs' ability in exploiting opportunities: transformation of University or institute produced knowledge into market-oriented innovations. Knowledge could not produce the growth itself, but through the utilisation and spillover of knowledge by the entrepreneur. These activities are based on the network between research and entrepreneurs. Therefore, the growth is more likely attributed to the entrepreneur's ability to exploit knowledge through research-business cooperation, and spillover through the entrepreneur's informal network, rather than entrepreneurial activity itself.

Another reason why entrepreneurial activities lost their role to growth in these models can be explained by the geographical proximity theory (Boschma, 2005) of knowledge spillover. In many studies, knowledge spillover effect is considered as the main contribution of entrepreneurship to economic growth. Unlike large companies which usually operate their own R&D departments (Fritsch and Lukas 2001; Mohnen and Hoareau 2002; Laursen and Salter 2003; Busom and Fernández-Ribas 2004), small firms face high R&D expenditures combined with high technological risks and uncertainties. Therefore, small firms have downsized their R&D activity. They are more likely to acquire knowledge benefiting from connections with public research organisations, Universities (Adams et al., 2001) and informal networks of knowledge spillover (Jaffe, Trajenberg and Henderson, 1993; Feldman 1994). These connections and networks are usually embedded in a certain geographical location because of spatial proximity (Jaffe 1989; Acs, Audretsch et al. 1992; Varga 2000; Fritsch and Schwirten 2002). Part of knowledge, especially tacit knowledge, is personally embodied and only able to be disseminated within certain spatial constraint. Therefore, knowledge spillovers through these channels appear to be a local phenomenon (Audretsch and Feldman, 1996) and interaction between people and enterprise located in each other's proximity produce the highest likelihood of spillover effects. However, the scale of the OECD study is at broad national level without considering these location factors. It may affect the role of the entrepreneurship in the analysis result. Isolated with geographical proximity, factors of entrepreneurship activity here in these models show no influence on growth.

4.4 Findings of OECD Study

Main findings of this international study are summarized with the below table:

Table 4.8: Summary of OECD Result

Research Objective	**Detail Questions**	**Answer**	**Completion of Research Objective A**	**Contribution**		**Limitation**
				to Knowledge	**to Policy**	
Objective A: To discover the influence of University-business co-operation on technological progress and economic growth. It is also to find out how this network integrates with knowledge investment and entrepreneurship in the knowledge system	Q1: Does University-business co-operation influence economic growth?	Yes	● Demonstrates the positive effect of University-business co-operation on technological progress and economic growth ● Shows the evidence that knowledge investment in R&D and human capital indirectly influence growth ● Discovers the substitute relationship between University-business co-operation and entrepreneurship	● Knowledge Spillover Theory ● Endogenous Growth Theory ● National Innovation Systems ● Triple Helix Model ● University Activities	● Focus on the University-business cooperation to promote economic growth/ technological progress ● Consider the direct and indirect influence of knowledge investment, and priority ● Entrepreneurship network rather than entrepreneurship activity	● General discussion of Cooperation without activities details ● Lack of discussion about the nature of target business ● Factor and effect analysis based rather than the system based analysis, and without considering proximity ● National scale of framework could be too broad and not unified
	Q2: Does University-business co-operation influence technological progress?	Yes				
	Q3: What is the relationship between University-business co-operation and knowledge investment, in terms of R&D investment & human capital investment; and their roles in growth model?	R&D expenditure ↑ Entrepreneurship Human Capital ↑ University-business Cooperation				
	Q4: What is the relationship between University-business co-operation and entrepreneurship activity; and their roles in the growth model?	Substitution				

4.4.1 Answer of Research Question1 to 4

Firstly and most importantly, the results of the research in Q1 and Q2 demonstrate that the University-business co-operation has significant positive effects on both economic growth and technological progress. This answer not only emphasizes the importance of knowledge in economy, but also reveals that the interaction between University-business could be the main trigger of knowledge dissemination and business innovation. The result of Q3 does not find the direct relationship between knowledge investment (including R&D expenditure and human capital) and growth. However, it finds a positive relationship between R&D expenditure and entrepreneurship. It also found a positive relationship between human capital and University-business co-operation. This result tells that the investment in R&D and human capital does not directly bring either instant economic growth or technological progress. When R&D expenditure is found to influence the high-tech entrepreneurial activities, and human capital is found to contribute University-business co-operation, the investment in these resources is more likely to bring an indirect contribution to industrial innovation, and have a long-run effect to economic growth. The result of Q4 shows when the factor of University-business co-operation is introduced into the model, it substitutes entrepreneurship as an important generator to growth. It tells us that it is not the quantity of entrepreneurship, but instead that these start-ups who are best able to absorb knowledge through the University-business co-operation activities, are the main reason to explain innovation and growth.

4.4.2 Completion of Objective A

Based on the Answers of Q1-Q4, Research Objective A is completed with the following findings: University-business co-operation is demonstrated to have a positive effect of on technological progress and economic growth. Knowledge investment in R&D and human capital indirectly rather than directly influence growth. University-business co-operation and entrepreneurship are both reasons for growth, but University-business co-operation shows substitute entrepreneurship as the more important factor.

4.4.3 Contribution to Knowledge

These findings contribute to some groups of knowledge. First of all, the finding is consistent with the main ideas of knowledge based growth theory. The finding not only emphasizes the role of knowledge to growth, but also demonstrates the interaction between University and business, as an approach for knowledge spillover, is the most important reason to explain the technological progress and economic growth. This gives the empirical evidence for the knowledge spillover theory of entrepreneurship (Acs, et al, 2003; 2006). In addition, when the consequence of knowledge investment is always a debatable topic in the endogenous growth theory (Romer, 1986; Lucas,1988; and Rebelo,1991), the finding further provide evidence that the investment in knowledge is likely to contribute growth indirectly, through the gateway of University and entrepreneurship.

Secondly, as the findings discovered the importance of research-industry network to growth, it is consistent with the main argument of knowledge system theory and science-industry link theory, such as national innovation systems (Freeman, 1987; Lundvall; 1988 and 1992; and Nelson; 1993). To extend this, it is focused on the University-business co-operation specifically, and this is a coincidence with one dimension of triple helix model (Leydesdorff, 1998; Etzkowitz and Leydesdorff, 1997). It supplies the theory with the ideas that, among various relations involved in the innovation systems, the science-business interactions are likely to be the key to technological progress and economic growth. University-business relations especially show its significant contribution to business innovation and national/regional growth.

Moreover, this finding also stressed the role of the University in innovation and the economy. It provides a view that Universities generate growth through their knowledge spillover and business absorption, and this result is partially coincident with the recent framework of the University role and paradigm (Morgan, 2002; Braun, 2006; Abreu et al, 2008), which tries to reveal the knowledge outreach side of the University. This result emphasizes that besides the teaching and research function of the University, the University knowledge outreach function is equally important in the economy.

4.4.4 Contribution to Policy

This finding also contributes to the real practice. First of all, to promote economic growth or technological progress, policy incentives could be focused on the direction of encouraging University-business co-operation, with the solution such as developing the knowledge outhreach side of University function, knowledge absorption side of business, and the infrastructure to improve efficiency of knowledge dissemination. The formal co-operation between University and business, such as contract research and patent licensing, is important for the codified knowledge flow, and it needs to be promoted in the policy. Moreover, the casual University-business relations are demonstrated to be the necessary channel of tacit knowledge spillover, and policies need to focus either on the stimulation of the interaction between University and business, or the infrastructure building to enhance these interactions. Secondly, the knowledge investment needs to consider its direct and indirect, long-term and short-term influence. The priority of different types of investment needs to be set to match the development plan of a nation or region. Thirdly, the policy needs to switch from purely stimulating the entrepreneurship activity to the network formation between research and industry, to create more opportunities for business to get access the knowledge from the knowledge creators.

4.4.5 Limitation

There are some limitations in this chapter of OECD study. Firstly, this study only explored the general role of University-business co-operation on growth. According to the studies of University paradigms, the modern University developed its activities from traditional research and teaching to the entrepreneurial knowledge outreach with lots of detailed activities (Morgan,2002; Braun, 2006; Abreu et al, 2008). Different University activities may bring different consequences. Further investigation of the role of University activities and their influences on growth may be required to fully understand how University knowledge generates growth.

Secondly, this study lacks the discussion about the nature of target business. This study could have some bias by focusing only on the high-tech start-ups. According to the entrepreneurial literature (Schumpeterian1947, Acs et al, 2003), SMEs and non-SMEs show their different patterns in interaction with University, and the same interaction may result in different consequences for different businesses. Therefore, this nature of business needs to be considered respectively.

Moreover, University-business interaction and its consequences are more likely to be a local phenomenon because of the tacit knowledge and proximity. Taking the region as a unit to account for its knowledge proximity could be more precise for such an analysis. In addition, this piece of study is a factor and effect based study. However, knowledge is created, disseminated and utilised through the whole system as suggested by the knowledge system theory (Freeman, 1987; Asheim and Isaksen, 1997; and Cooke, 2003). Therefore, a regional knowledge system based analysis may need to combine these knowledge inputs, outputs, knowledge networks, and proximity.

Finally, this chapter is a national scale of broad studies. Different nations have different economy scales, policies, and regulations. Some knowledge factors shows different traits in different nations, and are unlikely to be unified and explained under the same framework. For example, Carree and Thurik (1999) indicate entrepreneurship plays a different role in countries in different stages of economic development. What is more, because of a lack of variable data in some nations, this OECD study could not cover the comprehensive information for all important knowledge factors.

To overcome these limitations, the next chapter of study is to analyze activities of University-business interaction under the same regional context. It is a UK regional-based study which tries to investigate University activities and its effect on growth, considering regional innovation proximity and business nature. It will give a more in-depth view of the role of University-business interaction in growth, with the knowledge system's point of view.

Chapter 5: Analysis and Finding of UK Regional Study

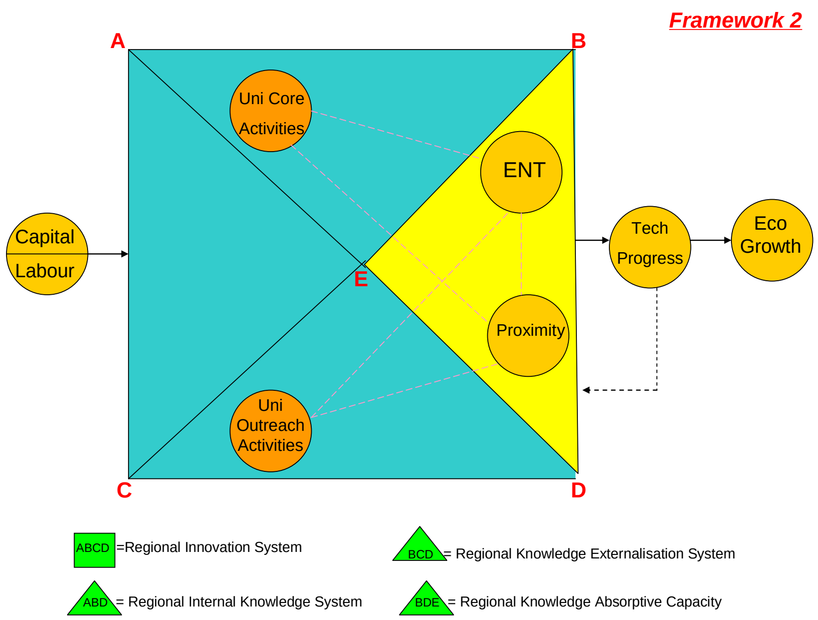
5.1 Introduction

According to the innovation system theory, the study in knowledge and growth is shifted from a historical linear concept of knowledge system, to a more recent web of interaction relationship. National innovation system theory (Freeman, 1987; Lundvall; 1988 and 1992; Nelson, 1993) tries to explain network and linkage among participants in a knowledge system. The triple helix model (Leydesdorff, 1998; Etzkowitz and Leydesdorff, 1997) focuses on interconnections between the University, industry and government. According to these studies, the interaction between research and industry shows a tremendous role in growth by facilitating knowledge dissemination and commercialisation. University, an important part of public research, is recognised as the main source of knowledge to innovation for both large companies and small firms (Adams et al., 2001). Expanding from its traditional function of research and education, Universities are also trying to mutate into agents of innovation and knowledge outreach for firms localised in a region (Braun, 2006).

Based on the idea provided by the above literature, and questions not answered in the last OECD study, this part of the UK regional study is trying to partition the activities of University, and find out their unique roles in the regional knowledge system and their contribution to growth. There are various regional networks and tacit involvement in the interaction between University and business, thus the location proximity is essential in the system to explain the knowledge spillover and absorption. This UK regional based study will start with factor analysis, which is trying to identify activities of University on different focus. Secondly this study will build two models of growth, namely economic growth and technology growth, to find out the influence of different Universities' activity on these growths. The Structural Equation Model (SEM) with Partial Least Squares (PLS) method will be introduced to investigate both direct and indirect relations and effects involved in the regional University based knowledge system.

This chapter of study is designed for the research Objective B, to answer the research question Q5-Q10. Data for this UK study is collected from the NUTS1 regions in the UK which includes North East, North West, Yorkshire and The Humber, East Midlands, West Midlands, East of England, London, South East England, South West England, Scotland, Wales and Northern Ireland. The data covers the years 2002-2009. Variable data is mainly from statistical databases in terms of Euro Statistics, Annual Business Inquiry (ABI), Global Entrepreneurship Monitor (GEM), and Higher Education-business and community interaction survey (HE-BCI). Ideas from Harris, Li, and Moffat (2012)'s research, Capital, labour and growth information in Annual Business Inquiry (ABI) can be used to calculate TFP. The higher education-business and community interaction survey (HE-BCI) is often used as a data source of research-industry interaction (Huggins et al., 2010). The information of the research framework, data, and variables is summarized by the table below:

Table 5.1: Summary of the UK Regional Study Design

Research Questions to Answer	Econometrics	Model Framework	Variables and Measurements
Q5: What activities of Universities contribute to regional economic growth?	$Ln(Y_t/Y_0)=\alpha_1 Ln(K_t/K_0)+\alpha_2 Ln(L_t/L_0)+\alpha_3 U_i+\alpha_4 Ent+\alpha_5 Pro+\varepsilon$		See below
Q6: What activities of Universities contribute to regional technological progress?			
Q7: What is the relationship between University Core Activities, entrepreneurship, and knowledge proximity?			
Q8: What is the relationship between University Knowledge Outreach Activities, entrepreneurship, and knowledge proximity?			
Q9: How are University activities, together with entrepreneurship and proximity involved in regional University-based knowledge system?			
Q10: Do the disparities in knowledge absorptive capacity across regions matter to the mode of University involvement in regional knowledge system?			

Variables and Measurements

GVA	Growth of Gros Value Added
TFP	Total Factor Productivity (Technological Progress)
CAPITAL	Growth of Net Capital Expenditure
LABOUR	Growth of Employment
HRST	Human Resources in Science and Technology, % Employment
AGG	Proximity, Agglomeration Externalities, Population Density, (Inhabitants per km2)
ENT	Total early stage Entrepreneurial Activity (TEA) Rate
RDP	Total intramural R&D expenditure in High Education Sector(£Thousands)
UCCS	Consultancy Contracts with SMEs
UCBN	Courses for Buisness Community with Non-SMEs (£Thousands)
UP	Collabourative research involving Public Funding and funding from business to University(£Thousands)
IPN	IP income from None-SMEs Commercial Businesses(£Thousands)
FSPIN	Formal spin-offs, not HEI owned, Number still active which have survived at least 3 years
SSPIN	Staff start-ups, Number still active which have survived at least 3 years

OECD's report (1998) explains how to represent capital in international comparisons of total factor productivity. There are a few proxies of capital, including: Gross capital stock; Net capital stock; Capital consumption; Gross fixed capital formation; Cost of capital. Though most similar studies choose the gross fixed capital formation to represent capital, UK data of gross fixed capital formation is not available for recent years. Therefore, my research chose the growth of net capital expenditure to represent regional capital growth. Labour growth is represented with the growth of employment. There are eight years data for UK regions from 2002-2009. Variables are calculated with fixed effects.

Similar to the OECD study, factors of R&D expenditure are included in the model. R&D expenditure explains the University's role in transferring R&D investment to output. In addition, Universities can act as a powerful magnet for attracting researchers and staff into the region. Moreover, through their teaching and education, Universities have the potential to add to the regional stock of human capital. This function of the University often intensifies the regional human resource and network. Thus the human resource as a factor is chosen in the model too. This model also covers the entrepreneurship and proximity factors. Entrepreneurship is represented by the total early stage entrepreneurial activity, and geographical proximity is represented with population density of each region. Other factors regarding to the roles of University in knowledge transfer and spillover are collected from the HE-BCI survey. These factors include collaborative research between University and business, University spin-offs, University contract research, and courses for business community.

5.2 Activities of University: Result of Factor Analysis

According to the role of the modern University, Universities are an important source of academically trained graduates and scientific knowledge to meet the needs of industrial sectors. The two activities of teaching and performing basic research have been complemented by the more recent entrepreneurial activities of Universities. Universities are no longer just suppliers of knowledge-intensive outputs such as students and research papers; they also proactively engage in research collaborations with private parties through licensing, sponsored research, and new venture creations (Etzkowitz and Leyersdorf, 1998). A group of literature about University paradigms introduced the different roles and activities of Universities (Morgan, 2002; Braun, 2006; Abreu et al., 2008; Saueret al., 2007; Hewitt-Dundas, 2008). Based on these studies, there are main two categories of University activities identified, including the core activities (e.g. teaching; research; contract research; etc) and knowledge outreach activities (e.g. business knowledge outreach; entrepreneurial Universities; spin-offs; etc).

To give a general framework for these activities, in this factor analysis, both codified knowledge and tacit knowledge are included. Moreover, it also includes the knowledge flow between Universities, and both large companies and small businesses. It tries to explain the University-business interaction with three stages of the knowledge system: knowledge creation (research expenditure; human resource), knowledge dissemination (collabourative research; courses for business community; consultancy contracts), and knowledge utilisation (spin-offs; IP income).

The tables below summarise the analysis and the results of exploratory factor analysis:

Table 5.2: KMO and Bartlett's Test Result

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.723
Bartlett's Test of Sphericity	Approx. Chi-Square	307.373
	df	28
	Sig.	.000

The results of the KMO and Bartlett's test in the table above show that the data is adequate for factor analysis, meeting the basic requirements (as identified in Norusis, 1985) with a KMO value of 0.723, and a highly significant Bartletts's test of sphericity (0.000). Only those factors with eigenvalues greater than 1 are chosen. The factor loading of 0.5 and above was used to identify items loading on a particular factor, items that cross loaded being deleted (Ramsey et al., 2008). With the eight initial variables, two new factors are created, which explain 63.266% of the total variance.

Table 5.3: Result of Factor Analysis in UK Region

Variables	University Activity 1	University Activity 2
RDP2: Total intramural R&D expenditure in High Education Sector	.904	
HRST: Human Resources in Science and Technology, % Employment	.883	
UCBN3: Courses for Business Community with non-SMEs Commercial	.870	
IPNX: IP income from None-SMEs Commercial Businesses	.594	
UP3: Collaborative research involving Public Funding and funding from business to University		.798
UCCS3: Consultancy Contracts with SMEs		.730
FSPIN2X: Formal spin-offs, not HEI owned, number still active which have survived at least three years		.841
STAFF2X: Staff start-ups, Number still active which have survived at least three years		.595
Eigenvalue	2.970	2.09
% of Variance	34.664	28.602
Cronbach's Alpha for Factors	.836	.736

University Activity 1 explains 34.664% variance with a Cronbach's alpha value of 0.836. University Activity 2 explains 28.602% variance with a Cronbach's alpha value of 0.736. These results meets internal consistency and scale reliability limits as used in Ramsey et al. (2008). Thus, factor analysis may be considered appropriate.

According to the results of factor analysis, interaction between University and business is distinguished with two activities with their different functions in knowledge creation dissemination and utilisation. University Activity 1 focuses on knowledge creation & non-SMEs, including those factors in terms of R&D expenditure, human resources, IP income and courses for non-SMEs. University Activity 2, which focuses on knowledge outreach and SMEs, covers factors of collaborative research, spin-offs, and consultancy contracts with SMEs. These activities focus on not only the traditional role of University in the knowledge creation, but also the entrepreneurial role of the University, which encourages the knowledge dissemination and utilisation, to serve the regional needs of innovation.

Combining the above result with University paradigm theories, University core activity can be represented by University Activitiy 1 (knowledge creation & Non-SMEs focus activity), and University knowledge outreach activity can be represented by University Activity 2 (knowledge outreach & SMEs focus activity).

The result of the above factor analysis will be used in the following regression analysis and path modelling analysis, to find out the direct and indirect effects of these activities on growth.

5.3 University Activities and Growth: Result of Structural Equation Modelling Analysis

Based on the knowledge production function and those factors created by factor analysis, this analysis is trying to find out the relationships between growth and University-business interaction, in terms of knowledge creation & non-SMEs focus activity (Activity 1) and knowledge outreach

& SMEs focus activity (Activity 2). This analysis is also trying to discover the relationships involved in the UK regional knowledge systems, among University activities, entrepreneurship, and regional proximity. There are two growth models tested, including the economic growth model and technological progress model.

This part of the study runs structural equation modelling with latent variables by SmartPLS software application. This study created the model according the theory, and run the bootstrapping (t value >=1.96 according to the case number) and path weighting with SmartPLS. The result can be summarised with the path weight graph and total effect table below.

5.3.1 University Activities and Economic Growth

Figure 5.1: UK Region Structural Equation Modelling Analysis Result of Economic Growth

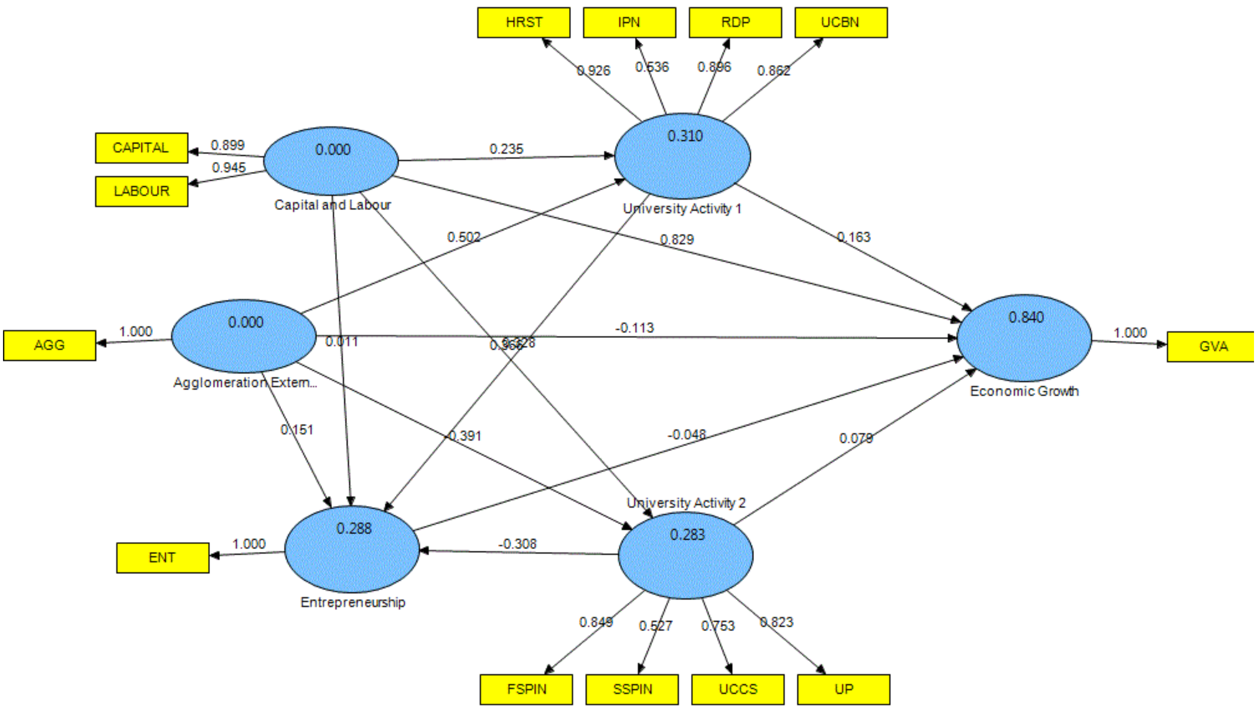


Table 5.4: UK Region Total Effects and Bootstrapping Result of Economic Growth

	Proximity	Capital and Labour	Economic Growth (Gross Value Added)	Entrepreneurship	University Activity 1	University Activity 2
Proximity (Agglomeration Externalities)			-0.083412 (1.869196)	0.436293 (1.219994)	0.502047* (3.560772)	-0.390856* (7.028400)
Capital and Labour			0.897534* (19.896136)	-0.025012 (0.100575)	0.234525* (2.162738)	0.365614* (5.013807)
Economic Growth						
Entrepreneurship			-0.048088 (1.132775)			
University Activity 1 (Knowledge Creation & Non-SMEs Focus)			0.147050* (2.914966)	0.328223* (3.837025)		
University Activity 2 (Knowledge Outreach & SMEs Focus)			0.094259 (1.541785)	-0.307758* (2.547725)		

Note: bootstrapping t-values in parentheses, * Significant (t>=1.96), case 96, sample 500

- University Activity 1 positively influences economic growth
- University Activity 1 and entrepreneurship have a positive relationship
- University Activity 2 and entrepreneurship have a negative relationship
- Proximity positively influences University Activity 1

- Proximity negatively influences University Activity 2

See also the result of PLS quality criteria including AVE, compostit reliability, R square, Cronbach Alpha, Communality, and Redudancy (Appendix IX)

5.3.2 University Activities and Technological Progress

Figure 5.2: UK Region Structural Equation Modelling Analysis Result of Technological Progress

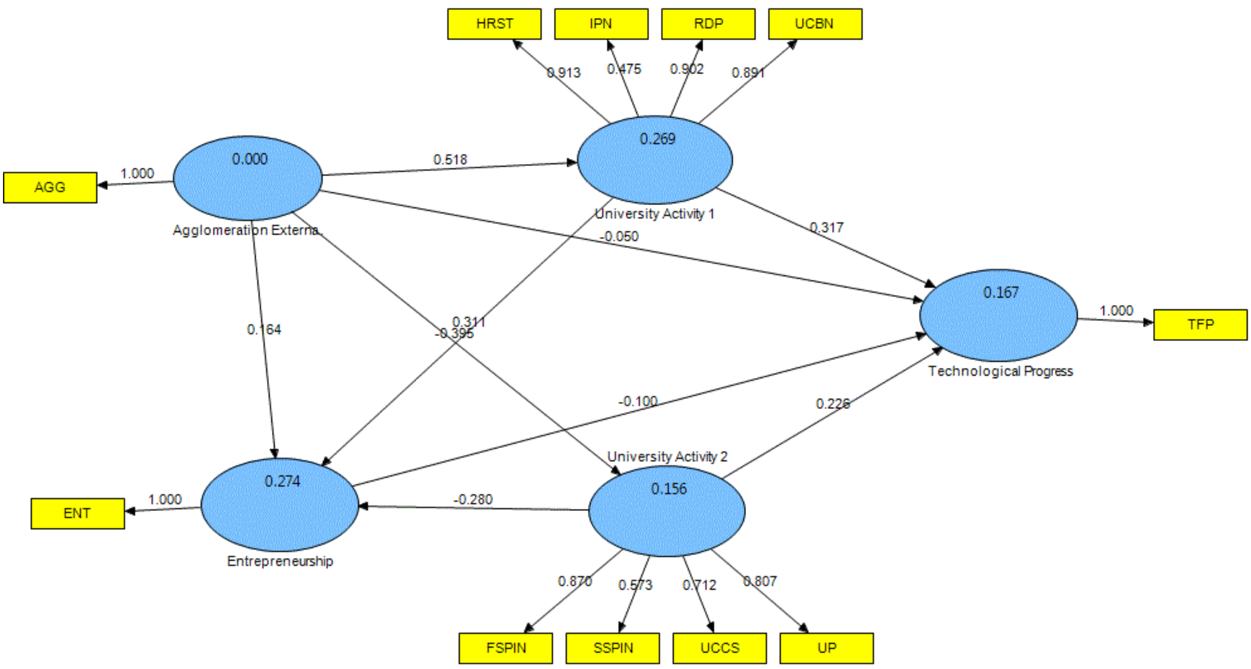


Table 5.5: UK Region Total Effects and Bootstrapping Result of Technological Progress

	Proximity	Entrepreneurship	Technological Progress	University Activity 1	University Activity 2
Proximity (Agglomeration Externalities)		0.436006 (1.298405)	-0.018131 (0.369795)	0.518394* (4.329326)	-0.394837* (6.720457)
Entrepreneurship			-0.099588 (1.172986)		
Technological Progress (Total Factor Productivity)					
University Activity 1 (Knowledge Creation & Non-SMEs Focus)		0.310820* (3.460763)	0.286394* (2.399384)		
University Activity 2 (Knowledge Outreach & SMEs Focus)		-0.280360* (2.610809)	0.254323* (2.008926)		

Note: bootstrapping t-values in parentheses, * Significant (t>=1.96), case 96, sample 500

- University Activity 1 positively influences technological progress
- University Activity 2 positively influences technological progress
- University Activity 1 and entrepreneurship have a positive relationship
- University Activity 2 and entrepreneurship have a negative relationship
- Proximity positively influences University Activity 1
- Proximity negatively influences University Activity 2

See also the result of PLS quality criteria including AVE, compostit reliability, R square, Cronbach Alpha, Communality, and Redudancy (Appendix X).

Similar to the OECD study, two growth models are built in terms of the economic growth model and technological progress model. In both the economic growth and technological progress models, factor of capital and labour shows significantly effect on the growth and this is consistant with production function theory. In addition, this study is adding two University activity factors into the model - knowledge creation & non-SMEs focus activity (Activity 1), and knowledge outreach & SMEs focus activity (Activity 2). The main finding is that Activity 1 has a significant contribution to both economic growth and technological progress, while the Activity 2 has a significant contribution to technological progress.

Entrepreneurship and proximity factor is added into the model, and they both show no direct influences on growth in both models. However there are some relationships found between University activities, entrepreneurship and proximity, which may result in the indirect effect on growth. In both models, a positive relationship is found between University Activity 1 and entrepreneurship. University Activity 1 is also found to have a positive relationship with proximity. In contrast, University Activity 2 has a negative relation with entrepreneurship, and there is also a negative relationship between University Activity 2 and proximity.

5.4 Discussion

5.4.1 University Core Activity

A positive effect of University Activity 1 is found on both economic growth and technological progress. It means that University Activity 1 accounts for an important reason to explain regional growth.

This finding is consistent with some studies regarding to the roles of University research in the economy. The role of the University in knowledge creation is often argued to be important for economic growth. The theories of endogenous growth suggest that the generation of knowledge would enhance the production of more efficient processes and products, and hence spur growth (Romer, 1986, 1990). Universities are the most prominent producers of fundamental knowledge, which has been argued to be one of the main drivers of economic growth. Universities expand the theoretical pool of knowledge upon which technical advances of commercial value can be built (Fleming and Sorenson, 2004). In addition, the role of the University in teaching and education are also recognized as crucial to the economy. Through this University role, the increase in human capital enables individuals to perform higher value-added tasks more efficiently and quickly, which translates in higher productivity of labour and capital (Becker, 1964; Barro, 1991; Lucas, 1988). Moreover, students may act as important channels through which knowledge is transmitted to the industry (Nelson and Wright, 1992;Murnmann, 2003). In addition, the role of the University in partnership with business is also considered as an important reason of growth. Universities are no longer only suppliers of knowledge-intensive outputs such as students and research papers, as they also proactively engage in research collaborations with private parties through licensing, sponsored research, and new venture creations (Etzkowitz and Leyersdorf, 1998).

Why the University Activity 1 significantly contributes to growth can be attributed to two main reasons. First of all, commercialisation of University created knowledge to large companies is one of important income for the University and region. It is found out that the linkage between Universities and non-SMEs, especially R&D-intensive companies, brings significantly higher levels of research income. In addition, firms with a greater number of links to high research income Universities invest more in R&D (Huggins et al, 2010). Veugelers et al (2003) found that large firms are more likely to have co-operative agreements with Universities. Co-operating with Universities is complementary to other innovation activities such as performing their own R&D, sourcing public information and co-operative agreements with suppliers and customers (Veugelers and Bruno Cassimanb, 2003). Secondly, the University created knowledge may be absorbed by entrepreneurship through the spillover via the informal networks. According to knowledge spillover theory of entrepreneurship, this knowledge may generate the economic growth through the innovation of entrepreneurship.

5.4.2 University Knowledge Outreach Activity

University Activity 2 is found to have a positive effect on total factor productivity (TFP) in the technological progress model. Total factor productivity can be taken as a measure of an economy's long-term technological change or technological dynamism. It is a measure of the efficiency of all inputs to a production process. Therefore University Activity 2 can be an important reason to explain regional efficiency in transferring knowledge to product. This result indicates that the University interaction with small business and its knowledge outreach are more valuable for the technological progress of a region.

The evidence found in this result is consistent with many studies of SME knowledge network. Technological progress (TFP) represents the efficiency of all inputs to a production process. In many studies, entrepreneurial innovation is considered as one of the most important reasons to explain technological progress. According to knowledge spillover theory of entrepreneurship, entrepreneurial innovation is based on the knowledge spillover through the knowledge networks. Small firms are therefore expected to have more local collabourations with knowledge organisations as University (Sonn and Stroper, 2003; Phlippen, 2008). In addition, it is argued that small firms are often found to rely mostly on personal, informal and trust based contacts, which are facilitated by geographical proximity (Cooke et al., 2000; Tödtling & Kaufmann, 2001).

There are a few reasons why this relationship exists between University Activity 2 and technological progress. University Activity 2 demonstrates that University actively outreaches its knowledge through the action such as interaction with SMEs, and spin-offs. According to Saxenian (1991), most small firms in science-based industries are University-spin offs that co-locate themselves by their originating University. Entrepreneurship is considered as the knowledge proxy that actively seeks opportunities and absorbs knowledge. Entrepreneurship assigns product and process innovation to sustain competitiveness, enhance returns and to diversify into promising market niches. The knowledge spillover from University to SMEs may contribute to the entrepreneurial innovation by the exploitation of the University knowledge. Regarding to the knowledge spillover, University informal contact with small firms and University spin-offs are important channels, which will lead to the business innovation.

5.4.3 University Activities, Entrepreneurship, and Proximity

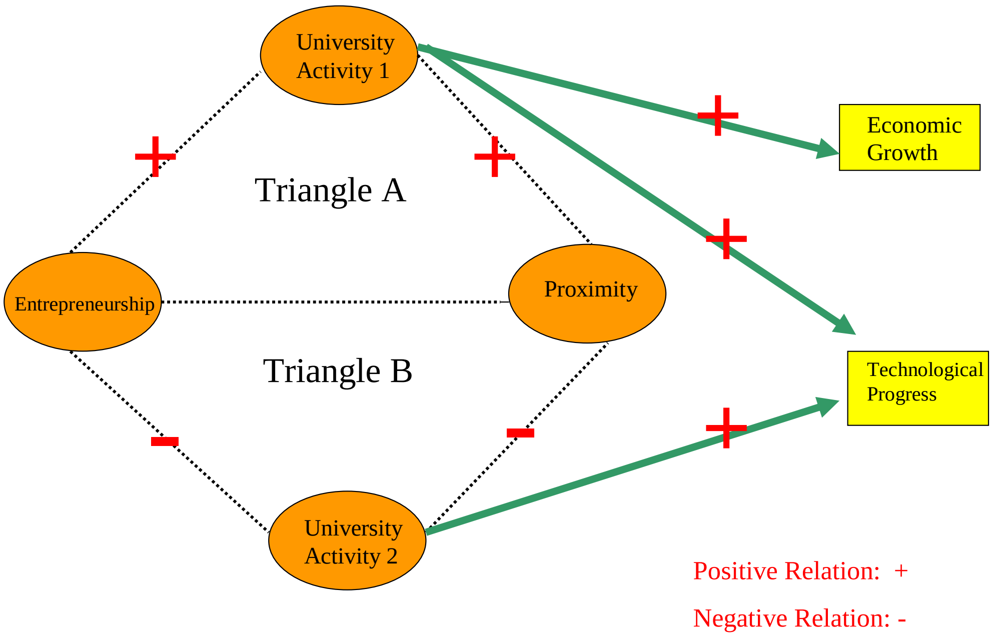
Many studies argue entrepreneurship has an important contribution to economic growth. New firms have been found to be a major mechanism of new market creation through the commercialisation of radical innovations (Audretsch, 1995; Prusa and Schmitz, 1991). However, according to the model result, there is no evidence that entrepreneurship directly affects regional economic growth and technological progress.

The role of entrepreneurship in regional growth may be debatable, as it is shown in the result that entrepreneurship has a positive relationship with University Activity 1. It implies that University Activity 1 and entrepreneurship are complementary to each other in the regional economy. Moreover, since University Activity 1 has a positive effect on the economic growth and technological progress, entrepreneurship has an indirect effect on the economic growth and technological progress. There is also a negative relationship found between entrepreneurship and University Activity 2. It implies that University Activity 2 and entrepreneurship substitute each other as the factors to explain regional growth. Because University Activity 2 has a positive influence on the technological progress, entrepreneurship would therefore have an indirect influence on the technological progress.

Similar to entrepreneurship studies, many geographical proximity studies argue that proximity has an important relation with innovation, and the innovation is likely to result in the regional economic growth and technological progress (e.g. technological cluster theory). However, according to the model result, there are no obvious relations found between geographical proximity and either economic growth or technological progress. The proximity is more likely to influence the growth indirectly because there is a positive relationship found between proximity and University Activity 1, and there is also a negative relationship found between proximity and University 2.

The analysis find no relationship between entrepreneurship and proximity, which implies that the proximity may be able to be broken, which is mentioned by (Boschma, 2005). But according to the result, when put University Activities, entrepreneurship, and proximity together to discuss, some implication of knowledge system is revealed. It is shown with the figure below:

Figure 5.3: University Activity and Regional Interaction System



Triangle A is the system which contributes to both economic growth and technological progress. This triangle is consisted of University Activity 1, entrepreneurship, and proximity. Triangle B is the system contributing to technological progress. This triangle is consisted with University Activity 2, entrepreneurship, and proximity.

In Triangle A, University Activity 1 is positively related with entrepreneurship and proximity. To interpret, those regions with higher knowledge absorptive capacity (represented with low proximity and entrepreneurship) usually experience the University Activity 1 (knowledge creation & Non-SMEs focus) as the engine of regional development, in terms of economic growth and technological progress. Entrepreneurship is a complement of University Activity 1 in the regional economy. These regions benefit from a higher pool of inhabitants, employees, firms or students, as well as to the proximity to firms, Universities and research institutions. Firms have better access to their labour force demand, and the interchange of employees between firms is easier due to spatial proximity. Knowledge spillover through the research-industry interaction is more likely to take place actively within intense knowledge networks.

In Triangle B, University Activity 2 is negatively related to entrepreneurship and proximity. It implies that those regions with lower knowledge absorptive capacity (represented with low proximity and entrepreneurship), usually more rely on the University Activity 2 (Knowledge Outreach & SMEs Focus) to enhance the technological progress. Entrepreneurship and University Activity 2 substitute each other in the regional economy. According to the knowledge spillover theory of entrepreneurship and geographical proximity theory, entrepreneurship innovation largely relies on the local networks and knowledge resource. Since the lack of knowledge networks and resources in those regions, entrepreneurship is usually difficult to access and exploitation the knowledge. The entrepreneurship's role in knowledge absorption is substituted by University Activity 2. Universities in those regions more actively look for the opportunities to outreach the knowledge to industry, through the interaction with business community and University spin-off companies. These activities would result in the technological progress.

5.5 Findings of UK Regional Study

The main findings of this UK regional study are summarized in the table below:

Table 5.6: Summary of UK Regional Result

Research Objective	Detail Questions	Answer	Completion of Objective B	Contribution		Limitation
				to Knowledge	**to Policy**	
Objective B: To investigate the effect of University activities on growth and the role of University activities in regional knowledge systems. It is also to find out if this role shows differences across those regions with different knowledge absorptive capacity	Q5: What activities of Universities contribute to regional economic growth?	Core Activities (Activity 1)	• Demonstrates the positive effect of University Core Activities (Activity 1) on technological progress and economic growth • Demonstrates the positive effect of University Knowledge Outreach Activity (Activity 2) on technological progress • Discovers Complement relationship between University Core Activity (Activity 1) and entrepreneurship	• Schumpeterian Growth Model • Knowledge Spillover Theory of Entrepreneurship • Regional Innovation System • Triple Helix Model • University Activities • Knowledge proximity • Regional Knowledge Absorptive Capacity	• Focus on University Core Activity to promote economic growth and technological progress • Focus on University Knowledge Outreach Activity to promote technological progress • In the region with high knowledge absorption capacity, develop the University core role • In the region with low knowledge absorption capacity, develop the University knowledge	• Process and routine to knowledge commercialisation is unclear • Need to identify channels of knowledge flow, and its effect on knowledge commercialisation • Lack of consideration about the different classification of University, and their each patterns in the knowledge process
	Q6: What activities of Universities contribute to regional technological progress?	Core Activities (Activity 1) Knowledge Outreach Activity (Activity 2)				
	Q7: What is the relationship between University Core Activities, entrepreneurship, and knowledge proximity?	Complement				
	Q8: What is the relationship between University Knowledge Outreach Activities, entrepreneurship, and knowledge proximity?	Substitution				

	Q9: How are University activities, together with entrepreneurship and proximity involved in regional University-based knowledge system?	entrepreneurship and proximity integrate in the University-based knowledge system, indirectly influence growth	● Discovers Substitution relationship between Knowledge Outreach Activity (Activity 2) and entrepreneurship ● Shows that regional disparities result in the different mode of University involvement in the regional knowledge system		outreach role ● Take account the disparities across regions, set the appropriate policy incentive according to the proximity and entrepreneurship in each region	
	Q10: Do the disparities in knowledge absorptive capacity across regions matter to the mode of University involvement in regional knowledge system?	Yes High absorptive region-Core Activities (Activity 1) Low absorptive region--Knowledge Outreach Activity (Activity 2)				

5.5.1 Answer of research question 5 to 10

First of all, the result of this study demonstrated the significant effect of University activities on growth. One University activity (Knowledge Creation & non-SME focus) accounts for both the regional economic growth and technological progress. Another University activity (Knowledge Outreach & SMEs focus) mainly accounts for the technological progress in a region. This result provides the answer for Q5 and Q6.

The study also found that entrepreneurship activity and geographical proximity are related to both University activities. Entrepreneurship and proximity has a positive relation with University core activity (University Activity 1), and negative relation with University knowledge outreach activity (University Activity 2). This provides the answer for Q7 and Q8. The answer to Q9 shows that entrepreneurship and proximity integrate in the University-based knowledge system, indirectly influence economic growth and technological progress. Together from the answers to Q7 Q8 and Q9, it can be seen that University core activity (Knowledge Creation & non-SME focus) is complemented by entrepreneurship activity, and University outreach activity (Knowledge Outreach & SMEs focus) is substituted with entrepreneurship.

This results in the answer for Q10. In regions with high knowledge absorptive capacity, University core activity (University Activity 1) plays a vital role in regional development, and it complemented with entrepreneurship. In regions with relatively low knowledge absorptive capacity, University knowledge outreach activity (University Activities 2) is the engine of technological progress by outreach the knowledge to business, which substitutes the entrepreneurship activities in those regions where the business lacks the ability of accessing the knowledge actively.

5.5.2 Completion of Objective B

The findings of this chapter complete the research Objective B with the following evidence. Role of different University activities is discovered respectively. It not only demonstrates the positive effect of University core activities (Activity 1) on technological progress and economic growth, but also demonstrates the positive effect of University knowledge outreach activity (Activity 2) on technological progress. Furthermore, it discovers that the University, proximity and entrepreneurship forms a regional University knowledge based system. In this system, entrepreneurship is a complement of University core activity (Activity 1), while it is a substitution of University knowledge outreach activity (Activity 2). When there are regional disparities in knowledge absorption in existence, this results in the different mode of University integration in the regional knowledge system. High knowledge absorptive regions benefit from the University core activity more, while regions with relatively low knowledge absorptive capacity may rely more on the University knowledge outreach activities to disseminate knowledge from research to business.

5.5.3 Contribution to Knowledge

These findings contribute to four main groups of knowledge. First of all, the result demonstrated the role of University activities in the economy, especially the University knowledge outreach activity. It is consistent with the main argument of the knowledge spillover theory of entrepreneurship (Acs, et al, 2003; 2006) which emphasizes the entrepreneurship and its knowledge network is the main reason to explain business innovation. In addition, it complements the theory by not only focusing on the knowledge receiver of entrepreneurship, but also the provider of the University. However, whilst the knowledge spillover theory of entrepreneurship considers the business user end, the result of this study points out that the University end is not only the provider of knowledge and resource, but also the engine of the knowledge system. This result gives more specific ideas that these activities, regarding to the knowledge spillover from University to business, are the fundamental trigger of innovation. This result does not neglect the role of entrepreneurship activities itself. It supplies the Schumpeterian growth model with the evidence that entrepreneurship has an important indirect effect on the economy.

Secondly, the result also demonstrates the importance of interaction between research and business to innovation. It shows that University activities, entrepreneurship, and proximity are the fundamental elements of the University knowledge based system, and they are inter-related to each other. Through this system, University knowledge is diffused to business to generate innovation. This result develops the knowledge system theories such as regional innovation system (Asheim and Isaksen, 1997; Cooke, 2003; Wolfe, 2003) and triple helix model (Leydesdorff, 1998; Etzkowitz and Leydesdorff, 1997) by zooming in to clarify the University-business specific relationship and its roles in the system. It discover two parts which has not clearly highlighted by the triple helix model, which are the University and entrepreneurship.

Thirdly, the result of this chapter also contributes to the theoretical model of University paradigm (Morgan, 2002; Braun, 2006; and Abreu et al, 2008), with empirical evidence that modern University has two distinct categories of activities: the core activities, and knowledge outreach activities. Both types of activity show their substantial influences in regional innovation and economy. The result also develops University paradigm theory with two fresh ideas: University core activity is a complement of entrepreneurship, and University knowledge outreach activity is a substitution to entrepreneurship. According to this result, University and entrepreneurship have a dynamic relationship. University activities need to match the ability of regional entrepreneurship to give the best economic performance.

Finally, the result contributes the science -industry link studies (Cohen, Nelsen and Walsh, 2002; Spencer, 2001; Mansfield, 1998). It defines the interaction between University and business with channels, such as non-SME interaction, SME interaction, Spin-offs, etc. It also provides a framework for these interaction channels, in terms of core activity and knowledge outreach activity. These channels and activities are shown as a constraint to the geographical proximity. Thus the region is suggested to be the unit to analyse knowledge and its effect, especially for tacit knowledge. In addition, it contributes to the theory with the ideas that there are regional disparities existing across regions in knowledge absorption. Different from the previous arguments about the relationship between University and business, the result in this chapter debates that these relationships could be different in separate regions.

5.5.4 Contribution to Policy

These findings provide some suggestions to the practice in innovation policy incentives.

There are two main obstacles of knowledge transfer involved in the UK innovation systems, which are summarised by some authors (Kelly, et al., 2002; Charles and Conway, 2001; Charles, 2003; Wright, et al., 2006). Firstly, governments have failed to fully realize the significant direct and indirect contribution Universities make to its local, regional and national economies. It results in the suggestion that the performance of many Universities in the area of knowledge transfer and commercialisation has not matched their overall potential. According to the results of this chapter, it is suggested that to promote economic growth and technological progress, policy needs to always focus on these University core activities, such as University knowledge creation and interaction with non-SMEs. Similarly, University knowledge outreach activities could not be omitted when promoting technological progress, especially in these regions where businesses lack the ability to get access to knowledge. Therefore policies could focus on these knowledge outreach channels, such as University interaction with SMEs and Spin-offs.

The second obstacle, however, is that there is an imbalance of knowledge absorptive capacity existing across UK regions. Therefore, policymakers should take into account the disparities across regions, and set the appropriate policy incentive according to the business knowledge sourcing ability and knowledge intensity of the region. For example, in regions with high knowledge absorption capacity, they should develop the University core role, as the knowledge created in University would be efficiently accessed and utilised by business through the well-developed knowledge infrastructure and networks. In contrast, in the regions with low knowledge absorption capacity, developing the University knowledge outreach role could be an ideal choice, because either businesses in these regions are less capable to access and use the knowledge created by University, or the regional knowledge system lacks efficiency to transfer knowledge. Thus Universities in these regions should have the initiative to pass the knowledge to businesses for their needs.

Moreover, the results of this chapter also suggest that a University-based knowledge system is the engine of regional innovation. As the centre of the system, the University has a dynamic relationship with entrepreneurship. They could either complement or substitute with each other, depending on the regional knowledge absorptive capacity and innovation proximity. According to this result, policies to promote University activities and entrepreneurship need to be considered together with their trade-off. There is no best policy other than the most suitable policy which is able to maximise the potential of the University and current entrepreneurship ability of the region. To improve the economic performance, policy should not only consider the short-term return of economy, but also the long-term influence of technological progress, because the progress is likely to further result in the improvement of the regional "efficiency" and "capability" in transferring the knowledge to growth. Therefore, regions with high knowledge intensity are suggested to focus on the technological advance as a competitive advantage. Those regions with relatively low knowledge intensity are advised to develop these knowledge infrastructure and networks for long-term benefit.

5.5.5 Limitation

There are still some questions not covered by the results of this chapter.

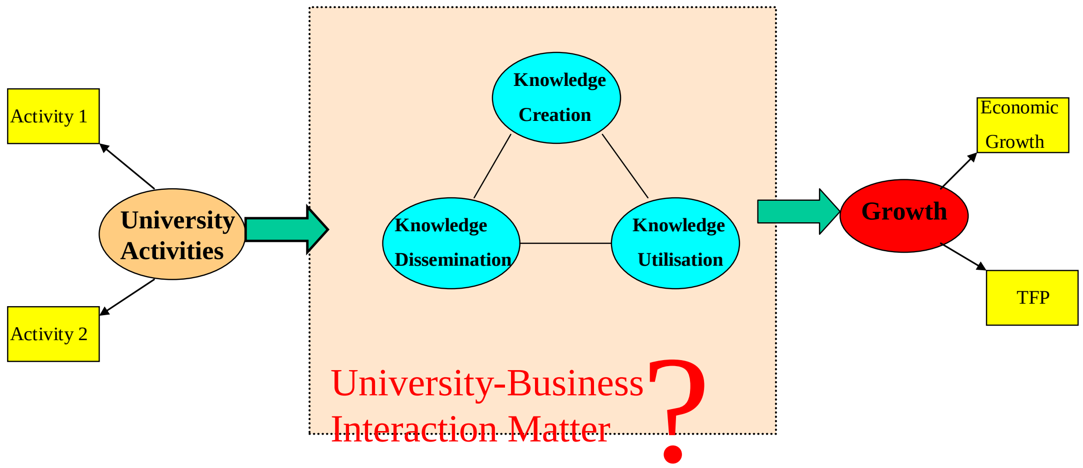
First of all, although the results of this chapter discover the role of the University activities in growth, the process and routine of knowledge transfer through this University knowledge based system are still unclear. Rich's Study (1991) gives some clues about this process. It considers knowledge going through three stages of process in terms of knowledge creation, dissemination, and utilisation of knowledge. University-business interaction involved in these stages and its economic consequences need to be revealed.

Secondly, Many studies indicated that economic relevance of University knowledge is the commercialisation of the results that knowledge produces (Acs et al., 2009; Audretsch and Keilbach, 2008; Braunerhjelm et al., 2010). The utilisation of University knowledge, in terms of knowledge commercialisation (Etzkowitz, 1998; Bok, 2003) and University spin-off (D'Este and Patel, 2005), is considered an important contribution to regional growth. Thus channels of University-business knowledge flow need to be identified, and their effect on University knowledge commercialisation need to be found out.

Thirdly, when University paradigm theory defines various University activities, it categories classification/type of University in the mean time. UK evidence shows that many regions traditionally rely on elite Universities such as the Russell Group as the main key of innovation. However, when Universities expand their traditional role to knowledge outreach side, many Universities show their different specialties in economy. The patterns of business interaction between different types of University could be distinct. Thus there is a need to see how knowledge commercialisation takes place through University business interaction by considering University specialties respectively.

All these can are summarised with the figure below, and it links to next chapter of UK University study

Figure 5.4: University Activity, Knowledge Process, and Growth



Chapter 6: Analysis and Finding of UK University Study

6.1 Introduction

In the OECD study, those factors which contribute to economic growth and technological progress are found, especially emphasising the role of the co-operation between Universities and businesses. In the regional study of the UK, those elements have been specifically focused on the University activities in creation, outreach knowledge, and their relationship with growth. However, how the utilisation of this part of University study based on UK Universities is to try to illustrate the patterns and processes of University knowledge based systems and the effect of it on knowledge commercialisation. It is also to see if this effect is different among different paradigms of Universities by considering their specialities.

Compared with the OECD UK Regional Study, there are three main specific focuses in this UK University Study: knowledge process, firm size, and knowledge channels.

According to Rich (1991), the growth effect knowledge will be through the process of knowledge creation, dissemination and utilisation. Universities have important roles in industrial innovation, and the evidences are found in both large companies and small firms. For large companies, the

University contract research is the main source of market aimed production (Fritsch and Lukas 2001; Mohnen and Hoareau 2002; Laursen and Salter 2003; Busom and Fernández-Ribas 2004). For small firms, the knowledge spillover from Universities is recognized as the main reason for SME innovation (Acs et al., 1994; Henderson et al., 1998; Jaffe, 1989). In addition, University knowledge will result in the University spin-offs activities. These activities have been coupled with notions of "entrepreneurial Universities"(Smilor, et al., 1993; Slaughter and Leslie, 1997; Etzkowitz, et al., 2000; Powers, 2004) and "academic entrepreneurs"(Meyer, 2003; Shane, 2004). The spin-off activities with the exploitation of University knowledge, highly involved in venturing and commercialisation activities such as the establishment of spin-off firms, and the exploitation of intellectual property rights through the licensing of technology and patent registration (D'Este and Patel, 2005). The model of this chapter tries to cover the entrepreneur's role in the exploitation of the knowledge which is not fully appropriated and commercialised by those incumbent firms. This is why both non-SMEs and SMEs are included in the model.

Industry–University interaction is found to be important for industrial innovation (Meyer-Krahmer and Schmoch, 1998, Beise and Stahl, 1999; Schartinger et al., 2002). The channels of knowledge transfer are considered to be crucial (Powell et al. 1996, Stuart 2000). There are two main types of channels according to the nature of knowledge. Many studies discuss the role of codified knowledge channels between research and industry in knowledge transfer. For instance, Narin et al. (1997) found that 73% of the papers cited in US industry patents were published by researchers working for public research organisations, such as Universities. Moreover, based on responses from R&D unit managers, Cohen et al. (2002) find that the most important channels for

Universities to have an impact on industrial R&D are published papers and reports. Studies based on a much wider survey, such as the community innovation survey, find that most benefits for firms from interaction with Universities come from formal collaboration rather than from knowledge and information externalities (Monjon and Waelbroeck, 2003). Tacit knowledge channels are also regarded as crucial, such as public conferences, the mobility of students, and collaborative R&D (Cohen et al., 2002). Using a survey to University researchers, Meyer-Krahmer and Schmoch (1998) found that collaborative research is the most widespread form of knowledge transfer. Additionally, employment of University researchers was found to be a way to effectively transfer knowledge from Universities to firms, especially in areas like chemistry or biotechnology (Meyer-Krahmer and Schmoch, 1998, Gübeli and Doloreux, 2005 and Zucker et al., 2002).

The model in this chapter covers some available channels of the University-business interaction based on the HE Business and Community Interaction Survey (see http://www.hesa.ac.uk/component/option,com_pubs/Itemid,122/). These channels include contract research; consultancy contracts; facilities and equipment related services; and courses for business and the community. Moreover, this model includes the University interaction both with non-SMEs and SMEs. The model and variables for this University study are summarised in the table below (Table 6.1), and it shows many similarities with the variables in last UK regional study (see the comparison in Table 6.2).

Table 6.1: Summary of the UK University Study

<table>
<tr><th>Research Questions to Answer</th><th>Econometrics</th><th>Model Framework</th><th>Variables and Measurements</th></tr>
<tr>
<td>Q11: How do University knowledge creation and dissemination processes affect University knowledge utilisation, and then the commercialisation of the knowledge?

Q12: Does University-business interaction in the knowledge dissemination process, in terms of non-SMEs interaction channels and SMEs interaction channels, affects the knowledge commercialisation?

Q13: Do different types of University show different patterns in the University knowledge creation-dissemination-utilisation process?</td>
<td>$\Delta KU = \alpha_1 \Delta KC$

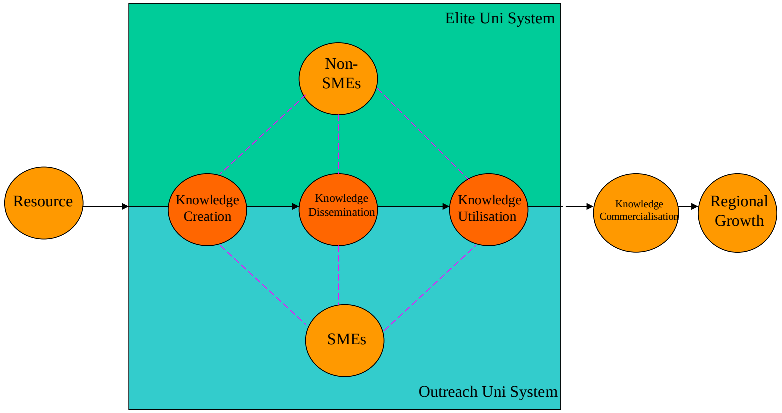
$+ \alpha_2 \Delta KD + \varepsilon$</td>
<td>*Framework 3*

</td>
<td><table>
<tr><td>AS</td><td>Number of Academic staff</td></tr>
<tr><td>CRT</td><td>Research Contracts Total (£Thousands)</td></tr>
<tr><td>CCN</td><td>Consultancy Contracts with Non-SMEs Commercial (£Thousands)</td></tr>
<tr><td>CN</td><td>Courses for Business Community with Non-SMEs Commercial (£Thousands)</td></tr>
<tr><td>EFN</td><td>Facility and Equipment Related Service with Non-SMEs Commercial (£Thousands)</td></tr>
<tr><td>CCS</td><td>Consultancy Contracts with SMEs (£Thousands)</td></tr>
<tr><td>CS</td><td>Courses for Business Community with SMEs (£Thousands)</td></tr>
<tr><td>EFS</td><td>Facility and Equipment Related Service with SMEs (£Thousands)</td></tr>
<tr><td>PF</td><td>Income from research related activities - collabourative research involving public funding (£Thousands)</td></tr>
<tr><td>SPINH</td><td>Number of Spin-offs with some HEI ownership</td></tr>
<tr><td>IP</td><td>Intellectual Property Income Total (£Thousands)</td></tr>
</table></td>
</tr>
</table>

Table 6.2: Data Comparison between UK regional study and University Study

Variables	Comparison with UK Regional Study
AS	HRST: Human Resources in Science and Technology
CRT	RDP2: Total intramural R&D expenditure in High Education Sector
CCN	IPNX: IP income from Non-SMEs Commercial Businesses
CN	UCBN3: Courses for Business Community with None-SMEs Commercial
EFN	
CCS	UCCS3: Consultancy Contracts with SMEs
CS	
EFS	
PF	UP3: Income from research related activities - collabourative research involving public funding
SPINH	FSPIN2X: Formal spin-offs, not HEI owned; STAFF2X: Staff start-ups, Number of active firms
IP	IPNX: IP income from Non-SMEs Commercial Businesses

This University study in particular examines Universities in the UK with 3 years data from 2007-2009. We also consider the interaction takes place in the knowledge creation and dissemination process. Those variables in terms of academic staff (AF) and research contract (CRT), represent the University-business interaction in knowledge creation. These knowledge dissemination variables includes the interaction between University and Non-SMEs in terms of consultancy contract with non-SMEs (CCN), courses for non-SMEs (CN), and facility and equipment services to non-SMEs (EFN). It also includes the interaction between Universities and SMEs, in terms of in terms of consultancy contract with SMEs (CCS), courses for SMEs (CS), and facility and equipment s to SMEs (EFS), In addition, the variables including intellectual property income (IP), collaborative research income (PF), and spin-offs (SPINH), represent the consequence of University knowledge utilisation, i.e. the contribution to regional growth.

Run SmartPLS and factor analysis with these variables based on UK 2009 HEI (University) data. The results are displayed with the table below.

Table 6.3: Model Information with Factor Analysis Result

Model	**Creation**		**Dissemination**	**Utilisation**	
	Elements	**Loading**	**(Variables)**	**Elements**	**Loading**
Factors	Academic Staff (AS)	0.921	Consultancy Contract with SMEs (CCS)	Intellectual Property (IP)	0.801
	Research Contracts (CRT)	0.906	Consultancy Contract with non-SMEs (CCN)	Income from Collabourative research (PF)	0.858
			Equipment and Facility with SMEs (EFS)	HEI Spin-offs (SPINH)	0.735
			Equipment and Facility with non-SMEs (EFN)		
			Courses with SMEs (CS)		
			Courses with non-SMEs (CN)		
KMO	0.500			0.666	
Bartlett's Test of Sphericity	Sig.=.000			Sig.=.000	
Cronbachs Alpha	0.801			0.718	
EigenValue	1.669			1.920	
% of Variance	83.43%			64.009%	

With the above model and variables, this study will run a path modelling analysis based on the UK Universities. According to the above table, two channels (Academic Staff and Research Contract) represent the University-business interaction involved in knowledge creation process. The channels, in terms of Intellectual Property, Income from Collaborative research, and Spin-offs, together represent the University-interaction involved in the knowledge utilisation process. Interaction regarding to knowledge dissemination is represented by six channels respectively.

6.2 University-Business Interaction and Knowledge Utilisation

6.2.1 All Universities: Result of Structural Equation Modelling Analysis

With SmartPLS software, this part of research runs a one year structural equation modeling analysis (2009) and a three year path modelling analysis (2007-2009) based on the UK Universities. The results are shown below.

One Year Result

Figure 6.1: University-Business Interaction and Knowledge Utilisation in All Universities (One Year Result)

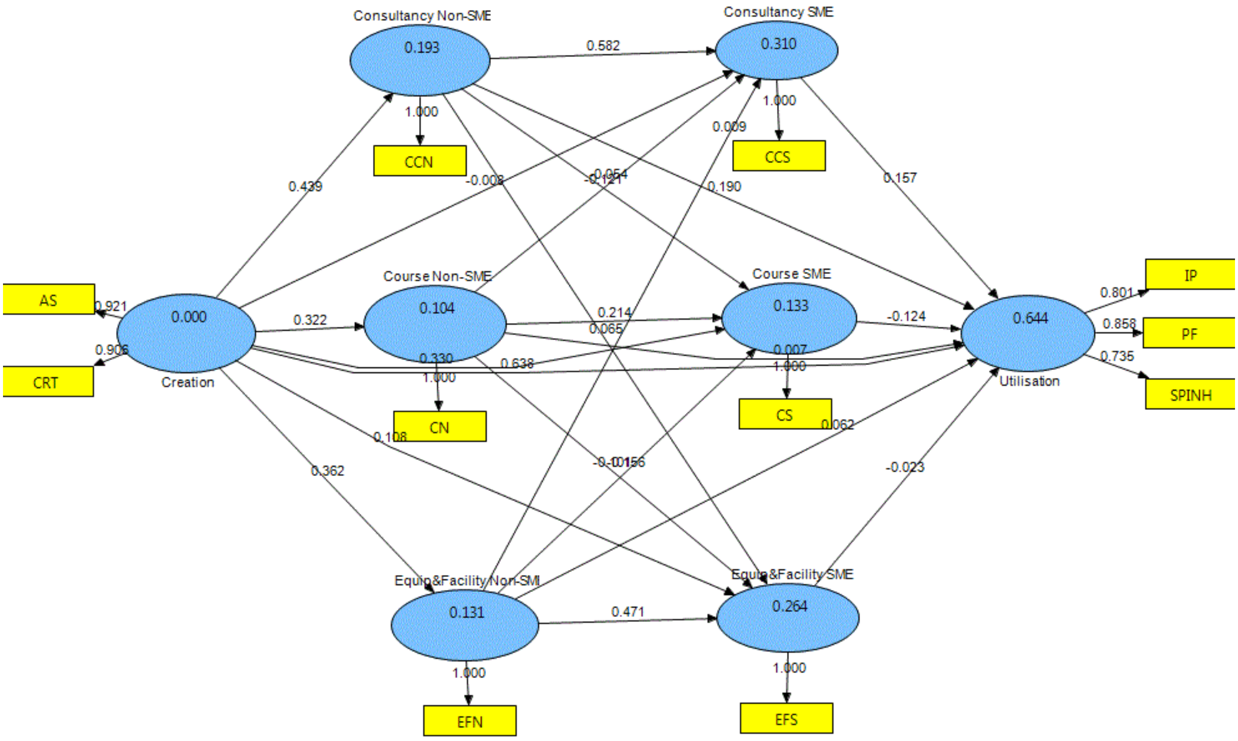


Table 6.4: Total Effects and Bootstrapping Result of Knowledge Utilisation in All Universities (One Year Result)

	Consultancy Contract Non-SME	Consultancy Contract SME	Course Non-SME	Course SME	Creation	Equipment and Facility Non-SME	Equipment and Facility SME	Utilisation
Consultancy Contract Non-SME		0.582189 (2.596877)*		-0.120871 1.293659			0.064958 0.733071	0.295024 1.499858
Consultancy Contract SME								0.156753 1.373558
Course Non-SME		-0.054404 1.104699		0.214146 1.623447			-0.101395 1.330148	-0.026019 0.096622
Course SME								-0.124162 (2.473839)*
Creation	0.438956 (3.786786)*	0.233445 0.139759	0.322372 (2.518675)*	0.289261 (2.428183)*		0.362443 (3.369096)*	0.274394 1.088807	0.740114 (6.513081)*
Equipment and Facility Non-SME		0.008998 0.139540		-0.155673 1.830330			0.470531 (2.282572)*	0.071846 0.824240
Equipment and Facility SME								-0.023146 0.476629
Utilisation								

Note: bootstrapping t-values in parentheses, * Significant (t>=1.96), case 161, sample 2000, Total Effect including all Universities, year of 2009

Findings of the one year study are listed as follows:

- Knowledge creation has a positive contribution to the University knowledge utilisation
- Knowledge dissemination through course SMEs is negative to the of University knowledge

utilisation

- Knowledge creation positively influences most knowledge dissemination channels (Consultancy Contract Non-SMEs, Course Non-SMEs, Course SMEs, Equipment and Facility Non-SMEs)
- Some knowledge dissemination between University and non-SMEs positively influences the Univeristy-SMEs knowledge dissemination (Consultancy Contract Non-SMEs to Consultancy Contact SMEs; Equipment and Facility Non-SMEs to Equipment and Facility SMEs)

<u>Three Years Result</u>

Figure 6.2: University-Business Interaction and Knowledge Utilisation in All Universities (Three Year Result)

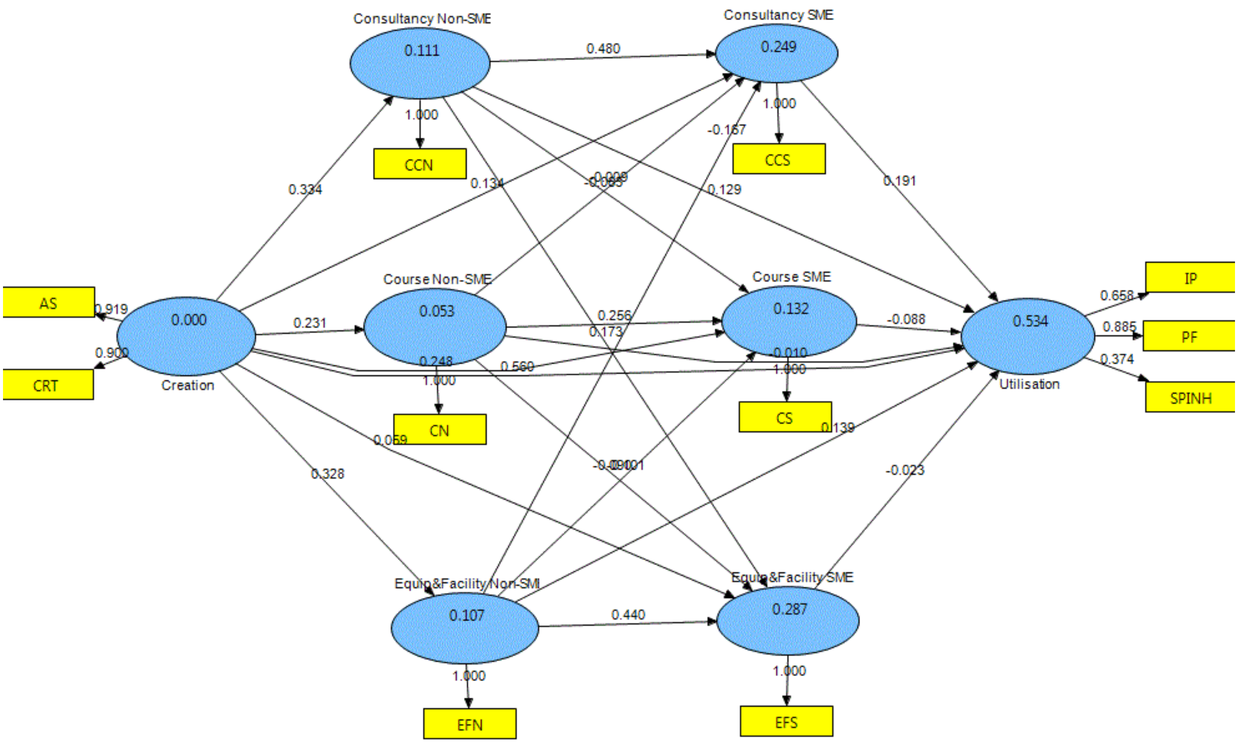


Table 6.5: Total Effects and Bootstrapping Result of Knowledge Utilisation in All Universities (Three Year Result)

	Consultancy Contract Non-SME	Consultancy Contract SME	Course Non-SME	Course SME	Creation	Equipment and Facility Non-SME	Equipment and Facility SME	Utilisation
Consultancy Contract Non-SME		0.479555 (3.636495)*		-0.063429 1.233095			0.173069 (2.198738)*	0.221724 1.211142
Consultancy Contract SME								0.190821 (2.730400)*
Course Non-SME		-0.009324 0.278389		0.255741 (3.367979)*			-0.089825 (2.671246)*	-0.031887 0.294323
Course SME								-0.088385 (3.003384)*
Creation	0.333555 (5.458097)*	0.237025 (2.130307)*	0.231013 (2.788467)*	0.252428 (3.702638)*		0.327692 (6.344521)*	0.239643 1.150611	0.663651 (4.484549)*
Equipment and Facility Non-SME		-0.167470 (2.078998)*		-0.100961 (2.502316)*			0.439820 (3.759046)*	0.106249 1.382827
Equipment and Facility SME								-0.023192 0.614978
Utilisation								

Note: bootstrapping t-values in parentheses, * Significant (t>=1.96), case 482, sample 2000, Total Effect including all Universities, 3 years 2007-2009

Findings of the three year study are listed as follows:

- Knowledge creation has a positive contribution to the University knowledge utilisation
- Knowledge dissemination through course SMEs is negative to the University knowledge utilisation
- Knowledge dissemination through Consultancy Contract SMEs is positive to the University knowledge utilisation
- Knowledge creation interaction positively influences most knowledge dissemination channels (Consultancy Contract Non-SMEs, Consultancy Contract SMEs, Course Non-SMEs, Course SMEs, Equipment and Facility Non-SMEs)
- Knowledge dissemination between University and non-SMEs positively influences the Univeristy-SMEs knowledge dissemination (Consultancy Contract Non-SMEs to Consultancy Contact SMEs; Course Non-SMEs to Course SMEs; Equipment and Facility Non-SMEs to Equipment and Facility SMEs)

Although some of the loading in the outer model (utilisation) is not very high, it is already demonstrated (in exploratory factor analysis based on 2009 data) that these variables (IP, PF, SPINH) can be put together to explain University knowledge utilisation. The main focus of this research is the inner model.

The main findings of the one year study and three year study will be discussed below.

First of all, in this UK University study, it is discovered that University-business interactions in knowledge creation have a significant contribution to the utilisation of University knowledge. This result extends studies which argued that the wealth of a country or region is directly linked to levels of R&D and innovation (Pianta, 1995; DTI, 2003a; DTI, 2003b; HM Treasury, 2003). University contract research as one of the main of R&D activities, focuses on the creation of industrial demanding knowledge. The created knowledge is usually directly utilised for production through the business innovation process. In addition, the channel of academic staff is not only who executes R&D activities, but also human capital enhances the knowledge proximity by intensifying the regional knowledge networks and informal contacts. These networks help University knowledge, especially tacit knowledge flow, to be accessed by firms. These academic staff that have the key knowledge may also start their own businesses, which is part of University spin-offs.

Secondly, this study also investigated the knowledge dissemination channels. The findings show that there are some relations between knowledge dissemination channels and the utilisation of University knowledge. In both the one year and three years analysis, it shows that a University course for SMEs is negatively related to the University knowledge utilisation. It may be because those firms which obtain knowledge from the course would have the capability to carry out their own research and development activity. Thus they would rely less on the commercialisation of University knowledge, such as IP licensing and collaborative research. In addition, in the three year model, it is found that a consultancy contract with SMEs would result in the utilisation of University knowledge. In contrast, the knowledge dissemination between Universities and non-SME companies shows no relation with utilisation of University knowledge. However, it seems it positively affects the University-SMEs knowledge dissemination. Both models provide evidence that University consultancy contract with Non-SMEs enhances University consultancy contract with SMEs. Similarly University equipment and facility related service with non-SMEs enhances that with SMEs.

Moreover, the result of this analysis also found the University-business interaction in knowledge creation is positively related to the knowledge dissemination between University and industry. They complement each other as a mechanism to encourage utilisation of University knowledge.

In sum, this study which includes all Universities based in the UK, brings in some ideas on how to enhance the utilisation of University knowledge through the University-business interaction. However, according to phenomenon on Silicon Valley in the US (Rogers et al., 1984; Saxenian, 1994) and the Cambridge region in the UK (Keeble, 2001), leading Universities have a vital role in the economy through their interaction with industry. Arthur and Piatt (2010) also point out that Russell Group Universities, representing the 20 major research-intensive Universities of the UK, are actively vibrant in contributing to their local communities and economies. Compared with other Universities, these Universities in the Russell Group show different aspects in the engagement with business. Therefore, the next part of the study will run a cluster analysis on UK Universities regarding their activities in knowledge creation, dissemination and utilisation. The objective is to further investigate how the University-business interaction influences the University knowledge utilisation in different groups of Universities.

6.2.2 University Groups: Result of Cluster Analysis

According to University paradigm studies (Bob Morgan,2002; Gerald Braun, 2006; Abreu et al., 2008), two groups of Universities are clustered to distinguish their different aspects and functions in transferring knowledge to growth. Elite research-focused Universities emphasise the role of those Universities as the regional knowledge engine. These Universities not only focus on the R&D functions to create scientific and technological knowledge, but also play a crucial role in knowledge transfer, academic entrepreneurship, and regional economic strategy. Outreach Business-Facing University is the group of the Universities which is focused on their role of University knowledge outreach and spillover through its embedded regional networks.

Those variables in knowledge creation, dissemination and utilisation (11 variables) are included to run the cluster analysis (with year 2007- 2009 UK University data). Two clusters are found, as the following table shows:

Table 6.6: Result of Cluster Analysis

Cluster Analysis				
Number of Cases in each Cluster	1		65	
	2		417	
Valid			482	
Missing			0	
Variables	**Initial Cluster Centers**		**Final Cluster Centers**	
	1	2	1	2
Zscore(AS)	.08900	.22057	1.74154	-.25709
Zscore(PF)	.65818	-.16947	1.61133	-.25117
Zscore(IP)	18.53327	.45085	.89534	-.13956
Zscore(CRT)	.18766	-.05107	1.80315	-.28107
Zscore(CCS)	-.03422	-.33441	.87877	-.13698
Zscore(CCN)	3.59889	.18906	1.23876	-.19309
Zscore(EFS)	5.99967	-.35182	1.10915	-.17289
Zscore(EFN)	8.20765	-.30815	1.28862	-.20086
Zscore(CS)	-.36182	-.23716	.37437	-.05836
Zscore(CN)	.07777	-.19083	.73929	-.11524
Zscore(SPINH)	-.09051	18.59559	.69202	-.10787

The Russell Group represents 24 leading UK Universities which are committed to maintaining the very best research, an outstanding teaching and learning experience, and unrivalled links with business and the public sector (Russell Group Papers, 2010). Comparing those Universities in Cluster 1 with Russell Group Universities, there are 20 Universities the same as the Russell Group. It is also found that Cardiff University is the only 1994 Russell Group University which is not included in Cluster 1.

Table 6.7: Comparison between Cluster Analysis Result and Russell Group University

Russell Group University		**University in Cluster 1**	
University	**Year of Joining**	**University**	**Years in Cluster**
University of Bristol	1994	The University of Bristol	2008, 2009
University of Cambridge	1994	The University of Cambridge	2007,2008,2009
University of Edinburgh	1994	The University of Edinburgh	2007,2008,2009
University of Glasgow	1994	The University of Glasgow	2007,2008,2009
Imperial College London	1994	Imperial College of Science	2007,2008,2009
King's College London	1994	King's College London	2007,2008,2009
University of Leeds	1994	The University of Leeds	2007,2008,2009
University of Liverpool	1994	The University of Liverpool	2007,2008,2009
University of Manchester	1994	The University of Manchester	2007,2008,2009
Newcastle University	1994	The University of Newcastle	2007,2008,2009
University of Nottingham	1994	The University of Nottingham	2007,2008,2009
University of Oxford	1994	The University of Oxford	2007,2008,2009
University of Birmingham	1994	University of Birmingham	2009
Queen's University Belfast	2006	The Queen's University of Belfast	2008,2009
University of Sheffield	1994	The University of Sheffield	2007,2008,2009
University of Southampton	1994	The University of Southampton	2007,2008,2009
University College London	1994	University College London	2007,2008,2009
University of Warwick	1994	The University of Warwick	2007,2008,2009
University of York	2012	University of York	2007,2008,2009
London School of Economics and Political Science	1994	London School of Economics and Political Science	2007
Cardiff University	1994		
Durham University	2012		
University of Exeter	2012		
Queen Mary, University of London	2012		
		The Open University	2007,2008,2009
		The University of Surrey	2007,2008,2009
		The University of Reading	2007,2008,2009
		Cranfield University	2007,2008

With cluster analysis, two groups of Universities are distinct, namely Elite Research-Focused Universities and Outreach Business-Facing Universities. The next step of the study is trying to find out how the interaction between Universities and business affects the utilisation of University knowledge in each group.

6.2.3 Elite Research-Focus University: Result of Structural Equation Modelling Analysis

Run the structural equation modeling analysis with data of elite research-focus University, and the result is shown with the figure and table below. The model is analyzed with three years of data (2007-2009).

Figure 6.3: University-Business Interaction and Knowledge Utilisation in Elite Universities (One Year Result)

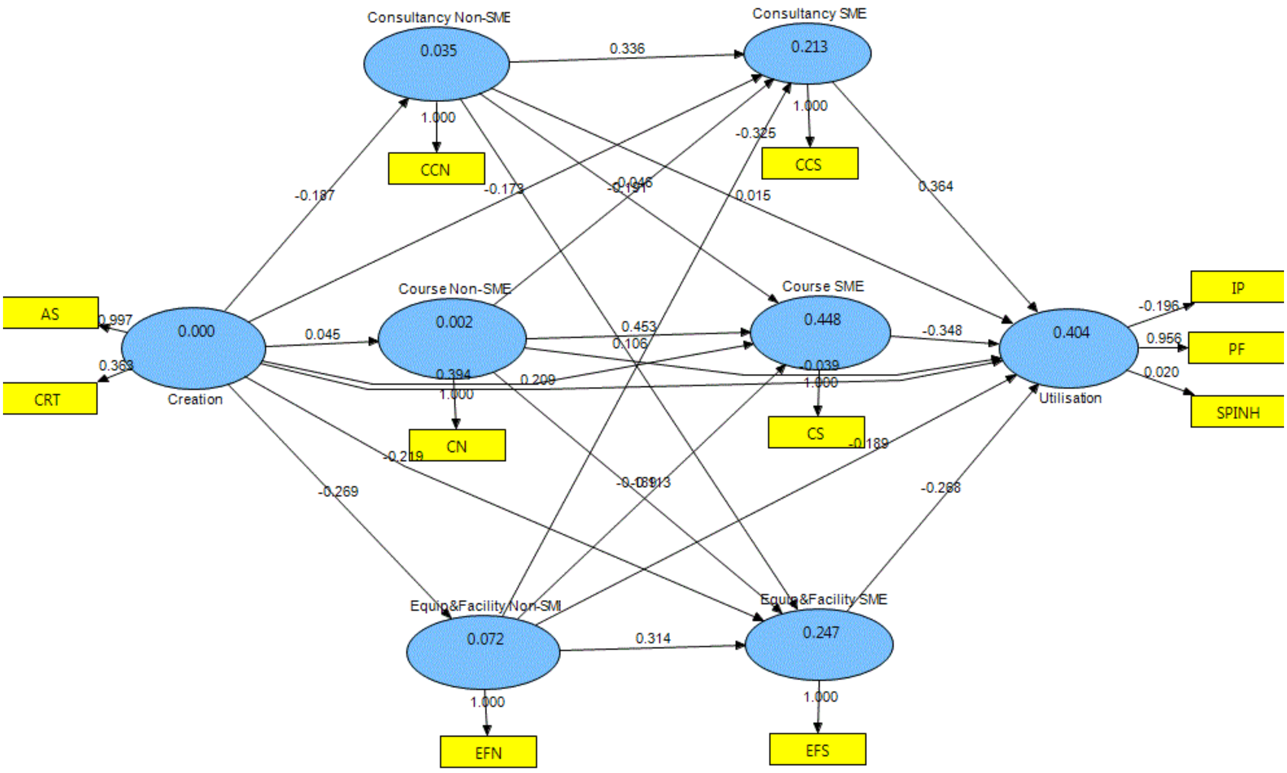


Table 6.8: Total Effects and Bootstrapping Result of Knowledge Utilisation in Elite Universities (Three Year Result)

	Consultancy Contract Non-SME	Consultancy Contract SME	Course Non-SME	Course SME	Creation	Equipment and Facility Non-SME	Equipment and Facility SME	Utilisation
Consultancy Contract Non-SME		0.336079 1.769110		-0.190735 1.471574			0.105646 1.329530	0.175468 0.085031
Consultancy Contract SME								0.363771 (2.453457)*
Course Non-SME		-0.045624 0.629679		0.453262 (2.486706)*			-0.188933 (2.415605)*	-0.162805 0.289709
Course SME								-0.347891 1.762342
Creation	-0.186611 (2.490789)*	-0.150919 1.856716	0.045197 0.370638	0.480469 1.802643		-0.268593 (2.767017)*	-0.331688 (2.555233)*	0.122157 0.765244
Equipment and Facility Non-SME		-0.324710 (3.150899)*		-0.112590 1.209993			0.314444 (2.154254)*	-0.352355 1.115702
Equipment and Facility SME								-0.267575 (2.276311)*
Utilisation								

Note: bootstrapping t-values in parentheses, * Significant (t>=1.96), case 65, sample 2000, Total Effect including Elite Research-Focus Universities, 3 years 2007-2009

Findings from the three year study on this Elite Research-Focus University Group are listed as follows:

- Knowledge creation shows no relation with the University knowledge utilisation
- Knowledge creation shows no relation with the University knowledge utilisation
- Knowledge creation negatively influences the knowledge dissemination, both for Non-SMEs dissemination (Consultancy Contract Non-SME; Equipment and Facility Non-SME) and SMEs dissemination (Equipment and Facility SME)
- The utilisation of University knowledge in this University group only attributes to some knowledge dissemination activities. One of the knowledge dissemination channels, Consultancy Contract SME, positively contributes to the University knowledge utilisation growth, and the other dissemination channel, Equipment and Facility SME, negatively links with the University knowledge utilisation

Although some of the loading in the outer model (utilisation) is not very high, it is already demonstrated (in exploratory factor analysis based on 2009 data) that these variables (IP, PF, SPINH) can be put together to explain University knowledge utilisation. The main focus of this research is the inner model.

It can be seen that the results of elite research-focus Universities show a different result from the all University results. First of all, the interaction between Universities and business in knowledge creation has no influence on the utilisation of University knowledge. Encouraging contract research or research staff may not directly result in that regional growth attributed to the University knowledge commercialisation. The reason may be because the knowledge creation in elite research-focus Universities may have a long-run blue sky strategy. In general, research suggests that a combination of short-run (static) effects and long-run (dynamic) effects will result from public investment in R&D (Hewitt-Dundas et al., 2007). Although the knowledge created in these elite research-focus Universities may not show its commercial return in a short time, the advanced technology it produced will contribute to the competitiveness of the University and the innovativeness of the region.

In addition, the result of the knowledge dissemination between University and SMEs matters to the utilisation of University knowledge. The contribution of entrepreneurship knowledge spillover is demonstrated in this University group. Consultancy contact with SMEs shows its positive relation with University knowledge utilisation. This result shows that in elite research-focused Universities, knowledge dissemination has a significant effect on University knowledge commercialisation. Another University-business knowledge dissemination, facility and equipment service to SMEs, shows a negative relation. It means that when firms rely more on the University as a laboratory, they are usually less likely to purchase the knowledge from the University. These Universities provide focus on the facility and equipment service network with SMEs, which may not lead to commercialisation of the University knowledge by their own activities, such as University spin-offs.

The result also discovers that the interaction of University-business in knowledge creation and knowledge dissemination shows that they are substitutions to each other. This means that when these University-business interactions focus on the knowledge creation, usually there would be less knowledge disseminating from University to business, and vice versa.

The research result in this group of elite research-focused Universities is as different as that in all University groups. This could be because these elite Universities are usually research intensive, and they are mostly located in high innovative regions. Evidence can be found in some regions such as Cambridge. The knowledge creation in these universalities are more focused on the purpose of regional development, to encourage the innovation and long term technological competitiveness, rather than a University's own development via the commercialisation of University knowledge. In addition, benefiting from the advanced regional innovation system (e.g. science park; technological cluster; etc), businesses surrounding the University or in the cluster may efficiently absorb knowledge and transfer it to industrial innovation. Firms in these areas are likely to use a short term and low risk way (e.g. University consultancy contract) to access knowledge they need to support their own research. The University, for these businesses, is mainly the knowledge resource for problem solving during the business innovation process, not the pure R&D supplier. This knowledge dissemination can also be a useful way to for University to start a long term relationship with firms which could lead to student placements and research projects. It will consolidate the University-business relationship, and lead to more University knowledge utilisation by firms.

6.2.4 Outreach Business-Facing University: Result of Structural Equation Modelling Analysis

After running the structural equation modelling analysis for the group of outreach business-facing Universities with one year (2009) and three years data (2007-2009), the result of the three year is shown with the figure and table below.

Figure 6.4: University-Business Interaction and Knowledge Utilisation in Outreach Universities (Three Year Result)

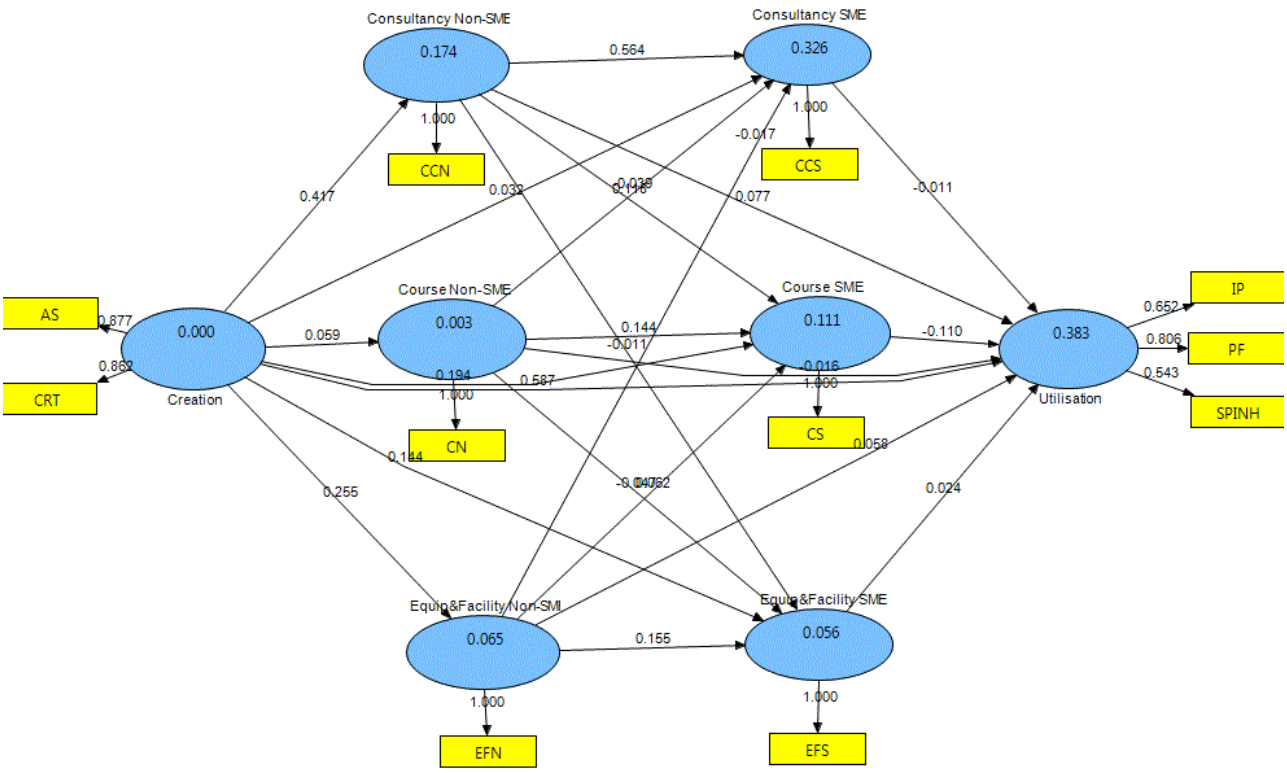


Table 6.9: Total Effects and Bootstrapping Result of Knowledge Utilisation in Outreach Universities (Three Year Result)

	Consultancy Contract Non-SME	Consultancy Contract SME	Course Non-SME	Course SME	Creation	Equipment and Facility Non-SME	Equipment and Facility SME	Utilisation
Consultancy Contract Non-SME		0.563521 (4.849470)*		0.117781 (1.984177)*			-0.011113 0.464786	0.057545 1.201190
Consultancy Contract SME								-0.011448 0.290429
Course Non-SME		-0.039038 0.996075		0.144138 (2.117293)*			-0.046567 (2.555205)*	-0.032135 0.492822
Course SME								-0.110003 (2.893925)*
Creation	0.417417 (6.667008)*	0.260530 0.618122	0.058730 0.760401	0.266930 (4.118528)*		0.254534 (4.628593)*	0.176127 (3.853711)*	0.605472 (11.421042)*
Equipment and Facility Non-SME		-0.017269 0.473894		0.061801 1.321344			0.154788 (2.762251)*	0.055193 0.923223
Equipment and Facility SME								0.024335 0.764064
Utilisation								

Note: bootstrapping t-values in parentheses, * Significant (t>=1.96), case 417, sample 2000, Total Effect including Outreach Business-Facing Universities, 3 years 2007-2009

- Knowledge creation has a positive contribution to the University knowledge utilisation
- Knowledge dissemination through Course SMEs is negative to the University knowledge

utilisation

- Knowledge creation positively influences most knowledge dissemination channels (Consultancy Contract Non-SMEs, Course SMEs, Equipment and Facility non-SMEs, Equipment and Facility SMEs)
- Knowledge dissemination between University and non-SMEs positively influences the Univeristy-SMEs knowledge dissemination (Consultancy Contract Non-SMEs to Consultancy Contact SMEs; Course Non-SMEs to Course SMEs; Equipment and Facility Non-SMEs to Equipment and Facility SMEs)

Although some of the loading in the outer model (utilisation) is not very high, it is already demonstrated (in exploratory factor analysis based on 2009 data) that these variables (IP, PF, SPINH) can be put together to explain University knowledge utilisation. The main focus of this research is the inner model.

The main finding with this group of outreach business-facing Universities shows some similarities with the results for all Universities. First of all, University knowledge utilisation is mainly affected by University-business interaction in creation. Some knowledge dissemination activities between the University and SME matters, but in a negative manner. The research in elite research-focus Universities shows two marks. It usually aims to develop the advanced technology for the regional long-run growth, and a big portion of research is large firm based. Unlike the elite research-focused Universities, outreach business-facing Universities are usually more entrepreneurship friendly. They are usually more embedded with local firms and outreach the

University knowledge to the needs of entrepreneurship. Thus big parts of the knowledge it created was through University-SMEs collaboration. This knowledge is market oriented and tends to be used by firms.

Another finding which is opposite to the result of the elite research-focus University, is that University-business interaction in knowledge creation is complemented by the knowledge dissemination. Actually, the co-operation between Universities and business in research encourages the knowledge dissemination activities. There is evidence that this group of outreach Universities are involved in business in terms of both knowledge creation and dissemination process. Any type of interaction may lead to the further knowledge transfer between Universities and industry.

Thirdly, these activities between Universities and non-SMEs in knowledge dissemination would contribute to the knowledge University-SMEs knowledge dissemination. This can be explained with knowledge proximity. These outreach Universities are facing local business. Thus the knowledge transfer between these Universities and business are constrained to the geographical proximity of the region. The knowledge generated from the University-non SME interaction, may diffuse to SMEs via the localised knowledge network, and contribute regional growth through the knowledge spillover of entrepreneurship.

One of the knowledge dissemination activities, Course-SMEs, shows a negative relation with University knowledge utilisation. This may be because with the training and courses provided by the University, entrepreneurs turn out to be more capable to do their R&D and innovation. They would less rely on other University knowledge, such as IP and collaborative projects.

6.3 DISCUSSION

Combining all the above results, the effect of University-industry interaction on the knowledge utilisation in different University groups is summarised with the table below:

Table 6.10: Summary of UK University Result

Interaction to Growth	**All University**	**Elite Research-Focus University**	**Outreach Business-Facing University**
Creation→Utilisation	Creation ↑ Utilisation	Creation X Utilisation	Creation ↑ Utilisation
Dissemination→Utilisation	Dissemination ↑↓ Utilisation	Dissemination ↑↓ Utilisation	Dissemination ↓ Utilisation
Creation→Dissemination	Creation ↑ Dissemination	Creation ↓ Dissemination	Creation ↑ Dissemination
Dissemination Non-SMEs→Dissemination SMEs	Dissemination Non-SMEs ↑ Dissemination SMEs	Dissemination Non-SMEs ↑↓ Dissemination SMEs	Dissemination Non-SMEs ↑ Dissemination SMEs

Note: Positive effect: ↑ ; Negative effect: ↓ ; No effect: X; Both positive and negative: ↑↓

First of all, in the group of all UK Universities, the result discovered that the University-business interaction in knowledge creation contributes to the utilisation of University knowledge. This result expands previous University paradigm studies (Morgan, 2002; Braun, 2006; and Abreu et al, 2008) by focusing on different University groups according to their roles in regional economy. In elite research-focused Universities, it shows no relationship between University-business interaction in knowledge creation and utilisation of knowledge. There is however a positive relationship between these two in outreach business-facing Universities. This may be because R&D in elite research-focus University usually has a long-run objective (Anselin et al., 2000; Woodward et al., 2003). This evidence gives some ideas regarding how to enhance that part of growth attributing to the utilisation of University knowledge. In outreach business-facing Universities, encouraging the University-business interaction in knowledge creation (contract research, academic staff) may become a solution.

Secondly, the knowledge dissemination between University and SMEs influences the knowledge utilisation, while the University and non-SMEs dissemination shows no influence. This result is found in all three University groups. In the group of all Universities and the group of elite research-focus Universities, the knowledge dissemination between the University and SMEs may positive or negatively affect knowledge utilisation, depending on different dissemination activities. In the group of outreach business-facing University, as a knowledge dissemination activity, Courses for SMEs shows negative relation with the knowledge utilisation. It infers that in this group of University, the knowledge dissemination could substitute the knowledge utilisation to generate the knowledge commercialisation in some degree. This result shows that promoting the knowledge dissemination activity in elite research-focus Universities, such as the consultancy contract to SMEs, may result in the increase of knowledge utilisation.

Moreover, this result also revealed the relationship between the University-business interaction in knowledge creation and the dissemination. In the group of all Universities and the group of outreach business-facing Universities, the interaction between the University and business in knowledge creation is complemented by the University-business knowledge dissemination activities. In contrast, in elite research-facing Universities, the interaction in knowledge creation and knowledge dissemination are substituted with each other. This result suggests that in an outreach business-facing University, encouraging R&D activities may likewise enhance the knowledge dissemination from University to business. However, too much focus on R&D interaction in elite research-focus Universities may result in the less knowledge dissemination from University to business.

There is also another important finding in this UK University study. The knowledge dissemination between a University and non-SMEs, would affect the knowledge dissemination activities between Universities and SMEs. There are mainly positive influences which can be found in the group of all Universities and the group of outreach business-facing Universities. In elite research-focus Universities, the result is vague because it shows both positive and negative influences. The result suggests that encouraging those knowledge dissemination activities between outreach business-facing Universities and large companies may also indirectly help the knowledge disseminate from these Universities to small firms.

6.4 Findings of UK University Study

The findings of the UK University Study are summarised with the table below:

Table 6.11: Summary of the UK University Study

Research Objective	Detail Questions	Answer	Completion of Objective C	Contribution		Limitation
				to Knowledge	to Policy	
Objective C: To illustrate the patterns & processes of University knowledge based systems and the effect of it on knowledge commercialisation. It is also to see if this effect is different among different paradigms of Universities by considering their specialities	Q11: How do University knowledge creation and dissemination processes affect University knowledge utilisation, and then the commercialisation of the knowledge?	Creation and dissemination influence the utilisation of knowledge. Creation and dissemination influence each other	● Demonstrates the creation and dissemination of knowledge has an effect on the knowledge commercialisation ● Showes that University interaction with SMEs directly results in the knowledge commercialisation ● Discovers different University shows different relationships among knowledge creation- ● dissemination-utilisation, there is substitution relationship in Elite Universities and complement relationship in Outreach Universities	● New Growth Theory ● Knowledge Spillover Theory of Entrepreneurship ● Knowledge Dissemination Channels ● University Paradigm ● Schumpeterian Growth Model	● Focus on creation but also dissemination through University-business interaction channels ● Different policies for University interaction with None-SMEs and SMEs, as SMEs interaction more direct links with knowledge commercialisation ● Design different policy incentives according to different types/specialties of Universities	● Have to use knowledge commercialisation as an indicator of growth ● Lack of data to cover all knowledge transfer channels ● the result are only based on UK University and may have difficulties to apply in other nations
	Q12: Does University-business interaction in the knowledge dissemination process, in terms of Non-SMEs interaction and SMEs interaction, affects the knowledge commercialisation?	SMEs interaction has a contribution to knowledge commercialisation Non-SMEs interaction affect the SMEs interaction				
	Q13: Do different types of University show different patterns in the University knowledge creation-dissemination-utilisation process?	Yes Elite University-Substitution relationship Outreach University-Complement relationship				

6.4.1 Answer of research questions Q11-Q13

The findings of this chapter give answers for following research questions. For Q11, the result shows that generally both University knowledge creation and University dissemination influence the utilisation of University knowledge. Furthermore, University knowledge creation and dissemination influence each other as well. The result of Q12 clarifies the role of interaction between University and Non-SMEs and SMEs in knowledge commercialisation. University-SMEs interaction shows a direct influence on the knowledge commercialisation, while the University non-SMEs interaction appears to be indirectly influence on knowledge commercialisation through its impact on SMEs. The result of Q13 shows various patterns in the University knowledge creation-dissemination-utilisation process between different types of University. In the group of elite research-focus Universities, knowledge creation and dissemination have a substitution relationship. In contrast, in the outreach business-facing University group, the knowledge creation shows complement relationship with knowledge dissemination.

6.4.2 Completion of Objective C

The result of this chapter completes the research Objective C with following the evidence. It not only demonstrates that the creation and dissemination of knowledge has an effect on the knowledge commercialisation, but also shows that University interaction with SMEs directly results in the knowledge commercialisation. Moreover, it discovers that Universities show different relationships among knowledge creation-dissemination-utilisation, and there is a substitution relationship in Elite Universities which complement the relationship in Outreach Universities.

6.4.3 Contribution to Knowledge

The findings of this study mainly contribute to four groups of knowledge: Knowledge Based Growth Theory, Knowledge System, University Paradigm, and Science and Industry Link.

First of all, when the results highlighted the relation between knowledge creation, dissemination and utilisation, it helps to contribute to the development of new growth theory (Romer, 1986; Lucas,1988; and Rebelo,1991) and knowledge spillover theory (Acs, et al, 2003; 2006) with direct evidence. New growth stands on the "knowledge creation" side, to explain knowledge investment role in growth model. Knowledge spillover theory, however, is more on the side of "knowledge dissemination". It stresses that the channels of knowledge dissemination is the reason why the knowledge spillover take place, and this would result in the knowledge commercialisation. This chapter of UK University based study tries to combine elements of both "knowledge creation" and "knowledge dissemination" under the same framework, to give a more comprehensive understanding on how each influence the commercial result. The analysis result shows that both knowledge creation and dissemination have a significant effect on knowledge commercialisation, and there is a relation between knowledge creation and dissemination as well. This result not only solidifies the main argument of growth theory, but also adds an idea to consider knowledge creation and dissemination as integration. Their impacts on growth depend on the circumstances of regional knowledge system, and also the proportion of each in the whole integration.

Another important contribution is derived from the finding that different types of University show different patterns in the knowledge creation-dissemination-utilisation process. This gives substantial empirical evidence to University paradigm theory (Morgan, 2002; Braun, 2006; Abreu et al, 2008). It provides the hints that Elite types of University are more specialised in their core activities, while Outreach types of University are more active in the knowledge outreach activities, since the knowledge created in these Universities are more targeted on business usage. On the other hand, the findings also contribute to the theory of Science and Industry Link by showing a new aspect of University-business relationship. That substitution relation found between knowledge creation and dissemination in elite types of University, and complements relationships found in outreach types of University, strongly illustrates that investment in the same stage of the process could have different consequences between different Universities. This allows us to more precisely describe the University-business interaction by considering these differences in specialty between Universities.

Thirdly, the result supports the knowledge spillover theory of entrepreneurship (Acs, et al, 2003; 2006) by confirming the direct effect of entrepreneurship. The result is also consistent with the main idea of the Schumpeterian Growth Model, which considers that entrepreneurship is what seeks business opportunities. What is more, it contributes Science and Industry Link literature with some fresh ideas. Previous studies of non-SME knowledge either focuses on its economic return, or the formal interaction with research bodies. However, this study extends the theory by showing that University and non-SMEs interaction does not contribute to growth directly; instead, it has an influence on the University and SME interaction. This indicates that the formal co-operation between Universities and non-SMEs benefit those casual interactions between Universities and SMEs. In addition to the codified knowledge it created, this formal co-operation builds tacit knowledge, human resource and knowledge networks. All these provide a good base for the knowledge spillover, and benefits the entrepreneurship knowledge absorption.

6.4.4 Contribution to Policy

First of all, to improve University knowledge commercialisation and the full use of University knowledge, general policies could look at both the knowledge creation stage, and dissemination stage. However, unique and specific policy is needed according to the type/specialty of the University and the regional knowledge system. In these regions with the elite University knowledge system, knowledge creation and knowledge dissemination are substitutes of each other. Therefore, policy incentives need to consider the economic consequences, since the investment in knowledge may not immediately result in regional growth (Rebelo, 1991; Segerstorm, 1995; Acs et al., 2003). However, the knowledge creation activities are more likely to increase the regional knowledge stock, and human capital intensity through the University training and research, this is consistent with some studies of University paradigm (Morgan, 2002; Braun, 2006; Abreu et al, 2008; Sauer et al, 2007). All this provides the region with a long-term economic effect with technological advances. On the other hand, encouraging knowledge dissemination between Universities and SMEs is likely to help the commercialisation of University knowledge. Building the University-business knowledge dissemination channel could be an ideal choice to instantly boost the regional economy, especially the tacit knowledge channels such as Consultancy Contract SME. However, because too much investment in knowledge dissemination in this system will bring about a decrease of knowledge creation, which stage to develop between the two needs to be carefully compared, before making a decision in policy.

In these regions with an outreach University knowledge system, the story is different. The result shows that investment in University knowledge creation in this system contributes more directly to the knowledge commercialisation and growth. For an economic growth purpose, the knowledge creation in outreach business-facing Universities could be a potential field to develop in policy. Moreover, the knowledge creation tends to help the knowledge dissemination as well in this system. Therefore, the more knowledge that is created in outreach Universities, the more interaction between Universities and business will take place, which in turn would bring more opportunities for businesses.

According to many studies (Davenport, 2005; Castells, 1995; Cohen and Levinthal, 1990) in this field, the University interaction with non-SMEs and SMEs between is another topic faced by policymakers. In both the elite and outreach University-based knowledge systems, there is a relationship found in the analysis result, between University non-SMEs knowledge dissemination, and SME knowledge dissemination. When policies focus on the interaction between Universities and SMEs, it is more likely to bring about the result of University knowledge commercialisation. On the other side, the non-SME interaction is also worth looking at by policymakers. Policy to stimulate knowledge dissemination between Universities and non-SMEs intensified regional knowledge, especially tacit knowledge such as human capital, expertise, personal networks, and skills. The increase of tacit knowledge strengthens the knowledge dissemination channels, and the entrepreneur's ability for knowledge absorption. Therefore, focusing on the non-SMEs could be a policy to consider, for the purpose of encouraging University-business interaction and knowledge commercialisation.

6.4.5 Limitation

There are some limitations in this study which need to be considered.

First of all, because of data availability, this chapter has to use knowledge commercialisation as a proxy of growth. It could therefore have a problem with accuracy. Further research can choose more direct indications of growth, such as growth value added (GVA) and total factor productivity (TFP), when there is data available for UK regions. Secondly, this study covers some but not all knowledge dissemination channels. One reason is that the form of the data itself as the data source covers only some main types of University-business interaction measurement. The other reason is that because the model tries to define three distinct stages in terms of knowledge creation, dissemination and utilisation, these indicators of interaction related to dissemination are limited to the availability in the data source. However, in real practice, there would be more types of knowledge dissemination channels between Universities and business. In the future this area could be considered to develop the model. Thirdly, because the model is only based on the UK regions and Universities, it reveals some evidence for the UK University knowledge based system. However, whether these findings could be applied similarly in other nations or regions is still unclear. This is because the model result depends largely on factors such as the regional knowledge absorptive capacity, a University's ability for knowledge creation and outreach, and skills of businesses in seeking knowledge. These factors are likely to alter in different countries with differing economic scales, University systems, and innovation institutions.

This part of the University study gave an in-depth view of the University-business interaction, with three stages involved in the knowledge process. Together with an international study and regional study, the research questions are answered with different hierarchies. The next chapter will review these results with the research objectives. After a further discussion with the regional context, the policy recommendation will be given, and followed with a conclusion.

Chapter 7: Conclusion

This chapter takes the results of the OECD study, the UK regional study, and the UK University study together, to see the completion of all research objectives and overall findings. In addition, according to these answers, the contribution to knowledge is made, followed by a discussion of practical recommendations in terms of policy direction and practical solutions. Finally, the main conclusions (including contribution to knowledge, practice and methodology) and limitations of this research will be shown, and mentioned with the possible focus of further study.

7.1 Summary of Findings

In the field of knowledge economy, there is a prevalent argument about the role of science and industry in growth. Knowledge spillover theory, however, tries to consider the influences from both the science and industry sides. The interaction between Universities and business as a main form of science-industry interaction are focused in the research. On the industry side, there is a desire to gain access to associated research activity and research results (Cohen et al., 1997; Audretsch et al., 2012). On the University side, financial pressures are the motivating force to stimulate faculties to engage in applied commercial research with industry (Henderson et al., 1995; Zeckhauser, 1996; Siegel, et al.,1999). The needs of regional development also require this University-industry interaction to encourage the improvement in knowledge stock and innovation.

Universities, because of their great R&D ability and entrepreneurial flexibility, are more adept at responding to changes in the specific needs of the particular region or industry. Research has been done that suggests that Universities are in a stronger position than government labs and private research to provide the research necessary to stimulate economic growth (Leyden and Link, 2011).

Based on these arguments, this research focuses on the interaction between Universities and business. The aim of this research is to investigate the role of University-business interaction in the knowledge system and its effect on growth. This research is formed with three layers of study, including the OECD study, the UK regional study, and the UK University study, which were specifically designed for three research objectives. The completion of these research objectives are summarised in the table below, and based on them, the overall findings are shown. These results not only give the theory notes which contribute to the knowledge, but also provide the policy notes which are likely to contribute in practice.

Table 7.1: Summary of Research Findings

Aim	**Objectives**	**Completion of Objectives** **(Theory Notes)**	**Overall Findings** **(Policy Notes)**
To investigate the role of University-business interaction in knowledge system and its effect on growth	Objective A: To discover the influence of University-business co-operation on technological progress and economic growth. It is also to find out how this network integrates with knowledge investment and entrepreneurship in the knowledge system **(OECD Study)**	1. Demonstrates the positive effect of University-business co-operation on technological progress and economic growth 2. Shows the evidence that knowledge investment in R&D and human capital indirectly influence growth 3. Discovers the substitute relationship between University-business co-operation and entrepreneurship	1. University-business interaction is the key of the University based knowledge system of knowledge process, and it has significant effect on both economic growth and technological progress 2. Different University activities have different roles in the regional knowledge system. University Core Activity contributes to both long –term and short term growth. University Knowledge Outreach Activity is more likely to contribute to long-term growth of a region 3. Economy of regions with high knowledge absorptive capacity benefit directly from the Core Activity, while growth of regions with relatively low knowledge absorptive capacity more relies on the University Knowledge Outreach Activity 4. Both University knowledge creation and dissemination influence University knowledge commercialisation. In Elite University, knowledge creation and knowledge dissemination substitute each other; while in Outreach University, knowledge creation and knowledge dissemination complement each other
	Objective B: To investigate the effect of University activities on growth and the role of University activities in regional knowledge systems. It is also to find out if this role shows differences across those regions with different knowledge absorptive capacity **(UK Regional Study)**	4. Demonstrates the positive effect of University Core Activity on technological progress and economic growth 5. Demonstrates the positive effect of University Knowledge Outreach Activity on technological progress 6. Discovers Complement relationship between University Core Activity and entrepreneurship 7. Discovers Substitution relationship between Knowledge Outreach Activity and entrepreneurship 8. Shows that regional disparities result in the different mode of University involvement in the regional knowledge system	
	Objective C: To illustrate the patterns & processes of University knowledge based systems and the effect of it on knowledge commercialisation. It is also to investigate if this effect is different	9. Demonstrates the creation and dissemination of knowledge has an effect on the knowledge commercialisation 10. Shows that University interaction with SMEs directly results in the knowledge	

	among different paradigms of Universities by considering their specialities **(UK University Study)**	commercialisation 11. Discovers different University shows different relationships among knowledge creation-dissemination-utilisation, there is substitution relationship in Elite Universities and complement relationship in Outreach Universities	

The objective of the OECD study is to discover the influence of University-business co-operation on technological progress and economic growth. It is also to find out how this network integrates with knowledge investment and entrepreneurship in the knowledge system. The results of the OECD study demonstrate the positive effect of University-business co-operation on technological progress and economic growth. It also shows evidence that knowledge investment in R&D and human capital indirectly influence growth. In addition, it discovers the substitute relationship between University-business co-operation and entrepreneurship.

The objective of the UK regional study is to investigate the effect of University activities on growth, and the role of University activities in regional knowledge systems. It is also to find out if this role shows differences across those regions with different knowledge absorptive capacity. The results of the UK regional study demonstrate the positive effect of University core activity on technological progress and economic growth. It also demonstrates the positive effect of University knowledge outreach activity on technological progress. In addition, it discovers the complementary relationship between University core activity and entrepreneurship, and in contrast, the substitution relationship between knowledge outreach activity and entrepreneurship. Moreover, the result also shows that regional disparities result in the different modes of University involvement in the regional knowledge system.

The objective of the UK University study is to illustrate the patterns and processes of University knowledge based systems, and the effect of it on knowledge commercialisation. It is also to see if this effect is different among different paradigms of Universities by considering their specialities**.** The results of the UK University study demonstrate that creation and dissemination of knowledge has an effect on the knowledge commercialisation. It also shows that University interaction with SMEs directly results in the knowledge commercialisation. In addition, it discovers that different Universities show different relationships among knowledge creation-dissemination-utilisation, and there is a substitution relationship in elite Universities, and a complementary relationship in outreach Universities.

The results from the three layers of study together provide four main findings with regards to improving the economic return, and benefiting from the utilisation of University knowledge. First of all, University-business interaction is the key to the University based knowledge system of knowledge process, and it has a significant effect on both economic growth and technological progress. Secondly, different University activities have different roles in the regional knowledge system. University core activity contributes to both long term and short term growth. University knowledge outreach activity is more likely to contribute to the long-term growth of a region. Thirdly, the economy of regions with high knowledge absorptive capacity benefits directly from the core activity, while growth of regions with relatively low knowledge absorptive capacity relies more on the University knowledge outreach activity. Finally, both University knowledge creation and dissemination influence University knowledge commercialisation. In elite Universities, knowledge creation and knowledge dissemination substitute each other; while in outreach Universities, knowledge creation and knowledge dissemination complement each other. All these findings bring contributions to three fields in terms of knowledge, practice, and methodology. These contributions are shown in turn below.

Given these results, the research makes contributions to knowledge, practice and methodology, which will be discussed in turn.

7.2 Contribution to Knowledge

These findings contributes to the knowledge in the research fields including the nature of knowledge, growth theory, knowledge system, a University's role and the science-industry link, which are summarised in the table below.

Table 7.2: Contribution to Knowledge

Completion of Objectives **(Theory Notes)**	**Support for Existing Theory**	**Contribution to Knowledge**
1. Demonstrates the positive effect of University-business co-operation on technological progress and economic growth	--Endogenous growth theory --Knowledge spillover theory --National innovation system --Model 2 --Triple helix model --University-business link	**Nature of Knowledge** (based on result Note 4, 5, 9)
2. Showes the evidence that knowledge investment in R&D and human capital indirectly influence growth	--Endogenous growth theory	**Growth Theory** (based on result Note 1, 2, 4, 5, 9, 10)
3. Discoveres the substitute relationship between University-business co-operation and entrepreneurship	--Schumpeterian growth model --Knowledge spillover theory	**Knowledge System** (based on result Note 1, 3, 4, 5, 6, 7, 10)
4. Demonstrates the positive effect of University Core Activity on technological progress and economic growth	--Codified and tacit knowledge --Knowledge Indicator --Knowledge spillover theory --Triple helix model --University Mission	**University Role** (based on result Note 4, 5, 11)
5. Demonstrates the positive effect of University Knowledge Outreach Activity on technological progress	--Codified and tacit knowledge --Knowledge Indicator --Knowledge spillover theory --Triple helix model --University Mission	**Science-Business Link** (based on result Note 1, 6, 7, 8)
6. Discovers Complement relationship between University Core Activity and entrepreneurship	--Regional innovation system --Triple helix model --University-Business Link --Channels of knowledge transfer	
7. Discovers Substitution relationship between Knowledge Outreach Activity and entrepreneurship	--Regional innovation system --Triple helix model --University-Business Link --Channels of knowledge transfer	
8. Shows that regional disparities result in the different mode of University involvement in the regional knowledge system	--Regional innovation system --Knowledge proximity --Knowledge absorptive capacity	

9. Demonstrates the creation and dissemination of knowledge has an effect on the knowledge commercialisation	--Knowledge indicator --Endogenous growth theory	
10. Shows that University interaction with SMEs directly results in the knowledge commercialisation	--Knowledge Spillover Theory --Triple helix model --University business link	
11. Discovers different University shows different relationships among knowledge creation-dissemination-utilisation, there is substitution relationship in Elite Universities and complement relationship in Outreach Universities	--Triple helix model --University Mission --University Paradigm	

7.2.1 To Nature of Knowledge

(Based On Theory Note 4, 5, 9)

This research clarifies the role of the University with two indicators, in terms of University core activity and University knowledge outreach activity, and discovers the effect on growth of each respectively. The core activity covers the side of knowledge creation and codified knowledge transfer, while the knowledge outreach activity mainly refers to knowledge dissemination and tacit knowledge transfer. Although codified knowledge and tacit knowledge are in the same theory framework, the previous discussion of their role in growth broadly covers the combination of both. The findings of this research expands the nature of knowledge, by arguing when the contribution and consequence of knowledge need to distinguish the codified and tacit nature of the knowledge. The discussion of codified knowledge is more likely to connect with its role in knowledge creation, as this type of knowledge is usually easy to transfer, and is a direct resource of knowledge creation. The discussion of tacit knowledge is more likely to connect with knowledge outreach, since the approach of transfer is the main topic in front of this type of knowledge. This result modelled the University core activity and outreach activity, and statistically demontsrates the unique effect of each on growth, and the role of each in the innovation system.

In addition, measuring knowledge - especially tacit knowledge - is always a challenge in this research field. This research applies the process of knowledge creation-dissemination-utilisation, systematically investigating knowledge from input, flow, and then to output. It defines a framework example of knowledge measurement by combining two types of knowledge, and three stages of knowledge. It also suggests the nature of knowledge includes its dynamic side as a system, in addition to its static aspect.

7.2.2 To Growth Theory

(Based On Theory Note 1, 2, 4, 5, 9, 10)

First of all, the endogenous growth theory states that knowledge is an internal factor involved in the innovation system, which contributes to growth. Knowledge spillover theory, accordingly, stresses that the science-business link and the knowledge spillover through it is the main reason to explain innovation and growth. Based on these theories, this research contributes to the growth model by focusing on the specific interaction between Universities and business. In the OECD study, it shows that University-business interaction is the key to the University based knowledge system, and it has significant effects on both short-term economic growth and long-term technological progress. Moreover, by adding University-industry interaction as a factor to the model, this research extends and modifies the base model of production function with a dimension of knowledge flow. An in-depth view is given to different University activities in the UK regional study. It further discovers that University core activity contributes to both long-term regional growth and short-term regional growth. University knowledge outreach activity is more likely to contribute to the long-term growth of a region. This result supplies the knowledge spillover theory with more activity details to demonstrate the interaction between academia and industry amplifies the permeability of the knowledge filter, increases the flow of knowledge, and thus spurs growth. In the UK University study, it provides the growth model with a dynamic and systematic view of University knowledge. When knowledge commercialisation is considered as an indicator of innovation, the University knowledge creation and dissemination activity shows their influences to the University knowledge utilisation. It expands the idea of the growth model by not only considering the commercialisation side of University knowledge, but also the different stages of the knowledge process. Accordingly, it suggests the knowledge creation resources and dissemination channels determine the utilisation of University knowledge, and need to be taken into account as a dynamic system contributing to regional growth.

Secondly, whilst the consequence of knowledge investment on growth is debatable in the endogenous growth model, this research provides solid evidence regarding the role of R&D investment for the endogenous growth model. In the OECD study, it is found that R&D expenditure and human capital have an indirect role in the growth model. R&D expenditure in the results positively affect high-tech entrepreneurship activities, which tend to result in entrepreneurial innovation and economic return in the long run. On the other hand human capital, which significantly benefits from research-industry co-operation, indirectly contributes to the long term growth too. The result on one side demonstrates the importance of knowledge investment to growth. On the other side, it argues that the influence of knowledge investment on growth is indirect, and is targeted to the long-term benefits.

Thirdly, this research also supports and develops the role of entrepreneurship in growth. The Schumpeterian growth model realised the entrepreneur's role in opportunity seeking, and the knowledge spillover theory of entrepreneurship further confirms the contribution of this role in innovation and the economy by penetrating the filter of knowledge transfer. This research shows that, compared with entrepreneurship activity itself, the interaction between firms and Universities shows a more significant effect on growth. This expands the entrepreneurship theory by switching from the mono knowledge utilisation end of entrepreneurship, to the pole linkage between Universities and business. Furthermore, in the UK regional and University studies, it was found that compared to large companies, University interaction with SMEs more directly contribute to the University knowledge commercialisation. It shows that small firms usually could not produce the growth itself, but through the utilisation of knowledge by the entrepreneur. The transformation of science-produced knowledge into market-oriented innovations depends on the quality of entrepreneurship, and more straightforward, the network between Universities and business. When firms interact with academics, these partnerships especially stimulate new ideas and are instrumental in creating and bringing to the market radical innovations.

7.2.3 To Knowledge System

(Based On Theory Note 1, 3, 4, 5, 6, 7, 10)

This research also contributes to the knowledge system. It is consistent with the prevalent theory of knowledge systems (e.g. triple helix model; regional innovation system; Model 2) by emphasising the importance of knowledge networks in transferring knowledge between science and business in economies. It shows the contribution of these nodes in the knowledge system (Universities, entrepreneurship, proximity, etc.), and the networks among them which lead to growth. It particularly develops the triple helix model with not only proving the dimension of University-business interaction is the engine of regional growth, but also clarifies the relationship between Universities and different nodes in the knowledge system.

Previous knowledge systems already realised that Universities trigger regional innovation through its knowledge activities and networks. This research expands the theory and considers the roles of University core activity and knowledge outreach activity respectively. The findings provide the knowledge system with the idea that the University core activity has a complementary relationship with entrepreneurship. The activity includes the first and second missions of a University such as teaching, research, and training. This activity mainly created codified knowledge, and supplied regions with human resources. Because of the codified nature of this activity, it is less constrained to geographical proximity. One product of this core activity- technological knowledge, is partially used by industry and then contributes to the economy. The other product of University core activity enhances the stock of regional knowledge and human capital. This product improves the regional intensiveness of knowledge and knowledge networks. Thus entrepreneurship is either trained with more knowledge and skills, or it is easier to find opportunities through the well built knowledge stock and networks. Therefore, this University core activity complements the entrepreneurship in the regional knowledge system.

In contrast, the University knowledge outreach activity shows a substitution relationship with entrepreneurship. This activity more often refers to the third mission of University. It is formed with University activities such as knowledge dissemination and spill-offs. This activity mainly focuses on the outreach of University knowledge. Regional knowledge systems and Schumpeterian entrepreneurship theory both confirm that entrepreneurship is an essential element of the knowledge system, since its nature is in seeking and using knowledge. This study adds some views to previous theories by showing that Universities could actively outreach their created knowledge to businesses, through activities such as building the knowledge interaction channels with business, or University spill-offs. This function of University partially substitutes the entrepreneurship's role in knowledge seeking. However, which one is dominant between Universities and entrepreneurship is, according to the maturity of regional innovation systems, the intensiveness of the regional knowledge stock, and the ability of entrepreneurship.

In addition, this research also contributes to the knowledge system by revealing the relationship between non-SMEs and SMEs. For large incumbent companies, previous models of knowledge system and knowledge spillover usually focus on their direct economic return. The part of their role in knowledge spillover is often either omitted, or less weighted to the importance of SMEs.

The UK University study put non-SMEs and SMEs under the same structural model, and found the relationship and distinctions between the two. Although the knowledge dissemination between University and large firm knowledge does not show a direct effect on knowledge commercialisation, as SMEs do, there is an indirect effect found, as this interaction is shown to positively contribute to the University-SME interaction. These findings brings in some new information to the knowledge system. It infers that the University's formal collaboration with non-SMEs enhances the informal social network, which is a crucial mechanism of entrepreneurship knowledge spillover.

7.2.4 To University Role

(Based On Theory Note 4, 5, 11)

The findings of this research contribute to the field of the University role, which specifically distinguishes two University activities (University Core Activity & University Knowledge Outreach Activity), and two University paradigms (Elite University & Outreach University).

More specifically, this result demonstrates that the output of R&D activities, such as patents, is an important form of accessible knowledge that is being developed by the University. The core activity of Universities not only results in greater knowledge for use in the economy, it also is more likely to increase human capital, skills and networks, which may increase the efficiency of transferring capital to growth. This result is consistent with the main mission of a University. The

University knowledge outreach activity supplies the University with regional functions of knowledge dissemination. These knowledge channels between Universities and business created through this activity increases the chance of University knowledge commercialisaion, and it is an important factor of regional long-run growth. This result demonstrates the third mission of a University in economic and regional growth.

The result of this research also provides two University paradigms to the University role field. Both University knowledge creation and dissemination are demonstrated to influence knowledge commercialisation, however this process shows differences amongst two paradigms of Universities, in terms of the elite University and an outreach University. Their unique patterns in knowledge commercialisation and interaction with business are discovered and compared. Elite Universities serve as the engine of innovation to a region, by focusing on research to produce the knowledge for both short-run knowledge commercialisation, and the long-run advantage of technology. Two main functions of this type of University are knowledge creation, and knowledge dissemination. In the elite Universities, it is found that knowledge creation has no influence on the utilisation of University knowledge. In addition, it shows a negative relationship with knowledge dissemination. It implies that in this group of Universities, the investment in knowledge creation resources may not result in that part of growth which is attributed to the utilisation of University knowledge. The increase in the resource of knowledge creation may even decrease the knowledge dissemination to local businesses. It may be because of the non-localised networks in those leading Universities (Huggins and Izushi, 2007). With good capability and reputation in R&D, these Universities are able to build their cross-locational network with industry, which can be seen in many examples. In contrast, in outreach business-facing Universities, knowledge creation is one of the main determinants of knowledge utilisation. In addition, knowledge creation and dissemination are found to complement each other in this University paradigm. This group of Universities tends to embed in local networks with regional business. Because of this relationship between knowledge creation and utilisation, the investment in the resource of knowledge creation is likely to result in the utilisation of University-created knowledge by local firms. In addition, this investment also contributes to the knowledge dissemination from Universities to businesses via local knowledge channels.

7.2.5 To Science-Industry Link

(Based On Theory Note 1, 6, 7, 8)

This research develops some aspects of the science-industry link. First of all, it confirms the significant role of University-business interaction in the knowledge system. This is consistent with some studies which argue that Universities are in a stronger position than government labs and private research to provide the research necessary to stimulate economic growth (Leyden and Link, 2011).

Secondly, this research brings some fresh ideas to the field of science-industry link. It points out that although the role of University-business interaction is demonstrated, which modes to apply needs to be in accordance with the knowledge absorptive capacity of a region. On the one hand, according to the innovation proximity theory, the University-entrepreneurship interaction and the knowledge spillover via it is usually constrained to certain geographical areas. Thus this interaction needs to be discussed together with geographical proximity as it is an indicator of knowledge transfer efficiency. On the other hand, entrepreneurs seek opportunities and exploit knowledge, thus the entrepreneurship activity is considered as the indicator of regional knowledge consumption. Proximity and entrepreneurship together, to some extent, form the degree of regional knowledge absorptive capacity. Therefore, the mode application of University knowledge based systems need to match the level of regional knowledge proximity, and the ability of entrepreneurship.

More specifically, in the UK regional study, it is found that regional disparities in knowledge absorption matter to the mode of University based knowledge system. The economy of regions with high knowledge absorptive capacity benefits directly from the University core activity, while growth of regions with relatively low knowledge absorptive capacity relies more on the University knowledge outreach activity. These results are in accordance with the arguments of some authors in this field (Cohen and Lenvinthal, 1990; Huggins, 2008; Drejer and Lund Vinding, 2005).

Those firms in higher absorptive capacity regions not only rely on local University-business networks, they could also connect to other regional sciences bodies such as government labs. In addition, they could also have the inter-firm networks with other non-SMEs and SMEs, or they may even connect to global networks because of their good ability for knowledge seeking and absorption. Universities could focus on their core activities in these regions, since the knowledge created is likely to be absorbed by local businesses efficiently. University core activity is the key to this mode, surrounded by intensive science-business networks and good quality SMEs, non-SMEs and research bodies. In contrast, firms in relatively low knowledge absorptive regions usually lack knowledge ability and channels. Therefore, they tend to rely on a localised University's activity in knowledge outreach. University knowledge outreach activity is the key to this mode, providing the region with channels of knowledge transfer and spin-off companies. These results add useful ideas to the research field, regarding the mode application of University-based knowledge systems, which is consistent with and develops some studies, such as Goldstein and Drucker (2006), who accesses the regional importance and geographic extent of spatial spillovers arising from University activities.

7.3 Contribution to Practice

At the international level, whether the innovation policy should focus on the dimension of the University role is still debatable. This may be because of different Universities' abilities in knowledge creation, different entrepreneurship ability in knowledge utilisation, and various contexts in the innovation systems across nations. In the UK, there are also some problems involved in the regional systems of innovation, which is mentioned in some studies**.** For example, Kelly et al. (2002) point out that governments have failed to fully realise the significant direct and indirect contribution Universities make to its local, regional and national economies. Some other studies show that the performance of many Universities in the area of knowledge transfer and commercialisation activities has not matched their overall potential (Charles and Conway, 2001; Charles, 2003; Wright, et al., 2006). In addition, there are also disparities of knowledge absorption existing among regions (Huggins 2003; Huggins and Izushi, 2008), and an imbalance of knowledge utilisation among Universities (Huggins, 2008).

In the policy field, the University-business interaction is taking a prevalent role within government policies at a number of levels (Lambert, 2003). Many governments and their agencies are increasingly turning their attention to the role of University knowledge commercialisation in developing innovative, sustainable and prosperous regional and national economies (Drucker and Goldstein, 2007). Moreover, there is also an increasing policy emphasis being placed on promoting innovation through SMEs and their regional knowledge networks (DTI, 2003). In addition, it is mentioned that the University-industry interaction shows different aspects and consequences between regions with high knowledge capacity, and those with low knowledge capacity (Huggins and Johnston, 2009). It is also argued that different types of Universities have different roles in terms of University-industry interaction and knowledge commercialisation (Huggins, 2008).

The regional knowledge interaction between Universities and business are becoming a prevalent focus of regional policy in recent years, as much literature shows. According to the above answers to research questions, Universities are seen as potential key elements of innovation systems through the transferring knowledge to industry innovation. As this innovation is an important reason to explain regional growth and development, the role of Universities in interaction with business has come to the fore of regional innovation and economic development policy.

While the impact on regional growth of University-business interaction is generally positive, there is still a lack of understanding of how to create an effective impact through knowledge transfer from Universities, as Porter and Ketels (2003) argued. Policy Notes (1-4) of this research provide a range of areas that need to be focused on in policy practice to seek the optimal economic output, and more effective knowledge transfer of regions. The interaction between Universities and business could be a substantial reason to explain the regional differences in knowledge commercialisation. There are short-run and long-run effects of it. Thus the policy needs to consider the short-term economic return and long-term technological progress respectively. Moreover, the potential regional development impact of University knowledge is shaped by a number of key factors. These factors include different activities of the University, in terms of knowledge creation, non-SME focus, knowledge outreach, and SME focus. They also include the regional variety in knowledge absorptive capacity in terms of regional entrepreneurship and knowledge proximity. In addition University specialty also matters, as the elite University and outreach University show different aspects and consequences in transferring knowledge to business. Thus policy is also suggested to take into account the influence of key factors.

In sum, according to these Policy Notes, a list of policy directions is suggested to improve the performance of UK regional innovation system:

- Policy on University-Business Interaction: Long-Term and Short-Term (Based on Policy

Notes 1, 2)

- University Specialty and Policy: Elite VS Outreach (Based on Policy Notes 2, 4)
- Regional Variety and Policy: High Absorption VS Low Absorption (Based on Policy Notes 2,3)

These policy directions are discussed one by one as follows:

7.3.1 To Policy Direction

Policy on University-Business Interaction: Long-Term and Short-Term

(Based on Policy Notes 1, 2)

According to the empirical results and finding, in OECD countries, policy is suggested to focus on the University-business co-operation because it improves the linkage and interface between knowledge supply and demand, and directly contributes to economic growth and technological progress. The policy may also need to match the regional long-term and short-term aims of development. According to the findings of the OECD study, factors of R&D expenditure and human capital contribute to regional long-run advantages, as R&D expenditure has a positive effect on the high-tech entrepreneurial activities, and human capital has a positive effect on the University-business co-operation. Therefore, in order to stimulate the long-run development, public policy should also consider promoting the investment in R&D and human capital, such as research facilities, academic staff, graduates.

Moreover, policy may need to take into account the different types of University activity, to enhance the role of the University in the regional economy. The core activities, such as teaching, research, and formal interaction with large companies, are likely to result in both short-term and long-term regional growth. Therefore, to encourage these activities is always a potential dimension of policy to consider. The knowledge outreach activity of University should not be neglected too, because these activities, including University spill-offs and interaction with SMEs, are likely to improve the infrastructure of regional knowledge system such as channels of knowledge transfer. Therefore, for long-term technological advance purpose, regional policy could consider these policies to promote. More specifically, policy could target the informal network with SMEs, such as sharing facilities and expertise. Other possible dimensions of policy to promote could be University spin-offs, or academic entrepreneurship.

University Specialty and Policy: Elite VS Outreach

(Based on Policy Notes 2, 4)

To improve knowledge commercialisation is always an objective of regional policy. However, these policy stimulations are suggested to take into account the University specialty, to achieve the optimal results. According to the finding of the UK University study, knowledge creation and dissemination in different groups of University may result in different consequences of growth. Therefore, policymakers need to consider the University specialty to find out the most appropriate policies.

There are obvious differences in the wealth generated by Universities according to types of institution, as Huggins and Johnston (2009) argued. Universities in more competitive regions are generally more productive than those located in less competitive regions. Also, elite Universities are generally more productive in R&D and global focus than outreach Universities, which usually serve within the regional networks. Although some Universities are relatively weak economic and innovation performers on a national scale, at a regional level they play a vital role as the providers of both wealth and innovation capacity (Abreu et al., 2008).

To encourage the knowledge commercialisation in University, the policy incentives could be set on the knowledge creation resource and knowledge dissemination channels. In specific, policy could focus on the stimulation of knowledge creation, such as academic staff and contract research; or the knowledge dissemination between University and SMEs, such as the consultancy contract, courses, and facilities. However, in elite Universities, because the knowledge creation and dissemination substitute with each other, the comparison and trade-off between the two need to be carefully considered. In outreach Universities, both knowledge creation and dissemination incentives could be considered as they complement with each other in this types of University.

Regional Variety and Policy: High Absorption VS Low Absorption

(Based on Policy Notes 2, 3)

Different regions have different capacities in knowledge absorption. Entrepreneurship and proximity account for the regional knowledge absorptive capacity in this study. The entrepreneurship could represent business and human capital, which are related to knowledge utilisation, while proximity could represent the network of knowledge access, which is related to the efficiency of knowledge transfer. According to Huggins et al (2008), there is considerable variability in the capability of Universities to effectively transfer their knowledge and of regional businesses to effectively absorb such knowledge. It is also found that, in regions with relatively low absorptive capacity, the knowledge created by regional Universities may not be fully applicable or absorbable by firms, especially SMEs (Huggins et al., 2008).

Therefore the regional policy is suggested to be made according to the regional capability of knowledge absorption. In regions with high knowledge absorptive capacity, there is evidence of a greater role being played by non-localised networks (Huggins and Izushi, 2007). To encourage the growth in regions with high capacity of knowledge absorption, regional policies need to focus on the University R&D activity and interaction with non-SMEs. To encourage growth in the regions with relatively low capacity of knowledge absorption, regional policies need to focus on the University knowledge outreach activities, and interaction with SMEs.

Policies could also have a focus on entrepreneurship. Entrepreneurial policy could aim to attract venture capital, which is important for new start-ups. It could also stimulate entrepreneurial awareness and develop entrepreneurial skills. In addition, a University's role in teaching and education is also as important, because it helps the regional human capital and knowledge networks. It also needs to be considered that it could be promoted by policy. Above all, for the long-run benefit, policies could be expanded to the knowledge proximity side, such as to encourage the immigration of qualified personnel and graduates, and the University's role in teaching and training. In addition, the legal infrastructure such as intellectual property law and standardized rules are also essential conditions for efficient research partnerships. These policies are likely to enhance the regional knowledge absorptive capacity, and contribute to the long-run competitive advantages of the region.

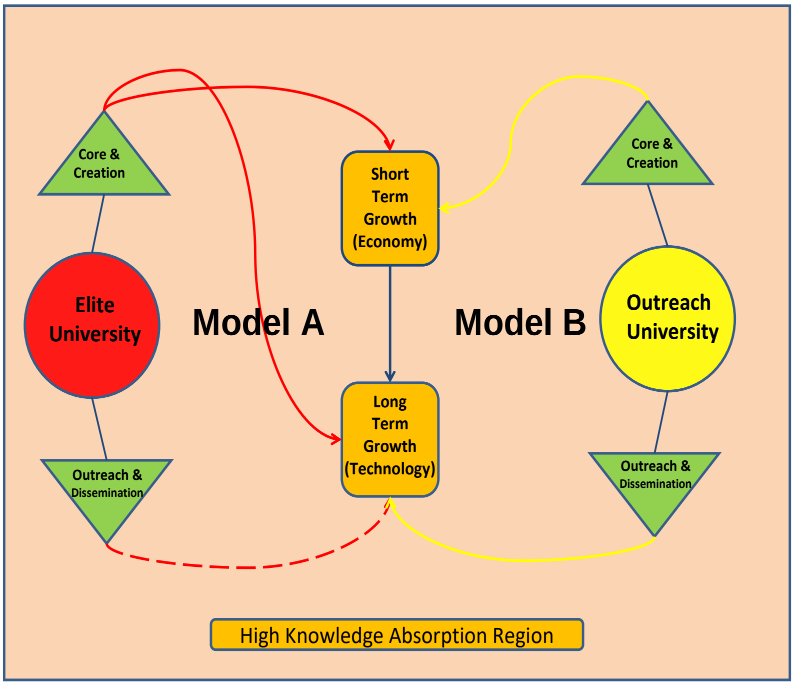
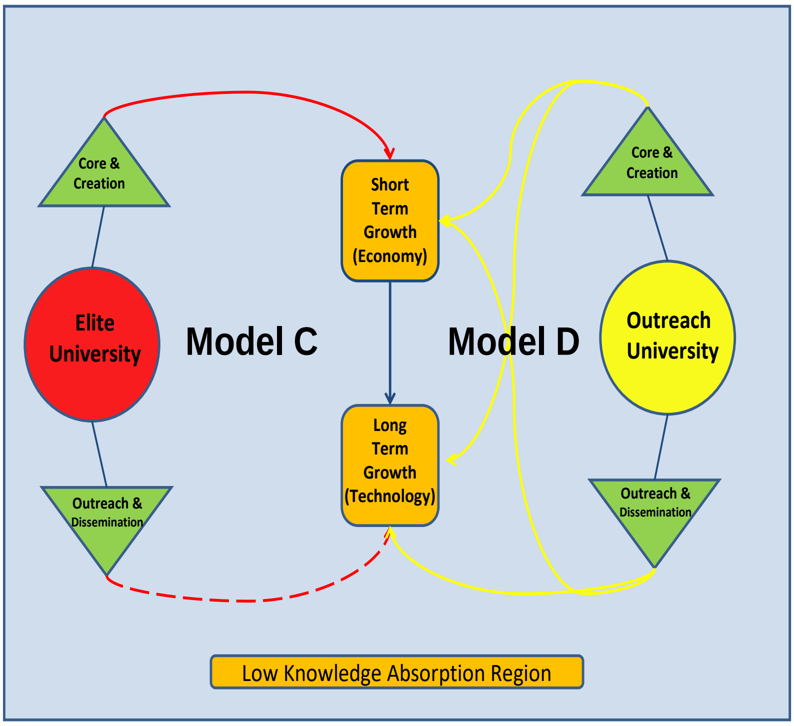
7.3.2 To Practical Model and Policy Recommendation

University activities show an effect on either long-term of short-term growth of a region. According to the policy direction, the region or the University is different, the pattern of the University based knowledge system and its effect could be different. In other words, regional disparities in knowledge absorptive capacity and University speciality define the practical model of a University-based knowledge system. Based on the above, four typical models could be found in the UK: Model A is regarding to the elite University based knowledge system in high knowledge absorption region; Model B is regarding to the outreach University based knowledge system in high knowledge absorption region; Model C is regarding to the elite University based knowledge system in low knowledge absorption region; Model D is regarding to the outreach University based knowledge system in low knowledge absorption region.

On the other hand, there are some regions with successful experiences in promoting innovation and growth through the University activities. Reviewing these experiences may bring a better understanding of the potential policy interventions. Some famous international examples are Silicon Valley and Route 128 (Saxenian, 1994; 2005). UK examples include the high knowledge absorptive region of Cambridge (SQW1985, 2000; Camagni, 1991) and the relatively low knowledge absorptive region of Scotland (Scottish Government, 2008). The main information is summarised with the table in Appendix XI, which helps the policy recommendation for each practical model of a University based knowledge system.

The model framework and potential policies together give the template of practical model. The structure and pattern of each model is shown in the table below, followed with the policy recommendation to try and maximise the performance of University knowledge.

Table 7.3: Practical Model and Policy Recommendation

Policy Direction		Practical Model	Model Graph	Policy Recommendation
Regional Capacity	**University Specialty**			
High	Elite	Model A		-International University and network -Technology transfer agent -R&D affiliation -Science parks and technology incubators -High-tech cluster
High	Outreach	Model B		-Technology transfer agent -Contract research -University-industry alliance -Share facility and expertise -Legal infrastructure
Low	Elite	Model C		-International University and network -Contract research -Spin-offs and academic entrepreneurship -University-firm network -Firm to firm network
Low	Outreach	Model D		-Contract research -Outreach programme -Knowledge intermediary -Spin-offs and academic entrepreneurship -Venture Capital -Entrepreneurship culture and awareness

Model A:

Model A is the elite University based knowledge system in high knowledge absorption region. In model A, the University Core & Knowledge Creation Activity shows contributions to both short-term economic growth and long-term technological progress of a region. University Outreach & Knowledge Dissemination Activity mainly contribute to long-term technological progress of a region. However, these two activities show a substitution relationship, and which one to promote in regional policy needs to be carefully compared based on the regional context and development plan. According to those successful experiences from similar regions with similar University systems, to promote the University Core & Knowledge Creation Activity, the potential policy could consider the following aspects to develop: International University and network; Technology transfer agent; and R&D affiliation. Similarly, to promote the University Outreach & Knowledge Dissemination Activity, policy is recommended to focus on these aspects to develop: science parks and technology incubators; and high-tech clusters.

Model B:

Model B is the outreach University based knowledge system in high knowledge absorption region. In Model B, the University Core & Knowledge Creation Activity shows contributions to short-term economic growth of a region. University Outreach & Knowledge Dissemination Activity mainly contribute to long-term technological progress of a region. According to those successful experiences from similar region with similar University system, to promote the University Core & Knowledge Creation Activity, the potential policy could consider the following aspects to develop: technology transfer agents; and University contract research. Similarly, to promote the University Outreach & Knowledge Dissemination Activity, policy is recommended to focus on these aspects to develop: University-industry alliance; share facility and expertise; and legal infrastructure of innovation systems.

Model C:

Model A is the elite University based knowledge system in low knowledge absorption region. In Model C, the University Core & Knowledge Creation Activity shows a contribution to the short-term economic growth of a region. University Outreach & Knowledge Dissemination Activity mainly contribute to long-term technological progress of a region. However, these two activities show a substitution relationship, and which one to promote in regional policy needs to be carefully considered based on the regional context and development plan. According to those successful experiences from similar regions with similar University systems, to promote the University Core & Knowledge Creation Activity, the potential policy could consider the following aspects to develop: international Universities and networks; and contract research. Similarly, to promote the University Outreach & Knowledge Dissemination Activity, policy is recommended to focus on these aspects to develop: spin-offs and academic entrepreneurship; University-firm network; and firm to firm networks.

Model D:

Model D is the outreach University based knowledge system in low knowledge absorption regions. In Model D, the University Core & Knowledge Creation Activity shows contributions to both the short-term economic growth and long-term technological progress of a region. University Outreach & Knowledge Dissemination Activity mainly contribute to both short-term economic growth and long-term technological progress of a region. According to those successful experiences from similar regions with similar University systems, to promote the University Core & Knowledge Creation Activity, the potential policy could consider the following aspects to develop: contract research. Similarly, to promote the University Outreach & Knowledge Dissemination Activity, policy is recommended to focus on these aspects to develop: outreach programmes; knowledge intermediaries; spin-offs and academic entrepreneurship; business venture capital; and entrepreneurship culture and awareness.

7.4 Contribution to Methodology

This research contributes to methodology with aspects in research design, analysis techniques, and statistical tools. All these are summarised with the table below with a discussion:

Table 7.4: Contribution to Methodology

Contribution	Aspects	Details	Studies
To Research Design	Three Layers of Study	• Overall answer of research question with different scales • Consider the application of the model according to the regional context	• All
	Multi-Objectives	• Long-term and Short-Term • Economic Growth and technological Progress	• All
	Construct level of Study	• Drawing the main factors from the complex • System view • Network view	• All
	Group Study	• University Activities • University paradigms	• UK Regional Study • UK University Study
To Analysis Techniques	Regression Analysis	• Cause and effect between independent variables and dependent variable	• OECD Study
	Path Analysis	• Routine and relationship between variables	• OECD Study
	Factor Analysis	• Relevant elements form/reflect variables	• UK Regional Study • UK University Study
	Cluster Analysis	• Group activities and types	• UK University Study
	Structural Equation Modelling	• Structural level of analysis with considering the latent variables and inter-relationship among variables	• UK Regional Study • UK University Study
To Statistical Tools	SPSS	• Regression Analysis • Factor Analysis • Cluster Analysis	• All
	SmartPLS	• Path Analysis • Structural Equation Modelling	• All

7.4.1 To Research Design

First of all, this research is formed with three layers of study. This provides a comprehensive view of the research's aim. It not only gives an overall answer of research questions with different scales, but also allows to consider the application of the model according to more specific regional context. Secondly, it chooses a multi-objectives task. As knowledge is recognised as an endogenous factor of growth according to the knowledge production function (Cobb-Douglas ,1947; Solow and Swan, 1956; Romer, 1986; Lucas, 1988; Rebelo, 1991), the influence of Universities are to both economic return and total factor productivity. The research makes both objectives possible by the choice of dependent variables include the short-term effect of economic growth and also long-term technological progress. The indirect relationships are able to be found to estimate the long-term effect. This provide an dynamic idea of University based knowledge and its consequences. Thirdly, this research applies a construct level of study which allows the studies switch from the linear perspective to the network perspective. It is not only focused on the direct relationship between independent variables and dependent variables, but also on the relationship among independent variables. The advantage of it is to provide a systemic view of the University knowledge based system. Moreover, this research chose to group those University activities and University types. It helps to clarify those various activities of University, and distinguishes their main effect in different University paradigms.

7.4.2 To Analysis Techniques

This research is in use of multiple analysis techniques including, linear regression analysis, path analysis, factor analysis, cluster analysis and structural equation modelling (SEM). The result of novel analysis techniques, such as SEM in model building and analysing, are combined and compared with traditional techniques such as linear regression. This gives the solidity and confidence to the results. It also provides a pioneering example of an application of model framework and method in the research field. In specific and respectively, regression analysis is based on a modification model of knowledge production function, which aims to find out cause and effect between independent variables and dependent variables; Path analysis is to investigate the routine relationship between variables; Factor and cluster analysis helps to group and integrate those elements such as activities and Universities, and enables the comparison between groups; while Structural Equation Modelling (SEM) is applied to give a structural level of analysis, considering the latent variables and inter-relationship among variables.

7.4.3 To Statistical Tools

The main statistical packages used in this research are SPSS and SmartPLS. SPSS is used for linear regression analysis, factor analysis and cluster analysis. SmartPLS are applied for path analysis and Structural Equation Modelling. SmartPLS is tool based on the technique of Partial Least Squares (PLS) approach of Structural Equation Modelling (SEM). Thus it contains the advantages of both the PLS method and the SEM technique. There are some main advantages and contributions of the SmartPLS application. Firstly, these are many inter-related elements involved in the University-knowledge based system. Traditional tools and methods struggle in investigating the inter-relationship and indirect relations involved among variables. SmartPLS allows to draw the relevant factors and latent factors from the complex, and further helps to find out the relationship among them. Secondly, PLS has its advantages over other techniques when analysing small sample sizes or data with non-normal distributions. Because of the data size and nature in this research, SmartPLS is shown to be an ideal tool to choose. Thirdly, SmartPLS is an easy to use tool with graphical user interface. This drag and drop based tool enables the model be clear, and easy to analyse and modify. The use of SmartPLS in this research brings in a possible solution for the research field, especially for those quantitative studies with small data samples and complex varieties of related variables. This research also provides an experience with the combination of multiple statistical tools, and the inter-proved results from each other.

7.5 Limitation and Further Research

There are also some limitations involved in this research. The limitation of layer of study is summarised with the table below, together with further research directions.

Table 7.5: Limitations and Further Research Directions

Studies	Limitation	Further Research
The OECD Study	• Only co-operation without activities details • Effect analysis based rather than the system based analysis • OECD based national scale of framework could be too broad • Lack of consideration regional context • Only quantitative based and could be rigid	• Choose location with similar infrastructure • Apply more specific framework but based on the dataset availability • Supply with some qualitative information • Logistic model to fully utilise the information contained in categorical data and quantifiable data
The UK Regional Study	• Lack of consideration of the difference in University classification and some activities involved • Panel data with FE may not be the best choice for small panel data samples • Only based on UK region and generalisation of result may have challenge	• Give more details to possible activities • Consider potential appropriate technique dealing with panel data • Choose those regions with similar levels of knowledge infrastructure and intensity • Similar research specific design for regions of other nation with considering regional context there
The UK University Study	• Use the proxy of knowledge commercialisation as an indicator of growth • Could not cover all main interaction channels between University and business Only based on UK University and generalisation of result may has challenge	• Use other possible proxy or direct indicator of growth • Include more types of interaction channels and activities • Similar research specific design for regions of other nation with considering the University situation there

7.5.1 Limitations in the OECD Study and Further Research

The OECD study is based on an broad national framework and general discussion of University-business cooperation without giving too much details of University activities and regional involvement. Since informal and tacit knowledge networks are usually strongly embedded within a geographical context, this scale of national framework could be too broad, and not able to identify differences in knowledge infrastructure among nations, in terms of knowledge systems, legal and policy support, innovation ability. In addition, this study is a factor and effect based analysis rather than the system based analysis. Therefore, it lacks an in-depth view on geographical proximity, nature of target business, regional context, etc. Thirdly, the conclusion is purely according to the result of statistical model. This quantitative result sometimes could be too abstract and rigid to apply in the real practice.

To solve these potential problems, the possible further research could choose target nations with similar knowledge infrastructure and systems to investigate, to give more precise results. When the data is available, further research could apply a framework with more specific indicators of national knowledge transfer. It could also consider supplying the statistical model with some qualitative information for the purpose of real practice in policy. Further research could also consider applying a logistic model to fully utilise the information contained in categorical data and quantifiable data from the dataset.

7.5.2 Limitations in the UK Regional Study and Further Research

There are also some problems involved in the UK regional study. Firstly, this study focuses on the unique activities of University, but without providing information about the different classification of University, which could be an important factor influence the model result. Secondly, the nature of data has both time and location dimension. This study chose the technique of Fixed Effect (FE) to deal with this type of panel data. However there are many statistical methods targeting the problem of panel data samples. Each has their own advantages and shortcomings. It is not able to absolutely conclude that the result generated by this FE method is more credible and reliable over others. A further comparison of these methods could help with the choice of the most appropriate method for the available data. What is more, this study is only based on UK region-specific information. The generalisation and application of the result in other regions or nations may have some challenges. Similarly, because there are obvious disparities existing in knowledge system and absorption capability among UK regions, the results of this study could only give general information, which may not reflect the real circumstances of a certain UK region.

In addition to the current model, further research could consider giving more details to possible activities and University types when the data is available. It could also look at those regions with similar levels of knowledge infrastructure to analyse, to give a more accurate result. Similarly, research of regions in other nations is suggested to add their regional specific factors knowledge indicators. For the problem in data, further research could make a comparison of relevant methods dealing with panel data. For example: Choice of one year data with a few regions; Choice of one region data with a few years; With the advantages of other statistical tools or techniques, such as Hausman test in Eviews, to help the discrimination of the Fix Effect (FE), Random Effect (RE) or Mixed Effects for the model analysis; Meta Analysis could be another possible choice, which is the statistical analysis of large collections of analysis results from individual cells, and then integrating the finding.

7.5.3 Limitations in the UK University Study and Further Research

There are some main limitations in the UK University study too. Firstly, because the direct data of growth is not available in the University scale, this study have to use proxy of knowledge commercialisation as an indicator of growth. It also lacks comprehensive coverage of data regarding to knowledge transfer channels between University and business, since the HEI-BC dataset only include some main types of interaction. In addition to those channels included in the study, other channels and activities could have the potential effect on the commercialisation of University knowledge too. Finally, the result and conclusion are only based on UK University situation, and may have difficulties to apply in other nations.

Accordingly, further research direction could be the use of other possible proxies or direct indicators of growth when data is available for other regions or nations, or over different time periods. It also worth investigating more types of channels and activities for formal and informal University-business interaction. With the framework of the current model, similar research designed for regions in other countries needs to include the University and regional context there.

7.6 Concluding Comments

The aim of this research is to investigate the role of University-business interaction in knowledge systems and its effect on growth. This research aim is fulfilled with three research objectives, which is designed with three layers of study respectively, including the OECD study, the UK regional study, and the UK University study. The objective of the OECD study is to discover the influence of University-business co-operation on technological progress and economic growth. The objective of the UK regional study is to investigate the effect of University activities on growth, and the role of University activities in regional knowledge systems. The objective of the UK University study is to illustrate the patterns and processes of University knowledge based systems, and the effect of it on knowledge commercialisation.

The results from three layers of study, together provide four main findings regarding improving the economic return benefiting from the utilisation of University knowledge. Firstly, University-business interaction is the key of the University based knowledge system of knowledge process, and it has significant effect on both economic growth and technological progress.

Secondly, different University activities have different roles in the regional knowledge system. University core activity contributes to both long term and short term growth. University knowledge outreach activity is more likely to contribute to the long-term growth of a region. Thirdly, the economy of regions with high knowledge absorptive capacity benefit directly from the core activity, while growth of regions with relatively low knowledge absorptive capacity rely more on the University knowledge outreach activity. Finally, both University knowledge creation and dissemination influence University knowledge commercialisation. In elite Universities, knowledge creation and knowledge dissemination substitute each other; while in outreach Universities, knowledge creation and knowledge dissemination complement each other.

These findings contribute to some research fields including the nature of knowledge, growth theory, knowledge system, University roles and science-industry link. This research expands the nature of knowledge, by arguing that when the contribution and consequence of knowledge need to distinguish the codified and tacit nature of the knowledge. It defines a framework example of knowledge measurement by combining two types of knowledge, and three stages of knowledge, with a dynamic point of view. This result supplies the knowledge spillover theory with more activity details, to demonstrate that the interaction between academia and industry amplifies the permeability of the knowledge filter, increases the flow of knowledge, and thus spurs growth. In addition, it generates the idea of the growth model that not only the commercialisation side of University knowledge, but also the different stages of knowledge process. This research also provides solid evidence to distinguish the role R&D investment for the endogenous growth model, and develops the role of entrepreneurship in growth, but indirectly. The findings are consistent with prevalent theory of knowledge systems (e.g. triple helix model; regional innovation system; Model 2) by emphasising the importance of knowledge networks in transferring knowledge between science and business in the economy. It particularly develops the triple helix model in not only proving the dimension of University-business interaction is the engine of regional growth, but also clarifying the relationships of Universities, and different nodes in the knowledge system. This research also contributes the knowledge system by revealing the relationship between non-SMEs and SMEs. This research contributes to the field of the University role by specifically distinguishing two University activities (University Core Activity & University Knowledge Outreach Activity) and two University paradigms (Elite University & Outreach University). It confirms the significant role of University-business interaction in the knowledge system. It points out that although the role of University-business interaction is demonstrated, which mode to apply needs to be according to the knowledge absorptive capacity of a region. It also shows the evidence that regional disparities in knowledge absorption matter to the mode of University based knowledge system.

According to the findings of the research, regional innovation policies are suggested to focus on three directions: the University-business interaction with considering its long term effect and short term effect; University specialty including elite paradigm and outreach paradigm; and regional variety in knowledge absorption. Policy is suggested to look at the University-business co-operation because it improves the linkage and interface between knowledge supply and demand, and directly contributes to economic growth and technological progress. Policy may need to take into account the different types of University activity. The core activities, such as teaching, research, and formal interaction with large companies, are likely to result in both short-term and long-term regional growth. The knowledge outreach activity of University cannot be neglected too, because these activities, including University spill-offs and interaction with SMEs, are likely to improve the infrastructure of regional knowledge system such as channels of knowledge transfer. These policy stimulations are also suggested to take into account the University specialty to design the most appropriate incentives, since knowledge creation and dissemination in different groups of Universities may result in different consequences of growth. In addition, policy needs to consider the regional capability in knowledge absorption. In regions with high capacity of knowledge absorption, potential policies could focus on the University R&D activity and interaction with non-SMEs. In regions with low capacity of knowledge absorption, potential policies could focus more on the University knowledge outreach activities and interaction with SMEs.

Based on the above policy direction, four models of practice are shown with potential policy details. Model A is the elite University based knowledge system in high knowledge absorption regions. Under this model framework, to promote the University Core & Knowledge Creation Activity, the potential policy could consider the following aspects to develop: international University and networks; technology transfer agents; and R&D affiliation. Similarly, to promote the University Outreach & Knowledge Dissemination Activity, policy is recommended to focus on these aspects to develop: science parks and technology incubators; and high-tech clusters. Model B is the outreach University based knowledge system in high knowledge absorption region. Under this model framework, to promote the University Core & Knowledge Creation Activity, the potential policy could consider the following aspects to develop: technology transfer agents; and

University contract research. Similarly, to promote the University Outreach & Knowledge Dissemination Activity, policy is recommended to focus on these aspects to develop: University-industry alliance; share facility and expertise; and the legal infrastructure of innovation systems. Model C is the elite University based knowledge system in low knowledge absorption regions. Under this model framework, to promote the University Core & Knowledge Creation Activity, the potential policy could consider the following aspects to develop: international University and networks; and contract research. Similarly, to promote the University Outreach & Knowledge Dissemination Activity, policy is recommended to focus on these aspects to develop: spin-offs and academic entrepreneurship; University-firm networks; and firm to firm networks. Model D is the outreach University based knowledge system in low knowledge absorption region. Under this model framework, to promote the University Core & Knowledge Creation Activity, the potential policy could consider the following aspects to develop: contract research. Similarly, to promote the University Outreach & Knowledge Dissemination Activity, policy is recommended to focus on these aspects to develop: outreach programmes; knowledge intermediary; spin-offs and academic entrepreneurship; business venture capital; and entrepreneurship culture and awareness.

This research contributes to methodology with aspects in research design, analysis techniques, and statistical tools. This research is designed with three layers of study and multi-objectives task. Choice of dependent variables include the short-term effect of economic growth and also long-term technological progress. This research applies a structural level of study, which allows the studies to switch from the linear perspective to the network perspective. The research is also designed to group University activities and University types. It helps to clarify those various activities of University, and distinguish their main effect in different University paradigms. This research is in use in multiple analysis techniques, including linear regression analysis, path analysis, factor analysis, cluster analysis and structural equation modelling (SEM). The result of novel analysis techniques, such as SEM in model building and analysis, are combined and compared with traditional techniques such as linear regression. This gives the solidity and confidence to the results. It also provides an pioneer example of application of model framework and method in the research field. The statistical package used in this research are SPSS and SmartPLS. SmartPLS is an easy to use tool with graphical user interface. SmartPLS has some outstanding advantages over other statistical tools, because it allows us to draw the relevant factors and latent factors from the complex, and further helps to find out the relationships among them. It also has advantages in analysing small sample sizes, or data with non-normal distributions.

There are some limitation in each part of study, mainly from the finding application, generalisation and data availability. The possible further research for national scale, could choose target nations with similar knowledge infrastructure and system to investigate. Further research could also consider applying a framework with more specific indicators of national knowledge transfer. It could think to supply the statistical model with some qualitative information for the purpose of real practice in policy. For the regional scale, further research could consider giving more details to possible activities and University types, when the data is available. It could also look at those regions with similar levels of knowledge infrastructure to analyse, to give a more accurate result. Similarly, research of regions in other nation is suggested to add their regional specific factors knowledge indicators. For the problem in data, further research could make a comparison of relevant methods dealing with panel data. It could also consider using other datasets based on the data availability, or other indicators of regional growth and University-business interaction.

7.7 Reflection of Learning

Life is a journey. These years of Phd research are an important part of this journey for me, which leave lots of memories. These memories are like pictures flying by with happiness, sadness, gain, and pain.

I remember that the very beginning of the research idea started in the school canteen, where I had a discussion with Professor David Pickernell regarding the effect of FDI (Foreign Direct Investment) to regional economies. With his advice and guidance, we narrowed this topic down to the knowledge creation-dissemination-utilisation process. After a period study of literature, we managed to further focus specifically on the knowledge dissemination through the University-business interaction.

I remember the confused morning when I was first facing such big groups of literature. I remember the hard evening when I was making an effort to find the appropriate analysis technique to match the size and nature of the data. I also remember the excitement at the moment when I found the interesting bits from the analysis results.

During these years of research, my personal life was undergoing fundamental changes, and I had

some very difficult times. I appreciate my supervisor Professor David Pickernell who always gives me great help and flexibility. I also appreciate those families and friends who support and trust me in my research and in my life.

This study not only provided me with the knowledge in this subject, but also equipped me with the statistical analysis skills, which benefit me significantly in my current occupation as a data analyst. More importantly, it gave me confidence and experience in problem solving, when facing difficulties in study, work, and life.

The life journey is on-going. The end of this thesis is not the end of learning, since the big world offers lots for me to discover. It is the ending of this chapter, but my life will be heading towards the next chapter. What I gained from this Phd study will benefit my whole life, and I believe, make the journey more colourful and meaningful.

Appendices

Appendix I: Descriptive Statistics OECD Study

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Co-operation with Universities or other higher education institutions,Percentage,2002-2008	65	.0216	.3599	.123735	.0651315
Ln R&D Expenditure Euro per Inhabitant, 2002,2004,2006	65	2.1282	7.1667	5.142165	1.4612254
High Tech Entreprise Birth Rate (% Active Entreprises), 2002-2008	65	.1323	.4530	.268817	.0795629
A % of Human Resource in Science and Technology between 25-64, 2002,2004,2006	65	.1460	.4510	.315338	.0773503
Valid N (listwise)	65				

Appendix II: Activities Definition in HE-BCI Survey

Spin-off activity

Spin-offs are companies set-up to exploit intellectual property (IP) that has originated from within the HEI. All investment from the HEI and external partners are included but any investment from HEFCE/BIS third stream funds (such as the Higher Education Innovation Fund in England or the Third Mission Fund in Wales) is excluded.

Spin-offs with some HEI ownership are companies set-up to exploit IP that has originated from within the HEI, where the HEI continues to have some ownership.

Formal spin-offs, not HEI-owned are companies set-up based on IP that has originated from within the HEI but which the HEI has released ownership (usually through the sale of shares and/or IP).

Staff start-ups are companies set-up by active (or recent) HEI staff but not based on IP from the institution.

Graduate start-ups include all new business started by recent graduates (within two years) regardless of where any IP resides, but only where there has been formal business/enterprise support from the HEI.

Spin-off activity is further analysed by the **number** of new spin off companies for the reporting period; the **number of active firms** (the 'number' and 'number still active which have survived at least 3 years' plus those companies which have been active for between one and three years); **estimated current employment of all active firms (FTE)**; **estimated current turnover of all active firms (£000s)** and **estimated external investment received (£000s)** (from external partners but excluding investment from HEFCE/BIS third stream funds).

Note: estimates for estimated current employment of all active firms (FTE), estimated current turnover of all active firms (£000s), and estimated external investment received (£000s) (from external partners but excluding investment from HEFCE/BIS third stream funds) are provided by HEIs where possible.

Collaborative research involving public funding

This includes research projects' public funding from at least one public body, and a material contribution from at least one external non-academic collaborator. The collaborative contribution may be cash or 'in-kind' (if this is specified in a collaborative agreement and auditable). In-kind contributions include contributions to the project from the non-academic collaborators (for example staff time, use of equipment and other resources, materials, provision of data etc.) as described in the project collaboration agreement.

Contract research

This includes contract numbers and income identifiable by the institution as meeting the specific research needs of external partners, excluding any already returned in collaborative research involving public funding and excluding basic research council grants.

Business and community services

Consultancy contracts

This includes contract numbers and income associated with consultancy, which are crucially dependent on a high degree of intellectual input from the institution to the client (commercial or non-commercial) without the creation of new knowledge. Consultancy may be carried out either by academic staff or by members of staff who are not on academic contracts, such as senior University managers or administrative/support staff.

Facilities and equipment related services

This includes the use and income associated with the use the HEI's physical academic resources by external parties, and captures provision which can be uniquely provided by an HEI. Examples may include aerospace company use of a HEI's wind tunnel, or media company use of a digital media suite. It does not include simple trading activities such as commercial hire of conference facilities or academic conferences.

Courses for business and the community

This includes revenue generated by Continuing Professional Development (CPD) courses, defined as a range of short and long training programmes for learners already in work who are undertaking the course for purposes of professional development, upskilling or workforce development.

Regeneration and development programmes

Regeneration funding is an important way for HEIs to invest intellectual assets in economic, physical and socially beneficial projects. The majority of regeneration funding comes from European sources, specifically the European Regional Development Fund, the European Social Fund, UK Government regeneration funds and development agencies in the UK Regional Development Agencies

Intellectual property (IP)

IP is a vital indicator for the value added by the HEI when interacting with a range of external partners. It is commonly in the form of licenses granted to private companies, allowing them to exploit an invention protected by a patent. IP includes patents, copyright, design registrations and trade marks.

IP income includes income from upfront or milestone fees, royalties and patents cost reimbursement.

Small and medium enterprises (SMEs) includes enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million. SMEs include micro, small and medium enterprises and sole traders.

Other (non-SME) commercial businesses includes other commercial businesses which do not match the above definition of SMEs.

Non-commercial organisations includes organisations from which its shareholders or trustees do not benefit financially.

Appendix III: Descriptive Statistics UK Regional Study

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
RDP	96	4.0893	5.7442	4.7578	.3811
HRST	96	30.8	56.8	38.324	5.5110
Entrepreneurship	96	2.9	10.0	5.470	1.1473
Agglomeration Externalities	96	4.1697	8.5028	5.7392	1.000
UP	96	2.0776	22.9290	10.9480	5.008
UCCS	96	.1848	2.3024	.7396	.4960
UCBN	96	.0059	5.5673	1.4978	1.3942
IPN	96	.0000	1.9956	.4027	.4435
FSPIN	96	.0000	12.0679	2.1984	2.3788
SSPIN	96	.0000	8.6820	2.3830	2.2196
Valid N (listwise)	96				

Appendix IV: Fixed Effects Calculation

Region (Year)	Variable Value	Fixed Effects (FE)
Region (i)	X1	X1-(X1+X2+X3+……+Xi)/（t+1）
Region (i+1)	X2	X2-(X1+X2+X3+……+Xi)/（t+1）
Region (i+2)	X3	X3-(X1+X2+X3+……+Xi)/（t+1）
……	……	
Region (i+t)	Xi	Xi-(X1+X2+X3+……+Xi)/（t+1）

Appendix V: University Samples in HE-BCI Survey

Institutions
Total England
Anglia Ruskin University
Aston University
Bath Spa University
The University of Bath
University of Bedfordshire
Birkbeck College
Birmingham City University
The University of Birmingham
University College Birmingham
Bishop Grosseteste University College Lincoln
The University of Bolton
The Arts University College at Bournemouth
Bournemouth University
The University of Bradford
The University of Brighton
The University of Bristol
Brunel University
Buckinghamshire New University
The University of Buckingham
The University of Cambridge
The Institute of Cancer Research
Canterbury Christ Church University
The University of Central Lancashire
Central School of Speech and Drama
University of Chester
The University of Chichester
The City University
Conservatoire for Dance and Drama
Courtauld Institute of Art
Coventry University
Cranfield University
University for the Creative Arts
University of Cumbria
De Montfort University
University of Derby
University of Durham
The University of East Anglia
The University of East London
Edge Hill University

The University of Essex

The University of Exeter

University College Falmouth

University of Gloucestershire

Goldsmiths College

The University of Greenwich

Guildhall School of Music and Drama

Harper Adams University College

University of Hertfordshire

Heythrop College

The University of Huddersfield

The University of Hull

Imperial College of Science, Technology and Medicine

Institute of Education

The University of Keele

The University of Kent

King's College London

Kingston University

The University of Lancaster

Leeds College of Music

Leeds Metropolitan University

The University of Leeds

Leeds Trinity University College

The University of Leicester

The University of Lincoln

Liverpool Hope University

Liverpool John Moores University

The Liverpool Institute for Performing Arts

The University of Liverpool

University of the Arts, London

London Business Schoo

University of London (Institutes and activities)

London Metropolitan University

London South Bank University

London School of Economics and Political Science

London School of Hygiene and Tropical Medicine

Loughborough University

The Manchester Metropolitan University

The University of Manchester

Middlesex University

The University of Newcastle-upon-Tyne

Newman University College

The University of Northampton

The University of Northumbria at Newcastle

Norwich University College of the Arts
The University of Nottingham
The Nottingham Trent University
The Open University
Oxford Brookes University
The University of Oxford
University College Plymouth St Mark and St John
The University of Plymouth
The University of Portsmouth
Queen Mary and Westfield College
Ravensbourne
The University of Reading
Roehampton University
Rose Bruford College
Royal Academy of Music
Royal Agricultural College
Royal College of Art
Royal College of Music
Royal Holloway and Bedford New College
Royal Northern College of Music
The Royal Veterinary College
St George's Hospital Medical School
St Mary's University College, Twickenham
The University of Salford
The School of Oriental and African Studies
The School of Pharmacy
Sheffield Hallam University
The University of Sheffield
Southampton Solent University
The University of Southampton
Staffordshire University
University Campus Suffolk
The University of Sunderland
The University of Surrey
The University of Sussex
The University of Teesside
Thames Valley University
Trinity Laban Conservatoire of Music and Dance
University College London
The University of Warwick
University of the West of England, Bristol
The University of Westminster
The University of Winchester
The University of Wolverhampton

The University of Worcester

Writtle College

York St John University

The University of York

Total Wales

Aberystwyth University

Bangor University

Cardiff University

University of Wales Institute, Cardiff

University of Glamorgan

Glyndŵr University

The University of Wales, Lampeter

The University of Wales, Newport

Swansea Metropolitan University

Swansea University

Trinity University College

Total Scotland

The University of Aberdeen

University of Abertay Dundee

The University of Dundee

Edinburgh College of Art

Edinburgh Napier University

The University of Edinburgh

Glasgow Caledonian University

Glasgow School of Art

The University of Glasgow

Heriot-Watt University

Queen Margaret University, Edinburgh

The Robert Gordon University

The Royal Scottish Academy of Music and Drama

The University of St Andrews

Scottish Agricultural College

The University of Stirling

The University of Strathclyde

UHI Millennium Institute

The University of the West of Scotland

Total Northern Ireland

The Queen's University of Belfast

St Mary's University College

Stranmillis University College

University of Ulster

Appendix VI: Descriptive Statistics UK University Study

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Academic staff	161	25.00	7770.00	1120.8696	1127.77014
Contract Research Total (Thousands)	161	.00	95324.00	6108.4286	13984.82237
Consultancy Contract with Non-SME (Thousands)	161	.00	12949.00	526.2795	1243.29490
Courses with Non-SME	161	.00	12558.00	657.2298	1784.98645
Equipment and Facility with Non-SME	161	.00	5320.00	204.0000	627.34502
Consultancy Contract with SME (Thousands)	161	.00	9406.00	348.5404	966.83666
Courses with SME	161	.00	3710.00	180.0559	413.39691
Equipment and Facility with SME	161	.00	5393.00	224.0807	620.88223
collaborative research income involving public funding (Thousands)	161	.00	55631.00	4651.2050	8483.71355
Spin-offs with HEI ownership, Turnover, Thousand	161	.00	90600.00	4610.5776	13712.74948
Total IP revenues (Thousands)	161	.00	12431.00	519.8075	1671.04797
Valid N (listwise)	161				

Appendix VII: Result of PLS Quality Criteria In OECO Economic Growth Model

	AVE	Composite Reliability	R Square	Cronbachs Alpha	Communality	Redundancy
Capital	1.000000	1.000000		1.000000	1.000000	
Co-Uni	1.000000	1.000000	0.188973	1.000000	1.000000	0.008084
Ent	1.000000	1.000000	0.504820	1.000000	1.000000	-0.044710
GOV	1.000000	1.000000	0.783791	1.000000	1.000000	0.536612
HR	1.000000	1.000000	0.065356	1.000000	1.000000	0.065356
Labour	1.000000	1.000000		1.000000	1.000000	
R&D Expenditure	1.000000	1.000000	0.177052	1.000000	1.000000	0.177052

Appendix VIII: Result of PLS Quality Criteria In OECO Technological Progress Model

	AVE	Composite Reliability	R Square	Cronbachs Alpha	Communality	Redundancy
Co-Uni	1.000000	1.000000	0.177630	1.000000	1.000000	0.091878
ENT	1.000000	1.000000	0.492188	1.000000	1.000000	-0.144082
HR	1.000000	1.000000		1.000000	1.000000	
R&D Exp	1.000000	1.000000		1.000000	1.000000	
TFP	1.000000	1.000000	0.426892	1.000000	1.000000	-0.038114

Appendix IX: Result of PLS Quality Criteria In UK Regional Economic Growth Model

	AVE	Composite Reliability	R Square	Cronbachs Alpha	Communality	Redundancy
Agglomeration Externalities	1.000000	1.000000		1.000000	1.000000	
Capital and Labour	0.850394	0.919103		0.827563	0.850394	
Economic Growth	1.000000	1.000000	0.839878	1.000000	1.000000	0.003748
Entrepreneurship	1.000000	1.000000	0.288316	1.000000	1.000000	0.108999
University Activity 1	0.672780	0.887922	0.309752	0.835925	0.672780	0.142569
University Activity 2	0.560498	0.832057	0.283166	0.736225	0.560498	0.081213

Appendix X: Result of PLS Quality Criteria In UK Regional Technological Progress Model

	AVE	Composite Reliability	R Square	Cronbachs Alpha	Communality	Redundancy
Agglomeration Externalities	1.000000	1.000000		1.000000	1.000000	
Entrepreneurship	1.000000	1.000000	0.273597	1.000000	1.000000	0.116213
Technological Progress	1.000000	1.000000	0.166826	1.000000	1.000000	-0.000676
University Activity 1	0.666892	0.883688	0.268733	0.835925	0.666892	0.145125
University Activity 2	0.561224	0.833395	0.155897	0.736225	0.561224	0.082287

Appendix XI: US and UK University Policy

Case					
Region		**Core University**	**System**	**Policy and Experience**	
US	Silicon Valley	Stanford University	Network based-Horizontal	University-industry Alliances Technology incubators and Science park Share facility Share expertise Technology transfer offices Financial support Entrepreneurial economy Legal support Intellectual property Knowledge capital	Contract research Organisation Spin-off firms Academic entrepreneurship Informal communication and collabouration among firms
	Route 128	MIT and Harvard University	Network based-Vertical		Business consultancy Contract research Spin-off firms Venture capital Education and research Internal firm social and technical networks
UK	Cambridge Region	Cambridge University	Collective Learning	Technology transfer offices Science parks Outreach programme Education and training	Technology parks International University Small firm cluster R&D-focused business cluster High-tech entrepreneurial start-ups
	Scotland	Elite Universities and	Intermediary of Knowledge Commercialisation		Commercialisation of local academic research Intermediary Technology

		Outreach Universities			Institutes Work with SMEs Entrepreneurial culture

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